THE PALATE.

The **palate** forms the roof of the mouth: it consists of two portions, the hard palate in front, the soft palate behind.

The **hard palate** is bounded in front and at the sides by the alveolar arches and gums; behind, it is continuous with the soft palate. It is covered by a dense structure formed by the periosteum and mucous membrane of the mouth, which are intimately adherent. Along the middle line is a linear ridge or raphé, which terminates anteriorly in a small papilla corresponding with the inferior opening of the anterior palatine fossa. This papilla receives filaments from the naso-palatine and anterior palatine nerves. On either side and in front of the raphé the mucous membrane is thick, pale in color, and corrugated; behind, it is thin, smooth, and of a deeper color: it is covered with squamous epithelium, and furnished with numerous glands (palatal glands), which lie between the mucous membrane and the surface of the bone.

The **soft palate** (*velum pendulum palati*) is a movable fold suspended from the posterior border of the hard palate, and forming an incomplete septum between the mouth and pharynx. It consists of a fold of mucous membrane enclosing muscular fibres, an aponeurosis, vessels, nerves, adenoid tissue, and mucous glands. When occupying its usual position (*i. e.* relaxed and pendent) its anterior surface is concave, continuous with the roof of the mouth, and marked by a median ridge or raphe, which indicates its original separation into two lateral halves. Its posterior surface is convex, and continuous with the mucous membrane covering the floor of the posterior nares. Its upper border is attached to the posterior margin of the hard palate, and its sides are blended with the pharynx. Its lower border is free.

Hanging from the middle of its lower border is a small, conical-shaped pendulous process, the *uvula*, and arching outward and downward from the base of the uvula on each side are two curved folds of mucous membrane, containing muscular fibres, called the *arches*, or *pillars of the soft palate*, or *pillars of the fauces*.

The *anterior pillars* run downward, outward, and forward to the sides of the base of the tongue, and are formed by the projection of the Palato-glossi muscles, covered by mucous membrane.

The *posterior pillars* are nearer to each other and larger than the anterior; they run downward, outward, and backward to the sides of the pharynx, and are formed by the projection of the Palato-pharyngei muscles, covered by mucous membrane. The anterior and posterior pillars are separated below by a triangular interval in which the tonsil is lodged.

The space left between the arches of the palate on the two sides is called the *isthmus of the fauces*. It is bounded, above, by the free margin of the soft palate; below, by the back of the tongue; and on each side, by the pillars of the fauces and the tonsil.

The *mucous membrane of the soft palate* is thin, and covered with squamous epithelium on both surfaces, excepting near the orifice of the Eustachian tube, where it is columnar and ciliated.[1] Beneath the mucous membrane on the oral surface of the soft palate is a considerable amount of adenoid tissue. The palatine glands form a continuous layer on its posterior surface and round the uvula.

The *aponeurosis of the soft palate* is a thin but firm fibrous layer attached above to the posterior border of the hard palate, and becoming thinner toward the free margin of the velum. Laterally, it is continuous with the pharyngeal aponeurosis. It forms the framework of the soft palate, and is joined by the tendon of the Tensor palati muscle.

[1] According to Klein, the mucous membrane on the nasal surface of the soft palate in the fœtus is covered throughout by columnar ciliated epithelium, which subsequently becomes squamous; and some anatomists state that it is covered with columnar ciliated epithelium, except at its free margin, throughout life.

The *muscles of the soft palate* are five on each side: the Levator palati, Tensor palati, Azygos uvulæ, Palato-glossus, and Palato-pharyngeus (see page 329). The following is the relative position of these structures in a dissection of the soft palate from the posterior or nasal to the anterior or oral surface: Immediately beneath the nasal mucous membrane is a thin stratum of muscular fibres, the posterior fasciculus of the Palato-pharyngeus muscle, joining with its fellow of the opposite side in the middle line. Beneath this is the Azygos uvulæ, consisting of two rounded fleshy fasciculi, placed side by side in the median line of the soft palate. Next comes the aponeurosis of the Levator palati, joining with the muscle of the opposite side in the middle line. Fourthly, the anterior fasciculus of the Palato-pharyngeus, thicker than the posterior, and separating the Levator palati from the next muscle, the Tensor palati. This muscle terminates in a tendon which, after winding round the hamular process, expands into a broad aponeurosis in the soft palate, anterior to the other muscles which have been enumerated. Finally, we have a thin muscular stratum, the Palato-glossus muscle, placed in front of the aponeurosis of the Tensor palati, and separated from the oral mucous membrane by adenoid tissue.

The **Tonsils** (*amygdalæ*) are two prominent bodies situated one on each side of the fauces, between the anterior and posterior pillars of the soft palate. They are of a rounded form, and vary considerably in size in different individuals. A recess, the *fossa supra-tonsillaris*, may be seen, directed upward and backward above the tonsil. His regards this as the remains of the lower part of the second visceral cleft. It is covered by a fold of mucous membrane termed the *plica triangularis*. Externally the tonsil is in relation with the inner surface of the Superior constrictor, to the outer side of which is the Internal pterygoid muscle. The internal carotid artery lies behind and to the outer side of the tonsil, and nearly an inch (20 to 25 mm.) distant from it. It corresponds to the angle of the lower jaw. Its *inner surface* presents from twelve to fifteen orifices, leading into small recesses, from which numerous follicles branch out into the substance of the gland. These follicles are lined by a continuation of the mucous membrane of the pharynx, covered with epithelium; around each follicle is a layer of closed capsules imbedded in the submucous tissue. These capsules are analogous to those of Peyer's glands, consisting of adenoid tissue. No openings from the capsules into the follicles can be recognized. They contain a thick grayish secretion. Surrounding each follicle is a close plexus of lymphatic vessels. From these plexuses the lymphatic vessels pass to the deep cervical glands in the upper part of the neck, which frequently become enlarged in affections of these organs.

The *arteries* supplying the tonsil are the dorsalis linguæ from the lingual, the ascending palatine and tonsillar from the facial, the ascending pharyngeal from the external carotid, the descending palatine branch of the internal maxillary, and a twig from the small meningeal.

The *veins* terminate in the tonsillar plexus, on the outer side of the tonsil.

The *nerves* are derived from Meckel's ganglion and from the glosso-pharyngeal.

THE SALIVARY GLANDS (Fig. 483).

The principal salivary glands communicating with the mouth and pouring their secretion into its cavity are the parotid, submaxillary, and sublingual.

The **parotid gland**, so called from being placed near the ear (παρά, near; οὖς, ὠτός, the ear), is the largest of the three salivary glands, varying in weight from half an ounce to an ounce. It lies upon the side of the face immediately below and in front of the external ear. It is limited above by the zygoma; below, by the angle of the jaw and by a line drawn between it and the mastoid process; anteriorly, it extends to a variable extent over the Masseter muscle; posteriorly, it is bounded by the external meatus, the mastoid process, and the Sterno-mastoid and Digastric muscles, slightly overlapping the two muscles.

Its *anterior surface* is grooved to embrace the posterior margin of the ramus of the lower jaw, and advances forward beneath the ramus, between the two Pterygoid muscles and superficial to the ramus over the Masseter muscle. Its *outer surface*, slightly lobulated, is covered by the integument and parotid fascia, and has one or two lymphatic glands resting on it. Its *inner surface* extends deeply into the neck by means of two large processes, one of which dips behind the styloid process and projects beneath the mastoid process and the Sterno-mastoid muscle; the other is situated in front of the styloid process, and passes into the back part of the glenoid fossa, behind the articulation of the lower jaw. The structures passing through the parotid gland are—the external carotid artery, giving off its three terminal branches: the posterior auricular artery emerges from the gland behind; the temporal artery above; the transverse facial, a branch of the temporal, in front;

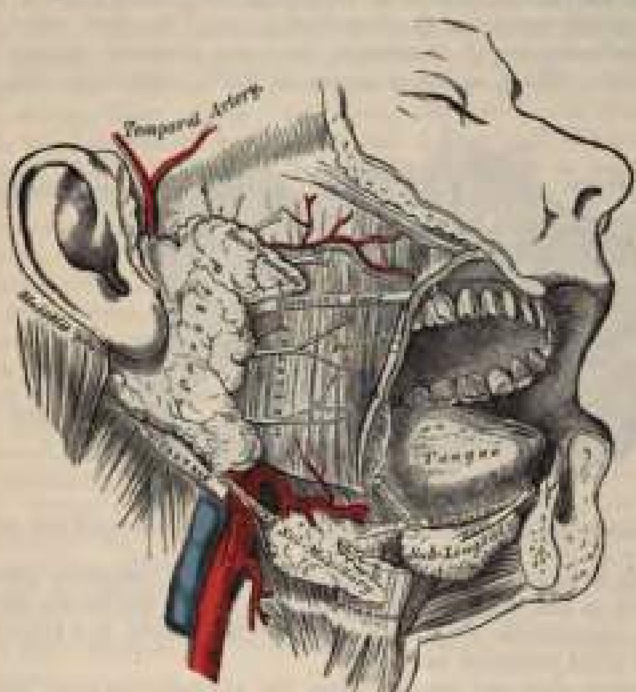


FIG. 482.—The salivary glands.

and the internal maxillary winds through it as it passes inward, behind the neck of the jaw. Superficial to the external carotid is the trunk formed by the union of the temporal and internal maxillary veins; a branch, connecting this trunk with the internal jugular, also passes through the gland. It is also traversed by the facial nerve and its branches, which emerge at its anterior border; branches of the great auricular nerve pierce the gland to join the facial, and the auriculo-temporal branch of the inferior maxillary nerve emerges from the upper part of the gland. The internal carotid artery and internal jugular vein lie close to its deep surface.

The **duct of the parotid gland** (*Stenson's*) is about two inches and a half in length. It commences by numerous branches from the anterior part of the gland, crosses the Masseter muscle, and at its anterior border dips down into the substance of the Buccinator muscle, which it pierces; it then runs for a short distance obliquely forward between the Buccinator and mucous membrane of the mouth, and opens upon the inner surface of the cheek by a small orifice opposite the second molar tooth of the upper jaw. While crossing the Masseter it receives the duct of a small detached portion of the gland, *socia parotidis*, which occasionally exists as a separate lobe, just beneath the zygomatic arch. In this position it has the transverse facial artery above it and some branches of the facial nerve below it.

Structure.—The parotid duct is dense, of considerable thickness, and its canal about the size of a crowquill, but at its orifice on the inner aspect of the cheek its lumen is greatly reduced in size; it consists of an external or fibrous coat, of considerable density, containing contractile fibres, and of an internal or mucous coat lined with short columnar epithelium.

Surface Form.—The direction of the duct corresponds to a line drawn across the face about a finger's breadth below the zygoma; that is, from the lower margin of the concha to midway between the free margin of the upper lip and the ala of the nose.

Vessels and Nerves.—The *arteries* supplying the parotid gland are derived from the external carotid, and from the branches given off by that vessel in or near its substance. The *veins* empty themselves into the external jugular through some of its tributaries. The *lymphatics* terminate in the superficial and deep cervical

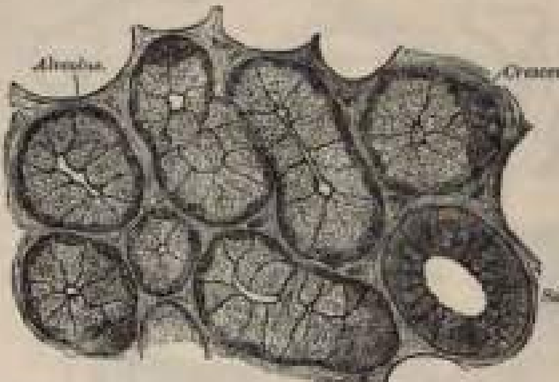


FIG. 494.—A highly magnified section of the submaxillary gland of the dog, stained with carmine. (Kölliker.)

glands, passing in their course through two or three lymphatic glands placed on the surface and in the substance of the parotid. The *nerves* are derived from the plexus of the sympathetic on the external carotid artery, the facial, the auriculo-temporal, and great auricular nerves.

It is probable that the branch from the auriculo-temporal nerve is derived from the glosso-pharyngeal through the otic ganglion (which see). At all events, in some of the lower animals this has been proved experimentally to be the case.

The **submaxillary gland** is situated below the jaw, in the anterior part of the submaxillary triangle of the neck. It is irregular in form and weighs about two drachms (8–10 grammes). It is covered by the integument, Platysma, deep cervical fascia, and the body of the lower jaw, corresponding to a depression on the inner surface of the bone, and lies upon the Mylo-hyoid, Hyo-glossus, and Stylo-glossus muscles, a portion of the gland passing beneath the posterior border of the Mylo-hyoid. In front of it is the anterior belly of the Digastric; behind, it is separated from the parotid gland by the stylo-maxillary ligament, and from the sublingual gland in front by the Mylo-hyoid muscle. The facial artery lies imbedded in a groove in its posterior and upper border.

The **duct of the submaxillary gland** (*Wharton's*) is about two inches in length, and its walls are much thinner than those of the parotid duct. It commences by numerous branches from the deep portion of the gland which lies on the upper surface of the Mylo-hyoid muscle, and passes forward and inward between the Mylo-hyoid and the Hyo-glossus and Genio-hyo-glossus muscles, then between the sublingual gland and the Genio-hyo-glossus, and opens by a narrow orifice on the summit of a small papilla at the side of the frænum linguæ. On the Hyo-glossus muscle it lies between the lingual and hypoglossal nerves, but at the anterior border of the muscle it crosses under the lingual nerve, and is then placed above it.

Vessels and Nerves.—The *arteries* supplying the submaxillary gland are branches of the facial and lingual. Its *veins* follow the course of the arteries. The *nerves* are derived from the submaxillary ganglion, through which it receives filaments from the chorda tympani of the facial and lingual branch of the inferior maxillary, sometimes from the mylo-hyoid branch of the inferior dental, and from the sympathetic.

The **sublingual gland** is the smallest of the salivary glands. It is situated beneath the mucous membrane of the floor of the mouth, at the side of the frænum linguæ, in contact with the inner surface of the lower jaw, close to the symphysis. It is narrow, flattened, in shape somewhat like an almond, and weighs about a drachm. It is in relation, *above*, with the mucous membrane; *below*, with the Mylo-hyoid muscle; *in front*, with the depression on the side of the symphysis of the lower jaw, and with its fellow of the opposite side; *behind*, with the deep part of the submaxillary gland; and *internally*, with the Genio-hyo-glossus, from which it is separated by the lingual nerve and Wharton's duct. Its excretory ducts (*ducts of Rivinus*), from eight to twenty in number; some join Wharton's duct; others open separately into the mouth, on the elevated crest of mucous membrane caused by the projection of the gland, on either side of the frænum linguæ. One or more join to form a tube which opens into the Whartonian duct; this is called the *duct of Bartholin*.

Vessels and Nerves.—The sublingual gland is supplied with blood from the sublingual and submental arteries. Its nerves are derived from the lingual.

Structure of Salivary Glands.—The salivary are compound racemose glands, consisting of numerous lobes, which are made up of smaller lobules connected together by dense areolar tissue, vessels, and ducts. Each lobule consists of the ramifications of a single duct, "branching frequently in a tree-like manner," the branches terminating in dilated ends or alveoli, on which the capillaries are distributed. These alveoli, however, as Pflüger points out, are not necessarily spherical, though sometimes they assume that form; sometimes they are perfectly cylindrical, and very often they are mutually compressed. The alveoli are enclosed by a basement membrane which is continuous with the membrana propria of the duct. It presents a peculiar reticulated structure, having the appearance of a basket with open meshes, and consisting of a network of branched and flattened nucleated cells.

The alveoli of the salivary glands are of two kinds, which differ both in the appearance of their secreting cells, in their size, and in the nature of their secretion. The one variety secretes a ropy fluid which contains mucin, and has therefore been named the *mucous*, whilst the other secretes a thinner and more watery fluid, which contains serum-albumin, and has been named *serous* or *albuminous*. The sublingual gland may be regarded as an example of the former variety, the parotid of the latter. The submaxillary is of the mixed variety, containing both mucous and serous alveoli, the latter, however, preponderating.

Both alveoli are lined by cells, and it is by the character of these cells that the nature of the gland is chiefly to be determined. In addition, however, the alveoli of the serous glands are smaller than those of the mucous ones.

The **cells in the mucous alveoli** are spheroidal in shape, glassy, transparent, and dimly striated in appearance. The nucleus is usually situated in the part of the cell which is next the basement membrane, against which it is sometimes flattened. The most remarkable peculiarity presented by these cells is, that they give off an extremely fine process, which is curved in a direction parallel to the surface of the alveolus, lies in contact with the membrana propria, and overlaps the process of neighboring cells. The cells contain a quantity of mucin, to which their clear, transparent appearance is due.

Here and there in the alveoli are seen peculiar half-moon-shaped bodies lying between the cells and the membrana propria of the alveolus. They are termed the *crescents of Gianuzzi* or the *demilunes of Heidenhain* (Fig. 484), and are composed of polyhedral granular cells, which Heidenhain regards as young epithelial cells destined to supply the place of those salivary cells which have undergone disintegration. This view, however, is not accepted by Klein.

Serous Alveoli.—In the serous alveoli the cells almost completely fill the cavity, so that there is hardly any lumen perceptible. Instead of presenting the clear, transparent appearance of the cells of the mucous alveoli, they present a granular appearance, due to distinct granules of an albuminous nature imbedded in a closely reticulated protoplasm. The ducts which originate out of the alveoli are lined at their commencement by epithelium which differs little from the pavement type. As the ducts enlarge, the epithelial cells change to the columnar type, and the part of the cell next the basement-membrane is finely striated. The lobules of the salivary glands are richly supplied with blood-vessels which form a dense network in the interalveolar spaces. Fine plexuses of nerves are also found in the interlobular tissue. The nerve-fibrils pierce the basement-membrane of the alveoli, and end in branched varicose filaments between the secreting cells. There is no doubt that ganglia are to be found in some salivary glands in connection with the nerve-plexuses in the interlobular tissue; they are to be found in the submaxillary, but not in the parotid.

In the submaxillary and sublingual glands the lobes are larger and more loosely united than in the parotid.

Mucous Glands.—Besides the salivary glands proper, numerous other glands are found in the mouth. They appear to secrete mucus only, which serves to keep the mouth moist during the intervals of the salivary secretion, and which is mixed with that secretion in swallowing. Many of these glands are found at the posterior part of the dorsum of the tongue, behind the circumvallate papillæ, and also along its margins as far forward as the apex.[1] Others lie around and in the tonsil between its crypts, and a large number are present in the soft palate. These glands are of the ordinary compound racemose type.

Surface Form.—The orifice of the mouth is bounded by the lips, two thick, fleshy folds covered externally by integument and internally by mucous membrane, and consisting of muscles, vessels, nerves, areolar tissue, and numerous small glands. The size of the orifice of the mouth varies considerably in different individuals, but seems to bear a close relation to the size and prominence of the teeth. Its corners correspond pretty accurately to the outer border of the canine teeth. In the Mongolian tribes, where the front teeth are large and inclined forward, the mouth is large; and this, combined with the thick and everted lips which appear to be associated with prominent teeth, gives to the negro's face much of the peculiarity by which it is characterized. The smaller teeth and the slighter prominence of the alveolar arch of the more highly civilized races render the orifice of the mouth much smaller, and thus a small mouth is an indication of intelligence, and is regarded as an evidence of the higher civilization of the individual.

Upon looking into the mouth, the first thing we may note is the tongue, the upper surface of which will be seen occupying the floor of the cavity. This surface is convex, and is marked along the middle line by a raphe which divides it into two symmetrical portions. The anterior two-thirds is rough and studded with papillæ; the posterior third smooth and tuberculated, covered by numerous glands which project from the surface. Upon raising the tongue the mucous membrane which invests the upper surface may be traced covering the sides of the under surface, and then reflected over the floor of the mouth on to the inner surface of the lower jaw, a part of which it covers. As it passes over the borders of the tongue it changes its character, becoming thin and smooth and losing the papillæ which are to be seen on the upper surface. In the middle line the mucous membrane on the under surface of the tip of the tongue forms a distinct fold, the *frænum linguæ*, by which this organ is connected to the symphysis of the jaw. Occasionally it is found that this frænum is rather shorter than natural, and, acting as a bridle, prevents the complete protrusion of the tongue. When this condition exists and an attempt is made to protrude the organ, the tip will be seen to remain buried in the floor of the mouth, and the dorsum of the tongue is rendered very convex, and more or

[1] It has been shown by Ebner that many of these glands open into the trenches around the circumvallate papillæ, and that their secretion is more watery than that of ordinary mucous glands. He supposes that they assist in the more rapid distribution of the substance to be tasted over the region where the special apparatus of the sense of taste is situated.

less extruded from the mouth; at the same time a deep furrow will be noticed to appear in the middle line of the anterior part of the dorsum. Sometimes, a little external to the frenum, the ranine vein may be seen immediately beneath the mucous membrane. The corresponding artery, being more deeply placed, does not come into view, nor can its pulsation be felt with the finger. On either side of the frenum, in the floor of the mouth, is a longitudinal elevation or ridge, produced by the projection of the sublingual gland, which lies immediately beneath the mucous membrane. And close to the attachment of the frenum to the tip of the tongue may be seen on either side the slit-like orifices of Wharton's ducts, into which a fine probe may be passed without much difficulty. By everting the lips the smooth mucous membrane lining them may be examined, and may be traced from them on to the outer surface of the alveolar arch. In the middle line, both of the upper and lower lip, a small fold of mucous membrane passes from the lip to the bone, constituting the *frena;* these are not so large as the frenum linguæ. By pulling outward the angle of the mouth, the mucous membrane lining the cheeks can be seen, and on it may be perceived a little papilla which marks the position of the orifice of Stenson's duct—the duct of the parotid gland. The exact position of the orifice of the duct will be found to be opposite the second molar tooth of the upper jaw. The introduction of a probe into this duct is attended with considerable difficulty. The teeth are the next objects which claim our attention upon looking into the mouth. There are, as stated above, ten in either jaw in the temporary set, and sixteen in the permanent set. The gums, in which they are implanted, are dense, firm, and vascular.

At the back of the mouth is seen the *isthmus of the fauces,* or, as it is popularly called, "the throat:" this is the space between the pillars of the fauces on either side, and is the means by which the mouth communicates with the pharynx. Above, it is bounded by the soft palate, the anterior surface of which is concave and covered with mucous membrane, which is continuous with that lining the roof of the mouth. Projecting downward from the middle of its lower border is a conical-shaped projection, the *uvula.* On either side of the isthmus of the fauces are the anterior and posterior pillars, formed by the Palato-glossus and Palato-pharyngeus muscles respectively, covered over by mucous membrane. Between the two pillars on either side is situated the tonsil. The extirpation of this body is not unattended with danger of hemorrhage. Dr. Weir has stated that he believes that when hemorrhage occurs after their removal it arises from one of the palatine arteries having been wounded. These vessels are large; they lie in the muscular tissue of the palate, and when wounded are constantly exposed to disturbance from the contraction of the palatine muscles. The vessels of the tonsil, Dr. Weir states, are small and lie in the soft tissue, and readily contract when wounded.

When the mouth is wide open a prominent tense fold of mucous membrane may be seen and felt, extending upward and backward from the position of the fang of the last molar tooth to the posterior part of the hard palate. This is caused by the Pterygo-maxillary ligament, which is attached by one extremity to the apex of the internal pterygoid plate, and by the other to the posterior extremity of the mylo-hyoid ridge of the lower jaw. It connects the Buccinator with the Superior constrictor of the pharynx. The fang of the last molar tooth indicates the position of the lingual (gustatory) nerve, where it is easily accessible, and can with readiness be divided in cases of cancer of the tongue (see page 735). On the inner side of the last molar tooth we can feel the hamular process of the internal pterygoid plate of the sphenoid bone, around which the tendon of the Tensor palati plays. The exact position of this process is of importance in performing the operation of staphylorraphy. About one-third of an inch in front of the hamular process, and the same distance directly inward from the last molar tooth, is the situation of the opening of the posterior palatine canal, through which emerges the posterior or descending palatine branch of the internal maxillary artery and one of the descending palatine nerves from Meckel's ganglion. The exact position of the opening on the subject may be ascertained by driving a needle through the tissues of the palate in this situation, when it will be at once felt to enter the canal. The artery emerging from the opening runs forward in a groove in the bone just internal to the alveolar border of the hard palate, and may be wounded in the operation for the cure of cleft palate. Under these circumstances the palatine canal may require plugging. By introducing the finger into the mouth the anterior border of the coronoid process of the jaw can be felt, and is especially prominent when the jaw is dislocated. By throwing the head well back a considerable portion of the posterior wall of the pharynx may be seen through the isthmus faucium, and on introducing the finger the anterior surface of the bodies of the upper cervical vertebræ may be felt immediately beneath the thin muscular stratum forming the wall of the pharynx. The finger can be hooked around the posterior border of the soft palate, and by turning it forward the posterior nares, separated by the septum, can be felt, or the presence of any adenoid or other growths in the naso-pharynx ascertained.

THE PHARYNX.

The **pharynx** is that part of the alimentary canal which is placed behind the nose, mouth, and larynx. It is a musculo-membranous tube, somewhat conical in form, with the base upward and the apex downward, extending from the under surface of the skull to the level of the cricoid cartilage in front and that of the intervertebral disk between the fifth and sixth cervical vertebræ behind.

The pharynx is about four inches and a half in length, and broader in the transverse than in the antero-posterior diameter. Its greatest breadth is opposite the cornua of the hyoid bone; its narrowest point, at its termination in the œsophagus. It is limited, *above*, by the body of the sphenoid and basilar process of the occipital bone; *below*, it is continuous with the œsophagus; *posteriorly*, it is connected by loose areolar tissue with the cervical portion of the vertebral column and the Longi colli and Recti capitis antici muscles; *anteriorly*, it is incomplete, and is attached in succession to the internal pterygoid plate, the pterygo-maxillary ligament, the lower jaw, the tongue, hyoid bone, and thyroid and cricoid cartilages; *laterally*, it is connected to the styloid processes and their muscles, and is in contact with the common and internal carotid arteries, the internal jugular veins, and the glosso-pharyngeal, pneumogastric, hypoglossal, and sympathetic nerves, and above with a small part of the Internal pterygoid muscles.

It has seven openings communicating with it—the two posterior nares, the two Eustachian tubes, the mouth, larynx, and œsophagus.

The pharynx may be subdivided from above downward into three parts, nasal, oral, and laryngeal. The nasal part of the pharynx (*pars nasalis*) or naso-pharynx lies behind the nose and above the level of the soft palate: it differs from the two lower parts of the tube in that its cavity always remains patent. In front it communicates through the choanæ with the nasal fossæ. On its lateral wall is the pharyngeal orifice of the Eustachian tube, which presents the appearance of a vertical cleft bounded behind by a firm prominence, the *cushion*, caused by the inner extremity of the cartilage of the tube impinging on the deep surface of the mucous membrane. A vertical fold of mucous membrane, the *plica salpingo-pharyngea*, stretches from the lower part of the cushion to the pharynx; it contains the Salpingo-pharyngeus muscle. A second and smaller mucous fold may be seen stretching from the upper part of the cushion to the palate, the *plica salpingo-palatina*. Behind the orifice of the Eustachian tube is a deep recess, the *fossa of Rosenmüller*, which represents the remains of the upper part of the second branchial cleft.

The oral part of the pharynx (*pars oralis*) reaches from the soft palate to the level of the hyoid bone. It opens anteriorly, through the isthmus faucium, into the mouth, while in its lateral wall, between the two pillars of the fauces, is the tonsil.

The laryngeal part of the pharynx (*pars laryngea*) reaches from the hyoid bone to the lower border of the cricoid cartilage, where it is continuous with the œsophagus. In front it presents the triangular aperture of the larynx, the base of which is directed forward and is formed by the epiglottis, while its lateral boundaries are constituted by the aryteno-epiglottidean folds. On either side of the laryngeal orifice is a recess, termed the *sinus pyriformis*; it is bounded internally by the aryteno-epiglottidean fold, externally by the thyroid cartilage and thyro-hyoid membrane.

Structure.—The pharynx is composed of three coats—mucous, fibrous, and muscular.

The *pharyngeal aponeurosis*, or *fibrous coat*, is situated between the mucous and muscular layers. It is thick above, where the muscular fibres are wanting, and is firmly connected to the basilar process of the occipital and petrous portion of the temporal bones. As it descends it diminishes in thickness, and is gradually lost. It is strengthened posteriorly by a strong fibrous band which is attached above to the pharyngeal spine on the under surface of the basilar portion of the occipital bone, and passes downward, forming a median raphe, which gives attachment to the Constrictor muscles of the pharynx.

The *mucous coat* is continuous with that lining the Eustachian tubes, the nares, the mouth and the larynx. In the naso-pharynx it is covered by columnar ciliated epithelium; in the buccal and laryngeal portions the epithelium is of the squamous variety. Beneath the mucous membrane are found racemose mucous glands; they are especially numerous at the upper part of the pharynx around the orifices of the Eustachian tubes. Throughout the pharynx are also numerous crypts or recesses, the walls of which are surrounded by lymphoid tissue similar to what is found in the tonsils. Across the back part of the pharyngeal cavity, between the two Eustachian tubes, a considerable mass of this tissue exists, and has been named the *pharyngeal tonsil*. Above this in the middle line is an irregular, flask-shaped depression of the mucous membrane, extending up as far as the basilar process of the occipital bone. It is known as the *bursa pharyngea*, and was regarded by Luschka as the remains of the diverticulum, which is concerned in the development of the anterior lobe of the pituitary body. Other anatomists believe that it is connected with the formation of the pharyngeal tonsils.

The *muscular coat* has been already described (page 328).

Surgical Anatomy.—The internal carotid artery is in close relation with the pharynx, so that its pulsations can be felt through the mouth. It has been occasionally wounded by sharp-pointed instruments introduced into the mouth and thrust through the wall of the pharynx. In aneurism of this vessel in the neck the tumor necessarily bulges into the pharynx, as this is the direction in which it meets with the least resistance, nothing lying between the vessel and the mucous membrane except the thin Constrictor muscle, whereas on the outer side there is the dense cervical fascia, the muscles descending from the styloid process, and the margin of the Sterno-mastoid.

The mucous membrane of the pharynx is very vascular, and is often the seat of inflammation, frequently of a septic character, and dangerous on account of its tendency to spread to the larynx. On account of the tissue which surrounds the pharyngeal wall being loose and lax, the inflammation is liable to spread through it far and wide, extending downward into the posterior mediastinum along the œsophagus. Abscess may form in the connective tissue behind the pharynx, between it and the vertebral column, constituting what is known as retro-pharyngeal abscess. This is most commonly due to caries of the cervical vertebræ, but may also be caused by suppuration of a lymphatic gland which is situated in this position opposite the axis, and which receives lymphatics from the nares, or by a gumma or by acute pharyngitis. In these cases the pus may be easily evacuated by an incision, with a guarded bistoury, through the mouth, but, for aseptic reasons, it is desirable that the abscess should be opened from the neck. In some instances this is perfectly easy; the abscess can be felt bulging at the side of the neck and merely requires an incision for its relief, but this is not always so, and then an incision should be made along the posterior border of the Sterno-mastoid and the deep fascia divided. A director is now to be inserted into the wound, the forefinger of the left hand being introduced into the mouth and pressure made upon the swelling. This acts as a guide, and the director is to be pushed onward until pus appears in the groove. A pair of sinus forceps are now inserted along the director and the opening into the cavity dilated.

Foreign bodies not infrequently become lodged in the pharynx, and most usually at its termination at about the level of the cricoid cartilage, just beyond the reach of the finger, as the distance from the arch of the teeth to the commencement of the œsophagus is about six inches.

THE ŒSOPHAGUS.

The **œsophagus**, or **gullet**, is a muscular canal, about nine inches in length, extending from the pharynx to the stomach. It commences at the upper border of the cricoid cartilage, opposite the intervertebral disk between the fifth and sixth cervical vertebræ, descends along the front of the spine through the posterior mediastinum, passes through the Diaphragm, and, entering the abdomen, terminates at the cardiac orifice of the stomach opposite the tenth dorsal vertebra or the intervertebral disk between the tenth and eleventh dorsal vertebræ. The general direction of the œsophagus is vertical, but it presents two or three slight curves in its course. At its commencement it is placed in the median line, but it inclines to the left side as far as the root of the neck, gradually passes to the middle line again, and finally again deviates to the left as it passes forward to the œsophageal opening of the Diaphragm. The œsophagus also presents an antero-posterior flexure, corresponding to the curvature of the cervical and thoracic portions of the spine. It is the narrowest part of the alimentary canal, being most contracted at its commencement and at the point where it passes through the Diaphragm.

Relations.—*In the neck* the œsophagus is in relation, *in front*, with the trachea, and at the lower part of the neck, where it projects to the left side, with the thyroid gland and thoracic duct; *behind*, it rests upon the vertebral column and Longi colli muscles; *on each side*, it is in relation with the common carotid artery (especially the left, as it inclines to that side) and part of the lateral lobes of the thyroid gland; the recurrent laryngeal nerves ascend between it and the trachea.

In the thorax, it is at first situated a little to the left of the median line; it then passes behind the aortic arch, separated from it by the trachea, and descends in the posterior mediastinum, along the right side of the aorta, nearly to the Diaphragm, where it passes in front and a little to the left of the artery, previous to entering the abdomen. It is in relation, *in front*, with the trachea, the arch of the aorta, the left carotid and left subclavian arteries, which incline toward its left side, the left bronchus, the pericardium, and the Diaphragm; *behind*, it rests upon the vertebral column, the Longi colli muscles, the right intercostal arteries, and the vena azygos minor; and below, near the Diaphragm, upon the front of the aorta; *laterally*, it comes in contact with both pleuræ, especially with the left pleura above and the right pleura below: it overlaps the vena azygos major, which lies on its right side, while the descending aorta is placed on its left side. The pneumogastric nerves descend in close contact with it, the right nerve passing down behind, and the left nerve in front of it; the two nerves uniting to form a plexus (the *plexus gulæ*) around the tube.

In the lower part of the posterior mediastinum the thoracic duct lies to the right side of the œsophagus; higher up, it is placed behind it, and, crossing about the level of the fourth dorsal vertebra, is continued upward on its left side.

Structure.—The œsophagus has three coats—an external or muscular; a middle or areolar; and an internal or mucous coat.

The *muscular coat* is composed of two planes of fibres of considerable thickness, an external longitudinal and an internal circular.

The *longitudinal fibres* are arranged, at the commencement of the tube, in three fasciculi: one in front, which is attached to the vertical ridge on the posterior surface of the cricoid cartilage; and one at each side, which is continuous with the fibres of the Inferior constrictor: as they descend they blend together and form a uniform layer, which covers the outer surface of the tube.

Accessory slips of muscular fibres are described by Cunningham as passing between the œsophagus and the left pleura, where it covers the thoracic aorta (almost always), or the root of the left bronchus (usually), or the back of the pericardium, as well as other still more rare accessory fibres. In Fig. 485, taken from a dissection in the Museum of the Royal College of Surgeons of England, several of these accessory slips may be seen passing from the œsophagus to the pleura, and two slips to the back of the trachea just above its bifurcation.

The *circular fibres* are continuous above with the Inferior constrictor; their direction is transverse at the upper and lower parts of the tube, but oblique in the central part.

The muscular fibres in the upper part of the œsophagus are of a red color, and consist chiefly of the striped variety, but below they consist for the most part of involuntary muscular fibre.

The *areolar coat* connects loosely the mucous and muscular coats.

The *mucous coat* is thick, of a reddish color above and pale below. It is disposed in longitudinal folds, which disappear on distension of the tube. Its surface is studded with minute papillæ, and it is covered throughout with a thick layer of stratified pavement epithelium. Beneath the mucous membrane, between it and the areolar coat, is a layer of longitudinally arranged non-striped muscular fibres. This is the *muscularis mucosæ*. At the commencement it is absent, or only represented by a few scattered bundles; lower down it forms a considerable stratum.

The *œsophageal glands* are numerous small compound racemose glands scattered throughout the tube; they are lodged in the submucous tissue, and open upon the surface by a long excretory duct. They are most numerous at the lower part of the tube, where they form a ring round the cardiac orifice.

Vessels of the Œsophagus.—The arteries supplying the œsophagus are derived from the inferior thyroid branch of the thyroid axis of the subclavian, from the descending thoracic aorta, and from the gastric branch of the cœliac axis, and from the left inferior phrenic of the abdominal aorta. They have for the most part a longitudinal direction.

Nerves of the Œsophagus.—The nerves are derived from the pneumogastric and from the sympathetic; they form a plexus in which are groups of ganglion-cells between the two layers of the muscular coats, and also a second plexus in the submucous tissue.

Surgical Anatomy.—The relations of the œsophagus are of considerable practical interest to the surgeon, as he is frequently required, in cases of stricture of this tube, to dilate the canal by a bougie, when it is of importance that the direction of the œsophagus and its relations to surrounding parts should be remembered. In cases of malignant disease of the œsophagus, where its tissues have become softened from infiltration of the morbid deposit, the greatest care is requisite in directing the bougie through the strictured part, as a false passage may easily be made, and the instrument may pass into the mediastinum, or into one or the other pleural cavity, or even into the pericardium.

The student should also remember that obstruction of the œsophagus, and consequent symptoms of stricture, are occasionally produced by an aneurism of some part of the aorta pressing upon this tube. In such a case the passage of a bougie could only hasten the fatal issue.

In passing a bougie the left fore finger should be introduced into the mouth and the epiglottis felt for, care being taken not to throw the head too far backward. The bougie is then to be passed beyond the finger until it touches the posterior wall of the pharynx. The patient is now asked to swallow, and at the moment of swallowing the bougie is passed gently onward, all violence being carefully avoided.

It occasionally happens that a foreign body becomes impacted in the œsophagus which can neither be brought upward nor moved downward. When all ordinary means for its removal have failed, excision is the only resource. This, of course, can only be performed when it is not very low down. If the foreign body is allowed to remain, extensive inflammation and ulceration of the œsophagus may ensue. In one case the foreign body ultimately penetrated the intervertebral substance, and destroyed life by inflammation of the membranes and substance of the cord.

The operation of œsophagotomy is thus performed: The patient being placed upon his back, with the head and shoulders slightly elevated, an incision, about four inches in length, should be made on the left side of the trachea, from the thyroid cartilage downward, dividing the skin, Platysma, and deep fascia. The edges of the wound being separated, the Omo-hyoid muscle should, if necessary, be divided, and the fibres of the Sterno-hyoid and Sterno-thyroid muscles drawn inward; the sheath of the carotid vessels, being exposed, must be drawn outward, and retained in that position by retractors: the œsophagus will now be exposed, and should be divided over the foreign body, which can then be removed. Great care is necessary to avoid wounding the thyroid vessels, the thyroid gland, and the laryngeal nerves.

FIG. 485.—Accessory muscular fibres between the œsophagus and pleura, and œsophagus and trachea. [From a preparation in the Museum of the Royal College of Surgeons of England.]

The œsophagus may be obstructed not only by foreign bodies, but also by changes in its coats, producing stricture, or by pressure on it from without of new growths or aneurism, etc.

The different forms of stricture are: (1) the spasmodic, usually occurring in nervous women, and intermittent in character, so that the dysphagia is not constant; (2) fibrous, due to cicatrization after injuries, such as swallowing corrosive fluids or boiling water; and (3) malignant, usually epitheliomatous in its nature. This is situated generally either at the upper end of the tube, opposite to the cricoid cartilage, or at its lower end at the cardiac orifice, but is also occasionally found at that part of the tube where it is crossed by the left bronchus.

The operation of œsophagostomy has occasionally been performed in cases where the stricture in the œsophagus is at the upper part, with a view to making a permanent opening below the stricture through which to feed the patient, but the operation has been far from a successful one, and the risk of setting up diffuse inflammation in the loose planes of connective tissue deep in the neck is so great that it would appear to be better, if any operative interference is undertaken, to perform gastrostomy. The operation is performed in the same manner as œsophagotomy, but the edges of the opening in the œsophagus are stitched to the skin incision.

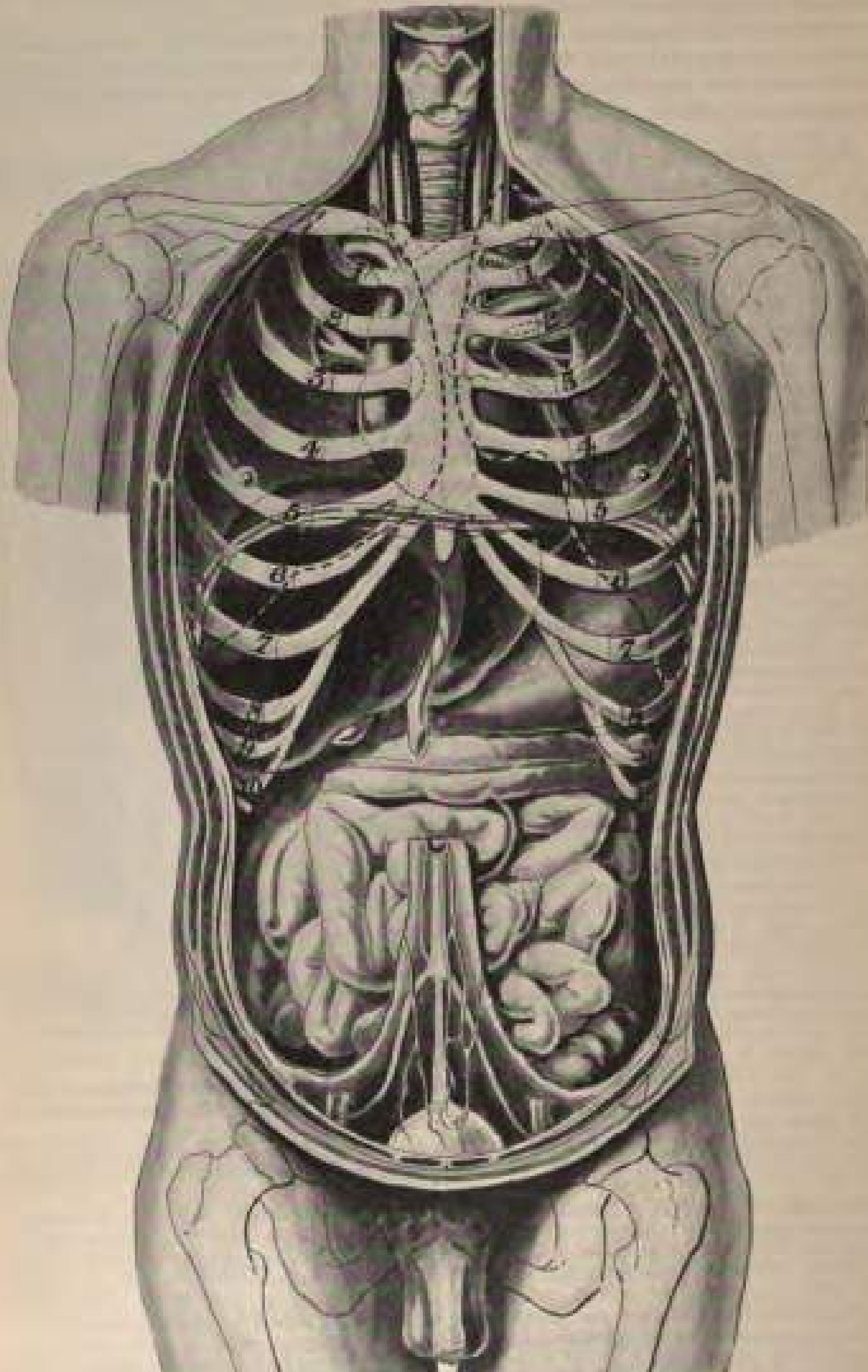


FIG. 486.—Topography of thoracic and abdominal viscera.

THE ABDOMEN.

The **Abdomen** is the largest cavity in the body. It is of an oval form, the extremities of the oval being directed upward and downward: the upper one being formed by the under surface of the Diaphragm, the lower by the upper concave surface of the Levatores ani. In order to facilitate description, it is artificially divided into two parts: an upper and larger part, the *abdomen proper*; and a lower and smaller part, the *pelvis*. These two cavities are not separated from each other, but the limit between them is marked by the brim of the true pelvis. The space is wider above than below, and measures more in the vertical than in the transverse diameter.

The abdomen proper differs from the other great cavities of the body in being bounded for the most part by muscles and fasciæ, so that it can vary in capacity and shape according to the condition of the viscera which it contains; but, in addition to this, the abdomen varies in form and extent with age and sex. In the adult male, with moderate distention of the viscera, it is oval or barrel-shaped, but at the same time flattened from before backward. In the adult female, with a fully developed pelvis, it is conical with the apex above, and in young children it is conical with the apex below.

Boundaries.—The boundary between the thorax and abdomen is the Diaphragm. This muscle forms a dome over the abdomen, and the cavity extends high into the bony thorax, reaching to the level of the junction of the fourth costal cartilage with the sternum. The lower end of the abdomen is limited by the structures which clothe the inner surface of the bony pelvis, principally the Levatores ani and Coccygei muscles on either side. These muscles are sometimes termed the *Diaphragm of the pelvis*. The **abdomen proper** is bounded *in front* and *at the sides* by the lower ribs, the abdominal muscles, and the venter ilii; *behind*, by the vertebral column and the Psoas and Quadratus lumborum muscles; *above*, by the Diaphragm; *below*, by the brim of the pelvis. The muscles forming the boundaries of the cavity are lined upon their inner surface by a layer of fascia, differently named, according to the part which it covers.

The abdomen contains the greater part of the alimentary canal; some of the accessory organs to digestion, viz., the liver and pancreas; the spleen, the kidneys, and suprarenal capsules. Most of these structures, as well as the wall of the cavity in which they are contained, are covered by an extensive and complicated serous membrane, the *peritoneum*.

The *apertures* found in the walls of the abdomen, for the transmission of structures to or from it, are, the *umbilicus*, for the transmission (in the fœtus) of the umbilical vessels; the *caval opening* in the Diaphragm, for the transmission of the inferior vena cava; the *aortic opening*, for the passage of the aorta, vena azygos major, and thoracic duct; and the *œsophageal opening*, for the œsophagus and pneumogastric nerves. *Below*, there are two apertures on each side: one for the passage of the femoral vessels, and the other for the transmission of the spermatic cord in the male, and the round ligament in the female.

Regions.—For convenience of description of the viscera, as well as of reference to the morbid conditions of the contained parts, the abdomen is artificially divided into nine regions. Thus, if two circular lines are drawn round the body, the one through the extremities of the ninth ribs where they join their costal cartilages, and the other through the highest point of the crests of the ilia, the abdominal cavity is divided into three zones—an upper, a middle, and a lower. If two parallel lines are drawn perpendicularly upward from the centre of Poupart's ligament, each of these zones is subdivided into three parts—a middle and two lateral.[1]

[1] Anatomists are far from agreed as to the best method of subdividing the abdominal cavity. Cunningham suggests that the lower line should encircle the body on a level with the highest point of the iliac crest, as seen from the front—a point corresponding with a prominent tubercle on the outer lip of the iliac crest about two inches behind the anterior superior spine. Addison,[1] in a careful analysis of the abdominal viscera in forty subjects, adopts the following lines: (1) a median,

[1] *Journal of Anatomy and Physiology*, vols. xxxiv. and xxxv.

The middle region of the upper zone is called the *epigastric* (ἐπί, *over*; γαστήρ, *the stomach*); and the two lateral regions, the *right* and *left hypochondriac* (ὑπό, *under*; χόνδρος, *the cartilages*). The central region of the middle zone is the *umbilical*; and the two lateral regions, the *right* and *left lumbar*. The middle region of the lower zone is the *hypogastric* or *pubic region*; and the lateral regions are the *right* and *left inguinal* or *iliac*. The viscera contained in these different regions are the following (Fig. 487).

Right Hypochondriac.	*Epigastric Region.*	*Left Hypochondriac.*
The greater part of right lobe of the liver, the hepatic flexure of the colon, and part of the right kidney.	The greater part of the stomach, including both cardiac and pyloric orifices, the left lobe and part of the right lobe of the liver and the gall-bladder, the pancreas, the duodenum, the suprarenal capsules, and parts of the kidneys.	The fundus of the stomach, the spleen and extremity of the pancreas, the splenic flexure of the colon, and part of the left kidney.
Right Lumbar.	*Umbilical Region.*	*Left Lumbar.*
Ascending colon, part of the right kidney, and some convolutions of the small intestines.	The transverse colon, part of the great omentum and mesentery, transverse part of the duodenum, and some convolutions of the jejunum and ileum, and part of both kidneys.	Descending colon, part of the omentum, part of the left kidney, and some convolutions of the small intestines.
Right Inguinal (Iliac).	*Hypogastric Region.*	*Left Inguinal (Iliac).*
The cæcum and vermiform appendix.	Convolutions of the small intestines, the bladder in children, and in adults if distended, and the uterus during pregnancy.	Sigmoid flexure of the colon.

If the anterior abdominal wall is reflected in the form of four triangular flaps by means of vertical and transverse incisions—the former from the ensiform cartilage to the symphysis pubis, the latter from flank to flank at the level of the umbilicus—the abdominal or peritoneal cavity is freely opened into and the contained viscera are in part exposed.[1]

Above and to the right side is the liver, situated chiefly under the shelter of the right ribs and their cartilages, but extending across the middle line, and reaching for some distance below the level of the ensiform cartilage. Below and to the left of the liver is the stomach, from the lower border of which an apron-like fold of peritoneum, the *great omentum*, descends for a varying distance, and obscures, to a greater or lesser extent, the other viscera. Below it, however, some of the coils of the small intestine can generally be seen, while in the right and left iliac regions respectively the *cæcum* and the *sigmoid flexure* of the colon are exposed. The bladder occupies the anterior part of the pelvis, and, if distended, will project

from symphysis pubis to ensiform cartilage; (2) two lateral lines drawn vertically through a point midway between the anterior superior iliac spine and the symphysis pubis; (3) an upper transverse line halfway between the symphysis pubis and the supra-sternal notch; and (4) a lower transverse line midway between the last and the upper border of the symphysis pubis.

[1] It must be borne in mind that, although the term abdominal cavity is used, there is, under normal conditions, only a potential cavity or lymph-space, since the viscera are everywhere in contact with the parietes.

above the symphysis pubis; the rectum lies in the concavity of the sacrum, but is usually obscured by the coils of the small intestine.

If the stomach is followed from left to right it will be found to be continuous with the first part of the small intestine, or *duodenum*, the point of continuity being marked by a thickened ring which indicates the position of the pyloric valve. The duodenum passes toward the under surface of the liver, and then curving downward, is lost to sight. If, however, the great omentum be thrown upward over the chest, the terminal part of the duodenum will be observed passing across the spine toward the left side, where it becomes continuous with the *coils of the small intestine*. These measure some twenty feet in length, and if followed downward will be seen to end in the right iliac fossa by opening into the *cæcum* or commencement of the *large intestine*. From the cæcum the large intestine takes an arched course, passing at first upward on the right side, then across the middle line and downward on the left side, and forming respectively the *ascending, transverse, and descending parts of the colon*. In the left iliac region it makes still another bend, the *sigmoid flexure*, and then follows the curve of the sacrum as the *rectum*.

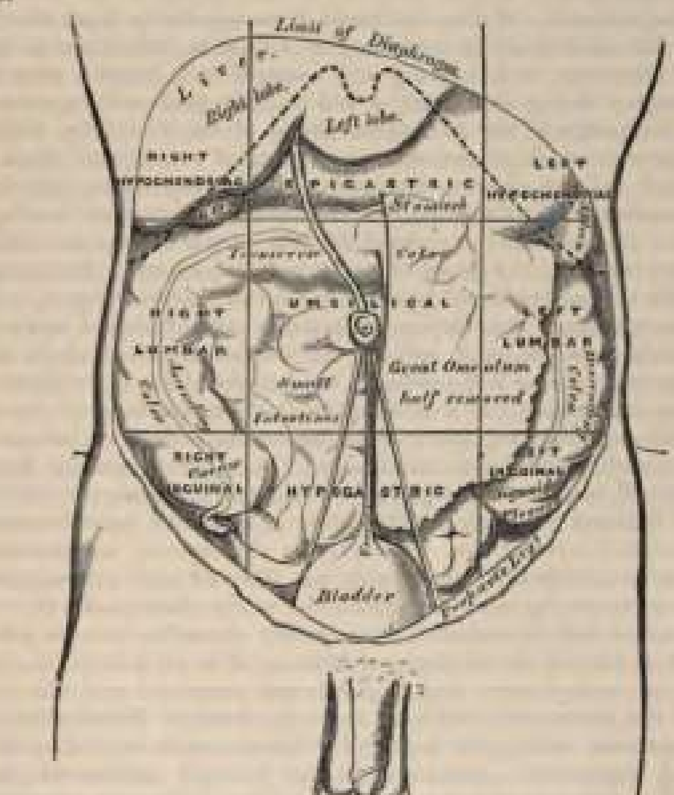


FIG. 487.—The regions of the abdomen and their contents. (Edge of costal cartilages in dotted outline.)

The *spleen* lies behind the stomach in the left hypochondriac region, and may be in part exposed by pulling the stomach over toward the right side.

The glistening appearance of the deep surface of the abdominal wall and of the exposed viscera is due to the fact that the former is lined and the latter more or less completely covered by a serous membrane, the *peritoneum*.

The Peritoneum.

The peritoneum is the largest serous membrane in the body, and consists, in the male, of a closed sac, a part of which is applied against the abdominal parietes, while the remainder is reflected over the contained viscera. In the female the peritoneum is not a closed sac, since the free extremities of the Fallopian tubes open directly into the peritoneal cavity. The former constitutes the *parietal*, the latter the *visceral* part of the peritoneum. The *free surface* of the membrane is smooth, covered by a layer of flattened endothelium, and lubricated by a small quantity of serous fluid. Hence the viscera can glide freely against the wall of the cavity or upon one another with the least possible amount of friction. Its *attached surface* is rough, being connected to the viscera and inner surface of the parietes by means of *areolar tissue* termed the *subserous areolar tissue*. The parietal portion is loosely connected with the fascia lining the abdomen and pelvis, but more closely to the under surface of the Diaphragm and also in the middle line of the abdomen.

The peritoneum differs from the other serous membranes of the body in presenting a much more complex arrangement—an arrangement which can only be clearly understood by following the changes which take place in the alimentary canal during its development; and therefore the student is advised to preface his study of the peritoneum by reviewing the chapter dealing with this subject in the section on Embryology.

To trace the continuity of the membrane from one viscus to another, and from the viscera to the parietes, it is necessary to follow its reflections in the vertical and horizontal directions, and in doing so it matters little where a start is made.

If the stomach is drawn downward, a fold of peritoneum will be seen stretching from its lesser curvature to the transverse fissure of the liver (Fig. 488). This is the *gastro-hepatic* or *small omentum*, and consists of two layers; these, on being traced downward, split to envelop the stomach, covering respectively its anterior and posterior surfaces. At the greater curvature of the stomach they again come into contact and are continued downward in front of the transverse colon, forming the anterior two layers of the *great* or *gastro-colic* omentum. Reaching the free edge of this fold they are reflected upward as its two posterior layers, and thus the great omentum consists of four layers of peritoneum. Followed upward the two posterior layers separate so as to enclose the transverse colon, above which they once more come into contact and pass backward to the abdominal wall as the *transverse mesocolon*. Reaching the abdominal wall about the level of the transverse part of the duodenum, the two layers of the transverse mesocolon become separated from each other and take different directions; the upper or anterior layer ascends (ascending layer of transverse mesocolon) in front of the pancreas, and its further course will be followed presently. The lower or posterior layer is carried downward, as the anterior layer of the *mesentery*, by the superior mesenteric vessels to the small intestine, around which it may be followed and subsequently traced upward as the posterior layer of the mesentery to the abdominal wall. From the posterior abdominal wall it sweeps downward over the aorta into the pelvis, where it invests the first part of the rectum and attaches it to the front of the sacrum by a fold termed the *mesorectum*. Leaving first the sides and then the front of the second part of the rectum it is reflected on to the back of the bladder, and, after covering the posterior and upper aspects of this viscus, is carried by the urachus and obliterated hypogastric arteries on to the posterior surface of the anterior abdominal wall. Between the rectum and bladder it forms a pouch, the *recto-vesical pouch*, bounded on each side by a crescentic or *semilunar fold*; the bottom of this pouch is about on a level with the middle of the vesiculæ seminales—*i. e.*, three inches or so from the orifice of the anus. When the bladder is distended the peritoneum is carried up with the expanded viscus, so that a considerable part of the anterior surface of the latter lies directly against the abdominal wall without the intervention of the peritoneal membrane.

In the female the peritoneum is reflected from the rectum on to the upper part of the posterior vaginal wall, forming the *recto-vaginal pouch* or *pouch of Douglas*. It is then carried over the posterior aspect and fundus of the uterus on to its anterior surface, which it covers as far as the junction of the body and cervix uteri, forming here a second but shallower depression, the *utero-vesical pouch*. It is also reflected from the sides of the uterus to the lateral walls of the pelvis as two expanded folds, the *broad ligaments of the uterus*, in the free margin of each of which can be felt a thickened cord-like structure, the *Fallopian tube*.

On following the parietal peritoneum upward on the back of the anterior abdominal wall it is seen to be reflected around a fibrous band, the *ligamentum teres* or *obliterated umbilical vein*, which reaches from the umbilicus to the under surface of the liver. Here the membrane forms a somewhat triangular fold, the *falciform* or *suspensory ligament* of the liver, which attaches the upper and anterior surfaces of that organ to the Diaphragm and abdominal wall. With the exception of the line of attachment of this ligament the periteneum covers the under surface of the anterior part of the Diaphragm and is reflected from it on to the upper surface of the liver as the *anterior* or *superior layer of the coronary ligament*. Covering the upper and anterior surfaces of the liver it is reflected round its sharp margin on to its under surface as far as the transverse fissure, where it is continuous with the anterior layer of the small omentum from which a start was made. The posterior layer of this omentum is carried backward from the transverse fissure over the under surface and Spigelian lobe of the liver, and is then reflected, as the *posterior* or *inferior layer of the coronary ligament*, on to the Diaphragm and is prolonged downward over the pancreas to become continuous with the ascending layer of the transverse mesocolon. Between the two layers of the coronary ligament there is a triangular surface of the liver which is devoid of peritoneum; it is named the *bare area* of the liver, and is attached to the Diaphragm by connective tissue. If, however, the two layers of the coronary ligaments are traced toward the right and left margins of the liver, they approach each other, and, ultimately fusing, they form the right and left lateral ligaments of the liver and attach its right and left lobes respectively to the Diaphragm.

If the small omentum is followed toward the right side it is seen to form a distinct free edge around which its anterior and posterior layers are continuous with each other and between which are situated the portal vein, hepatic artery, and bile-duct. If the finger is introduced behind this free edge, it passes through a somewhat constricted ring, the *foramen of Winslow*. This is the communication between what are termed the greater and lesser sacs of the peritoneum and has the following boundaries: in front, the free edge of the gastro-hepatic omentum with the portal vein, hepatic artery, and bile-duct between its two layers; behind, the vena cava inferior; above, the Spigelian and caudate lobes of the liver; below, the duodenum and the hepatic artery, as the latter passes forward and upward from the cœliac axis.

The *lesser sac of the peritoneum* therefore lies behind the small omentum and has the following dimensions: above, it is limited by the portion of the liver which lies behind the transverse fissure; below, it extends downward into the great omentum, reaching, in the fœtus, as far as its free edge; in the adult, however, its vertical extent is limited by adhesions between the layers of the omentum. In front, it is bounded by the small omentum, stomach, and anterior two layers of the great omentum; behind, by the two posterior layers of the great omentum, the transverse colon, and ascending layer of the transverse mesocolon which passes upward in front of the pancreas as far as the posterior surface of the liver. Laterally the lesser sac reaches from the foramen of Winslow on the right side as far as the spleen on the left, where it is limited by the lieno-renal ligament. The extent of the lesser sac and its relations to surrounding parts can be definitely made out by tearing through the small omentum and inserting the hand through the opening thus made.

It should be stated that during a considerable part of fœtal life the transverse colon is suspended from the posterior abdominal wall by a mesentery of its own—the two posterior layers of the great omentum passing, at this stage, in front of the colon. This condition sometimes persists throughout adult life, but as a rule adhesion occurs between the mesentery and the transverse colon and the posterior layer of the great omentum, with the result that the colon appears to receive its peritoneal covering by the splitting of the two posterior layers of the latter fold.

In addition to tracing the peritoneum vertically, it is necessary to trace it horizontally. If this is done below the transverse colon, the circle is extremely simple, as it includes only the greater sac of the peritoneum (Fig. 488). Above the level of the transverse colon the arrangement is more complicated, on account of the existence of the two sacs.

Starting from the linea alba, below the level of the transverse colon, and tracing the continuity in a horizontal direction to the right, the peritoneum covers the internal surface of the abdominal wall almost as far as the anterior border of the Quadratus lumborum muscle; it encloses the cæcum, and is reflected over the sides and anterior surface of the ascending colon, fixing it to the abdominal wall, from which it can be traced over the kidney to the front of the bodies of the vertebræ. It then passes along the mesenteric vessels to invest the small intes-

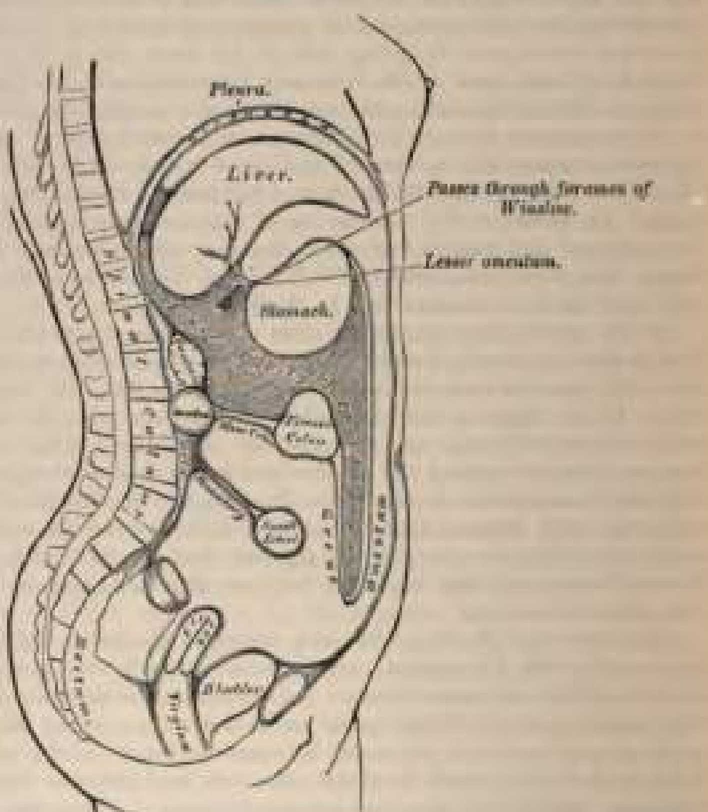


FIG. 488.—The reflections of the peritoneum, as seen in a vertical section of the abdomen.

tine, and back again to the spine, forming the mesentery, between the layers of which are contained the mesenteric blood-vessels, nerves, lacteals, and glands. Lastly, it passes over the left kidney to the sides and anterior surface of the descending colon, and, reaching the abdominal wall, is continued along it to the middle line of the abdomen.

Above the transverse colon (Fig. 489) the peritoneum can be traced, forming the greater and lesser cavities, and their communication through the foramen of Winslow can be demonstrated. Commencing in the middle line of the abdomen, the membrane may be traced lining its anterior wall, and sending a process backward to encircle the obliterated umbilical vein (the round ligament of the liver), forming the falciform or longitudinal ligament of the liver. Continuing its course to the right, it is reflected over the front of the upper part of the right kidney, across the vena cava inferior and aorta, and over the left kidney to the hilum of the spleen, forming the anterior layer of the *lieno-renal ligament*, the posterior layer being formed by the termination of the *cul-de-sac* of the greater cavity between the kidney and spleen. From the hilum of the spleen it is reflected to the stomach, forming the posterior layer of the *gastro-splenic omentum.* It covers the posterior surface of the stomach, and from its lesser curvature it passes around the portal vein, hepatic artery, and bile-duct, and back again to the stomach, as the lesser omentum, and thus it forms the anterior boundary of the foramen of Winslow. It now covers the front of the stomach, and upon reaching the cardiac extremity it passes to the hilum of the spleen, forming the anterior layer of the gastro-splenic omentum. From the hilum of the spleen it can be traced over the surface of this organ, to which it gives a serous covering; it is then reflected from the posterior border of the hilum on to the left kidney, forming the posterior layer of the lieno-renal ligament.

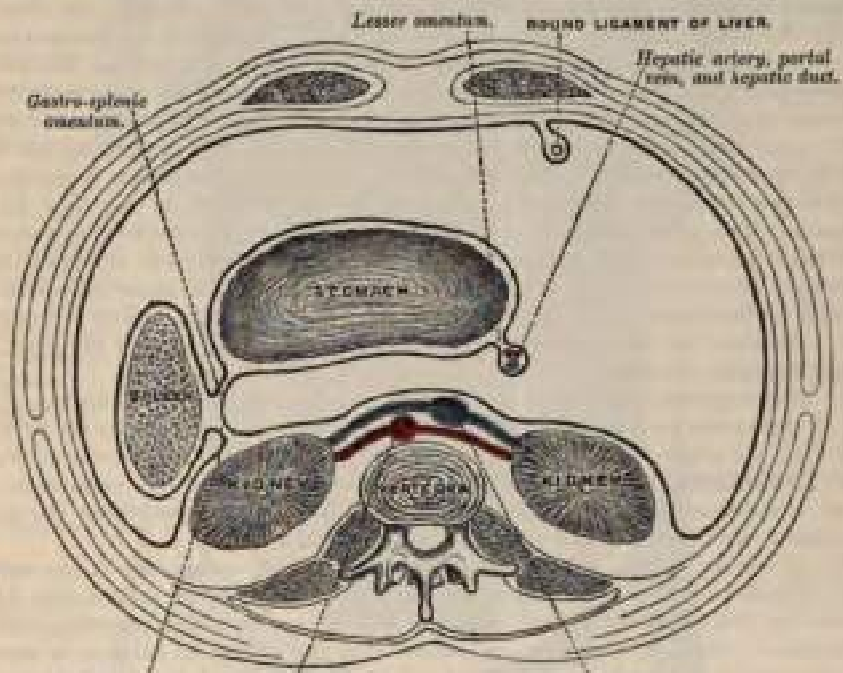


Fig. 489.—Transverse section of peritoneum.

Numerous folds, formed by the peritoneum, extend between the various organs or connect them to the parietes. These serve to hold them in position, and at the same time enclose the vessels and nerves proceeding to each part. Some of these folds are called *ligaments*, such as the ligaments of the liver and the false ligaments of the bladder. Others, which connect certain parts of the intestine with the abdominal wall, constitute the *mesenteries;* and lastly, those which proceed from the stomach to certain viscera in its neighborhood are called *omenta.*

The **Ligaments,** formed by folds of the peritoneum, include those of the liver, spleen, bladder, and uterus. They will be found described with their respective organs.

The **Omenta** are: the lesser omentum, the great omentum, and the gastro-splenic omentum.

The *lesser omentum* (*gastro-hepatic*) is the duplicature which extends between the transverse fissure of the liver and the lesser curvature of the stomach. It is extremely thin, and consists of two layers of peritoneum: that is, the two layers covering respectively the anterior and posterior surfaces of the stomach. When these two layers reach the lesser curvature of the stomach, they join together and ascend as the double fold to the transverse fissure of the liver; to the left of this fissure the double fold is attached to the fissure of the ductus venosus as far as the Diaphragm, where the two layers separate to embrace the end of the œsophagus. At the right border the lesser omentum is free, and the two layers of which it is composed are continuous. The anterior layer, which belongs to the greater sac, turns round the hepatic vessels to become continuous with the posterior layer belonging to the lesser one. They here form a free, rounded margin, which contains between its layers the hepatic artery, the common bile-duct, the portal vein, lymphatics, and the hepatic plexus of nerves—all these structures being enclosed in loose areolar tissue, called *Glisson's capsule*. Between the layers where they are attached to the stomach lie the gastric artery and the pyloric branch of the hepatic, anastomosing with it.

The *great omentum* (*gastro-colic*) is the largest peritoneal fold. It consists of four layers of peritoneum, two of which descend from the stomach, one from its anterior, the other from its posterior surface, and, uniting at its lower border, descend in front of the small intestines, sometimes as low down as the pelvis; they then turn upon themselves, and ascend again as far as the transverse colon, where they separate and enclose that part of the intestine. These separate layers may be easily demonstrated in the young subject, but in the adult they are more or less inseparably blended. The left border of the great omentum is continuous with the gastro-splenic omentum: its right border extends as far only as the duodenum. The great omentum is usually thin, presents a cribriform appearance, and always contains some adipose tissue, which in fat subjects accumulates in considerable quantity. Its use appears to be to protect the intestines from the cold, and to facilitate their movement upon each other during their vermicular action. Between its two anterior layers is the anastomosis between the right and left gastro-epiploic arteries.

The *gastro-splenic omentum* is the fold which connects the margins of the hilum of the spleen to the *cul-de-sac* of the stomach, being continuous by its lower border with the great omentum. It contains the vasa brevia vessels.

The **Mesenteries** are: the mesentery proper, the transverse mesocolon, the sigmoid mesocolon, and the mesorectum. In addition to these there are sometimes present an ascending and a descending mesocolon.

The *mesentery* (*μέσον ἔντερον*), so called from being connected to the middle of the cylinder of the small intestine, is the broad fold of peritoneum which connects the convolutions of the jejunum and ileum with the posterior wall of the abdomen. Its *root*, the part connected with the vertebral column, is narrow, about six inches in length, and directed obliquely from the left side of the second lumbar vertebra to the right sacro-iliac symphysis (Fig. 490). Its intestinal border is much longer; and here its two layers separate so as to enclose the intestine, and form its peritoneal coat. Its breadth, between its vertebral and intestinal border, is about eight inches. Its *upper border* is continuous with the under surface of the transverse mesocolon; its *lower border*, with the peritoneum covering the cæcum and ascending colon. It serves to retain the small intestines in their position, and contains between its layers the mesenteric vessels and nerves, the lacteal vessels, and mesenteric glands.

In most cases the peritoneum covers only the front and sides of the ascending and descending parts of the colon. Sometimes, however, these are surrounded by the serous membrane and attached to the posterior abdominal wall by an ascending and a descending mesocolon respectively. At the place where the transverse colon turns downwards to form the descending colon, a fold of peritoneum is continued to the under surface of the Diaphragm opposite the tenth and eleventh ribs. This is the *phreno-colic ligament*; it passes below the spleen, and serves to support this organ, and therefore it has received the second name of *sustentaculum lienis*.

The *transverse mesocolon* is a broad fold, which connects the transverse colon to the posterior wall of the abdomen. It is formed by the two ascending or posterior layers of the great omentum, which, after separating to surround the transverse colon, join behind it, and are continued backward to the spine, where they diverge in front of the duodenum. This fold contains between its layers the vessels which supply the transverse colon.

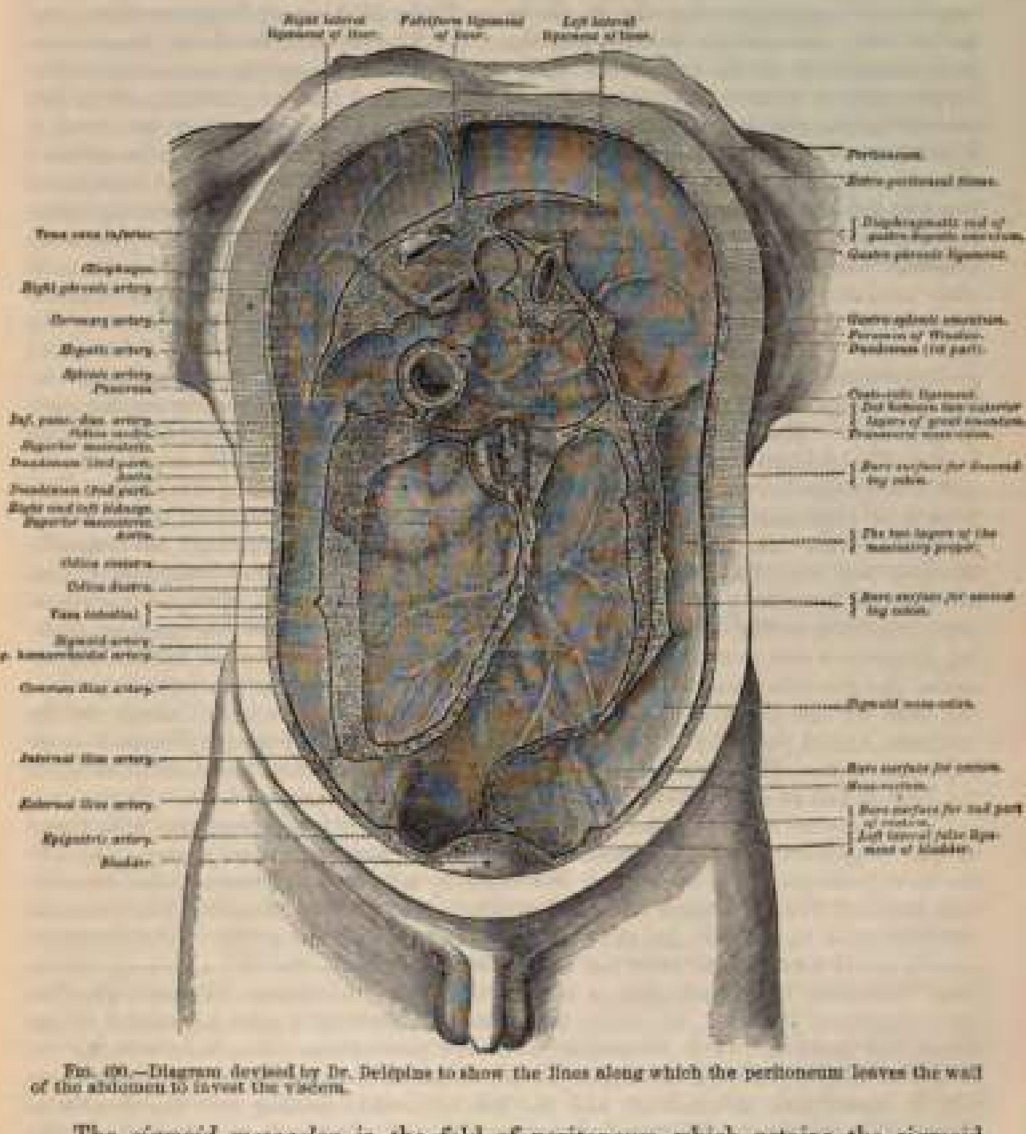


FIG. 490.—Diagram devised by Dr. Delépine to show the lines along which the peritoneum leaves the wall of the abdomen to invest the viscera.

The *sigmoid mesocolon* is the fold of peritoneum which retains the sigmoid flexure in connection with the left iliac fossa.

The *mesorectum* is the narrow fold which connects the upper part of the rectum with the front of the sacrum. It contains the superior hemorrhoidal vessels.

The *appendices epiploicæ* are small pouches of the peritoneum filled with fat and situated along the colon and upper part of the rectum. They are chiefly appended to the transverse colon.

Retro-peritoneal fossæ.—In certain parts of the abdominal cavity there are recesses of peritoneum forming *culs-de-sac* or pouches, which are of surgical interest in connection with the possibility of the occurrence of retro-peritoneal hernia. One of these is the lesser sac of the peritoneum, which may be regarded as a recess of peritoneum through the foramen of Winslow, in which a hernia may take place, but there are several others, of smaller size, which require mention.

These recesses of fossæ may be divided into three groups, viz.: (1) the duodenal fossæ; (2) pericæcal fossæ; and (3) the intersigmoid fossa.

1. *Duodenal Fossæ.*—Moynihan has described no less than nine fossæ as occurring in the neighborhood of the duodenum. Three of these are fairly constant, and are the only ones which require mention. (*a*) The *inferior duodenal fossa* is the most constant of all the peritoneal fossæ in this region, being present in from 70 to 75 per cent. of cases. It is situated opposite the third lumbar vertebra on the left side of the ascending portion of the duodenum. The opening into the fossa is directed upward, and is bounded by a thin sharp fold of peritoneum with a concave margin, called the *inferior duodenal fold.* The tip of the index finger introduced into the fossa under the fold passes some little distance up behind the ascending or fourth portion of the duodenum. (*b*) The *superior duodenal fossa* is the next most constant pouch or recess, being present in from 40 to 50 per cent. of cases. It often coexists with the inferior one, and its orifice looks downward, in the opposite direction to the preceding fossa. It lies to the left of the ascending portion of the duodenum. It is bounded by the free edge of the *superior duodenal fold*, which presents a semilunar margin; to the right it is blended with the peritoneum covering the ascending duodenum, and to the left with the peritoneum covering the perirenal tissues. The fossa is bounded in front by the superior duodenal fold; behind by the second lumbar vertebra; to the right by the duodenum. Its depth is 2 cm., and it terminates in the angle formed by the left renal vein crossing the aorta. This fossa is of importance, as it is in relation with the inferior mesenteric vein: that is to say, the vein almost always corresponds to the line of union of the superior duodenal fold with the posterior parietal peritoneum. (*c*) The *duodeno-jejunal fossa* can be seen by pulling the jejunum downward and to the right, after the transverse colon has been pulled upward. It will appear as an almost circular opening, looking downward and to the right, and bounded by two free borders or folds of peritoneum, the *duodeno-mesocolic ligaments.* The opening admits the little finger into the fossa to the depth of from 2 to 3 cm. The fossa is bounded above by the pancreas, to the right by the aorta, and to the left by the kidney; beneath is the left renal vein. The fossa exists in from 15 to 20 per cent. of cases, and has never yet been found in conjunction with any other form of duodenal fossa.

2. *Pericæcal Fossæ.*—There are at least three pouches or recesses to be found in the neighborhood of the cæcum, which are termed *pericæcal fossæ.* (1) The *ileo-colic fossa* (superior ileo-cæcal) is formed by a fold of peritoneum, the ileo-colic fold, arching over a branch of the ileo-colic artery, which supplies the ileo-colic junction, and appears to be the direct continuation of the artery. The fossa is a narrow chink situated between the ileo-colic fold in front, and the mesentery of the small intestine, the ileum, and a small portion of the cæcum behind. (2) The *ileo-cæcal fossa* (inferior ileo-cæcal) is situated behind the angle of junction of the ileum and cæcum. It is formed by a fold of peritoneum (the ileo-cæcal fold or bloodless fold of Treves), the upper border of which is attached to the ileum, opposite its mesenteric attachment, and the lower border, passing over the ileo-cæcal junction, joins the mesentery of the appendix, and sometimes the appendix itself; hence this fold is sometimes called the ileo-appendicular. Between this fold and the mesentery of the vermiform appendix is the ileo-cæcal fossa. It is bounded above by the posterior surface of the ileum and the mesentery; in front and below by the ileo-cæcal fold, and behind by the upper part of the mesentery of the appendix. (3) The *subcæcal fossa* (retro-cæcal) is situated immediately behind the cæcum, which has to be raised to bring it into view. It varies much in size and extent. In some cases it is sufficiently large to admit the index finger, and extends upward behind the ascending colon in the direction of the kidney; in others it is merely a shallow depression. It is bounded and formed by two folds: one, the *parieto-colic*,

which is attached by one edge to the abdominal wall from the lower border of the kidney to the iliac fossa and by the other to the postero-external aspect of the colon; and the other, *mesenterico-parietal*, which is in reality the insertion of the mesentery into the iliac fossa. In some instances the subcæcal fossa is double.

3. The *Intersigmoid fossa* is constant in the fœtus and during infancy, but disappears in a certain percentage of cases as age advances. Upon drawing the sigmoid flexure upward, the left surface of the sigmoid mesocolon is exposed, and on it will be seen a funnel-shaped recess of the peritoneum, lying on the external iliac vessels, in the interspace between the Psoas and Iliacus muscles. This is the orifice leading to the fossa intersigmoidea, which lies behind the sigmoid mesocolon, and in front of the parietal peritoneum. The fossa varies in size; in some instances it is a mere dimple, whereas in others it will admit the whole of the index finger.

Any of these fossæ may be the site of a retro-peritoneal hernia. The pericæcal fossæ are of especial interest, because hernia of the vermiform appendix frequently takes place into one of them, and may there become strangulated. The presence of these pouches also explains the course which pus has been known to take in cases of perforation of the appendix, where it travels upward behind the ascending colon as far as the Diaphragm.[1]

THE STOMACH.

The **Stomach** is the principal organ of digestion. It is the most dilated part of the alimentary canal, and is situated between the termination of the œsophagus and the commencement of the small intestine. Its form is somewhat pyriform with the large end (*fundus*) directed upward and the small end bent to the right. It is situated in the left hypochondriac and epigastric regions, and is placed, in part, immediately behind the anterior wall of the abdomen and beneath the Diaphragm. Viewing the stomach from in front it appears that the right margin of the œsophagus is continued downward as the upper two-thirds of the lesser curvature of the stomach, the remaining third of this border bending sharply backward and to the right, to complete the smaller curvature (Fig. 491). The greater curvature begins at the left border of the termination of the œsophagus in a somewhat acute angle; it then passes upward and to the left to the under surface of the Diaphragm, with which it lies in contact for some distance, and then sweeps downward with a convexity to the left, and, continued across the middle line of the body, finally turns upward and backward, to terminate at the commencement of the small intestine. It will thus be seen that the stomach may be divided into a main or *cardiac* portion, the long axis of which is directed downward, with a little inclination forward and to the right, and a smaller or *pyloric* portion, the long axis of which is horizontal with an inclination backward. Of the two openings, the *cardiac orifice*, by which it communicates with the œsophagus, is situated slightly to the left of the middle line of the body to the right of the *fundus*, or dilated upper extremity of the stomach, and is directed downward; the other, the *pyloric orifice*, by which it communicates with the small intestine, is on a lower plane, close to the right of the mid-line, and looks directly backward.

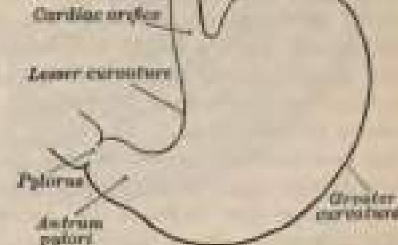


FIG. 491.—Diagrammatic outline of the stomach.

The stomach has two surfaces, called anterior and posterior, and two borders, termed the greater and lesser curvatures.

Surfaces.—With regard to the so-called anterior and posterior surfaces of the stomach, it must be borne in mind that these names are not strictly correct, as the anterior surface has a certain amount of inclination upward and the posterior downward.

[1] On the anatomy of these fossæ, see the *Arris and Gale Lectures* by Moynihan, 1899.

The *anterior* surface has a somewhat flattened appearance when the stomach is empty, but when it is full the surface becomes convex. It is in relation with the Diaphragm; the thoracic wall formed by the anterior parts of the seventh, eighth, and ninth ribs of the left side; the left lobe of the liver; and the anterior abdominal wall. Between the part covered by the liver and that covered by the left ribs there is a triangular segment of the anterior wall of the stomach, which is in contact with the abdominal wall and is the only part of the stomach which is visible when the abdominal wall is removed and the viscera allowed to remain *in situ*. It is of about 40 sq. cm. and is of great importance to the surgeon, as the stomach can readily be reached in this situation. Occasionally the transverse colon may be found lying in front of the lower part of the anterior surface of the stomach. The whole of this surface of the stomach is covered by peritoneum.

The *posterior* surface of the stomach is in relation with the Diaphragm, the gastric surface of the spleen, the left supra-renal capsule, the upper part of the left kidney, the anterior surface of the pancreas, the splenic flexure of the colon, and the ascending layer of the transverse mesocolon. These structures form a shallow concavity or *bed* on which this surface of the stomach rests. The transverse mesocolon intervenes between the stomach and the duodeno-jejunal junction and commencement of the ileum. Its greater curvature is in relation with the transverse colon and has attached to it the anterior two layers of the great omentum. Almost the whole of this surface is covered with peritoneum, but behind the cardiac orifice there is a small portion of the stomach which is uncovered by peritoneum and is in contact with the Diaphragm and frequently with the upper portion of the left supra-renal capsule.

The *lesser curvature* of the stomach extends between the cardiac and pyloric orifices along the right border of the organ. It descends in front of the left crus of the Diaphragm, along the left side of the eleventh and twelfth dorsal vertebræ, and then turning to the right it crosses the first lumbar vertebra and ascends to the pylorus. It gives attachment to the two layers of the gastro-hepatic omentum, between which blood-vessels and lymphatics pass to reach the organ.

The *greater curvature* is directed to the left, and is four or five times as long as the lesser curvature. Starting from the cardiac orifice, it forms an arch to the left with its convexity upward, the highest point of which is on a level with the costal cartilage of the sixth rib of the left side. It then passes nearly straight downward, with a slight convexity to the left, as low as the costal cartilage of the ninth rib and then turns to the right to end at the pylorus. As it crosses the median line the lowest edge of the greater curvature is about two fingers' breadth above the umbilicus. The lower part of the greater curvature gives attachment to the two anterior layers of the great omentum, between which layers, vessels and lymphatics pass to the organ..

The *cardiac orifice* is the opening by which the œsophagus communicates with the stomach. It is therefore sometimes termed the *œsophageal opening*. It is the most fixed part of the stomach, and is situated about two inches below the highest part of the fundus on a level with the body of the tenth or eleventh dorsal vertebra to the left and a little in front of the aorta. This would correspond on the anterior surface of the body to the articulation of the seventh left costal cartilage to the sternum.

The *pyloric orifice* communicates with the duodenum, the aperture being guarded by a valve. Its position varies with the movements of the stomach. When the stomach is empty the pylorus is situated just to the right of the median line of the body, on a level with the upper border of the first lumbar vertebra. On the anterior surface of the body its position would be indicated by a point one inch below the tip of the ensiform cartilage and a little to the right. As the stomach becomes distended the pylorus moves to the right, and in a fully distended stomach may be situated two or three inches to the right of the median line. Near the pylorus the stomach frequently exhibits a slight dilatation, which is named the *antrum pylorus*.

The size of the stomach varies considerably in different subjects. When moderately distended its greatest length, from the top of the fundus to the lowest part of the greater curvature, is from ten to twelve inches; and its diameter at the widest part from four to five inches. The distance between the two orifices is three to six inches, and the measurement from the anterior to the posterior wall three and a half inches. Its weight, according to Clendinning, is about four ounces and a half, and its capacity in the adult male is five to eight pints.

Alterations in Position.—There is no organ in the body the position and connections of which present such frequent alterations as the stomach. *When empty*, it lies at the back part of the abdomen, some distance from the surface. Its pyloric end is situated close to or very slightly to the right of the middle line, covered in front by the left lobe of the liver, and being on a level with the first lumbar vertebra. When empty, the stomach assumes a more or less cylindrical form, especially noticeable at its pyloric end. *When the stomach is distended*, its surfaces, which are flattened when the organ is empty, become convex. The greater curvature is elevated and carried forward, so that the anterior surface is turned more or less upward and the posterior surface downward, and the stomach brought well against the anterior wall of the abdomen. Its fundus expands and rises considerably above the level of the cardiac orifice: in doing this the

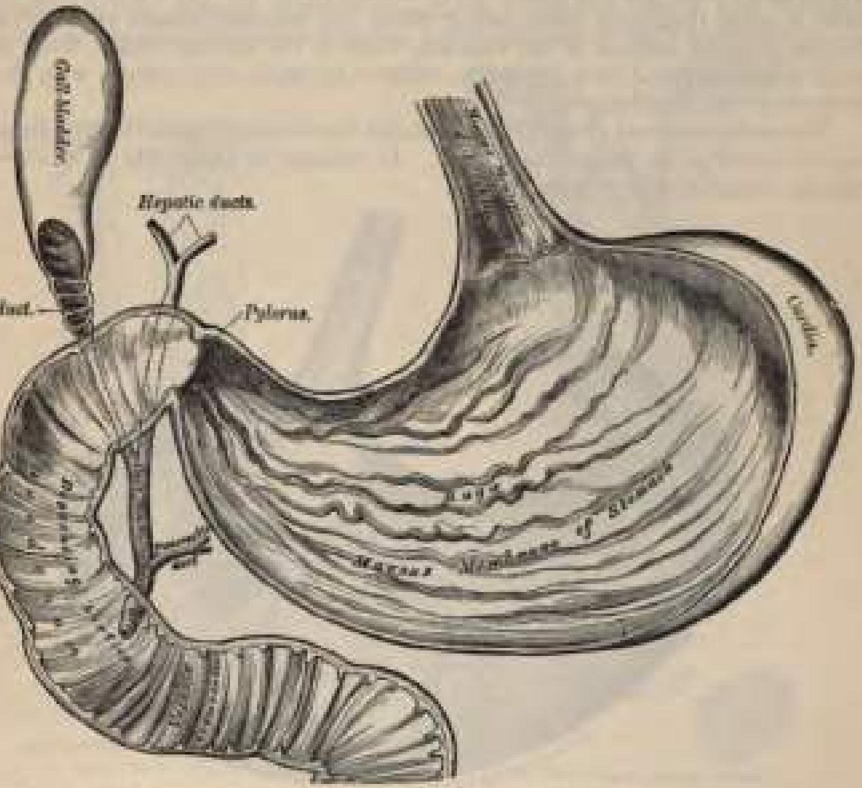


Fig. 692.—The mucous membrane of the stomach and duodenum with the bile-ducts.

Diaphragm is forced upward, contracting the cavity of the chest; hence the dyspnœa complained of, from inspiration being impeded. The apex of the heart is also tilted upward; hence the oppression in this region and the palpitation experienced in extreme distention of the stomach. The left lobe of the liver is pushed to the right side. When the stomach becomes distended the change in the position of the pylorus is very considerable; it is shifted to the right, some two or three inches from the median line, and lies under cover of the liver, near the neck of the gall-bladder. In consequence of the distention of the stomach the lesser *cul-de-sac* bulges over the pylorus, concealing it from view, and causing it to undergo a rotation, so that its orifice is directed backward. *During inspiration* the stomach is displaced downward by the descent of the Diaphragm, and elevated by the pressure of the abdominal muscles during expiration. *Pressure from without*, as from tight lacing, pushes the stomach down toward the pelvis. In disease, also, the position and connection of the organ may be greatly changed, from the accumulation of fluid in the chest or abdomen, or from alteration in size of any of the surrounding viscera. *Variations according to Age.*—In an early period of development the stomach is vertical, and in the newborn child it is more vertical than later on in life, as owing to the large size of the liver it is more pushed over to the left side of the abdomen, and the whole of the anterior surface is covered by the left lobe of this organ.

On looking into the pyloric end of the stomach, the mucous membrane is found projecting inward in the form of a circular fold, the *pyloric valve*, leaving a narrow circular aperture, about half an inch in diameter, by which the stomach communicates with the duodenum.

The *pyloric valve* is formed by a reduplication of the mucous membrane of the stomach, containing numerous circular fibres, which are aggregated into a thick circular ring; the longitudinal fibres and serous membrane being continued over the fold without assisting in its formation.

Structure.—The wall of the stomach consists of four coats: serous, muscular, areolar, and mucous, together with vessels and nerves.

The *serous coat* is derived from the peritoneum, and covers the entire surface of the organ, excepting along the greater or lesser curvatures, at the points of attachment of the greater and lesser omenta; here the two layers of peritoneum leave a small triangular space, along which the nutrient vessels and nerves pass. On the posterior surface of the stomach, close to the cardiac orifice, there is also a small area uncovered by peritoneum, where the organ is in contact with the under surfaces of the Diaphragm.

The *muscular coat* (Fig. 493) is situated immediately beneath the serous covering, to which it is closely connected. It consists of three sets of fibres—longitudinal, circular, and oblique.

FIG. 493.—The muscular coat of the stomach.

The *longitudinal fibres* are most superficial; they are continuous with the longitudinal fibres of the œsophagus, radiating in a stellate manner from the cardiac orifice. They are most distinct along the curvatures, especially the lesser, but are very thinly distributed over the surfaces. At the pyloric end they are more thickly distributed, and continuous with the longitudinal fibres of the small intestine.

The *circular fibres* form a uniform layer over the whole extent of the stomach beneath the longitudinal fibres. At the pylorus they are most abundant, and are aggregated into a circular ring, which projects into the cavity, and forms, with the fold of mucous membrane covering its surface, the *pyloric valve*. They are continuous with the circular fibres of the œsophagus.

The *oblique fibres* are limited chiefly to the cardiac end of the stomach, where they are disposed as a thick uniform layer, covering both surfaces, some passing obliquely from left to right, others from right to left, round the cardiac end.

The *areolar* or *submucous coat* consists of a loose, filamentous, areolar tissue, connecting the mucous and muscular layers. It supports the blood-vessels previous to their distribution to the mucous membrane: hence it is sometimes called the *vascular coat.*

The *mucous membrane* is thick; its surface smooth, soft, and velvety. In the fresh state it is of a pinkish tinge at the pyloric end, and of a red or reddish-brown color over the rest of its surface. In infancy it is of a brighter hue, the vascular redness being more marked. It is thin at the cardiac extremity, but thicker toward the pylorus. During the contracted state of the organ it is thrown into numerous plaits or rugæ, which for the most part have a longitudinal direction, and are most marked toward the lesser end of the stomach and along the greater curvature (Fig. 492). These folds are entirely obliterated when the organ becomes distended.

Structure of the Mucous Membrane.—When examined with a lens the inner surface of the mucous membrane presents a peculiar honeycomb appearance, from

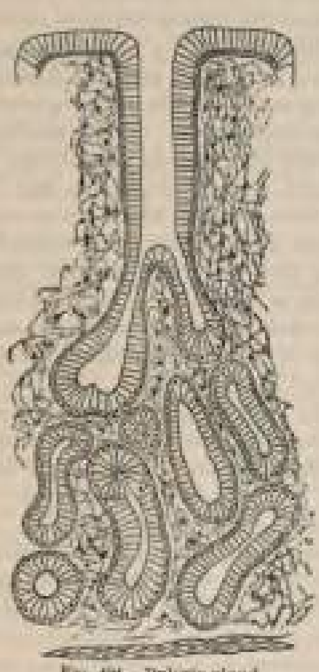


FIG. 494.—Pyloric gland.

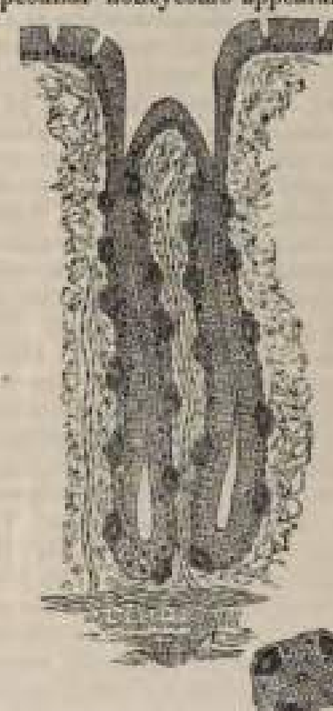


FIG. 493.—Peptic gastric gland.

being covered with small shallow depressions or alveoli of a polygonal or hexagonal form, which vary from $\frac{1}{100}$ to $\frac{1}{350}$ of an inch in diameter, and are separated by slightly elevated ridges. In the bottom of the alveola are seen the orifices of minute tubes, the *gastric glands*, which are situated perpendicularly side by side throughout the entire substance of the mucous membrane. The surface of the mucous membrane of the stomach is covered by a single layer of columnar epithelium; it lines the alveoli, and also for a certain distance the mouths of the gastric glands. This epithelium commences very abruptly at the cardiac orifice, where the cells suddenly change in character from the stratified epithelium of the œsophagus. The cells are elongated, and consist of two parts, the inner or attached portions being granular, and the outer or free parts being clear and occupied by a muco-albuminous substance.

The gastric glands are of two kinds, which differ from each other in structure, and it is believed also in the nature of their secretion. They are named respectively *pyloric* and *cardiac* or *oxyntic glands*. They are both tubular in character, and are formed of a delicate basement-membrane, lined by epithelium. The basement-membrane consists of flattened transparent endothelial cells, with processes which extend between and support the epithelium. The *pyloric glands* (Fig. 494) are most numerous at the pyloric end of the stomach, and from this fact have received their name. They consist of two or three short, closed tubes opening into a common duct, the external orifice of which is situated at the bottom of an alveolus. The cæcal tubes are wavy, and are of about equal length with the duct. The tubes and duct are lined throughout with epithelium, the duct being lined by columnar cells continuous with the epithelium lining the surface of the mucous membrane of the stomach, the tubes with shorter and more cubical cells which are finely granular. The *cardiac glands* (Fig. 495) are found all over the surface of the stomach, but occur most numerously at the cardiac end. Like the pyloric glands, they consist of a duct, into which open two or more cæcal tubes. The duct, however, in these glands is shorter than in the other variety, sometimes not amounting to more than one-sixth of the whole length of the gland; it is lined throughout by columnar epithelium. At the point where the terminal tubes open into the duct, and which is termed the neck, the epithelium alters, and consists of short columnar or polyhedral, granular cells, which almost fill the tube, so that the lumen becomes suddenly constricted, and is continued down as a very fine channel. They are known as the *chief* or the *central* cells of the glands. Between these cells and the basement-membrane are found other darker granular-looking cells, studded throughout the tube at intervals, and giving it a beaded or varicose appearance. These are known as the *parietal* or *oxyntic cells*. Between the glands the mucous membrane consists of a connective-tissue framework with lymphoid tissue. In places this latter tissue, especially in early life, is collected into little masses, which to a certain extent resemble the solitary glands of the intestine, and are by some termed the *lenticular* glands of the stomach. They are not, however, so distinctly circumscribed as the solitary glands. Beneath the mucous membrane, and between it and the submucous coat, is a thin stratum of involuntary muscular fibre (*muscularis mucosæ*), which in some parts consists only of a single longitudinal layer; in others, of two layers, an inner circular, and an outer longitudinal.

Vessels and Nerves.—The arteries supplying the stomach are—the gastric, the pyloric and right gastro-epiploic branches of the hepatic, the left gastro-epiploic and vasa brevia from the splenic. They supply the muscular coat, ramify in the submucous coat, and are finally distributed to the mucous membrane. The arrangement of the vessels in the mucous membrane is somewhat peculiar. The arteries break up at the base of the gastric tubules into a plexus of fine capillaries which run upward between the tubules, anastomosing with each other, and ending in a plexus of larger capillaries, which surround the mouths of the tubes and also form hexagonal meshes around the alveoli. From these latter the *veins* arise, and pursue a straight course downward between the tubules, to the submucous tissue, and terminate either in the splenic and superior mesenteric veins or directly in the portal vein. The *lymphatics* are numerous; they consist of a superficial and deep set, which pass through the lymphatic glands found along the two curvatures of the organ. The *nerves* are the terminal branches of the right and left pneumogastric, the former being distributed upon the back, and the latter upon the front part of the organ. A great number of branches from the sympathetic also supply the organ.

Surface Form.—The stomach lies for the most part in the left hypochondriac region, but also slightly in the epigastric region, and is partly in contact with the abdominal wall, partly under cover of the lower ribs on the left side, and partly under the left lobe of the liver. Its cardiac orifice corresponds to the articulation of the seventh left costal cartilage with the sternum. The pyloric orifice is in a vertical line drawn from the right border of the sternum, two and a half or three inches below the level of the sterno-xiphoid articulation. According to Braune, when the stomach is distended, the pylorus moves considerably to the right, as much sometimes as three inches. The fundus of the stomach reaches, on the left side, as high as the level of the sixth costal cartilage of the left side, being a little below and behind the apex of the heart. The portion of the stomach which is in contact with the abdominal walls, and is therefore accessible for opening in the operations of gastrotomy and gastrostomy, is represented by a triangular space, the base of which is formed by a line drawn from the tip of the tenth costal cartilage on the left side to the tip of the ninth costal cartilage on the right, and the sides by two lines drawn from the extremity of the eighth costal cartilage on the left side to the ends of the base line.

Surgical Anatomy.—Operations on the stomach are frequently performed. By "gastrotomy" is meant an incision into the stomach for the removal of a foreign body, the opening being immediately afterward closed—in contradistinction to "gastrostomy," the making of a more or less permanent fistulous opening. *Gastrotomy* is probably best performed by an incision in the linea alba, especially if the foreign body is large, by a cut from the ensiform cartilage to the umbilicus, but may be performed by an incision over the body itself, where this can be felt, or by one of the incisions for gastrostomy, to be mentioned immediately. The peritoneal cavity is opened, and the point at which the stomach is to be incised decided upon. This portion is then brought out of the abdominal wound and sponges carefully packed around. The stomach is now opened by a transverse incision and the foreign body extracted. The wound in the stomach is then closed by Lembert's sutures—*i. e.* by sutures passed through the peritoneal and muscular coats in such a way that the peritoneal surfaces on each side of the wound are brought into apposition, and in this way the wound is closed. *Gastrostomy* was formerly done in two stages by the *direct* method. The first stage consisted in opening the abdomen, drawing up the stomach into the external wound, and fixing it there; and the second stage, performed from two to four days afterward, consisted in opening the stomach. The operation is now done by a *valvular* method. An incision is commenced opposite the eighth intercostal space, two inches from the median line, and carried downward for three inches. By this incision the fibres of the Rectus muscle are exposed and these are separated from each other in the same line with a steel director. The posterior layer of the sheath, the transversalis fascia and the peritoneum, are then divided, and the peritoneal cavity opened. The anterior wall of the stomach is now seized and drawn out of the wound and a silk suture passed through its muscular and serous coats at the point selected for opening the viscus. This is held by an assistant so that a long conical diverticulum of the stomach protrudes from the external wound, and the parietal peritoneum and the posterior layer of the sheath of the rectus are sutured to it. A second incision is made through the skin, over the margin of the costal cartilage, above and a little to the outer side of the first incision. With a pair of dressing forceps a track is made under the skin through the subcutaneous tissue from the one opening to the other and the diverticulum of the stomach is drawn along this track by means of the suture inserted into it; so that its apex appears at the second opening. A small perforation is now made into the stomach through this protruding apex and its margins carefully and accurately sutured to the margin of the external wound. The remainder of this incision and the whole of the first incision are then closed in the ordinary way and the wound dressed.

In cases of gastric ulcer perforation sometimes takes place, and this was formerly regarded as an almost fatal complication. In the present day, by opening the abdomen and closing the perforation, which is generally situated on the anterior surface of the stomach, a considerable percentage of cases are cured, provided the operation is undertaken within twelve or fifteen hours after the perforation has taken place. The opening is best closed by bringing the peritoneal surfaces on either side into apposition by means of Lembert's sutures.

Excision of the pylorus has occasionally been performed, but the results of this operation are by no means favorable, and, in cases of cancer of the pylorus, before operative proceedings are undertaken, the tumor has become so fixed and has so far implicated surrounding parts that removal of the pylorus is impossible and gastro-enterostomy has to be substituted. The object of this operation is to make a fistulous communication between the stomach, on the cardiac side of the disease, and the small intestine, as high up as is possible.

Digital dilatation of the pylorus for simple stricture was first performed by Loreta. He exposed the stomach and opened it by a transverse incision near the pylorus. He then inserted the forefingers of both hands and passed these through the pylorus and stretched it with some degree of force. The operation has now, however, dropped out of use and been replaced by pyloro-plasty. This consists in making a longitudinal incision from the stomach through the pylorus into the duodenum, and converting this longitudinal incision into a transverse one by traction at the centre of the incision, and retaining it permanently in this position by sutures.

THE SMALL INTESTINE.

The small intestine is a convoluted tube, extending from the pylorus to the ileo-cæcal valve, where it terminates in the large intestine. It is about twenty feet in length,[1] and gradually diminishes in size from its commencement to its

[1] Treves states that, in one hundred cases, the average length of the small intestine in the adult male was 22 feet 6 inches, and in the adult female 23 feet 4 inches; but that it varies very much, the extremes in the male being 31 feet 10 inches in one case, and 15 feet 6 inches in another, a difference of over 15 feet. He states that he has convinced himself that the length of the bowel is independent, in the adult, of age, height, and weight.

termination. It is contained in the central and lower part of the abdominal cavity, and is surrounded above and at the sides by the large intestine; a portion of it extends below the brim of the pelvis and lies in front of the rectum; it is in relation, in front, with the great omentum and abdominal parietes; and connected to the spine by a fold of peritoneum, the mesentery. The small intestine is divisible into three portions—the duodenum, the jejunum, and ilium.

The **duodenum** has received its name from being about equal in length to the breadth of twelve fingers (ten inches). It is the shortest, the widest, and the most fixed part of the small intestine. Its course presents a remarkable curve, which in the adult, as regards the greater part of its extent, is U-shaped: though sometimes, in consequence of the transverse portion being very short or altogether wanting, it partakes more of the character of the letter V. In children, up to the age of about seven, the duodenum is annular; its two extremities are on about the same level; and between them it describes a regular curve embracing the head of the pancreas, the neck of which lies between the two extremities of the ring.

In the adult the course of the duodenum is as follows: commencing at the pylorus the direction of the first portion depends upon the amount of distention of the stomach and therefore upon the position of the pylorus. When the stomach is empty and the pylorus situated at the right of the upper border of the first lumbar vertebra, it is nearly horizontal and transverse; but where the stomach is distended, in consequence of the alteration of the position of the pylorus to the right the proximal end of the duodenum also becomes altered in position, while the distal end remains fixed and the direction of this portion of the bowel is now antero-posterior. Whether directed transversely or antero-posteriorly, it reaches the under surface of the liver, where it takes a sharp curve and descends along the right side of the vertebral column, for a variable distance, generally to the body of the fourth lumbar vertebra. It now takes a second bend, and passes across the front of the vertebral column from right to left and finally ascends on the left side of the vertebral column and aorta to the level of the upper border of the second lumbar vertebra and there terminates in the jejunum. As it unites with the jejunum it often turns abruptly forward, forming the *duodeno-jejunal angle*. From the above description it will be seen that the duodenum may be divided for purposes of description into four portions—superior, descending, transverse, and ascending.

The first or *superior portion* (Fig. 496) is very variable in length, but is usually estimated as being about two inches. Beginning at the pylorus, it ends at the neck of the gall-bladder. It is the most movable of the four portions. It is almost completely covered by peritoneum derived from the two layers of the lesser omentum, but a small part of its posterior surface near the neck of the gall-bladder and the inferior vena cava is uncovered. It is in such close relation with the gall-bladder that it is usually found to be stained by bile after death, especially on its anterior surface. It is in relation above and in front with the quadrate lobe of the liver and the gall-bladder; behind with the gastro-duodenal artery, the common bile-duct, and the vena porta; and below with the head of the pancreas.

The second or *descending portion* is between three and four inches in length, and extends from the neck of the gall-bladder on a level with the first lumbar vertebra along the right side of the vertebral column as low as the body of the fourth lumbar vertebra. It is crossed in its middle third by the transverse colon, the posterior surface of which is uncovered by peritoneum and is connected to the duodenum by a small quantity of connective tissue (Fig. 490). The portions of the descending part of the duodenum above and below this interspace are named the supra- and infra-colic portions, and are covered in front by peritoneum. The right side of the supra-colic portion is covered by peritoneum derived from the anterior surface of the right kidney, the left side of the same portion being covered by the peritoneum forming the lesser sac. The infra-colic part is covered by the right leaf of the mesentery. Posteriorly the descending portion of the duodenum is uncovered by peritoneum. It is in relation, in front, with the transverse colon, and above this with the liver; behind with the front of the right kidney, to which it is connected by loose areolar tissue, the renal vessels and the vena cava inferior; at its inner side is the head of the pancreas, and the ductus communis choledochus; to its outer side is the hepatic flexure of the colon. The common bile-duct and the

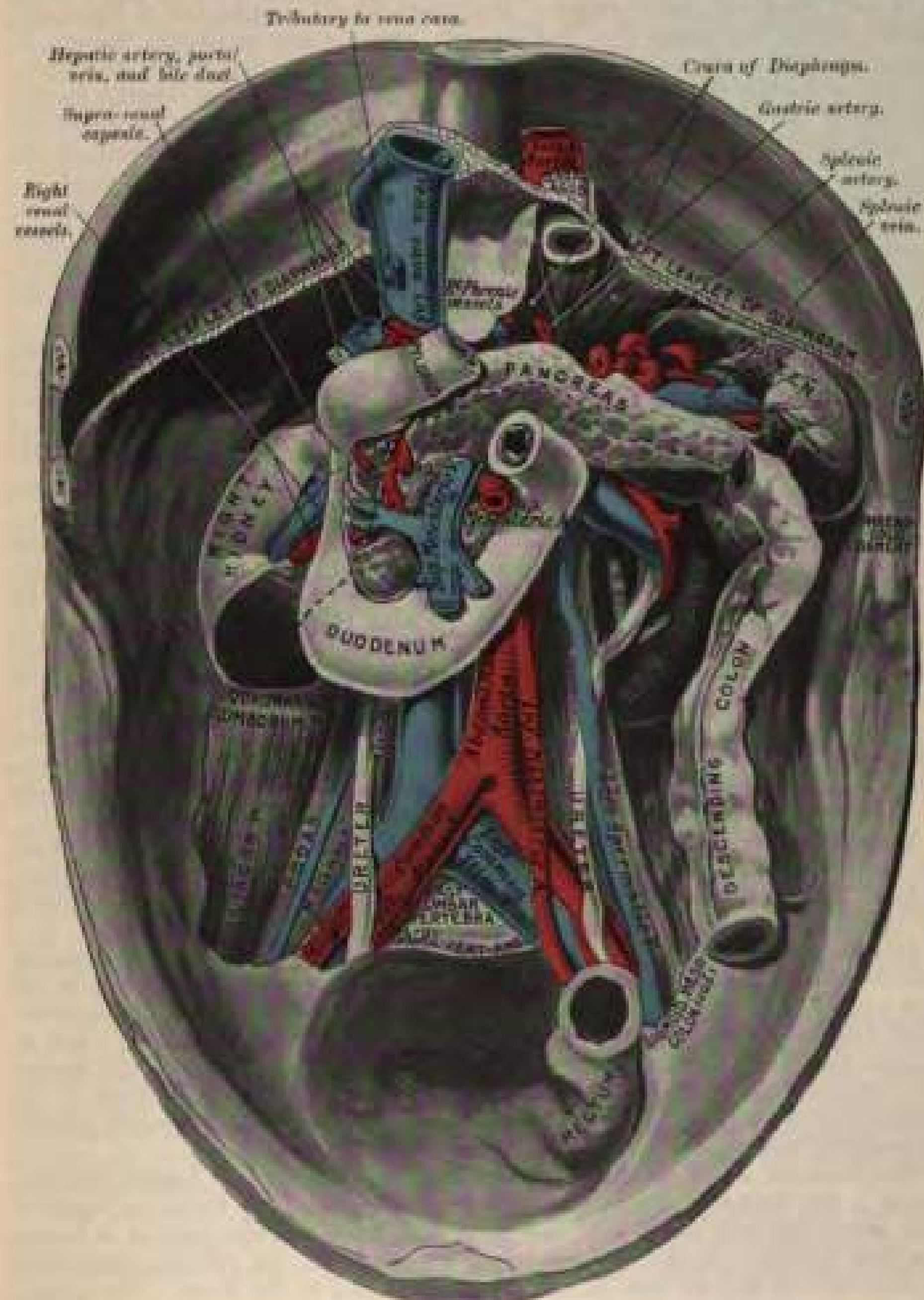


FIG. 496.—Relations of duodenum, pancreas and spleen. (From a cast by Professor Birmingham.[1]) The dotted line represents the line of attachment of the transverse mesocolon.

pancreatic duct perforate the inner side of this portion of the intestine obliquely, some three or four inches below the pylorus. The relations of the second part of the duodenum to the right kidney present considerable variations.

[1] In the subject from which the cast was taken the left kidney was lower than normal.

The third or *transverse portion* (pre-aortic portion) varies much in length: when the duodenum assumes the ordinary U-shaped form, it measures from two to three inches; but when it presents the rarer V-shaped form, it is practically wanting or very much reduced in length. It commences at the right side of the fourth lumbar vertebra and passes from right to left, with a slight inclination upward, in front of the great vessels and crura of the Diaphragm, and ends in the fourth portion just to the left of the abdominal aorta. It is crossed by the superior mesenteric vessels and mesentery. Its front surface is covered by the anterior layer of the mesentery, but near the middle line it is separated from this layer of the mesentery by the superior mesenteric vessels as they cross this portion of the duodenum. Its posterior surface is uncovered by peritoneum, except toward its left extremity, where the posterior layer of the mesentery may sometimes be found covering it to a variable extent. This surface rests upon the aorta, the vena cava inferior, and the crura of the Diaphragm. By its upper surface this portion of the duodenum is in relation with the head of the pancreas.

The fourth or *ascending portion* of the duodenum is about two inches long. It ascends on the left side of the vertebral column and aorta, as far as the level of the upper border of the second lumbar vertebra, where it turns abruptly forward to become the jejunum, forming the *duodeno-jejunal flexure*. It is covered entirely in front and partly at the sides by peritoneum, derived from the left portion of the mesentery. It touches the left kidney, slightly overlapping its inner margin, and rests upon the left crus of the Diaphragm.

The first part of the duodenum, as stated above, is somewhat movable, but the rest is practically fixed and is bound down to neighboring viscera and the posterior abdominal wall by the peritoneum. In addition to this, the fourth part of the duodenum and the duodeno-jejunal flexure is further bound down and fixed by a structure to which the name of *musculus suspensorius duodeni* has been given. This structure commences in the connective tissue around the cœliac axis and left crus of the Diaphragm, and passes downward to be inserted into the superior border of the duodeno-jejunal curve and a part of the ascending duodenum, and from this it is continued into the mesentery. It possesses, according to Treitz, plain muscular fibres mixed with the fibrous tissue, of which it is principally made up. It is of little importance as a muscle, but acts as a suspensory ligament.

Vessels and Nerves.—The *arteries* supplying the duodenum are the pyloric and pancreatico-duodenal branches of the hepatic, and the inferior pancreatico-duodenal branch of the superior mesenteric. The *veins* terminate in the splenic and superior mesenteric. The *nerves* are derived from the solar plexus.

Jejunum and Ileum.—The remainder of the small intestine from the termination of the duodenum is named *jejunum* and *ileum*; the former term being given to the upper two-fifths and the latter to the remaining three-fifths. There is no morphological line of distinction between the two, and the division is arbitrary; but at the same time it must be noted that the character of the intestine gradually undergoes a change from the commencement of the jejunum to the termination of the ileum, so that a portion of the bowel taken from these two situations would present characteristic and marked differences. These are briefly as follows:

The *jejunum*, which derives its name from the Latin word *jejunus* (empty), because it was formerly supposed to be empty after death, is wider, its diameter being about one inch and a half, and is thicker, more vascular, and of a deeper color than the ileum, so that a given length weighs more. Its valvulæ conniventes are large and thickly set and its villi are larger than in the ileum. The glands of Peyer are almost absent in the upper part of the jejunum, and in the lower part are less frequently found than in the ileum, and are smaller and tend to assume a circular form. Brunner's glands are only found in the upper part of the jejunum. By grasping the jejunum between the finger and thumb the valvulæ conniventes can be felt through the walls of the gut; these being absent in the lower part of the ileum, it is possible in this way to distinguish the upper from the lower part of the small intestine.

The *ileum*, so called from the Greek word εἰλεῖν (to twist), on account of its numerous coils and convolutions, is narrow, its diameter being one inch and a quarter, and its coats thinner and less vascular than those of the jejunum. It possesses but few valvulæ conniventes, and they are small and disappear entirely toward its lower end, but Peyer's patches are larger and more numerous. The jejunum for the most part occupies the umbilical and left iliac regions, while the ileum occupies chiefly the umbilical, hypogastric, right iliac, and pelvic regions, and terminates in the right iliac fossa by opening into the inner side of the commencement of the large intestine. The jejunum and ileum are attached to the posterior abdominal wall by an extensive fold of peritoneum, the *mesentery*, which allows the freest motion, so that each coil can accommodate itself to changes in form and position. The mesentery is fan-shaped; its posterior border, about six inches in length, is attached to the abdominal wall from the left side of the second lumbar vertebra to the right iliac fossa (Fig. 490). Its length is about eight inches from its commencement to its termination at the intestine, and it is rather longer about its centre than at either end of the bowel. According to Lockwood, it tends to increase in length as age advances. Between the two layers of which it is composed are contained blood-vessels, nerves, lacteals, and lymphatic glands, together with a variable amount of fat.

Meckel's Diverticulum.—Occasionally there may be found connected with the lower part of the ileum, on an average of about three and a half feet from its termination, a blind diverticulum or tube, varying in length. It is attached to and communicates with the lumen of the bowel by one extremity, and by the other is unattached or may be connected with the abdominal wall or some other portion of the intestine by a fibrous band. This is Meckel's diverticulum, and represents the remains of the vitelline or omphalo-mesenteric duct, the duct of communication between the umbilical vesicle and the alimentary canal in early fœtal life.

Structure.—The wall of the small intestine is composed of four coats—serous, muscular, areolar, and mucous.

The *serous coat* is derived from the peritoneum. The first or ascending portion of the duodenum is almost completely surrounded by this membrane near its pyloric end, but only in front at the other extremity; the second or descending portion is covered by it in front, except where it is carried off by the transverse colon; and the third or transverse portion lies behind the peritoneum, which passes over it, without being closely incorporated with the other coats of this part of the intestine, and is separated from it in the middle line by the superior mesenteric artery. The remaining portion of the small intestine is surrounded by the peritoneum, excepting along its attached or mesenteric border; here a space is left for the vessels and nerves to pass to the gut.

The *muscular coat* consists of two layers of fibres, an external or longitudinal, and an internal or circular layer. The *longitudinal fibres* are thinly scattered over the surface of the intestine, and are more distinct along its free border. The *circular fibres* form a thick, uniform layer; they surround the cylinder of the intestine in the greater part of its circumference, and are composed of plain muscle-cells of considerable length. The muscular coat is thicker at the upper than at the lower part of the small intestine.

The *areolar* or *submucous coat* connects together the mucous and muscular layers. It consists of loose, filamentous areolar tissue, which forms a nidus for the subdivision of the nutrient vessels, previous to their distribution to the mucous surface.

The *mucous membrane* is thick and highly vascular at the upper part of the small intestine, but somewhat paler and thinner below. It consists of the following structures: next the areolar or submucous coat is a layer of unstriped muscular fibres, the *muscularis mucosæ*; internal to this is a quantity of retiform tissue, enclosing in its meshes lymph-corpuscles, and in which the blood-vessels and nerves ramify. Lastly, a basement-membrane, supporting a single layer of epithelial cells, which throughout the intestines are columnar in character. They are granular in appearance, and possess a clear, oval nucleus. At their superficial or unattached end they present a distinct layer of highly refracting material, marked by vertical striæ, which were formerly believed to be minute channels by which the chyle was taken up into the interior of the cell, and by them transferred to the lacteal vessels of the mucous membrane.

The mucous membrane presents for examination the following structures contained within it or belonging to it:

Valvulæ conniventes.	Glands { Duodenal glands.
Villi.	Solitary glands.
Simple follicles.	Peyer's or agminate glands.

The **valvulæ conniventes** (valves of Kerkring) are large folds or valvular flaps projecting into the lumen of the bowel. They are composed of reduplications or folds of the mucous membrane, the two layers of the fold being bound together by submucous tissue; they contain no muscular fibres, and, unlike the folds in the stomach, they are permanent, and are not obliterated when the intestine is distended. The majority extend transversely across the cylinder of the intestine

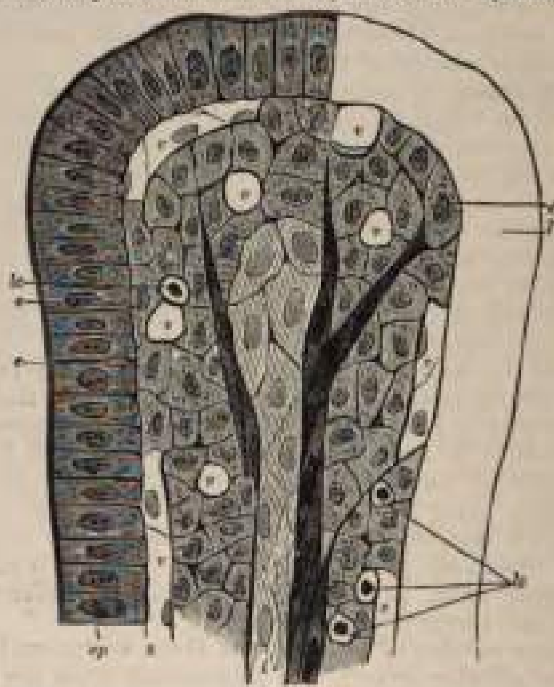


FIG. 497.—Diagrammatic section of a villus. (Watney.) *ep.* Epithelium only partially shaded in. *l.* Central chyle-vessel; the cells forming the vessel have been less shaded to distinguish them from the cells of the parenchyma of the villus. *m.* Muscle-fibres running up by the side of the chyle-vessel. It will be noticed that each muscle-fibre is surrounded by the reticulum, and by this reticulum the muscles are attached to the cells forming the membrana propria, as at *c'*, or to the reticulum of the villus. *lc.* Lymph-corpuscles, marked by a spherical nucleus and a clear zone of protoplasm. *l'.* Upper limit of the chyle-vessel. *c, c, c'.* Cells forming the membrana propria. It will be seen that there is hardly any difference between the cells of the parenchyma, the endothelium of the upper part of the chyle-vessel, and the cells of the membrana propria. *V.* Blood-vessels. *z.* Dark line at base of the epithelium formed by the reticulum. It will be seen that the reticulum penetrates between all the other elements of the villus. The reticulum contains thickenings or "nodal points." The diagram shows that the cells of the upper part of the villus are larger and contain a larger zone of protoplasm than those of the lower part. The cells of the upper part of the chyle-vessel differ somewhat from those of the lower part in that they more nearly resemble the cells of the parenchyma.

for about one-half or two-thirds of its circumference, but some form complete circles, and others have a spiral direction; the latter usually extend a little more than once round the bowel, but occasionally two or three times. The spiral arrangement is the characteristic one of the shark family of fishes. The larger folds are about one-third of an inch in depth at their broadest part; but the greater number are of smaller size. The larger and smaller folds alternate with each other. They are not found at the commencement of the duodenum, but begin to appear about one or two inches beyond the pylorus. In the lower part of the descending portion, below the point where the bile and pancreatic ducts enter the intestine, they are very large and closely approximated. In the transverse portion of the duodenum and upper half of the jejunum they are large and numerous; and from this point, down to the middle of the ileum, they diminish considerably in size. In the lower part of the ileum they almost entirely disappear; hence the comparative thinness of this portion of the intestine as compared with the duodenum and jejunum. The valvulæ conniventes retard the passage of the food along the intestines, and afford a more extensive surface for absorption.

The villi are minute, highly vascular processes, projecting from the mucous membrane of the small intestine throughout its whole extent, and giving to its surface a velvety appearance. In shape, according to Rauber, they are short and leaf-shaped in the duodenum, tongue-shaped in the jejunum, and filiform in the ileum. They are largest and most numerous in the duodenum and jejunum, and become fewer and smaller in the ileum. Krause estimates their number in the upper part of the small intestine at from fifty to ninety in a square line; and in the lower part from forty to seventy, the total number for the whole length of the intestine being about four millions.

Structure of the Villi (Fig. 497).—The structure of the villi has been studied by many eminent anatomists. We shall here follow the description of Watney,[1] whose researches have a most important bearing on the physiology of that which is the peculiar function of this part of the intestine, the absorption of fat.

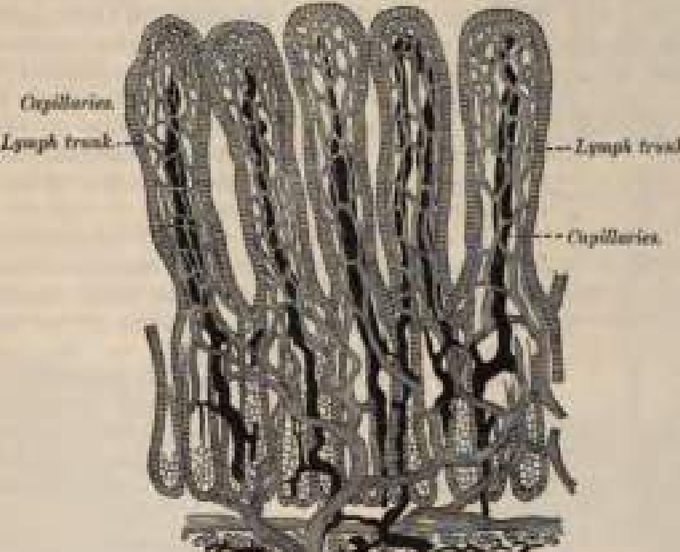


FIG. 497.—Villi of small intestine. (Cadiat.)

The essential parts of a villus are—the lacteal vessel, the blood-vessels, the epithelium, the basement membrane and muscular tissue of the mucosa, these structures being supported and held together by retiform lymphoid tissue.

These structures are arranged in the following manner: situated in the centre of the villus is the lacteal, terminating near the summit in a blind extremity; running along this vessel are unstriped muscular fibres: surrounding it is a plexus of capillary vessels, the whole being enclosed by a basement-membrane, and covered by columnar epithelium. Those structures which are contained within the basement-membrane—namely, the lacteal, the muscular tissue, and the blood-vessels—

[1] *Phil. Trans.*, vol. clxv., pt. ii.

are surrounded and enclosed by a delicate reticulum which forms the matrix of the villus, and in the meshes of which are found large flattened cells with an oval nucleus, and, in smaller numbers, lymph-corpuscles. These latter are to be distinguished from the larger cells of the villus by their behavior with reagents, by their size, and by the shape of their nucleus, which is spherical. Transitional forms, however, of all kinds are met with between the lymph-corpuscles and the proper cells of the villus. Nerve-fibres are contained within the villi; they form ramifications throughout the reticulum.

The *lacteals* are in some cases double, and in some animals multiple. Situated in the axis of the villi, they commence by dilated cæcal extremities near to, but not quite at, the summit of the villus. The walls are composed of a single layer of endothelial cells, the interstitial substance between the cells being continuous with the reticulum of the matrix.

The *muscular fibres* are derived from the muscularis mucosæ, and are arranged in bundles around the lacteal vessel, extending from the base to the summit of the villus, and giving off laterally, individual muscle-cells, which are enclosed by the reticulum, and by it are attached to the basement membrane.

The *blood-vessels* form a plexus between the lacteal and the basement membrane, and are enclosed in the reticular tissue; in the interstices of the capillary plexus, which they form, are contained the cells of the villus.

These structures are surrounded by the basement membrane, which is made up of a stratum of endothelial cells, and upon which is placed a layer of columnar epithelium. The reticulum of the matrix is continuous through the basement membrane (that is, through the interstitial substance between the individual endothelial cells) with the interstitial cement substance of the columnar cells on the surface of the villus. Thus we are enabled to trace a direct continuity between the interior of the lacteal and the surface of the villus by means of the reticular tissue, and it is along this path that the chyle passes in the process of absorption by the villi. That is to say, it passes first of all into the columnar epithelial cells, and, escaping from them, is carried into the reticulum of the villus, and thence into the central lacteal.

The **simple follicles**, or *crypts of Lieberkühn* (Figs. 499, 500), are found in considerable numbers over every part of the mucous membrane of the small intestine. They consist of minute tubular depressions of the mucous membrane, arranged perpendicularly to the surface, upon which they open by small circular apertures. They may be seen with the aid of a lens, their orifices appearing as minute dots scattered between the villi. Their walls are thin, consisting of a basement-membrane lined by columnar epithelium, and covered on their exterior by capillary vessels.

The **duodenal** or **Brunner's glands** are limited to the duodenum and commencement of the jejunum. They are small, flattened, granular bodies embedded in the submucous areolar tissue, and open upon the surface of the mucous membrane by minute excretory ducts. They are most numerous and largest near the pylorus. They are small compound acino-tubular glands, and much resemble the small glands which are found in the mucous membrane of the

FIG. 499.—Longitudinal section of crypts of Lieberkühn. Goblet-cells seen among the columnar epithelial cells. (Klein and Noble Smith.)

FIG. 500.—Transverse section of crypts of Lieberkühn. (Klein and Noble Smith.)

mouth. They are believed by Watney to be direct continuations of the pyloric glands of the stomach. They consist of a number of tubular alveoli, lined by epithelium, and opening by a single duct on the inner surface of the intestine.

The **solitary glands** (*glandulæ solitariæ*) are found scattered throughout the mucous membrane of the small intestine, but are most numerous in the lower part of the ileum. They are small, round, whitish bodies, from half a line to a line in diameter. Their free surface is covered with villi, and each gland is surrounded by the openings of the follicles of Lieberkühn. They are now recognized as lymph-follicles, and consist of a dense interlacing retiform tissue closely packed with lymph-corpuscles, and permeated with an abundant capillary network (Fig. 501). The interspaces of the retiform tissue are continuous with larger lymph-spaces at the base of the gland, through which they communicate with the lacteal system. They are situated partly in the submucous tissue, partly in the mucous membrane, whence they form slight projections of its epithelial layer, after having penetrated the muscularis mucosæ. The villi which are situated on them are generally absent from the very summit (or "cupola," as Frey calls it) of the gland.

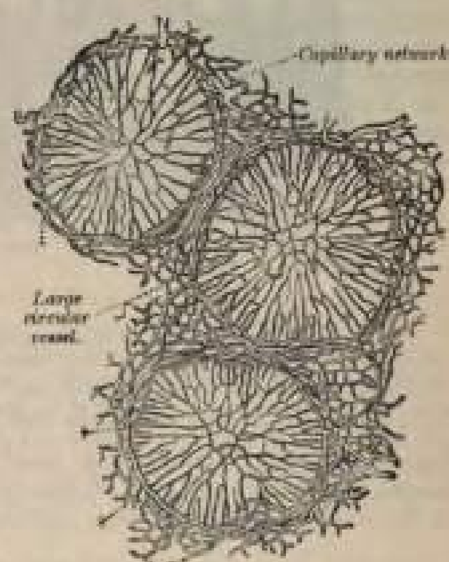


FIG. 501.—Transverse section through the equatorial plane of three of Peyer's follicles from the rabbit.

Peyer's glands (agminated glands) (Figs. 501 to 504) may be regarded as aggregations of solitary glands, forming circular or oval patches from twenty to thirty in number, and varying in length from half an inch to four inches. They are largest and most numerous in the ileum. In the lower part of the jejunum they are small, of a circular form, and few in number. They are occasionally seen in the duodenum. They are placed lengthwise in the intestine, and are situated in the portion of the tube most

FIG. 502.—Patch of Peyer's glands. From the lower part of the ileum.

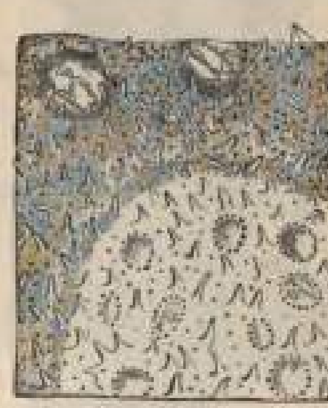


FIG. 503.—A portion of the above magnified.

distant from the attachment of the mesentery. Each patch is formed of a group of the above-described solitary glands covered with mucous membrane, and in almost every respect are similar in structure to them. They do not, however, as a rule, possess villi on their free surface. Each patch is surrounded by a circle of the crypts of Lieberkühn. They are best marked in the young subject, becoming indistinct in middle age, and sometimes altogether disappearing in advanced life.

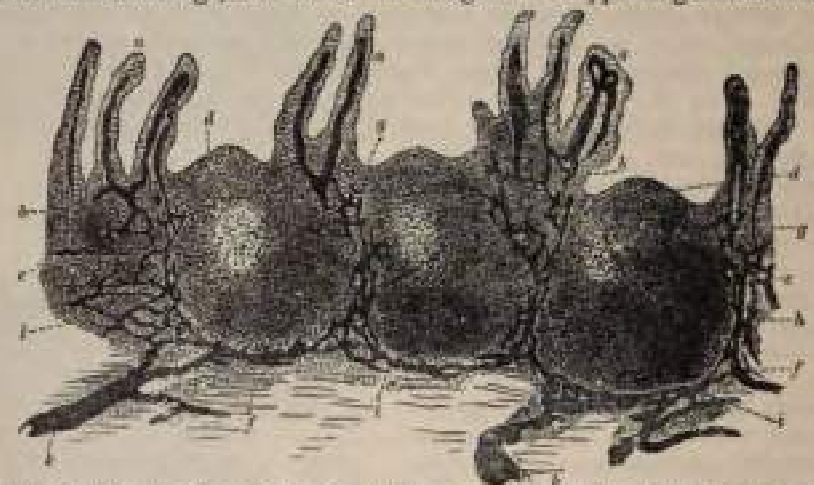


FIG. 504.—Vertical section of one of Peyer's patches from man, injected through its lymphatic canals. *a.* Villi with their chyle-passages. *b.* Follicles of Lieberkühn. *c.* Muscularis mucosæ. *d.* Cupola or apex of solitary glands. *e.* Mesial zone of glands. *f.* Base of glands. *g.* Points of exit of the chyle-passages from the villi, and entrance into the true mucous membrane. *h.* Retiform arrangement of the lymphatics in the mesial zone. *i.* Course of the latter at the base of the glands. *k.* Confluence of the lymphatics opening into the vessels of the submucous tissue. *l.* Follicular tissue of the latter.

They are largely supplied with blood-vessels, which form an abundant plexus around each follicle and give off fine branches which permeate the lymphoid tissue in the interior of the follicle. The lacteal plexuses which are found throughout

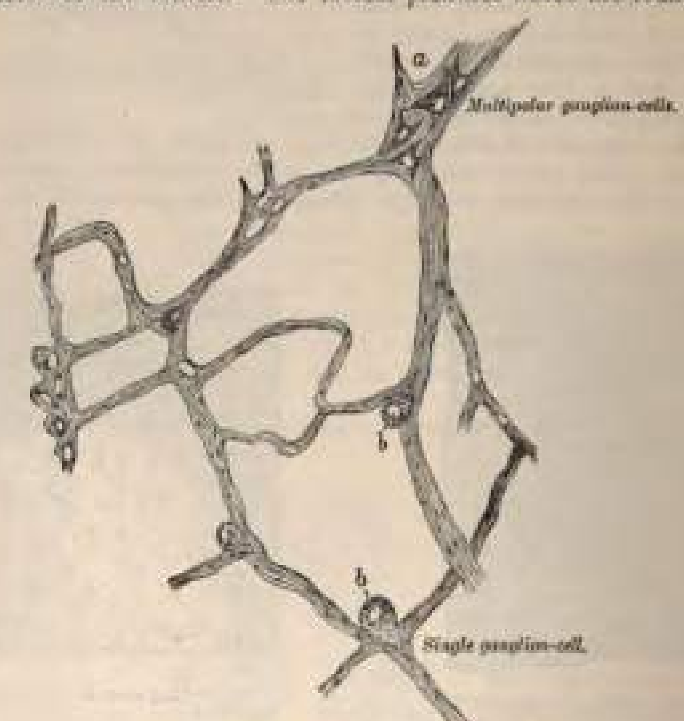


FIG. 505.—Meissner's plexus. (Klein and Noble Smith.)

the small intestine are especially abundant around these patches; here they form rich plexuses with sinuses around the glands (Fig. 504).

Vessels and Nerves.—The jejunum and ileum are supplied by the superior mesenteric artery, the branches of which, having reached the attached border of the bowel, run between the serous and muscular coats, with frequent inosculations to the free border, where they also anastomose with other branches running round the opposite surface of the gut. From these vessels numerous branches are given off, which pierce the muscular coat, supplying it and forming an intricate plexus in the submucous tissue. From this plexus minute vessels pass to the glands and villi of the mucous membrane. The veins have a similar course and arrangement to the arteries. The *lymphatics of the small intestines* (lacteals) are arranged in two sets, those of the mucous membrane, and those of the muscular coat. The lymphatics of the villi commence in these structures in the manner described above, and form an intricate plexus in the mucous and submucous tissue, being joined by the lymphatics from the lymph-spaces at the bases of the solitary glands, and from this pass to larger vessels at the mesenteric border of the gut. The lymphatics of the muscular coat are situated to a great extent between the two layers of muscular fibres, where they form a close plexus, and throughout their course communicate freely with the lymphatics from the mucous membrane, and empty themselves in the same manner into the commencement of the lacteal vessels at the attached border of the gut.

The *nerves of the small intestines* are derived from the plexuses of sympathetic nerves around the superior mesenteric artery. From this source they run to a plexus of nerves and ganglia situated between the circular and longitudinal muscular fibres (*Auerbach's plexus*), from which the nervous branches are distributed to the muscular coats of the intestine. From this plexus a secondary plexus is derived (*Meissner's plexus*), and is formed by branches which have perforated the circular muscular fibres (Fig. 505). This plexus lies between the muscular and mucous coats of the intestine. It is also gangliated, and from it the ultimate fibres pass to the muscularis mucosæ and to the villi and mucous membrane.

THE LARGE INTESTINE.

The large intestine extends from the termination of the ileum to the anus. It is about five feet in length, being one-fifth of the whole extent of the intestinal canal. It is largest at its commencement at the cæcum, and gradually diminishes as far as the rectum, where there is a dilatation of considerable size just above the anus. It differs from the small intestine in its greater size, its more fixed position, its sacculated form, and in possessing certain appendages to its external coat, the *appendices epiploicæ*. Further, its longitudinal muscular fibres do not form a continuous layer around the gut, but are arranged in three longitudinal bands or *tæniæ*. The large intestine, in its course, describes an arch, which surrounds the convolutions of the small intestine. It commences in the right inguinal region, in a dilated part, the *cæcum*. It ascends through the right lumbar and hypochondriac regions to the under surface of the liver; it here takes a bend (the *hepatic flexure*) to the left, and passes transversely across the abdomen on the confines of the epigastric and umbilical regions, to the left hypochondriac region; it then bends again (the *splenic flexure*), and descends through the left lumbar region to the left iliac fossa, where it becomes con-

FIG. 506.—The cæcum and colon laid open to show the ileo-cæcal valve.

voluted, and forms the sigmoid flexure; finally it enters the pelvis, and descends along its posterior wall to the anus. The large intestine is divided into the cæcum, colon, and rectum.

The **Cæcum** (*cæcus, blind*) is the large blind pouch, or *cul-de-sac*, situated below the ileo-cæcal valve, in which the large intestine commences (Fig. 506). Its blind end is directed downward, and its open end upward, communicating directly with the colon, of which this blind pouch appears to be the beginning or head, and hence the old name *caput cæcum coli* was applied to it. Its size is variously estimated by different authors, but on an average it may be said to be two and a half inches in length and three in breadth. It is situated in the right iliac fossa, above the outer half of Poupart's ligament: it rests on the Ilio-psoas muscle and lies immediately behind the abdominal wall. As a rule, it is entirely enveloped on all sides by peritoneum, but in a certain number of cases (6 per cent., Berry) the peritoneal covering is not complete, so that a small portion of the upper end of the posterior surface is uncovered and connected to the iliac fascia by connective tissue. The cæcum lies quite free in the abdominal cavity and enjoys a considerable amount of movement, so that it often becomes herniated down the right inguinal canal, and has occasionally been found in an inguinal hernia on the left side. The cæcum varies in shape, but, according to Treves, in man it may be classified under one of four types. In early fœtal life it is short, conical, and broad at the base, with its apex turned upward and inward toward the ileo-cæcal junction. It then resembles the cæcum of some of the monkey tribe, *e. g.*, Mangabey monkey. As the fœtus grows the cæcum increases in length more than in breadth, so that it forms a longer tube than in the primitive form and without the broad base, but with the same inclination inward of the apex toward the ileo-cæcal junction. This form is seen in others of the monkey tribe, *e. g.*, the spider monkey. As development goes on, the lower part of tube ceases to grow and the upper part becomes greatly increased, so that at birth there is a narrow tube, the vermiform appendix, hanging from a conical projection, the cæcum. This is the infantile form, and as it may persist throughout life, in about 2 per cent. of cases, it is regarded by Treves as the *first* of his four types of human cæca. The cæcum is conical and the appendix rises from its apex. The three longitudinal bands start from the appendix and are equidistant from each other. In the *second* type, the conical cæcum has become quadrate by the growing out of a saccule on either side of the anterior longitudinal band. These saccules are of equal size, and the appendix arises from between them, instead of from the apex of a cone. This type is found in about 3 per cent. of cases. The *third* type is the normal type of man. Here the two saccules, which in the second type were uniform, have grown at unequal rates; the right with greater rapidity than the left. In consequence of this an apparently new apex has been formed by the growing downward of the right saccule, and the original apex, with the appendix attached, is pushed over to the left toward the ileo-cæcal junction. The three longitudinal bands still start from the base of the appendix, but they are now no longer equidistant from each other, because the right saccule has grown between the anterior and postero-external bands, pushing them over to the left. This type occurs in about 90 per cent. of cases. The *fourth* type is merely an exaggerated condition of the third; the right saccule is still larger, and at the same time the left saccule has been atrophied, so that the original apex of the cæcum, with the appendix, is close to the ileo-cæcal junction, and the anterior band courses inward to the same situation. This type is present in about 4 per cent. of cases.

The **vermiform appendix** is a long, narrow, worm-shaped tube, which starts from what was originally the apex of the cæcum, and may pass in several directions: upward behind the cæcum; to the left behind the ileum and mesentery; or downward and inward into the true pelvis. It varies from one to nine inches in length, its average being about three inches. It is retained in position by a fold of peritoneum derived from the left leaf of the mesentery, which forms a mesentery for it. This is triangular in shape, but does not extend the whole length of the tube, but leaves the distal third free and completely covered by peritoneum. Between its two layers lies a considerable branch of the ileo-colic artery, the artery of the appendix. Its canal is small, extends throughout the whole length of the tube, and communicates with the cæcum by an orifice which is placed below and behind the ileo-cæcal opening. It is sometimes guarded, according to Gerlach, by a semilunar valve formed by a fold of mucous membrane, but this is by no means constant. Its coats are the same as those of the intestine: serous, muscular, submucous, and mucous, the latter containing an abundant supply of retiform tissue, especially in young subjects.

It is stated that the vermiform appendix tends to undergo obliteration as an involution change of a functionless organ.

The Ileo-cæcal Valve (*Valvula Bauhini*).—The lower end of the ileum terminates by opening into the inner and back part of the large intestine, at the point of junction of the cæcum with the colon. The opening is guarded by a valve, consisting of two semilunar segments, an upper or colic and lower or cæcal, which project into the lumen of the large intestine. The upper one, nearly horizontal in direction, is attached by its convex border to the point of junction of the ileum with the colon; the lower segment, which is more concave and longer, is attached to the point of junction of the ileum with the cæcum. At each end of the aperture the two segments of the valve coalesce, and are continued as a narrow membranous ridge around the canal for a short distance, forming the *fræna* or *retinacula* of the valve. The left or anterior end of the aperture is rounded; the right or posterior is narrow and pointed.

Each segment of the valve is formed by a reduplication of the mucous membrane and of the circular muscular fibres of the intestine, the longitudinal fibres and peritoneum being continued uninterruptedly across from one portion of the intestine to the other. When these are divided or removed, the ileum may be drawn outward, and all traces of the valve will be lost, the ileum appearing to open into the large intestine by a funnel-shaped orifice of large size.

The surface of each segment of the valve directed toward the ileum is covered with villi, and presents the characteristic structure of the mucous membrane of the small intestine; while that turned toward the large intestine is destitute of villi, and marked with the orifices of the numerous tubular glands peculiar to the mucous membrane of the large intestine. These differences in structure continue as far as the free margin of the valve.

When the cæcum is distended, the margins of the opening are approximated so as to prevent any reflux into the ileum.

The **colon** is divided into four parts—the ascending, transverse, descending, and the sigmoid flexure.

The **ascending colon** is smaller than the cæcum, with which it is continuous. It passes upward, from its commencement at the cæcum, opposite the ileo-cæcal valve, to the under surface of the right lobe of the liver, on the right of the gall-bladder, where it is lodged in a shallow depression, the impressio colica; here it bends abruptly inward to the left, forming the *hepatic flexure*. It is retained in contact with the posterior wall of the abdomen by the peritoneum, which covers its anterior surface and sides, its posterior surface being connected by loose areolar tissue with the Quadratus lumborum and Transversalis muscles, and with the front of the lower and outer part of the right kidney (Figs. 507 and 508). Sometimes the peritoneum almost completely invests it, and forms a distinct but narrow mesocolon.[1] It is in relation, in front, with the convolutions of the ileum and the abdominal parietes.

[1] Treves states that, after a careful examination of one hundred subjects, he found that in fifty-two there was neither an ascending nor a descending mesocolon. In twenty-two there was a descending mesocolon, but no trace of a corresponding fold on the other side. In fourteen subjects there was a mesocolon to both the ascending and the descending segments of the bowel; while in the remaining twelve there was an ascending mesocolon, but no corresponding fold on the left side. It follows, therefore, that in performing lumbar colotomy a mesocolon may be expected on the left side in 36 per cent. of all cases, and on the right in 26 per cent. (*The Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885, p. 55.)

The **transverse colon**, the longest part of the large intestine, passes transversely from right to left across the abdomen, opposite the confines of the epigastric and umbilical zones, into the left hypochondriac region, where it curves downward

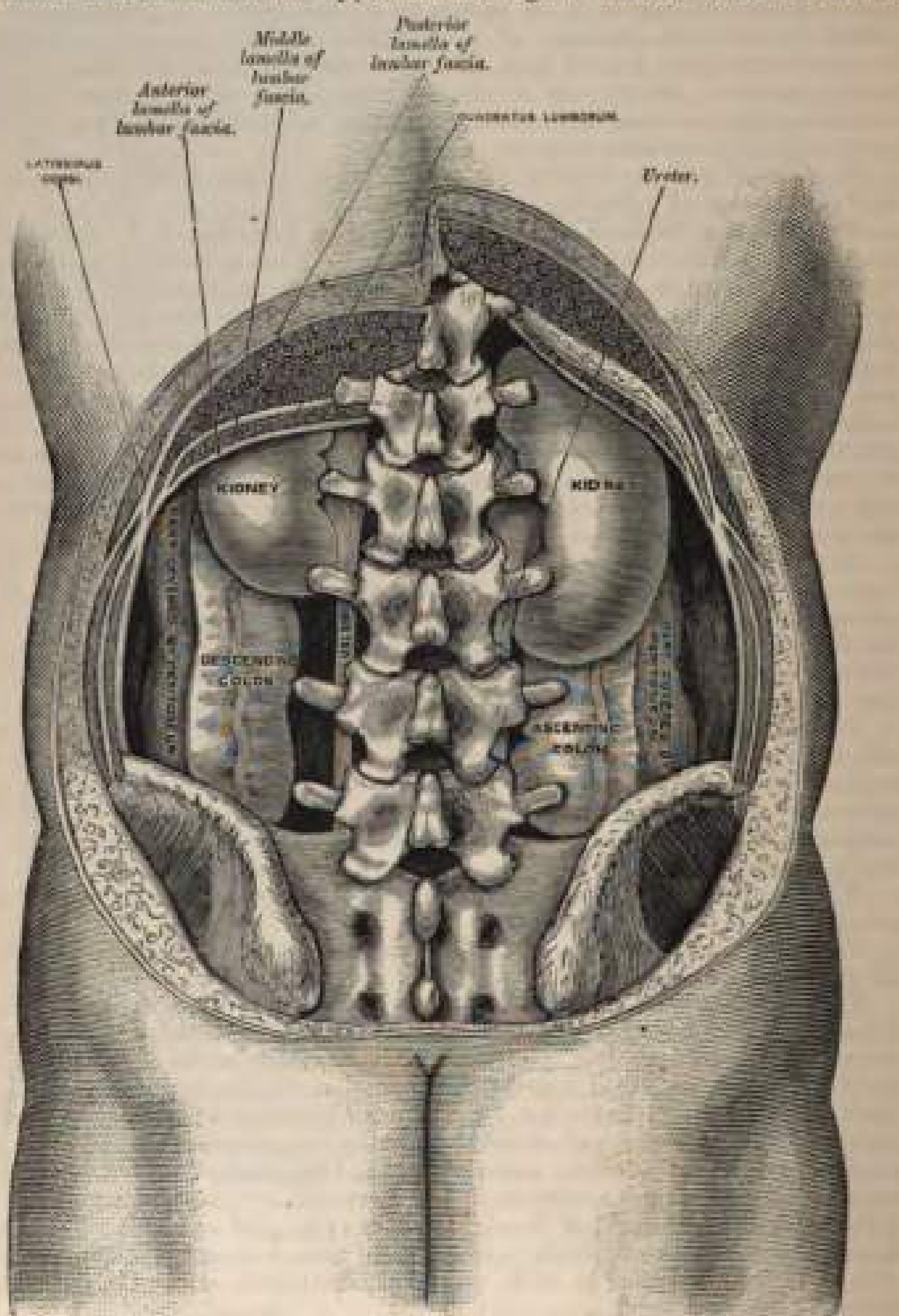


FIG. 507.—Diagram of the relations of the large intestine and kidney, from behind.

beneath the lower end of the spleen, forming the *splenic flexure*. In its course it describes an arch, the concavity of which is directed backward toward the vertebral column and a little upward; hence the name *transverse arch of the colon*. This is the most movable part of the colon, being almost completely invested by peritoneum, and connected to the spine behind by a large and wide duplicature of that membrane, the *transverse mesocolon.* It is in relation, by its upper surface, with the liver and gall-bladder, the great curvature of the stomach, and the lower end of the spleen; by its under surface, with the small intestines; by its anterior surface, with the anterior layers of the great omentum and the abdominal parietes; its posterior surface on the right side is in relation with the second portion of the duodenum, and on the left is in contact with some of the convolutions of the jejunum and ileum.

The **descending colon** passes downward through the left hypochondriac and lumbar regions along the outer border of the left kidney. At the lower end of the kidney it turns inward toward the outer border of the Psoas muscle, along which it descends to the crest of the ilium, where it terminates in the sigmoid flexure. At its commencement it is connected with the Diaphragm by a fold of peritoneum, the *phreno-colic* ligament (see page 902). It is retained in position by the peritoneum, which covers its anterior surface and sides, its posterior surface being connected by areolar tissue with the outer border of the left kidney, and the Quadratus lumborum and Transversalis muscles (Figs. 507, 508). It is smaller in calibre and more deeply placed than the ascending colon, and is more frequently covered with peritoneum on its posterior surface than the ascending colon (Treves).

The **sigmoid flexure** is the narrowest part of the colon: it is situated in the left iliac fossa, commencing from the termination of the descending colon, at the margin of the crest of the ilium, and ending in the rectum at the brim of the true pelvis opposite the left sacro-iliac symphysis. It curves in the first place forward, downward, and inward for about two inches, and then forms a loop, which varies in length and position, and which terminates in the rectum.[1] The first portion is in close relation with the iliac fascia, and is covered by peritoneum on its sides and anterior surface only. The loop is entirely surrounded by peritoneum, and is retained in its place by a loose fold of peritoneum, the *sigmoid mesocolon,* which connects it to the Psoas muscle. This loop, which normally hangs downward, sometimes into the true pelvis, is very movable, and may be displaced upward in cases of distention of the pelvic viscera. The sigmoid flexure is in relation in front with the small intestines and abdominal parietes. The sigmoid mesocolon is attached to a line running downward and inward from the crest of the ilium, across the Psoas muscle, to become continuous with the *mesorectum* near the bifurcation of the common iliac artery (Fig. 490). In its left layer is the inter-sigmoid fossa (see page 905).

The **rectum** is the terminal part of the large intestine, and extends from the sigmoid flexure to the anal orifice. The superior limit cannot be determined precisely, since there is no point of demarcation between the sigmoid flexure and the first part of the rectum; but the brim of the true pelvis, opposite the left sacro-iliac joint, is arbitrarily given as its point of commencement. From this point it passes downward, backward, and to the right to the level of the third sacral vertebra, where it lies in the middle line. This is the *first part* of the rectum. The *second part* curves forward and is continued downward as far as the apex of the prostate gland, about an inch in front of the tip of the coccyx. From this point the bowel is directed backward, and, passing downward, terminates at the anal orifice. This is the third portion of the rectum, or, as described by Symington, the *anal canal.* It will be seen, therefore, that the rectum presents two antero-posterior curves: the first, with its convexity backward, is due to the conformation of the sacro-coccygeal column, and represents the arc of a circle, the centre of which is opposite the third sacral vertebra. The lower one has its convexity forward, and is angular. Its centre corresponds to a line drawn between the anterior parts of the ischial tuberosities. Two lateral curves are also described:

[1] Treves describes the sigmoid flexure somewhat differently. He includes in his description of this portion of the bowel the upper part of the rectum, and makes it terminate opposite the third portion of the sacrum. Instead of forming a sigmoid curve, he describes it as a large loop or bend, more like the Greek letter Ω (omega).

the one to the right, opposite the junction of the third and fourth sacral vertebræ; the other to the left, opposite the sacro-coccygeal articulation. They are of little importance.

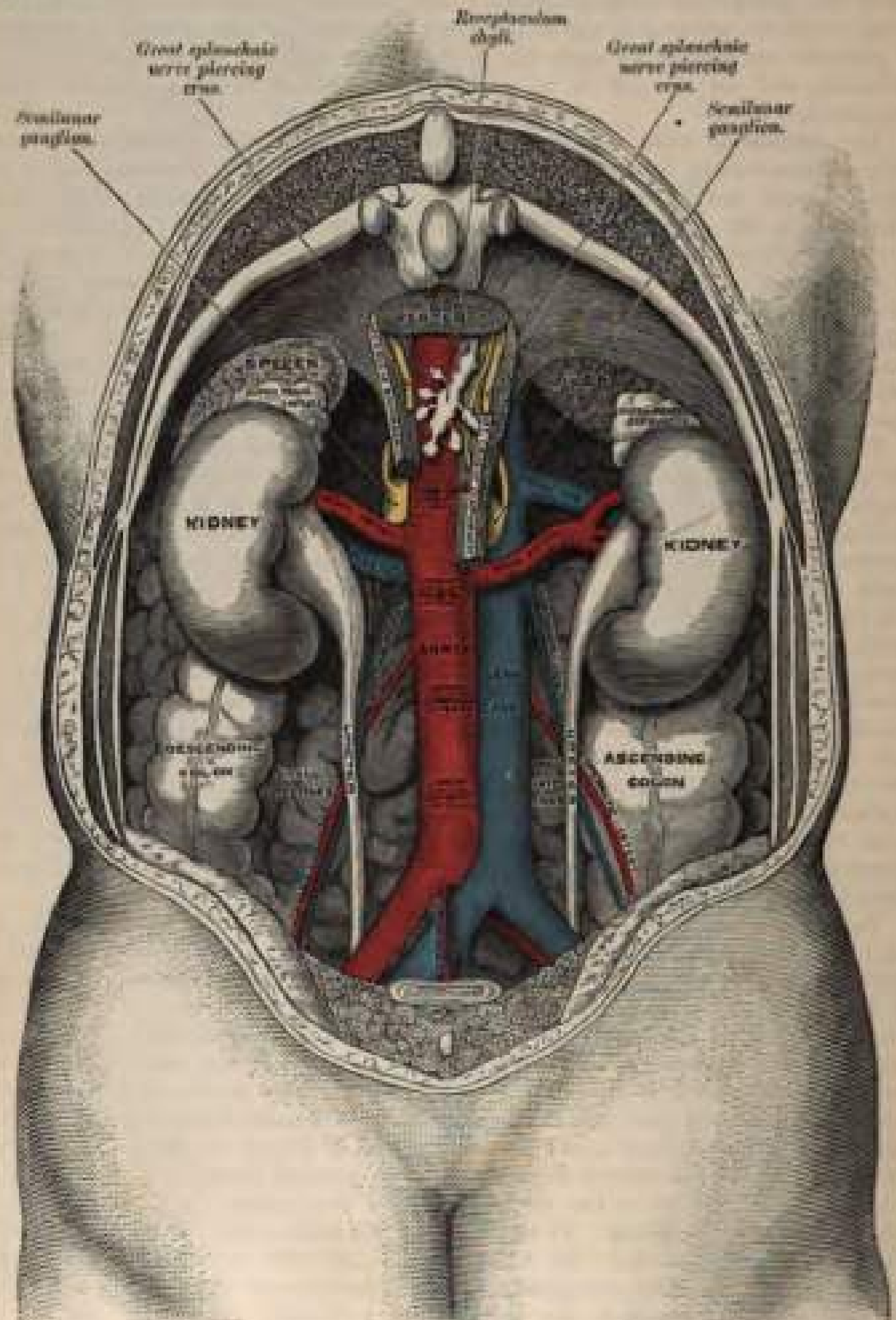


Fig. 368.—The relations of the viscera and large vessels of the abdomen. (Seen from behind, the last dorsal vertebra being well raised.)

The length of the rectum is about eight inches. The first part is four inches, the second three, and the third one to one and a half, being rather longer in the male than in the female. The rectum is narrower in its upper part than the sigmoid flexure, but is capable of considerable distention. In the lower part of the second portion it becomes a transverse slit, its anterior and posterior walls lying close together when the tube is empty, on account of the organs in the front part of the pelvis pushing the rectum backward on the sacrum and coccyx. The third part of the rectum, the anal canal, is also a slit, with, however, an antero-posterior direction, so that its lateral walls are in apposition (Fig. 509).

The first portion of the rectum is almost completely surrounded by peritoneum, and is connected to the anterior surface of the sacrum by a double fold, called the *mesorectum*, which is continuous above with the sigmoid mesocolon. The mesorectum is triangular in shape, the apex of which ends below at the third sacral vertebra; between its two layers is the superior hemorrhoidal artery. The second portion has no mesorectum, but is covered in front and laterally by peritoneum at its upper part; gradually the peritoneum leaves its sides, and about an inch above the prostate is reflected from the anterior surface of the bowel on to the posterior wall of the bladder in the male, and the upper fifth of the posterior wall of the vagina in the female, forming the recto-vesical and recto-vaginal pouches, respectively. The third portion of the rectum has no peritoneal covering. The level at which the peritoneum leaves the anterior wall of the rectum to be reflected on to the viscus in front of it is of considerable importance from a surgical point of view, in connection with removal of the lower part of the rectum. It is higher in the male than in the female. In the former the height of the recto-vesical pouch is about three inches; that is to say, the height to which an ordinary index finger can reach from the anus. In the female the height of the recto-vaginal pouch is about 2½ inches from the anal orifice.

FIG. 509.—Coronal section through the anal canal. (Symington.) B. Cavity of bladder. VD. Vas deferens. SV. Seminal vesicle. R. Second part of rectum. AC. Anal canal. L.A. Levator ani. IS. Internal sphincter. ES. External sphincter.

The *first portion* of the rectum is in relation, behind, with the mesorectum and the superior hemorrhoidal artery, the left Pyriformis muscle, and left sacral plexus of nerves, which separate it from the anterior surface of the upper sacral vertebræ; to its left side are the branches of the left internal iliac artery and the left ureter; in front it is separated, in the male, from the posterior surface of the bladder; in the female, from the posterior surface of the uterus and its appendages, by some convolutions of the small intestine, and frequently by the sigmoid flexure of the colon. The *second portion* of the rectum is in relation, in front, in the male, with the recto-vesical pouch, the triangular portion of the base of the bladder, the vesiculæ seminales, and vasa deferentia, and more anteriorly with the under surface of the prostate. In the female, with the posterior wall of the vagina below, and the recto-vaginal pouch above, in which are some convolutions of the small intestine. The *third portion* or *anal canal* is invested by the Internal sphincter, supported by the Levatores ani muscles, and surrounded at its termination by the External sphincter; in the empty condition it presents the appearance of a longitudinal slit. In the male it is separated from the membranous portion and bulb of the urethra by a triangular space; and in the female it is separated from the lower end of the vagina by the perineal body. Laterally is the fat in the ischio-rectal fossæ.

Structure.—The large intestine has four coats—serous, muscular, areolar, and mucous.

The *serous coat* is derived from the peritoneum, and invests the different portions of the large intestine to a variable extent. The cæcum is completely covered by the serous membrane, except in a small percentage of cases (5 or 6 per cent.), where a small portion of the upper end of the posterior surface is uncovered. The ascending and descending colon are usually covered only in front and at the sides; a variable amount of the posterior surface is uncovered.[1] The transverse colon is almost completely invested, the parts corresponding to the attachment of the great omentum and transverse mesocolon being alone excepted. The sigmoid flexure is completely surrounded, except along the line to which the sigmoid mesocolon is attached. The upper part of the rectum is completely invested by the peritoneum, except along the attachment of the mesorectum; the middle portion is covered only on its anterior surface, and part of its sides in the upper portion; and the lower portion is entirely devoid of any serous covering. In the course of the colon and upper part of the rectum the peritoneal coat is thrown into a number of small pouches filled with fat, called *appendices epiploicæ*. They are chiefly appended to the transverse colon.

The *muscular coat* consists of an external longitudinal and an internal circular layer of muscular fibres.

The *longitudinal fibres*, although found to a certain extent all round the intestine, do not form a uniform layer over the whole surface of the large intestine. In the cæcum and colon they are especially collected into three flat longitudinal bands or tæniæ, each being about half an inch in width. These bands commence at the attachment of the vermiform appendix, which is surrounded by a uniform layer of longitudinal muscular fibres, to the cæcum: one, the posterior, is placed along the attached border of the intestine; the anterior, the largest, corresponds along the arch of the colon to the attachment of the great omentum, but is in front in the ascending and descending colon and sigmoid flexure; the third, or lateral band, is found on the inner side of the ascending and descending colon, and on the under aspect of the transverse colon. These bands are nearly one-half shorter than the other coats of the intestine, and serve to produce the sacculi which are characteristic of the cæcum and colon; accordingly, when they are dissected off, the tube can be lengthened, and its sacculated character becomes lost. In the sigmoid flexure the longitudinal fibres become more scattered; but upon its lower part, and round the rectum, they spread out and form a layer which completely encircles this portion of the gut, but is thicker on the anterior and posterior surfaces, where it forms two bands, than on the lateral surfaces. In addition to the muscular fibres of the bowels, two bands of plain muscular tissue arise from the second and third coccygeal vertebræ, and pass downward and forward to blend with the longitudinal muscular fibres on the posterior wall of the anal canal. These are known as the *recto-coccygeal* muscles.

The *circular fibres* form a thin layer over the cæcum and colon, being especially accumulated in the intervals between the sacculi; in the rectum they form a thick layer, especially at its lower end, where they become numerous, and constitute the Internal sphincter.

The *areolar coat* connects the muscular and mucous layers closely together.

The *mucous membrane*, in the cæcum and colon, is pale, smooth, destitute of villi, and raised into numerous crescentic folds which correspond to the intervals between the sacculi. In the rectum it is thicker, of a darker color, more vascular, and connected loosely to the muscular coat, as in the œsophagus. When the lower part of the rectum is contracted, its mucous membrane is thrown into a number of folds, some of which, near the anus, are longitudinal in direction, and are effaced by the distention of the gut. Besides these there are certain permanent folds, of a semilunar shape, known as Houston's valves.[2] They are usually three in number; sometimes a fourth is found, and occasionally only two are present. One is situated

[1] See foot-note, p. 924. [2] *Dublin Hosp. Reports*, vol. v. p. 163.

near the commencement of the rectum, on the right side; another extends inward from the left side of the tube, opposite the middle of the sacrum; the largest and most constant one projects backward from the fore part of the rectum, opposite the base of the bladder. When a fourth is present, it is situated about an inch above the anus on the back of the rectum. These folds are about half an inch in width, and contain some of the circular fibres of the gut. In the empty state of the intestine they overlap each other, as Houston remarks, so effectually as to require considerable manœuvering to conduct a bougie or the finger along the canal of the intestine. Their use seems to be "to support the weight of fecal matter, and prevent its urging toward the anus, where its presence always excites a sensation demanding its discharge."

As in the small intestine, the mucous membrane consists of a muscular layer, the muscularis mucosæ; of a quantity of retiform tissue in which the vessels ramify; of a basement-membrane and epithelium, which is of the columnar variety, and exactly resembles the epithelium found in the small intestine. The mucous membrane of this portion of the bowel presents for examination simple follicles and solitary glands.

The *simple follicles* are minute tubular prolongations of the mucous membrane arranged perpendicularly, side by side, over its entire surface; they are longer, more numerous, and placed in much closer apposition than those of the small intestine; and they open by minute rounded orifices upon the surface, giving it a cribriform appearance.

The *solitary glands* (Fig. 510) in the large intestine are most abundant in the *cæcum* and *vermiform appendix*, but are irregularly scattered also over the rest of the intestine. They are similar to those of the small intestine.

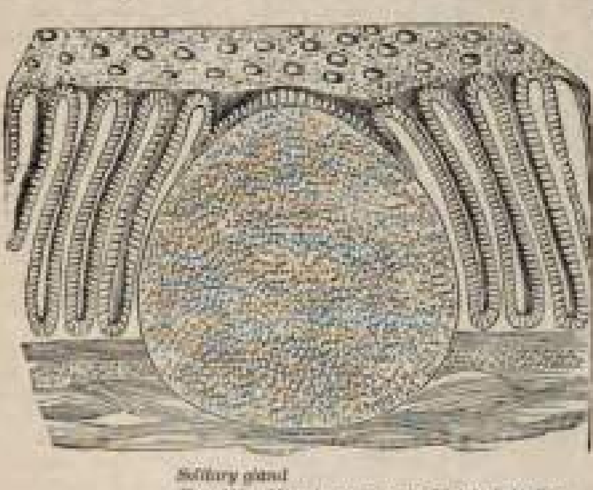


FIG. 510.—Minute structure of large intestine.

Vessels and Nerves.—The arteries supplying the large intestine give off large branches, which ramify between the muscular coats supplying them, and, after dividing into small vessels in the submucous tissue, pass to the mucous membrane The rectum is supplied mainly by the superior hemorrhoidal branch of the inferior mesenteric, but also at its lower end by the middle hemorrhoidal from the internal iliac, and the inferior hemorrhoidal from the pudic artery. The superior hemorrhoidal, the continuation of the superior mesenteric, divides into two branches, which run down either side of the rectum to within about five inches of the anus; they here split up into about six branches, which pierce the muscular coat and descend between it and the mucous membrane in a longitudinal direction, parallel with each other as far as the Internal sphincter, where they anastomose with the other hemorrhoidal arteries and form a series of loops around the anus. The veins of the rectum commence in a plexus of vessels which surrounds the lower extremity of the intestinal canal. In the vessels forming this plexus are small saccular dilatations just within the margin of the anus; from it about six vessels of considerable size are given off. These ascend between the muscular and mucous coats for about five inches, running parallel to each other; they then pierce the muscular coat, and, by their union, form a single trunk, the superior hemorrhoidal vein. This arrangement is termed the *hemorrhoidal plexus;* it communicates with the tributaries of the middle and inferior hemorrhoidal veins at its commencement, and thus a communication is established between the systemic and portal circulations. The nerves are derived from the plexuses of the sympathetic nerve around the branches of the superior and inferior mesenteric arteries that are distributed to the large intestine. They are distributed in a similar way to those in the small intestine. The lymphatic vessels of the large intestine are found in the submucosa, where they form a wide-meshed network, and also, more deeply seated, beneath the simple follicles. Those from the colon open into the mesenteric glands; those from the sigmoid flexure into the lumbar glands; those from the rectum enter the glands which are situated in the hollow of the sacrum; and those around the anus open into the glands in the groin.

Surface Form.—The coils of the small intestine occupy the front of the abdomen below the transverse colon, and are covered more or less completely by the great omentum. For the most part the coils of the jejunum occupy the left side of the abdominal cavity—*i. e.* the left lumbar and inguinal regions and the left half of the umbilical region—whilst the coils of the ileum are situated to the right, in the right lumbar and inguinal regions, in the right half of the umbilical region, and also the hypogastric. The cæcum is situated in the right inguinal region. Its position varies slightly, but the mid-point of a line drawn from the anterior superior spinous process of the ilium to the symphysis pubis will about mark the middle of its lower border. It is comparatively superficial. From it the ascending colon passes upward through the right lumbar and hypochondriac regions, and becomes more deeply situated as it ascends to the hepatic flexure, which is deeply placed under cover of the liver. The transverse colon crosses the belly transversely on the confines of the umbilical and epigastric regions, its lower border being on a level slightly above the umbilicus, its upper border just below the greater curvature of the stomach. The splenic flexure of the colon is situated behind the stomach in the left hypochondrium, and is on a higher level than the hepatic flexure. The descending colon is deeply seated, passing down through the left hypochondriac and lumbar regions to the sigmoid flexure, which is situated in the left inguinal region, and which can be felt in thin persons, with relaxed abdominal walls, rolling under the fingers when empty, and when distended forming a distinct tumor. The position of the base of the vermiform appendix is indicated by a point two inches from the anterior superior spinous process of the ilium, in a line drawn from this process to the umbilicus. This is known as *McBurney's spot.* Another mode of defining the position of the base of the appendix is to draw a line between the anterior superior spines of the ilia and marking the point where this line intersects the right semilunar line.

Upon introducing the finger into the rectum, the membranous portion of the urethra can be felt, if an instrument has been introduced into the bladder, exactly in the middle line; behind this the prostate gland can be recognized by its shape and hardness and any enlargement detected; behind the prostate the fluctuating wall of the bladder when full can be felt, and if thought desirable it can be tapped in this situation; on either side and behind the prostate the vesiculæ seminales can be readily felt, especially if enlarged by tuberculous disease. Behind, the coccyx is to be felt, and on the mucous membrane one or two of Houston's folds. The ischio-rectal fossæ can be explored on either side, with a view to ascertaining the presence of deep-seated collections of pus. Finally, it will be noted that the finger is firmly gripped by the sphincter for about an inch up the bowel. By gradual dilatation of the sphincter, the whole hand can be introduced into the rectum so as to reach the descending colon. This method of exploration is rarely, however, required for diagnostic purposes.

Surgical Anatomy.—The small intestines are much exposed to injury, but, in consequence of their elasticity and the ease with which one fold glides over another, they are not so frequently ruptured as would otherwise be the case. Any part of the small intestine may be ruptured, but probably the most common situation is the transverse duodenum, on account of its being more fixed than other portions of the bowel, and because it is situated in front of the bodies of the vertebræ, so that if this portion of the intestine is struck by a sharp blow, as from the kick of a horse, it is unable to glide out of the way, but is compressed against the bone and so lacerated. Wounds of the intestine sometimes occur. If the wound is a small puncture, under, it is said, three lines in length, no extravasation of the contents of the bowel takes place. The mucous membrane becomes everted and plugs the little opening. The bowels, therefore, may be safely punctured with a fine capillary trocar, in cases of excessive distension of the intestine with gas, without fear of extravasation. A longitudinal wound gapes more than a transverse, owing to the greater amount of circular muscular fibres. The small intestine, and most frequently the ileum, may become strangulated by internal bands, or through apertures, normal or abnormal. The bands may be formed in several different ways: they may be old peritoneal adhesions from previous attacks of peritonitis; or an adherent omentum from the same cause; or the band may be formed by Meckel's diverticulum, which has contracted adhesions at its distal extremity; or the band may be the result of the abnormal attachment of some normal structure, as the adhesion of two appendices epiploicæ, or an adherent vermiform appendix or Fallopian tube. Intussusception or invagination of the small intestine may take place in any part of the jejunum and ileum, but the most frequent situation is at the ileo-cæcal valve, the valve forming the apex of the entering tube. This form may attain great size, and it is not uncommon in these cases to find the valve projecting from the anus. Stricture, the impaction of foreign bodies, and twisting of the gut (*volvulus*) may lead to intestinal obstruction.

Resection of a portion of the intestine may be required in cases of gangrenous gut; in cases of intussusception; for the removal of new growth in the bowel; in dealing with artificial anus; and in cases of rupture. The operation is termed *enterectomy*, and is performed as follows: the abdomen having been opened and the amount of bowel requiring removal having been determined upon, the gut must be clamped on either side of this portion in order to prevent the escape of any of the contents of the bowel during the operation. The portion of bowel is then separated above and below by means of scissors. If the portion removed is small, it may be simply removed from the mesentery at its attachment and the bleeding vessels tied; but if it is large, it will be necessary to remove also a triangular piece of the mesentery, and, having secured the vessels, suture the cut edges of this structure together. The surgeon then proceeds to unite the cut ends of the bowel together by the operation of what is termed end-to-end anastomosis. There are many ways of doing this, which may be divided into two classes: one where the anastomosis is made by means of some mechanical appliance, such as Murphy's button, or one of the forms of decalcified bone bobbins; and the other, where the operation is performed by suturing the ends of the bowel in such a manner that the peritoneum covering the free divided ends of the bowel is brought into contact, so that speedy union may ensue.

The vermiform appendix is very liable to become inflamed. This condition may be set up by the appendix becoming twisted, owing to the shortness of its mesentery, in consequence of distention of the cæcum. As the result of this its blood-supply, which is mainly through one large artery running in the mesentery, becomes interfered with. Again, in rarer cases, the inflammation is set up by the impaction of a solid mass of fæces or a foreign body in it. The inflammation may result in ulceration and perforation, or, if the torsion is very acute, in gangrene of the appendix. These conditions may require operative interference, and in cases of recurrent attacks of appendicitis it is generally advisable to remove this diverticulum of the bowel. In external hernia the ileum is the portion of bowel most frequently herniated. When a part of the large intestine is involved, it is usually the cæcum, and this may occur even on the left side. In some few cases the vermiform appendix has been the part implicated in cases of strangulated hernia, and has given rise to serious symptoms of obstruction. Occasionally ulceration of the duodenal glands may occur in cases of burns, but is not a very common complication. The ulcer may perforate one of the large duodenal vessels, and may cause death from hemorrhage, or it may perforate the coats of the intestine and produce fatal septic peritonitis. The diameter of the large intestine gradually diminishes from the cæcum, which has the greatest diameter of any part of the bowel, to the point of junction of the sigmoid flexure with the rectum, at or a little below which point stricture most commonly occurs and diminishes in frequency as one proceeds upward to the cæcum. When distended by some obstruction low down, the outline of the large intestine can be defined throughout nearly the whole of its course—all, in fact, except the hepatic and splenic flexures, which are more deeply placed; the distention is most obvious in the two flanks and on the front of the abdomen just above the umbilicus. The cæcum, however, is that portion of the bowel which is, of all, most distended. It sometimes assumes enormous dimensions, and has been known to give way from the distention, causing fatal peritonitis. The hepatic flexure and the right extremity of the transverse colon are in close relationship with the liver, and abscess of this viscus sometimes bursts into the gut in this situation. The gall-bladder may become adherent to the colon, and gall-stones may find their way through into the gut, where they may become impacted or may be discharged per anum. The mobility of the sigmoid flexure renders it more liable to become the seat of a volvulus or twist than any other part of the intestine. It generally occurs in patients who have been the subjects of habitual constipation, and in whom, therefore, the meso-sigmoid flexure is elongated. The gut at this part being loaded with fæces, from its weight falls over the gut below, and so gives rise to the twist.

The surgical anatomy of the rectum is of considerable importance. There may be congenital malformation due to arrest or imperfect development. Thus, there may be no inflection of the epiblast, and consequently a complete absence of the anus; or the hind-gut may be imperfectly developed, and there may be an absence of the rectum, though the anus is developed; or the inflection of the epiblast may not communicate with the termination of the hind-gut from want of solution of continuity in the septum which in early fœtal life exists between the two. The mucous membrane is thick and but loosely connected to the muscular coat beneath, and thus favors prolapse, especially in children. The vessels of the rectum are arranged, as mentioned above, longitudinally, and are contained in the loose cellular tissue between the mucous and muscular coats, and receive no support from surrounding tissues, and this favors varicosity. Moreover, the veins, after running upward in a longitudinal direction for about five inches in the submucous tissue, pierce the muscular coats, and are liable to become constricted at this by the contraction of the muscular wall of the gut. In addition to this there are no valves in the superior hemorrhoidal veins, and the vessels of the rectum are placed in a dependent position, and are liable to be pressed upon and obstructed by hardened fæces. The anatomical arrangement, therefore, of the hemorrhoidal vessels explains the great tendency to the occurrence of piles. The presence of the Sphincter ani is of surgical importance, since it is the constant contraction of this muscle which prevents an ischio-rectal abscess from healing and causes it to become a fistula. Also, the reflex contraction of this muscle is the cause of the severe pain complained of in fissure of the anus. The relations of the peritoneum to the rectum are of importance in connection with the operation of removal of the lower end of the rectum for malignant disease. This membrane gradually leaves the rectum as it descends into the pelvis; first leaving its posterior surface, then the sides, and then the anterior surface to become reflected in the male on to the posterior wall of the bladder, forming the recto-vesical pouch, and in the female on to the posterior wall of the vagina, forming Douglas's pouch. The recto-vesical pouch of peritoneum extends to within three inches from the anus, so that it is not desirable to remove more than two and a half inches of the entire circumference of the bowel, for fear of the risk of opening the peritoneum. When, however, the disease is confined to the posterior surface of the rectum, or extends farther in this direction, a greater amount of the posterior wall of the gut may be removed, as the peritoneum does not extend on this surface to a lower level than five inches from the margin of the anus. The recto-vaginal or Douglas's pouch in the female extends somewhat lower than the recto-vesical pouch of the male, and therefore it is necessary to remove a less length of the tube in this sex. Of recent years, however, much more extensive operations have been done for the removal of cancer of the rectum, and in these the peritoneal cavity has necessarily been opened. If, in these cases, the opening is plugged with antiseptic wool until the operation is completed and then the edges of the wound in the peritoneum accurately brought together with sutures, no evil result appears to follow. For cases of cancer of the rectum which are too low to be reached by abdominal section, and too high to be removed by the ordinary operation from below, Kraske has devised an operation which goes by his name. The patient is placed on his right side and an incision is made from the second sacral spine to the anus. The soft parts are now separated from the back of the left side of the sacrum as far as its left margin, and the greater and lesser sacro-sciatic ligaments are divided. A portion of the lateral mass of the sacrum, commencing on the left border at the level of the third posterior sacral foramen, and running downward and inward through the fourth foramen to the cornu, is now cut away with a chisel. The left side of the wound being now forcibly drawn outward, the whole of the rectum is brought into view, and the diseased portion can be removed, leaving the anal portion of the gut, if healthy. The two divided ends of the gut can then be approximated and sutured together in front, the posterior part being left open for drainage.

The colon frequently requires opening in cases of intestinal obstruction, and by some surgeons this operation is performed in cases of cancer of the rectum, as soon as the disease is recognized, in the hope that the rate of growth may be retarded by removing the irritation produced by the passage of fecal matter over the diseased surface. The operation of colotomy may be performed either in the inguinal or lumbar region; but inguinal colotomy has in the present day almost superseded the lumbar operation. The main reason for preferring this operation is that a spur-shaped process of the meso-colon can be formed which prevents any fecal matter finding its way past the artificial anus and becoming lodged on the diseased structures below. The sigmoid flexure being almost entirely surrounded by peritoneum, a coil can be drawn out of the wound and the greater part of its calibre removed, leaving the remainder attached to the meso-colon, which forms a spur, much the same as in an artificial anus caused by sloughing of the gut after a strangulated hernia, and this prevents any fecal matter finding its way from the gut above the opening into that below. The operation is performed by making an incision two or three inches in length from a point one inch internal to the anterior superior spinous process of the ilium, parallel to Poupart's ligament. The various layers of abdominal muscles are cut through, and the peritoneum opened and sewn to the external skin. The sigmoid flexure is now sought for, and pulled out of the wound and fixed by passing a needle threaded with carbolized silk through the meso-colon close to the gut and then through the abdominal wall. The intestine is now sewn to the skin all round, the suture passing only through the serous and muscular coats. The wound is dressed, and on the second to the fourth day, according to the requirements of the case, the protruded coil of intestine is opened and removed with scissors.

Lumbar colotomy is performed by placing the patient on the side opposite to the one to be operated on, with a firm pillow under the loin. A line is then drawn from the anterior superior to the posterior superior spine of the ilium, and the mid-point of this line (Heath) or half an inch behind the mid-point (Allingham) is taken, and a line drawn vertically upward from it to he last rib. This line represents, with sufficient correctness, the position of the normal colon. An oblique incision four inches in length is now made midway between the last rib and the crest of the ilium, so that its centre bisects the vertical line, and the following parts successively divided: (1) The skin, superficial fascia, with cutaneous vessels and nerves and deep fascia. (2) The posterior fibres of the External oblique and anterior fibres of the Latissimus dorsi.

(3) The Internal oblique. (4) The lumbar fascia and the external border of the Quadratus lumborum. The edges of the wound are now to be held apart with retractors, and the transversalis fascia will be exposed. This is to be opened with care, commencing at the posterior angle of the incision. If the bowel is distended, it will bulge into the wound, and no difficulty will be found in dealing with it. If, however, the gut is empty, this bulging will not take place, and the colon will have to be sought for. The guides to it are the lower end of the kidney, which will be plainly felt, and the outer edge of the Quadratus lumborum. The bowel having been found, is to be drawn well up into the wound, and it may be opened at once and the margins of the openings stitched to the skin at the edge of the wound; or, if the case is not an urgent one, it may be retained in this position by two harelip pins passed through the muscular coat, the rest of the wound closed, and the bowel opened in three or four days, when adhesion of the bowel to the edges of the wound has taken place.

THE LIVER.

The **Liver** is the largest gland in the body, and is situated in the upper and right part of the abdominal cavity, occupying almost the whole of the right hypochondrium, the greater part of the epigastrium, and extending into the left hypochondrium as far as the mammary line. In the male it weighs from fifty to sixty ounces; in the female, from forty to fifty. It is relatively much larger in the fœtus than in the adult, constituting, in the former, about one-eighteenth, and in the latter, about one thirty-sixth of the entire body-weight. Its greatest transverse measurement is from eight to nine inches. Vertically, near its lateral or right surface, it measures about six or seven inches, while its greatest antero-posterior diameter is on a level with the upper end of the right kidney and is from four to five inches. Opposite the vertebral column its measurement from before backward is reduced to about three inches. Its consistence is that of a soft solid; it is, however, friable and easily lacerated; its color is a dark reddish-brown, and its specific gravity is 1.05.

To obtain a correct idea of its shape, it must be hardened *in situ*, and it will then be seen to present the appearance of a wedge, the base of which is directed

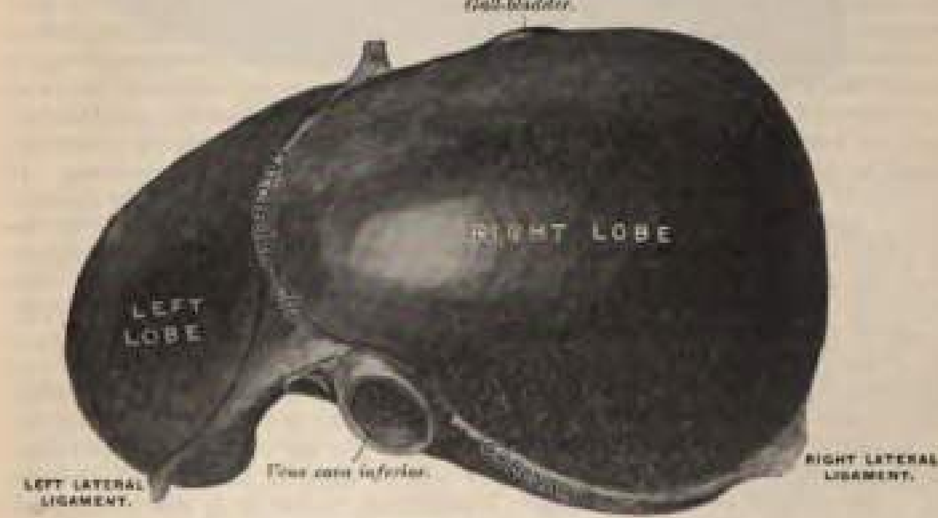


FIG. 511.—The liver. Upper surface. (Drawn from His's models.)

to the right and the thin edge toward the left. Symington describes its shape as that "of a right-angled triangular prism with the right angles rounded off." It possesses five surfaces, viz., superior, inferior, anterior, posterior, and lateral.

The superior and anterior surfaces are separated from each other by a thick rounded border, and are attached to the Diaphragm and anterior abdominal wall by a triangular or falciform fold of peritoneum, the *suspensory* or *falciform ligament*, which divides the liver into two unequal parts, termed the right and left lobes. Except along the line of attachment of this ligament to the liver, the superior and anterior surfaces are covered by peritoneum.

The *superior surface* (Fig. 511) comprises a part of both lobes, and, as a whole, is convex, and fits under the vault of the Diaphragm; its central part, however, presents a shallow depression, which corresponds with the position of the heart on the upper surface of the Diaphragm. It is separated from the anterior, posterior, and lateral surfaces by thick, rounded borders. Its left extremity is separated from the under surface by a prominent sharp margin.

The *anterior surface* is large and triangular in shape, comprising also a part of both lobes. It is directed forward, and the greater part of it is in contact with the Diaphragm, which separates it from the right lower ribs and their cartilages. In the middle line it lies behind the ensiform cartilage, to the left of which it is protected by the seventh and eighth left costal cartilages. In the angle between the diverging rib cartilages of opposite sides the anterior surface is in contact with the abdominal wall. It is separated from the inferior surface by a sharp margin, and from the superior and lateral surfaces by thick rounded borders.

The *lateral* or *right surface* is convex from before backward and slightly so from above downward. It is directed toward the right side, forming the base of the wedge, and lies against the lateral portion of the Diaphragm, which separates it from the lower part of the left pleura and lung, outside which are the right costal arches from the seventh to the eleventh inclusive.

Its *under* or *visceral surface* (Figs. 512, 513) is uneven, concave, directed downward and backward and to the left, and is in relation with the stomach and duodenum, the hepatic flexure of the colon, and the right kidney and suprarenal capsule. The surface is divided by a longitudinal fissure into a right and a left lobe, and is almost completely invested by peritoneum; the only parts where this covering is absent are where the gall-bladder is attached to the liver and at the transverse fissure, where the two layers of the lesser omentum are separated from each other by the blood-vessels and duct of the viscus. The under surface of the left lobe presents behind and to the left a depression where it is moulded over the cardiac part of the stomach, and to the right and near the centre a rounded eminence, the *tuber omentale*, which fits into the concavity of the lesser curvature, lying in front of the anterior layer of the lesser omentum. The under surface of the right lobe is divided into two unequal portions by a fossa, which lodges the gall-bladder, the *fossa vesicalis;* the portion to the left, the smaller of the two, is somewhat oblong in shape, its antero-posterior diameter being greater than its transverse. It is known as the *quadrate lobe*, and is in relation with the pyloric end of the stomach and the first portion of the duodenum. The portion of the under surface of the right lobe to the right of the fossa vesicalis presents two shallow concave impressions, one situated behind the other, the two being separated by a ridge. The anterior of these two impressions, the *impressio colica*, is produced by the hepatic flexure of the colon; the posterior, the *impressio renalis*, is occupied by the upper end of the right kidney. To the inner side of the latter impression is a third and slightly marked impression, lying between it and the neck of the gall-bladder. This is caused by the second portion of the duodenum, and is known as the *impressio duodenalis*. Just in front of the vena cava is a narrow strip of liver tissue, the caudate lobe, which connects the right inferior angle of the Spigelian lobe to the under surface of the right lobe. Immediately below it is the foramen of Winslow.

The *posterior surface* is rounded and broad behind the right lobe, but narrow on the left. Over a large part of its extent it is not covered by peritoneum; this uncovered portion is about three inches broad, and is in direct contact with the Diaphragm. It is marked off from the upper surface by the line of reflection of the upper or anterior layer of the coronary ligament. It is in the same way marked off from the under surface of the liver by the line of reflection of the lower layer of the coronary ligament. In its centre this posterior surface is deeply notched for the vertebral column and crura of the Diaphragm, and to the right of this it is indented for the inferior vena cava, which is often partly imbedded in its substance. Close to the right of this indentation and immediately above the renal impression is a small triangular depressed area (*impressio suprarenalis*), the greater part of which is devoid of peritoneum; it lodges the right suprarenal capsule. To the left of the inferior vena cava is the *Spigelian lobe*, which lies between the fissure for the vena cava and the fissure for the ductus venosus. Below and in front it projects and forms part of the posterior boundary of the transverse fissure. Here, to the right, it is connected with the under surface of the right lobe of the liver by the caudate lobe, and to the left it presents a tubercle, the *tuber papillaire*. It is opposite the tenth and eleventh dorsal vertebræ, and rests upon the aorta and crura of the Diaphragm, being covered by the peritoneum of the lesser sac. The lobe is nearly vertical in position, and is directed backward: it is longer from above downward than from side to side, and is somewhat concave in the transverse direction. On the posterior surface to the left of the Spigelian lobe is a groove indicating the position of the œsophageal orifice of the stomach.

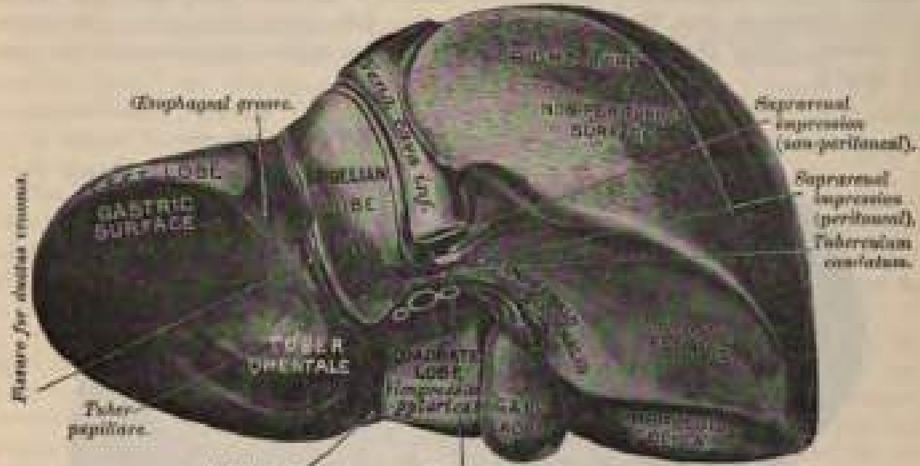


FIG. 512.—The liver. Posterior and inferior surfaces. (Drawn from His's models.)

The *inferior border* is thin and sharp, and marked opposite the attachment of the falciform ligament by a deep notch, the *umbilical notch*, and opposite the cartilage of the ninth rib by a second notch for the fundus of the gall-bladder. In adult males this border usually corresponds with the margin of the ribs in the right nipple line; but in women and children it usually projects below the ribs.

The *left extremity of the liver* is thin and flattened from above downward.

Fissures (Fig. 512).—Five fissures are seen upon the under and posterior surfaces of the liver, which serve to divide it into five lobes. They are, the umbilical fissure, the fissure of the ductus venosus, the transverse fissure, the fissure for the gall-bladder, and the fissure for the inferior vena cava. They are arranged in the form of the letter H. The left limb of the H is known as the *longitudinal fissure*. The right limb is formed in front by the *fissure for the gall-bladder*, and behind by the *fissure for the inferior vena cava;* these two fissures are separated from each other by the caudate lobe. The connecting bar of the H is the *transverse* or *portal fissure*. It separates the quadrate lobe in front from the caudate and Spigelian lobes behind.

The *longitudinal fissure* is a deep groove, which extends from the notch on the anterior margin of the liver to the upper border of the posterior surface of the organ. It separates the right and left lobes; the transverse fissure joins it, at right angles, and divides it into two parts. The anterior part is called the *umbilical fissure;* it is deeper than the posterior, and lodges the umbilical vein in the fœtus, and its remains (the round ligament) in the adult; the posterior part contains the ductus venosus, and is known as the *fissure of the ductus venosus.* This fissure lies between the quadrate lobe and the left lobe of the liver, and is often partially bridged over by a prolongation of the hepatic substance, the *pons hepatis.*

The *fissure of the ductus venosus* is the back part of the longitudinal fissure, and is situated mainly on the posterior surface of the liver. It lies between the left lobe and the lobe of Spigelius. It lodges in the fœtus the ductus venosus, and in the adult a slender fibrous cord, the obliterated remains of that vessel.

The *transverse* or *portal fissure* is a short but deep fissure, about two inches in length, extending transversely across the under surface of the left portion of the right lobe, nearer to its posterior surface than its anterior border. It joins, nearly at right angles, with the longitudinal fissure, and separates the quadrate lobe in front from the caudate and Spigelian lobes behind. By the older anatomists this fissure was considered the gateway (*porta*) of the liver; hence the large vein which enters at this fissure was called the *portal vein.* Besides this vein, the fissure transmits the hepatic artery and nerves, and the hepatic duct and lymphatics. At their entrance into the fissure, the hepatic duct lies in front and to the right, the hepatic artery to the left, and the portal vein behind and between the duct and artery.

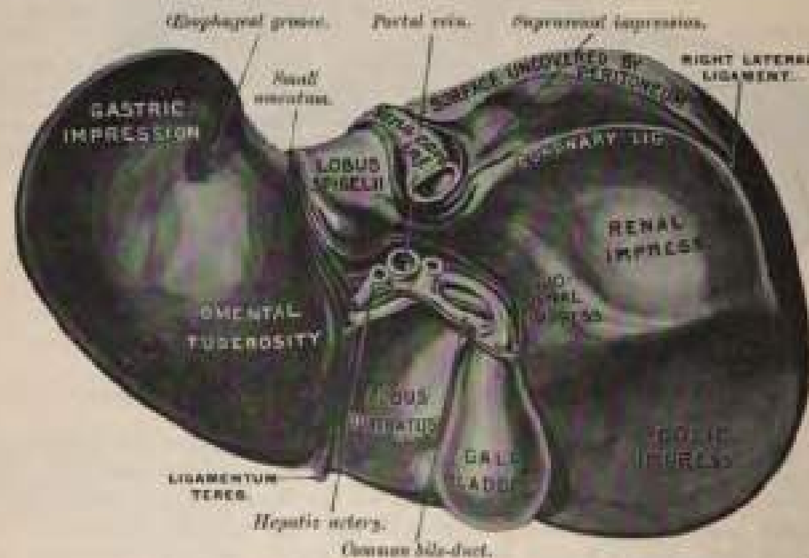


FIG. 5[illegible].—Posterior and under surfaces of the liver. (From Ellis.)

The *fissure for the gall-bladder* (*fossa vesicalis*) is a shallow, oblong fossa, placed on the under surface of the right lobe, parallel with the longitudinal fissure. It extends from the anterior free margin of the liver, which is notched for its reception, to the right extremity of the transverse fissure.

The *fissure for the inferior vena cava* is a short, deep fissure, occasionally a complete canal, in consequence of the substance of the liver surrounding the vena cava. It extends obliquely upward from the lobus caudatus, which separates it from the transverse fissure, on the posterior surface of the liver, and separates the Spigelian from the right lobe. On slitting open the inferior vena cava the orifices of the hepatic veins will be seen opening into this vessel at its upper part, after perforating the floor of this fissure.

Lobes.—The lobes of the liver, like the ligaments and fissures, are five in number—the right lobe, the left lobe, the lobus quadratus, the lobus Spigelii, and the lobus caudatus, the last three being merely parts of the right lobe.

The *right lobe* is much larger than the left; the proportion between them being as six to one. It occupies the right hypochondrium, and is separated from the left lobe, on its upper and anterior surfaces by the falciform ligament; on its under and posterior surfaces by the longitudinal fissure; and in front by the umbilical notch. It is of a somewhat quadrilateral form, its under and posterior surfaces being marked by three fissures—the transverse fissure, the fissure for the gall-bladder, and the fissure for the inferior vena cava, which separate its left part into three smaller lobes—lobus Spigelii, lobus quadratus, and lobus caudatus. On it are seen four shallow impressions, one in front (*impressio colica*), for the hepatic flexure of the colon; a second behind (*impressio renalis*), for the right kidney; a third internal, between the last-named and the gall-bladder (*impressio duodenalis*), for the second part of the duodenum; and a fourth on its posterior surface, for the suprarenal capsule (*impressio suprarenalis*).

The *lobus quadratus*, or square lobe, is situated on the under surface of the right lobe, bounded in front by the inferior margin of the liver; behind by the transverse fissure; on the right, by the fissure of the gall-bladder; and on the left by the umbilical fissure.

The *lobus Spigelii* is situated upon the posterior surface of the right lobe of the liver. It looks directly backward, and is nearly vertical in direction. It is bounded, above, by the upper layer of the coronary ligament; below, by the transverse fissure; on the right, by the fissure for the vena cava; and, on the left, by the fissure for the ductus venosus. Its left upper angle forms part of the groove for the œsophagus.

The *lobus caudatus*, or tailed lobe, is a small elevation of the hepatic substance extending obliquely outward, from the lower extremity of the lobus Spigelii to the under surface of the right lobe. It is situated behind the transverse fissure, and separates the fissure for the gall-bladder from the commencement of the fissure for the inferior vena cava.

The *left lobe* is smaller and more flattened than the right. It is situated in the epigastric and left hypochondriac regions. Its upper surface is slightly convex; its under surface is concave, and presents a shallow depression for the stomach (*gastric impression*). This is situated in front of the groove for the œsophagus, and is separated from the longitudinal fissure by the *omental tuberosity*, which lies against the small omentum and lesser curvature of the stomach.

Ligaments.—The liver is connected to the under surface of the Diaphragm and the anterior wall of the abdomen by five ligaments, four of which are peritoneal folds; the fifth is a round, fibrous cord, resulting from the obliteration of the umbilical vein. These ligaments are the falciform, two lateral, coronary, and round. It is also attached to the lesser curvature of the stomach by the gastro-hepatic or small omentum (see page 902).

The *falciform ligament* (broad or suspensory ligament) is a broad and thin antero-posterior peritoneal fold, falciform in shape, its base being directed downward and backward, its apex upward and backward. It is attached by one margin to the under surface of the Diaphragm, and the posterior surface of the sheath of the right Rectus muscle as low down as the umbilicus; by its hepatic margin it extends from the notch on the anterior margin of the liver, as far back as its posterior surface. It consists of two layers of peritoneum closely united together. Its base or free edge contains the round ligament between its layers.

The *lateral ligaments* (Fig. 511), two in number, right and left, are triangular in shape. They are formed by the apposition of the upper and lower layers of the coronary ligament, and extend from the Diaphragm to the liver—the right being attached to the border between its lateral and inferior surfaces, the left, the longer of the two, to the upper surface of the left lobe, where it lies in front of the œsophageal opening in the Diaphragm.

The *coronary ligament* connects the posterior surface of the liver to the Diaphragm. It is formed by the reflection of the peritoneum from the Diaphragm on to the upper and lower margins of the posterior surface of the organ. The coronary ligament consists of two layers, which are continuous on each side with the lateral ligaments; and, in front, with the falciform ligament. Between the layers a large triangular area is left uncovered by peritoneum, and is connected to the Diaphragm by firm areolar tissue.

The *round ligament* (ligamentum teres) is a fibrous cord resulting from the obliteration of the umbilical vein. It ascends from the umbilicus, in the free margin of the falciform ligament, to the notch in the anterior border of the liver, from which it may be traced along the longitudinal fissure on the under surface of the liver; on the posterior surface it is continued as the obliterated ductus venosus as far back as the inferior vena cava.

Vessels.—The vessels connected with the liver are also five in number: they are, the hepatic artery, the portal veins, the hepatic vein, the hepatic duct, and the lymphatics.

The *hepatic artery* and *portal vein*, accompanied by numerous lymphatics and nerves, ascend to the transverse fissure between the layers of the gastro-hepatic omentum. The *hepatic duct*, lying in company with them, descends from the transverse fissure between the layers of the same omentum. The relative position of the three structures is as follows: the hepatic duct lies to the right, the hepatic artery to the left, and the portal vein behind and between the other two. They are enveloped in a loose areolar tissue, the *capsule of Glisson*, which accompanies the vessels in their course through the *portal canals* in the interior of the organ.

The *hepatic veins* convey the blood from the liver. They commence in the substance of the liver, in the capillary terminations of the portal vein and hepatic artery; these tributaries, gradually uniting, usually form three veins, which converge toward the posterior surface of the liver and open into the inferior vena cava, while that vessel is situated in the groove at the back part of this organ. Of these three veins, one from the right and another from the left lobe open obliquely into the vena cava; that from the middle of the organ and lobus Spigelii having a straight course.

The hepatic veins have very little cellular investment; what there is binds their parietes closely to the walls of the canals through which they run; so that, on section of the organ, these veins remain widely open and solitary, and may be easily distinguished from the branches of the portal vein, which are more or less collapsed, and always accompanied by an artery and duct. The hepatic veins are destitute of valves.

Structure.—The substance of the liver is composed of lobules held together by an extremely fine areolar tissue, and of the ramifications of the portal vein, hepatic duct, hepatic artery, hepatic veins, lymphatics, and nerves, the whole being invested by a serous and a fibrous coat.

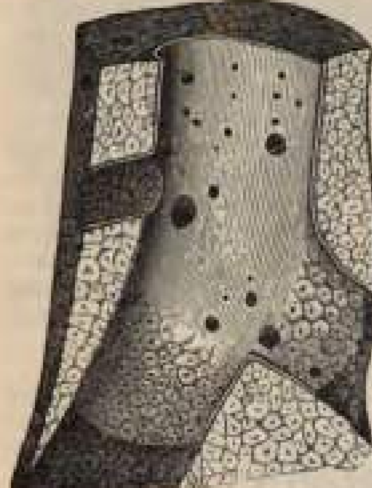
The *serous coat* is derived from the peritoneum, and invests the greater part of the surface of the organ. It is intimately adherent to the fibrous coat.

The *fibrous coat* lies beneath the serous investment and covers the entire surface of the organ. It is difficult of demonstration, excepting where the serous coat is deficient. At the transverse fissure it is continuous with the capsule of Glisson, and on the surface of the organ with the areolar tissue separating the lobules.

The *lobules* form the chief mass of the hepatic substance; they may be seen either on the surface of the organ or by making a section through the gland. They are small granular bodies about the size of a millet-seed, measuring from one-twentieth to one-tenth of an inch in diameter. In the human subject their outline is very irregular, but in some of the lower animals (for example, the pig) they are well-defined, and when divided transversely have a polygonal outline. If divided longitudinally they are more or less foliated or oblong. The bases of the lobules are clustered round the smallest radicles (*sublobular*) of the hepatic veins, to which each is connected by means of a small branch which issues from the centre of the lobule (*intralobular*). The remaining part of the surface of each lobule is imperfectly isolated from the surrounding lobules by a thin stratum of areolar tissue in which is contained a plexus of vessels (the *interlobular plexus*) and ducts. In some animals, as the pig, the lobules are completely isolated one from another by this interlobular areolar tissue.

If one of the sublobular veins be laid open, the bases of the lobules may be seen through the thin wall of the vein on which they rest, arranged in the form of a tesselated pavement, the centre of each polygonal space presenting a minute aperture, the mouth of an intralobular vein (Fig. 514).

Microscopic Appearance.—Each lobule is composed of a mass of cells (*hepatic cells*) surrounded by a dense capillary plexus, composed of vessels which penetrate from the circumference to the centre of the lobule, and terminate in a single



Orifices of intralobular veins.

FIG. 514.—Longitudinal section of an hepatic vein. (After Kiernan.)

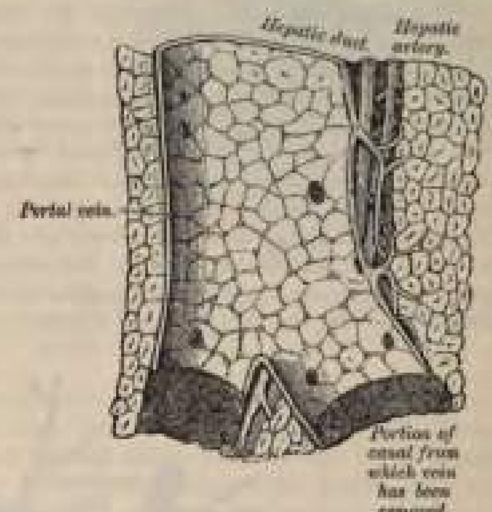


FIG. 515.—Longitudinal section of a small portal vein and canal. (After Kiernan.)

straight vein, which runs through its centre, to open at its base into one of the radicles of the hepatic vein. Between the cells are also the minute commencements of the bile-ducts. Therefore in the lobule we have all the essentials of a secreting gland; that is to say: (1) *cells*, by which the secretion is formed; (2) *blood-vessels*, in close relation with the cells, containing the blood from which the secretion is derived; and (3) *ducts*, by which the secretion, when formed, is carried away. Each of these structures will have to be further considered.

(1) The *hepatic cells* are of more or less spheroidal form, but may be rounded, flattened, or many-sided from mutual compression. They vary in size from the $\frac{1}{1000}$ to the $\frac{1}{2000}$ of an inch in diameter. They consist of a honeycomb network (Klein) without any cell-wall, and contain one or sometimes two distinct nuclei. In the nucleus is a highly refracting nucleolus with granules. Embedded in the honeycomb network are numerous yellow particles, the coloring matter of the bile, and oil-globules. The cells adhere together by their surfaces so as to form rows, which radiate from the centre to the circumference of the lobules.[1] As stated above, they are the chief agents in the secretion of the bile.

(2) *The Blood-vessels.*—The blood in the capillary plexus around the liver-cells is brought to the liver principally by the portal vein, but also to a certain extent by the hepatic artery. For the sake of clearness the distribution of the blood derived from the hepatic artery may be considered first.

[1] Delépine states that there are evidences of the arrangement of these cells in the form of columns, which form tubes with narrow lumina branching from terminal bile-ducts. This branching is evidenced by a divergence of the columns from lines extending between adjacent portal vessels. The columns of cells group round terminal bile-ducts, and not round the so-called intralobular veins. (*Lancet*, 1895, vol. i., p. 1254.)

The *hepatic artery*, entering the liver at the transverse fissure with the portal vein and hepatic duct, ramifies with these vessels through the portal canals. It gives off *vaginal branches* which ramify in the capsule of Glisson, and appear to be destined chiefly for the nutrition of the coats of the large vessels, the ducts, and the investing membranes of the liver. It also gives off *capsular branches* which reach the surface of the organ, terminating in its fibrous coat in stellate plexuses. Finally it gives off *interlobular branches* which form a plexus on the outer side of each lobule, to supply its wall and the accompanying bile-ducts. From this, lobular branches enter the lobule and end in the capillary network between the cells. Some anatomists, however, doubt whether it transmits any blood directly to the capillary network.

The *portal vein* also enters at the transverse fissure and runs through the portal canals, enclosed in Glisson's capsule, dividing into branches in its course, which finally break up into a plexus (the *interlobular plexus*) in the interlobular spaces. In their course these branches receive the vaginal and capsular veins, corresponding to the vaginal and capsular branches of the hepatic artery (Fig. 515). Thus it will be seen that all the blood carried to the liver by the portal vein and hepatic artery, except perhaps that derived from the interlobular branches of the hepatic artery, directly or indirectly finds its way into the interlobular plexus. From this plexus the blood is carried into the lobule by fine branches which pierce its wall and then converge from the circumference to the centre of the lobule, forming a number of converging vessels which are connected by transverse branches (Fig. 516). In the interstices of the network of vessels thus formed are situated,

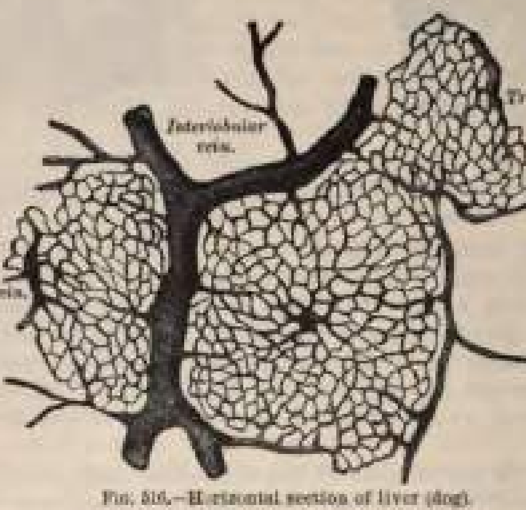


FIG. 516.—Horizontal section of liver (dog).

as before said, the liver-cells: and here it is that, the blood being brought into intimate connection with the liver-cells, the bile is secreted. Arrived at the centre of the lobule, all these minute vessels empty themselves into one vein, of considerable size, which runs down the centre of the lobules from apex to base and is called the *intralobular vein*. At the base of the lobule this vein opens directly into the *sublobular vein*, with which the lobule is connected, and which, as before mentioned, is a radicle of the hepatic vein. The sublobular veins, uniting into larger and larger trunks, end at last in the hepatic veins, which do not receive any intralobular veins. Finally, the hepatic veins, as mentioned at page 619, converge to form three large trunks which open into the inferior vena cava, while that vessel is situated in the fissure appropriated to it at the back of the liver.

(3) *The Ducts.*—Having shown how the blood is brought into intimate relation with the hepatic cells in order that the bile may be secreted, it remains now only to consider the way in which the secretion, having been formed, is carried away.

Several views have prevailed as to the mode of origin of the hepatic ducts; it seems, however, to be clear that they commence by little passages which are formed between the cells, and which have been termed *intercellular biliary passages* or *bile-capillaries*. These passages are merely little channels or spaces left between the contiguous surfaces of two cells or in the angle where three or more liver-cells meet (Fig. 517), and it seems doubtful whether there is any delicate membrane

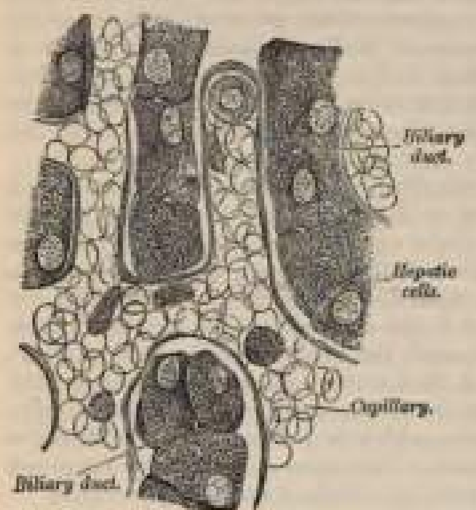


FIG. 517.—Section of liver.

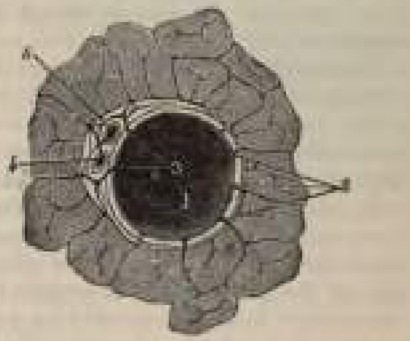


FIG. 518.—A transverse section of a small portal canal and its vessels. (After Kiernan.) 1. Portal vein. 2. Interlobular branches. 3. Vaginal branches. 4. Hepatic duct. 5. Hepatic artery.

forming the wall of the channel. The channels thus formed radiate to the circumference of the lobule, and, piercing its wall, form a plexus (*interlobular*) between the lobules. From this plexus ducts are derived which pass into the portal canals, become enclosed in Glisson's capsule, and, accompanying the portal vein and hepatic artery (Fig. 518), join with other ducts to form two main trunks, which leave the liver at the transverse fissure, and by their union form the hepatic duct.

Structure.—The coats of the smallest biliary ducts, which lie in the interlobular spaces, are a connective-tissue coat, in which are muscle-cells, arranged both circularly and longitudinally, and an epithelial layer, consisting of short columnar cells. In the larger ducts, which lie in the portal canals, there are a number of orifices disposed in two longitudinal rows, which were formerly regarded as the openings of mucous glands, but which are merely the orifices of tubular recesses. They occasionally anastomose, and from the sides of them saccular dilatations are given off.

Lymphatics of the Liver.—The lymphatics in the substance of the liver commence in lymphatic spaces around the capillaries of the lobules; they accompany the vessels of the interlobular plexus, often enclosing and surrounding them. These unite and form larger vessels, which run in the portal canals, enclosed in Glisson's capsule, and emerge at the portal fissure to be distributed in the manner described. Other superficial lymphatics form a close plexus, under the peritoneum, where this membrane covers the liver, and pass in various directions through the ligaments of the liver (page 634).

Nerves of the Liver.—The nerves of the liver derived from the pneumogastric and sympathetic enter the liver at the transverse fissure and accompany the vessels and ducts to the interlobular spaces. Here, according to Korolkow, the medullated fibres are distributed almost exclusively to the coats of the blood-vessels; while the non-medullated enter the lobules and ramify between the cells.

The Excretory Apparatus of the Liver.

The excretory apparatus of the liver consists of (1) the *hepatic duct*, which, as we have seen, is formed by the junction of the two main ducts, which pass out of the liver at the transverse fissure, and are formed by the union of the bile-capillaries; (2) the *gall-bladder*, which serves as a reservoir for the bile; (3) the *cystic duct*, which is the duct of the gall-bladder; and (4) the *common bile-duct*, formed by the junction of the hepatic and cystic ducts.

The Hepatic Duct.—Two main trunks of nearly equal size issue from the liver at the transverse fissure, one from the right, the other from the left lobe; these unite to form the hepatic duct, which then passes downward and to the right for about an inch and a half, between the layers of the lesser omentum, where it is joined at an acute angle by the cystic duct, and so forms the ductus communis choledochus. The hepatic duct, as it descends from the transverse fissure of the liver, between the two layers of the lesser omentum, lies in company with the hepatic artery and portal vein.

The **Gall-bladder** is the reservoir for the bile; it is a conical or pear-shaped musculo-membranous sac, lodged in a fossa on the under surface of the right lobe of the liver, and extending from near the right extremity of the transverse fissure to the anterior border of the organ. It is about four inches in length, one inch in breadth at its widest part, and holds from eight to ten drachms. It is divided into a fundus, body, and neck. The *fundus*, or broad extremity, is directed downward, forward, and to the right, and projects beyond the anterior border of the liver; the *body* and *neck* are directed upward and backward to the left. The upper surface of the gall-bladder is attached to the liver by connective tissue and vessels. The under surface is covered by peritoneum, which is reflected on to it from the surface of the liver. Occasionally the whole of the organ is invested by the serous membrane, and is then connected to the liver by a kind of mesentery.

Relations.—The *body of the gall-bladder* is in relation, by its upper surface, with the liver, to which it is connected by areolar tissue and vessels; by its under surface, with the commencement of the transverse colon; and further back, with the upper end of the descending portion of the duodenum or sometimes with the pyloric end of the stomach or first portion of the duodenum. The *fundus* is completely invested by peritoneum; it is in relation, in front, with the abdominal parietes, immediately below the ninth costal cartilage; behind with the transverse arch of the colon. The *neck* is narrow, and curves upon itself like the letter S; at its point of connection with the cystic duct it presents a well-marked constriction.

When the gall-bladder is distended with bile or calculi, the fundus may be felt through the abdominal parietes, especially in an emaciated subject: the relations of this sac will also serve to explain the occasional occurrence of abdominal biliary fistulæ, through which biliary calculi may pass out, and of the passage of calculi from the gall-bladder into the stomach, duodenum, or colon, which occasionally happens.

Structure.—The gall-bladder consists of three coats—serous, fibrous and muscular, and mucous.

The *external* or *serous coat* is derived from the peritoneum; it completely invests the fundus, but covers the body and neck only on their under surface.

The *fibro-muscular coat* is a thin but strong layer which forms the framework of the sac, consisting of dense fibrous tissue which interlaces in all directions and is mixed with plain muscular fibres which are disposed chiefly in a longitudinal direction, a few running transversely.

The *internal* or *mucous coat* is loosely connected with the fibrous layer. It is generally tinged with a yellowish-brown color, and is everywhere elevated into minute rugæ, by the union of which numerous meshes are formed; the depressed intervening spaces having a polygonal outline. The meshes are smaller at the fundus and neck, being most developed about the centre of the sac. Opposite the neck of the gall-bladder the mucous membrane projects inward in the form of oblique ridges or folds, forming a sort of screw-like valve.

The mucous membrane is covered with columnar epithelium, and secretes an abundance of thick viscid mucus; it is continuous through the hepatic duct with the mucous membrane lining the ducts of the liver, and through the ductus communis choledochus with the mucous membrane of the alimentary canal.

The **Cystic Duct**, the smallest of the three biliary ducts, is about an inch and a half in length. It passes obliquely downward and to the left from the neck of the gall-bladder, and joins the hepatic duct to form the common bile-duct. It lies in the gastro-hepatic omentum in front of the vena portæ, the hepatic artery lying to its left side. The mucous membrane lining its interior is thrown into a series of crescentic folds, from five to twelve in number, similar to those found in the neck of the gall-bladder. They project into the duct in regular succession, and are directed obliquely round the tube, presenting much the appearance of a continuous spiral valve. When the duct is distended, the spaces between the folds are dilated, so as to give to its exterior a sacculated appearance.

The **Ductus Communis Choledochus**, or *common bile-duct*, the largest of the three, is the common excretory duct of the liver and gall-bladder. It is about three inches in length, of the diameter of a goose-quill, and formed by the junction of the cystic and hepatic ducts.

It descends along the right border of the lesser omentum behind the first portion of the duodenum, in front of the vena portæ, and to the right of the hepatic artery; it then passes between the pancreas and descending portion of the duodenum, and running for a short distance along the right side of the pancreatic duct, near its termination, passes with it obliquely between the mucous and muscular coats. The two ducts open by a common orifice upon the summit of a papilla, situated at the inner side of the descending portion of the duodenum, a little below its middle and about three or four inches below the pylorus.

Structure.—The coats of the large biliary ducts are an external or fibrous, and an internal or mucous. The fibrous coat is composed of strong fibro-areolar tissue, with a certain amount of muscular tissue arranged, for the most part, in a circular manner around the duct. The mucous coat is continuous with the lining membrane of the hepatic ducts and gall-bladder, and also with that of the duodenum; and, like the mucous membrane of these structures, its epithelium is of the columnar variety. It is provided with numerous mucous glands, which are lobulated and open by minute orifices scattered irregularly in the larger ducts. The coats of the smallest biliary ducts, which lie in the interlobular spaces, are a connective-tissue coat, in which, according to Heidenhain, are muscle-cells arranged both circularly and longitudinally, and an epithelial layer, consisting of short columnar cells.

Surface Relations.—The liver is situated in the right hypochondriac and the epigastric regions, and is moulded to the arch of the Diaphragm. In the greater part of its extent it lies under cover of the lower ribs and their cartilages, but in the epigastric region it comes in contact with the abdominal wall, in the subcostal angle. The *upper limit of the right lobe of the liver* may be defined in the middle line by the junction of the mesosternum with the ensiform cartilage; on the right side the line must be carried upward as far as the fifth rib cartilage in the line of the nipple and then downward to reach the seventh rib at the side of the chest. The *upper limit of the left lobe* may be defined by continuing this line to the left with an inclination downward to a point about two inches to the left of the sternum on a level with the sixth left costal cartilage. The *lower limit of the liver* may be indicated by a line drawn half an inch below the lower border of the thorax on the right side as far as the ninth right costal cartilage, and thence obliquely upward across the subcostal angle to the eighth left costal cartilage. A slight curved line with its convexity to the left from this point—*i. e.*, the eighth left costal cartilage—to the termination of the line indicating the upper limit will denote the left margin of the liver. The fundus of the gall-bladder approaches the surface behind the anterior extremity of the ninth costal cartilage, close to the outer margin of the Right rectus muscle.

It must be remembered that the liver is subject to considerable alterations in position, and the student should make himself acquainted with the different circumstances under which this occurs, as they are of importance in determining the existence of enlargement or other diseases of the organ.

Its position varies according to the posture of the body. In the erect position in the adult male the edge of the liver projects about half an inch below the lower edge of the right costal cartilages, and its anterior border can be often felt in this situation if the abdominal wall is thin. In the supine position the liver gravitates backward and recedes above the lower margin of the ribs, and cannot then be detected by the finger. In the prone position it falls forward, and can then generally be felt in a patient with loose and lax abdominal walls. Its position varies also with the ascent or descent of the Diaphragm. In a deep inspiration the liver descends below the ribs; in expiration it is raised behind them. Again, in emphysema, where the lungs are distended and the Diaphragm descends very low, the liver is pushed down; in some other diseases, as phthisis, where the Diaphragm is much arched, the liver rises very high up. Pressure from without, as in tight-lacing, by compressing the lower part of the chest, displaces the liver considerably, its anterior edge often extending as low as the crest of the ileum; and its convex surface is often at the same time deeply indented from the pressure of the ribs. Again, its position varies greatly according to the greater or less distension of the stomach and intestines. When the intestines are empty the liver descends in the abdomen, but when they are distended it is pushed upward. Its relations to surrounding organs may also be changed by the growth of tumors or by collections of fluid in the thoracic or abdominal cavities.

Surgical Anatomy.—On account of its large size, its fixed position, and its friability, the liver is more frequently ruptured than any of the abdominal viscera. The rupture may vary considerably in extent, from a slight scratch to an extensive laceration completely through its substance, dividing it into two parts. Sometimes an internal rupture without laceration of the peritoneal covering takes place, and such injuries are most susceptible of repair; but small tears of the surface may also heal; when, however, the laceration is extensive, death usually takes place from hæmorrhage, on account of the fact that the hepatic veins are contained in rigid canals in the liver-substance and are unable to contract, and are moreover unprovided with valves. The liver may also be torn by the end of a broken rib perforating the Diaphragm. The liver may be injured by stabs or other punctured wounds, and when these are inflicted through the chest-wall both pleural and peritoneal cavities may be opened up and both lung and liver be wounded. In cases of wound of the liver from the front, hernia of a part of this viscus may take place, but can generally easily be replaced. In cases of laceration of the liver, when there is evidence that bleeding is going on, the abdomen must be opened, the laceration sought for, and the bleeding arrested. This may be done temporarily by introducing the forefinger into the foramen of Winslow and placing the thumb on the gastro-hepatic omentum and compressing the hepatic artery and portal vein between the two. Any bleeding points can then be seen and tied and the margins of the laceration, if small, brought together and sutured by means of a blunt curved needle passed from one side of the wound to the other. All sutures must be passed before any are tied, and this must be done with the greatest gentleness, as the liver substance is very friable. When the laceration is extensive it must be packed with iodoform gauze, the end of which is allowed to hang out of the external wound. Abscess of the liver is of not infrequent occurrence, and may open in many different ways on account of the relations of this viscus to other organs. Thus it has been known to burst into the lungs and the pus coughed up, or into the stomach and the pus vomited; it may burst into the colon, or into the duodenum; or, by perforating the diaphragm, it may empty itself into the pleural cavity. Frequently it makes its way forward, and points on the anterior abdominal wall, and finally it may burst into the peritoneal or pericardiac cavities. Abscesses of the liver frequently require opening, and this must be done by an incision in the abdominal wall, in the thoracic wall, or in the lumbar region, according to the direction in which the abscess is tracking. The incision through the abdominal wall is to be preferred when possible. The abdominal wall is incised over the swelling, and unless the peritoneum is adherent, sponges are packed all around the exposed liver surface and the abscess opened, if deeply seated preferably by the thermo-cautery. Hydatid cysts are more often found in the liver than in any other of the viscera. The reason of this is not far to seek. The embryo of the egg of the tænia echinococcus being liberated in the stomach by the disintegration of its shell, bores its way through the gastric walls and usually enters a blood-vessel, and is carried by the blood-stream to the hepatic capillaries, where its onward course is arrested, and where it undergoes development into the fully formed hydatid. Tumors of the liver have recently been subjected to surgical treatment by removal of a portion of the organ. The abdomen is opened and the diseased portion of liver exposed; the circulation is controlled by compressing the portal vein and the hepatic artery in the gastro-hepatic omentum and a wedge-shaped portion of liver containing the tumor removed; the divided vessels are ligated and the cut surfaces brought together and sutured in the manner directed above.

When the *gall-bladder* or one of its main ducts is ruptured, which may occur independently of laceration of the liver, death usually occurs from peritonitis. If the symptoms have led to the performance of a laparotomy and a rent is found, it should be sutured if small, or the gall-bladder removed if it is extensive. If the cystic duct is torn, its intestinal end must be closed and the gall-bladder removed. In rupture of either of the other ducts, the only thing which can be done is to provide for free drainage, in the hope that a biliary fistula may form.

The gall-bladder may become distended with bile in cases of obstruction of its duct or the common bile-duct, or from a collection of gall-stones within its interior, thus forming a large tumor. The swelling is pear-shaped, and projects downward and forward to the umbilicus. It moves with respiration, since it is attached to the liver. To relieve this condition the gall-bladder must be opened and the gall-stones removed. The operation is performed by an incision two or three inches long in the right semilunar line, commencing at the costal margin. The peritoneal cavity is opened, and, the tumor having been found, sponges are packed round it to protect the peritoneal cavity, and it is aspirated. When the contained fluid has been evacuated the flaccid bladder is drawn out of the abdominal wound and its wall incised to the extent of an inch; any gall-stones in the bladder are now removed and the interior of the sac sponged dry. If the case is one of obstruction of the duct, an attempt must be made to dislodge the stone by manipulation through the wall of the duct; or it may be crushed from without by the fingers or carefully padded forceps. If this does not succeed, the safest plan is to incise the duct, extract the stone, and close the incision by fine sutures in two layers. After all obstruction has been removed, four courses are open to the surgeon: 1. The wound in the gall-bladder may be at once sewn up, the organ returned into the abdominal cavity, and the external incision closed. 2. The edges of the incision in the gall-bladder may be sutured to the external wound, and a fistulous communication established between the gall-bladder and the exterior; this fistulous opening usually closes in the course of a few weeks. 3. The gall-bladder may be connected with the intestinal canal, preferably the duodenum, by means of a lateral anastomosis; this is known as cholecystenterostomy. 4. The gall-bladder may be completely removed.

THE PANCREAS.

Dissection.—The pancreas may be exposed for dissection in three different ways: 1. By raising the liver, drawing down the stomach, and tearing through the gastro-hepatic omentum and the ascending layer of the transverse mesocolon. 2. By raising the stomach, the arch of the colon, and great omentum, and then dividing the inferior layer of the transverse mesocolon and raising its ascending layer. 3. By dividing the two layers of peritoneum, which descend from the great curvature of the stomach to form the great omentum; turning the stomach upward, and then cutting through the ascending layer of the transverse mesocolon (see Fig. 488, page 909).

The **Pancreas** (*πάν-κρέας, all flesh*) is a compound racemose gland, analogous in its structure to the salivary glands, though softer and less compactly arranged than those organs. It is long and irregularly prismatic in shape, and has been compared to a human or a dog's tongue: its right extremity being broad, is called the *head*—this is connected to the main portion of the organ, the *body*, by a slight constriction, the *neck*; while its left extremity gradually tapers to form the *tail*. It is situated

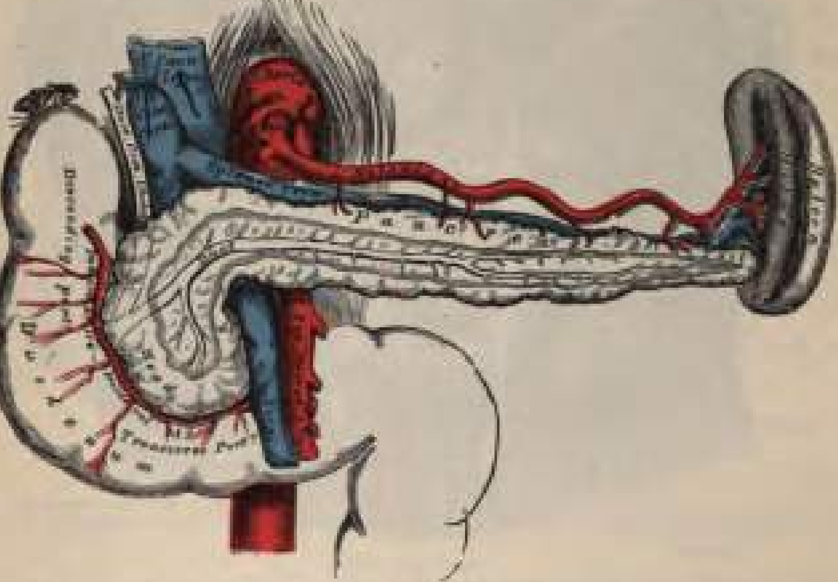


Fig. 519.—The pancreas and its relations.

transversely across the posterior wall of the abdomen, at the back of the epigastric and left hypochondriac regions. Its length varies from five to six inches, its breadth is an inch and a half, and its thickness from half an inch to an inch, being greater at its right extremity and along its upper border. Its weight varies from two to three and a half ounces, but it may reach six ounces.

The *right extremity* or *head of the pancreas* (Fig. 519) is shaped like the head of a hammer, being elongated both above and below; it is flattened from before backward, and conforms to the whole concavity of the duodenum, which is slightly overlapped by it. The anterior surface near its left border is crossed by the superior mesenteric vessels, and at its lower end it is crossed by the transverse colon and its mesocolon. Behind, the head of the pancreas is in relation with the inferior vena cava, the left renal vein, the right crus of the Diaphragm, and the aorta. The common bile-duct descends behind, between the duodenum and pancreas; and the pancreatico-duodenal artery descends in front between the same parts.

The *neck of the pancreas* is about an inch long, and passes upward and forward to the left, having the first part of the duodenum above it, and the termination of the fourth portion below. It lies in front of the commencement of the vena portæ, and is grooved on the right by the gastro-duodenal and superior pancreatico-duodenal arteries. The pylorus lies just above it.

The *body and tail of the pancreas* are somewhat prismatic in shape, and have three surfaces: anterior, posterior, and inferior.

The *anterior surface* is somewhat concave, and is covered by the posterior surface of the stomach which rests upon it, the two organs being separated by the lesser sac of the peritoneum. At its right extremity there is a well-marked prominence, called by His the *omental tuberosity*.

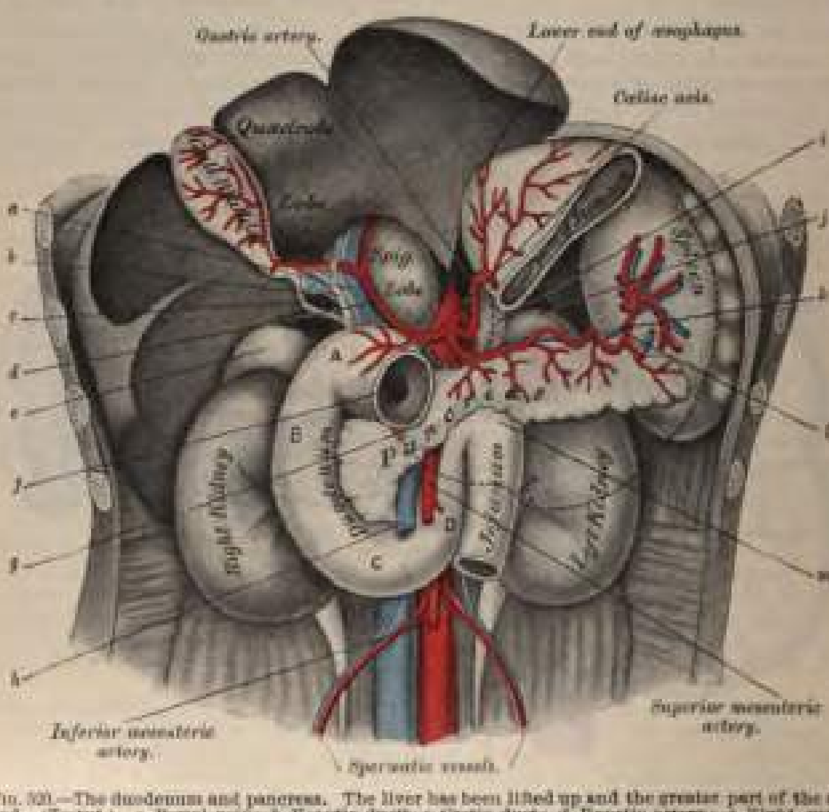


FIG. 520.—The duodenum and pancreas. The liver has been lifted up and the greater part of the stomach removed. (Testut.) *a*, Portal vein; *b*, Hepatic duct; *c*, Cystic duct; *d*, Hepatic artery; *e*, Right suprarenal capsule; *f*, Pyloric orifice; *g*, Right gastro-epiploic artery; *h*, Superior mesenteric vein; *i*, Left crus of diaphragm; *j*, Left suprarenal capsule; *k*, Splenic vein; *l*, Splenic artery; *m*, Duodeno-jejunal junction; A, B, C, D, The four portions of the duodenum.

The *posterior surface* is separated from the vertebral column by the aorta, the splenic vein, the left kidney and its vessels, the left suprarenal capsule, the pillars of the Diaphragm, and the origin of the superior mesenteric artery.

The *inferior surface* is narrow, and lies upon the duodeno-jejunal flexure and on some coils of the jejunum; its left extremity rests on the splenic flexure of the colon.

The *superior border* of the body is blunt and flat to the right; narrow and sharp to the left, near the tail. It commences to the right in the omental tuberosity, and is in relation with the cœliac axis, from which the hepatic artery courses to the right just above the gland, while the splenic branch runs in a groove along this border to the left.

The *anterior border* is the position where the two layers of the transverse meso-colon separate: the one passing upward in front of the anterior surface, the other backward below the inferior surface.

The *lesser end* or *tail of the pancreas* is narrow; it extends to the left as far as the lower part of the inner aspect of the spleen.

Birmingham describes the body of the pancreas as projecting forward as a prominent ridge into the abdominal cavity and forming a sort of shelf on which the stomach lies. He says: "The portion of the pancreas to the left of the middle line has a very considerable antero-posterior thickness; as a result the anterior surface is of considerable extent, it looks strongly upward, and forms a large and important part of the shelf. As the pancreas extends to the left toward the spleen it crosses the upper part of the kidney, and is so moulded on to it that the top of the kidney forms an extension inward and backward of the upper surface of the pancreas and extends the bed in this direction. On the other hand, the extremity of the pan-

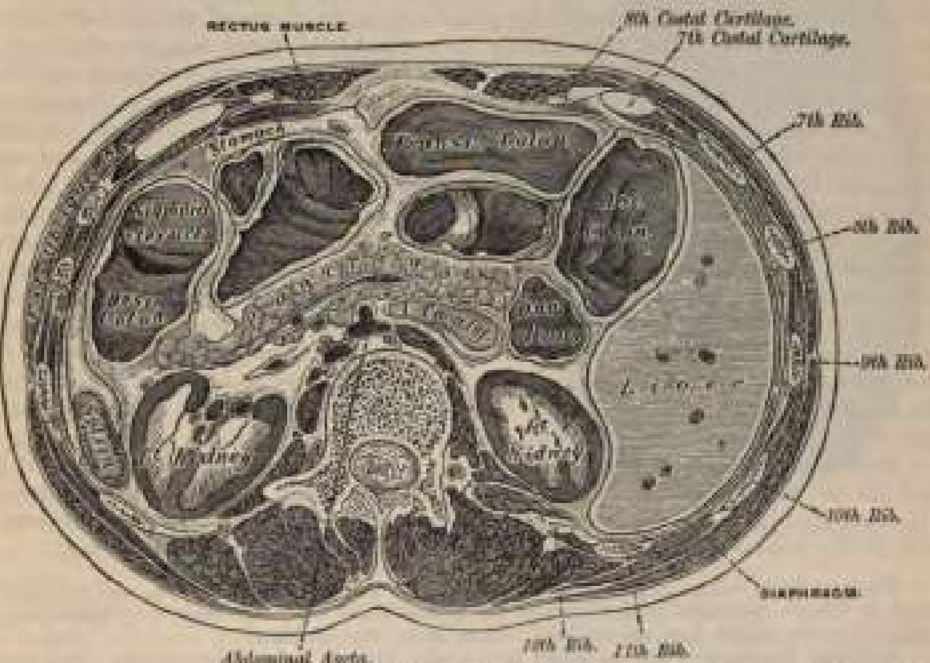


FIG. 521.—Transverse section through the middle of the first lumbar vertebra, showing the relations of the pancreas. (Braune.)

creas comes in contact with the spleen in such a way that the plane of its upper surface runs with little interruption upward and backward into the concave gastric surface of the spleen, which completes the bed behind and to the left, and running upward, forms a partial cap for the wide end of the stomach"[1] (see Fig. 496).

The principal excretory duct of the pancreas, called the **pancreatic duct** or **canal of Wirsung**, from its discoverer, extends transversely from left to right through the substance of the pancreas. In order to expose it, the superficial portion of the gland must be removed. It commences by the junction of the small ducts of the lobules situated in the tail of the pancreas, and, running from right to left through the body, it constantly receives the ducts of the various lobules composing the

[1] *Journal of Anatomy and Physiology*, vol. xxxi. pt. 1, p. 102.

gland. Considerably augmented in size, it reaches the neck, and turning obliquely downward, backward, and to the right, it comes into relation with the common bile-duct, lying to its left side; leaving the head of the gland, it passes very obliquely through the mucous and muscular coats of the duodenum, and terminates by an orifice common to it and the ductus communis choledochus upon the summit of an elevated papilla, situated at the inner side of the descending portion of the duodenum, three or four inches below the pylorus.

Sometimes the pancreatic duct and ductus communis choledochus open separately into the duodenum. Occasionally there is an accessory duct, which is given off from the canal of Wirsung in the neck of the pancreas and passes horizontally to the right to open into the duodenum about an inch above the orifice of the main duct. This is known as the *ductus pancreaticus accessorius* or *ductus Santorini*.

The pancreatic duct, near the duodenum, is about the size of an ordinary quill: its walls are thin, consisting of two coats, an external fibrous and an internal mucous; the latter is smooth, and furnished near its termination with a few scattered follicles.

In **structure**, the pancreas resembles the salivary glands. It differs from them, however, in certain particulars, and is looser and softer in its texture. It is not enclosed in a distinct capsule, but is surrounded by areolar tissue, which dips into its interior, and connects together the various lobules of which it is composed. Each lobule, like the lobules of the salivary glands, consists of one of the ultimate ramifications of the main duct, terminating in a number of cæcal pouches or alveoli, which are tubular and somewhat convoluted. The minute ducts connected with the alveoli are narrow and lined with flattened cells. The alveoli are almost completely filled with secreting cells, so that scarcely any lumen is visible. In some animals those cells which occupy the centre of the alveolus are spindle-shaped, and are known as the *centro-acinar cells of Langerhans*. The true secreting cells which line the wall of the alveolus are very characteristic. They are columnar in shape and present two zones: an outer one clear and finely striated next the basement-membrane, and an inner granular one next the lumen. During activity the granular zone occupies the greater part of the cell: before the cells are called into action, while in a condition of rest, the outer or clear zone is the larger. In some secreting cells of the pancreas is a spherical mass, staining more easily than the rest of the cells; this is termed the *paranucleus*, and is believed to be an extension from the nucleus. The connective tissue between the alveoli presents in certain parts collections of cells, which are termed *inter-alveolar cell-islets*.

Vessels and Nerves.—The *arteries of the pancreas* are derived from the splenic and the pancreatico-duodenal branches of the hepatic and the superior mesenteric. Its *veins* open into the splenic and superior mesenteric veins. Its *lymphatics* terminate in the lumbar glands. Its *nerves* are filaments from the splenic plexus.

Surface Form.—The pancreas lies in front of the second lumbar vertebra, and can sometimes be felt, in emaciated subjects, when the stomach and colon are empty, by making deep pressure in the middle line about three inches above the umbilicus.

Surgical Anatomy.—The pancreas presents but little of surgical importance. It is occasionally the seat of cancer, which usually affects the head or duodenal end, and therefore often speedily involves the common bile-duct, leading to persistent jaundice. Cysts are also occasionally found in it, which may present in the epigastric region, above and to the right of the umbilicus, and may require opening and drainage. The fluid in them contains some of the elements of the pancreatic secretion and is very irritating, so that, if allowed to come in contact with the skin of the abdominal wall, it is likely to produce intractable eczema. It has been said that the pancreas is the only abdominal viscus which has never been found in a hernial protrusion; but even this organ has been found, in company with other viscera, in rare cases of diaphragmatic hernia. The pancreas has been known to become invaginated into the intestine, and portions of the organ have sloughed off. In cases of excision of the pylorus great care must be exercised to avoid wounding the pancreas, as the escape of the pancreatic fluid may be attended with serious results. According to Billroth, it is likely, in consequence of its peptonizing qualities, to dissolve the cicatrix of the stomach.

THE SPLEEN.

The **Spleen** belongs to that class of bodies which are known as *ductless glands*. It is probably related to the blood-vascular system, but in consequence of its anatomical relationship to the stomach and its physiological relationship to the liver it is convenient to describe it in this place. It is situated principally in the left hypochondriac region, its upper and inner extremity extending into the epigastric region; lying between the fundus of the stomach and the Diaphragm. It is the largest of the ductless glands, and measures some five or six inches in length. It is of an oblong, flattened form, soft, of very brittle consistence, highly vascular, and of a dark purplish color.

Surfaces.—The *external* or *phrenic surface* is convex, smooth, and is directed upward, backward, and to the left, except at its upper end, where it is directed slightly inward. It is in relation with the under surface of the Diaphragm, which separates it from the eighth, ninth, tenth, and eleventh ribs of the left side, and in part from the lower border of the left lung and pleura.

FIG. 522.—The spleen, showing its gastric and renal surfaces. (Testut.)

The *internal surface* is concave, and divided by a ridge into an anterior or larger, and a posterior or smaller portion.

The *anterior portion* of the internal surface or *gastric surface*, which is directed forward and inward, is broad and concave, and is in contact with the posterior wall of the great end of the stomach; and below this with the tail of the pancreas. It presents near its inner border a long fissure, termed the *hilum*. This is pierced by several irregular apertures, for the entrance and exit of vessels and nerves.

The *posterior portion* of the internal surface or *renal surface* is directed inward and downward. It is somewhat flattened, does not reach as high as the gastric surface, is considerably narrower than the latter, and is in relation with the upper part of the outer surface of the left kidney and occasionally with the left suprarenal capsule.

The *upper end* is directed inward, toward the vertebral column, where it lies on a level with the eleventh dorsal vertebra. The *lower end*, sometimes termed the *basal surface*, is flat, triangular in shape, and rests upon the splenic flexure of the colon and the phreno-colic ligament, and is generally in contact with the tail of the pancreas. The *anterior* border is free, sharp, and thin, and is often notched, especially below. It separates the phrenic from the gastric surface. The *posterior* border is more rounded and blunter than the anterior. It separates the renal portion of the internal surface from the phrenic surface. It corresponds to the lower border of the eleventh rib and lies between the Diaphragm and left kidney. The *internal* border is the name sometimes given to the ridge which separates the renal and gastric portions of the internal surface.

The spleen is almost entirely surrounded by peritoneum, which is firmly adherent to its capsule, and is held in position by two folds of this membrane: one, the *lieno-renal ligament*, is derived from the layers of peritoneum forming the greater and lesser sacs, where they come into contact between the left kidney and the spleen. Between its two layers the splenic vessels pass (Fig. 489); the second, the *gastro-splenic omentum*, also formed of two layers, derived from the greater and lesser sacs, respectively, where they meet between the spleen and stomach (Fig. 489). Between these two layers run the vasa brevia of the splenic artery and vein. It is also supported by the phreno-colic ligament, upon which its lower end rests (see page 902).

The size and weight of the spleen are liable to very extreme variations at different periods of life, in different individuals, and in the same individual under different conditions. *In the adult*, in whom it attains its greatest size, it is usually about five inches in length, three inches in breadth, and an inch or an inch and a half in thickness, and weighs about seven ounces. *At birth*, its weight, in proportion to the entire body, is almost equal to what is observed in the adult, being as 1 to 350; while in the adult it varies from 1 to 320 and 400. *In old age*, the organ not only decreases in weight, but decreases considerably in proportion to the entire body, being as 1 to 700. The size of the spleen is increased during and

FIG. 524.—Transverse section of the spleen, showing the trabecular tissue and the splenic vein and its tributaries.

after digestion, and varies considerably according to the state of nutrition of the body, being large in highly fed, and small in starved animals. In intermittent and other fevers it becomes much enlarged, weighing occasionally from 18 to 20 pounds.

Frequently in the neighborhood of the spleen, and especially in the gastro-splenic and great omenta, small nodules of splenic tissue may be found, either isolated or connected to the spleen by thin bands of splenic tissue. They are known as *supernumerary* or *accessory spleens*. They vary in size from that of a pea to that of a plum.

Structure.—The spleen is invested by two coats—an external serous, and an internal fibro-elastic coat.

The *external* or *serous coat* is derived from the peritoneum; it is thin, smooth, and in the human subject intimately adherent to the fibro-elastic coat. It invests the entire organ, except at the places of its reflection on to the stomach and Diaphragm and at the hilum.

The *fibro-elastic coat* forms the framework of the spleen. It invests the organ, and at the hilum is reflected inward upon the vessels in the form of sheaths. From these sheaths, as well as from the inner surface of the fibro-elastic coat, numerous small fibrous bands, *trabeculæ* (Fig. 524), are given off in all directions; these uniting, constitute the framework of the spleen. This resembles a sponge-like material, consisting of a number of small spaces or *areolæ* formed by the trabeculæ, which are given off from the inner surface of the capsule, or from the sheaths prolonged inward on the blood-vessels. In these spaces or areolæ is contained the *splenic pulp*.

The proper coat, the sheaths of the vessels and the trabeculæ, consist of a dense mesh of white and yellow elastic fibrous tissues, the latter considerably predominating. It is owing to the presence of this tissue that the spleen possesses a considerable amount of elasticity, which allows of the very great variations in size that it presents under certain circumstances. In addition to these constituents of this tunic, there is found in man a small amount of non-striped muscular fibre, and in some mammalia (*e. g.* dog, pig, and cat) a very considerable amount, so that the trabeculæ appear to consist chiefly of muscular tissue. It is probably owing to this structure that the spleen exhibits, when acted upon by the galvanic current, faint traces of contractility.

The *proper substance of the spleen* or *spleen-pulp* is a soft mass of a dark reddish-brown color, resembling grumous blood. When examined, by means of a thin section, under a microscope, it is found to consist of a number of branching cells and an intercellular substance. The cells are connective-tissue corpuscles, and have been named the *sustentacular* or *supporting cells of the pulp*. The processes of these branching cells communicate with each other, thus forming a delicate reticulated tissue in the interior of the areolæ formed by the trabeculæ of the capsule; so that each primary space may be considered to be divided into a number of smaller spaces by the junction of these processes of the branching corpuscles. These secondary spaces contain blood, in which, however, the white corpuscles are found to be in larger proportions than they are in ordinary blood. The sustentacular cells are either small uni-nucleated or larger multi-nucleated cells; they do not become deeply stained with carmine, like the cells of the Malpighian bodies, presently to be described (W. Müller), but like them they possess amœboid movements (Cohnheim). In many of them may be seen deep red

FIG. 524.—Transverse section of the human spleen, showing the distribution of the splenic artery and its branches.

or reddish-yellow granules of various sizes which present the characters of the hæmatin of the blood. Sometimes, also, unchanged blood-disks are seen included in these cells, but more frequently blood-disks are found which are altered both in form and color. In fact, blood-corpuscles in all stages of disintegration may be noticed to occur within them. Klein has recently pointed out that sometimes these cells in the young spleen contain a proliferating nucleus; that is to say, the nucleus is of large size, and presents a number of knob-like projections, as if small nuclei were budding from it by a process of gemmation. This observation is of importance, as it may explain one possible source of the colorless blood-corpuscles.

The interspaces or areolæ formed by the framework of the spleen are thus filled by a delicate reticulum of branched connective-tissue corpuscles the interstices of which are occupied by blood, and in which the blood-vessels terminate in the manner now to be described.

Blood-vessels of the Spleen.—The splenic artery is remarkable for its large size in proportion to the size of the organ, and also for its tortuous course. It divides into six or more branches, which enter the hilum of the spleen and ramify throughout its substance (Fig. 524), receiving sheaths from the involution of the external fibrous tissue. Similar sheaths also invest the nerves and veins.

Each branch runs in the transverse axis of the organ from within outward, diminishing in size during its transit, and giving off in its passage smaller branches, some of which pass to the anterior, others to the posterior part. These ultimately leave the trabecular sheaths, and terminate in the proper substance of the spleen in small tufts or pencils of minute arterioles, which open into the interstices of the reticulum formed by the branched sustentacular cells. Each of the larger branches of the artery supplies chiefly that region of the organ in which the branch ramifies, having no anastomosis with the majority of the other branches.

The *arterioles*, supported by the minute trabeculæ, traverse the pulp in all directions in bundles or penicilli of straight vessels. Their external coat, on leaving the trabecular sheaths, consists of ordinary connective tissue, but it gradually undergoes a transformation, becomes much thickened, and is converted into a lymphoid material.[1] This change is effected by the conversion of the connective tissue into a lymphoid tissue, the bundles of connective tissue becoming looser and laxer, their fibrils more delicate, and containing in their interstices an abundance of lymph-corpuscles (W. Müller). This lymphoid material is supplied with blood by minute vessels derived from the artery with which they are in contact, and which terminates by breaking up into a network of capillary vessels.

The altered coat of the arterioles, consisting of lymphoid tissue, presents here and there thickenings of a spheroidal shape, the *Malpighian bodies of the spleen*. These bodies vary in size from about the $\frac{1}{170}$ of an inch to the $\frac{1}{40}$ of an inch in diameter. They are merely local expansions or hyperplasiæ of the lymphoid tissue of which the external coat of the smaller arteries of the spleen is formed. They are most frequently found surrounding the arteriole, which thus seems to tunnel them, but occasionally they grow from one side of the vessel only, and present the appearance of a sessile bud growing from the arterial wall. Klein, however, denies this, and says it is incorrect to describe the Malpighian bodies as isolated masses of adenoid tissue, but that they are always formed around an artery, though there is generally a greater amount on one side than the other, and that, therefore, in transverse sections the artery in the majority of cases is found in an eccentric position. These bodies are visible to the naked eye on the surface of a fresh section of the organ, appearing as minute dots of semi-opaque whitish color in the dark substance of the pulp. In minute structure they resemble the adenoid tissue of lymphatic glands, consisting of a delicate reticulum in the meshes of which lie ordinary lymphoid cells.

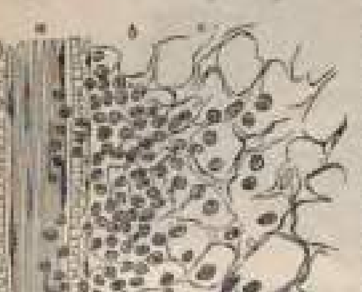


Fig. 525.—Part of a Malpighian capsule of the spleen of man. (Klein and Noble Smith.) a, Arterial branch in longitudinal section. b, Adenoid tissue, still containing the lymph-corpuscles; only their nuclei are shown. c, Adenoid reticulum, the lymph-corpuscles accidentally removed.

The reticulum of the tissue is made up of extremely delicate fibrils, and is comparatively open in the centre of the corpuscle, becoming closer at the periphery

[1] According to Klein, it is the sheath of the small vessel which undergoes this transformation, and forms a "solid mass of adenoid tissue which surrounds the vessel like a cylindrical sheath" (*Atlas of Histology*, p. 424).

of the body. The cells which it encloses, like the supporting cells of the pulp, are possessed of amœboid movements, but when treated with carmine become deeply stained, and can thus easily be recognized from those of the pulp.

The arterioles terminate in capillaries, which traverse the pulp in all directions;

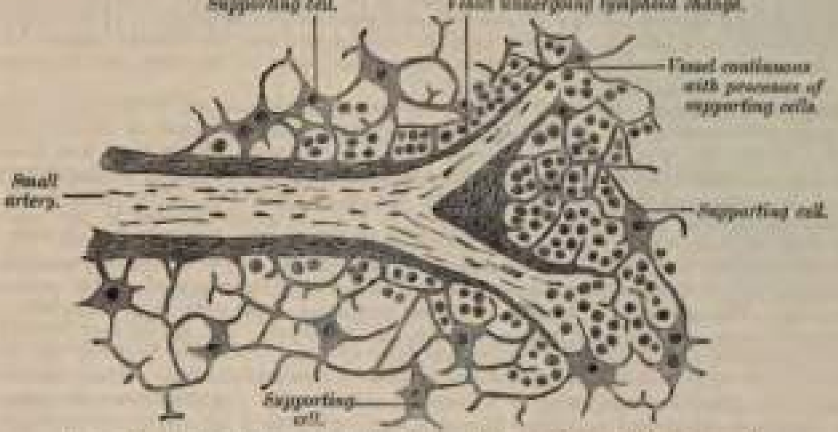


Fig. 526.—Section of spleen, showing the termination of the small blood-vessels.

their walls become much attenuated, lose their tubular character, and the cells of the lymphoid tissue of which they are composed become altered, presenting a branched appearance and acquiring processes which are directly connected with the processes of the sustentacular cells of the pulp (Fig. 526). In this manner the capillary vessels terminate, and the blood flowing through them finds its way into the interstices of the reticulated tissue formed by the branched connective-tissue corpuscles of the splenic pulp. Thus the blood passing through the spleen is brought into intimate relation with the elements of the pulp, and no doubt undergoes important changes.

After these changes have taken place the blood is collected from the interstices of the tissue by the rootlets of the veins, which commence much in the same way as the arteries terminate. Where a vein is about to commence the connective-tissue corpuscles of the pulp arrange themselves in rows in such a way as to form an elongated space or sinus. They become changed in shape, being elongated and spindle-shaped, and overlap each other at their extremities. They thus form a sort of endothelial lining of the path or sinus, which is the radicle of a vein. On the outer surface of these cells are seen delicate transverse lines or markings which are due to minute elastic fibrillæ arranged in a circular manner around the sinus. Thus the channel obtains a continuous external investment, and gradually becomes converted into a small vein, which after a time presents a coat of ordinary connective tissue, lined by a layer of fusiform epithelial cells which are continuous with the supporting cells of the pulp. The smaller veins unite to form larger ones which do not accompany the arteries, but soon enter the trabecular sheaths of the capsule, and by their junction form from six or more branches which emerge from the hilum and, uniting, form the splenic vein, the largest radicle of the vena porta.

The veins are remarkable for their numerous anastomoses, while the arteries hardly anastomose at all.

The lymphatics originate in two ways,—*i. e.*, from the sheaths of the arteries and in the trabeculæ. The former accompany the blood-vessels, the latter pass to the superficial lymphatic plexus, which may be seen on the surface of the organ. The two sets communicate in the interior of the organ. They pass through the lymphatic glands at the hilum, and terminate in the thoracic duct.

The *nerves* are derived from branches of the right and left semilunar ganglia, and from the right pneumogastric nerve.

Surface Form.—The spleen is situated under cover of the ribs of the left side, being separated from them by the Diaphragm, and above by a small portion of the lower margin of the left lung and pleura. Its position corresponds to the eighth, ninth, tenth, and eleventh ribs. It is placed very obliquely. "It is oblique in two directions, viz., from above downward and outward, and also from above downward and forward" (Cunningham). "Its highest and lowest points are on a level respectively with the ninth dorsal and first lumbar spines; its inner end is distant about an inch and a half from the median plane of the body, and its outer end about reaches the midaxillary line" (Quain).

Surgical Anatomy.—Injury of the spleen is less common than that of the liver, on account of its protected situation and connections. It may be ruptured by direct or indirect violence, torn by a broken rib, or injured by a punctured or gunshot wound. When the organ is enlarged the chance of rupture is increased. The great risk is hæmorrhage, owing to the great vascularity of the organ, and the absence of a proper system of capillaries. The injury is not, however, necessarily fatal, and this would appear to be due in a great measure to the contractile power of its capsule, which narrows the wound and prevents the escape of blood. In cases where the diagnosis is clear and the symptoms indicate danger to life laparotomy must be performed; and if the hæmorrhage cannot be stayed by ordinary surgical methods the spleen must be removed. The spleen may become displaced, producing great pain from stretching of the vessels and nerves, and this may require removal of the organ. The spleen may become enormously enlarged in certain diseased conditions, such as ague, leukæmia, syphilis, valvular disease of the heart, or without any obtainable history of previous disease. It may also become enlarged in lymphadenoma as a part of a general blood-disease. In these cases the tumor may fill the abdomen and extend into the pelvis, and may be mistaken for ovarian or uterine disease.

The spleen is sometimes the seat of cystic tumors, especially hydatids, and of abscess. These cases require treatment by incision and drainage; and in abscess great care must be taken if there are no adhesions between the spleen and abdominal cavity, to prevent the escape of any of the pus into the peritoneal cavity. If possible, the operation should be performed in two stages. Sarcoma and carcinoma are occasionally found in the spleen, but very rarely as a primary disease.

Extirpation of the spleen has been performed for wounds or injuries, in floating spleen, in simple hypertrophy, and in leukæmic enlargement; but in these latter cases the operation is now regarded as unjustifiable, as every case in which it has been performed has terminated fatally. The incision is best made in the left semilunar line; the spleen is isolated from its surroundings, and the pedicle transfixed and ligatured in two portions, before the tumor is turned out of the abdominal cavity, if this is possible, so as to avoid any traction on the pedicle, which may cause tearing of the splenic vein. In applying the ligature care must be taken not to include the tail of the pancreas, and in lifting out the organ to avoid rupturing the capsule.

THE ORGANS OF VOICE AND RESPIRATION.

THE LARYNX.

THE Larynx is the organ of voice, placed at the upper part of the air-passage. It is situated between the trachea and base of the tongue, at the upper and fore part of the neck, where it forms a considerable projection in the middle line. On either side of it lie the great vessels of the neck; behind, it forms part of the boundary of the pharynx, and is covered by the mucous membrane lining that cavity. Its vertical extent corresponds to the fourth, fifth, and sixth cervical vertebræ, but it is placed somewhat higher in the female and also during childhood. In infants between six and twelve months of age Symington found that the tip of the epiglottis was a little above the level of the cartilage, between the odontoid process and body of the axis, and that between infancy and adult life the larynx descends for a distance equal to two vertebral bodies and two intervertebral disks. According to Sappey, the average measurements of the adult larynx are as follows:

	In males.	In females.
Vertical diameter	44 mm.	36 mm.
Transverse diameter	43 "	41 "
Antero-posterior diameter . . .	36 "	26 "
Circumference	136 "	112 "

Until puberty there is no marked difference between the larynx of the male and that of the female. In the latter its further increase in size is only slight, whereas in the former it is great; all the cartilages are enlarged, and the thyroid becomes prominent as the *pomum Adami* in the middle line of the neck, while the length of the glottis is nearly doubled.

The larynx is broad above, where it presents the form of a triangular box, flattened behind and at the sides, and bounded in front by a prominent vertical ridge. Below, it is narrow and cylindrical. It is composed of cartilages, which are connected together by ligaments and moved by numerous muscles. It is lined by mucous membrane, which is continuous above with that lining the pharynx and below with that of the trachea.

The **Cartilages of the Larynx** are nine in number, three single, and three pairs:

Thyroid.	Two Arytenoid.
Cricoid.	Two Cornicula Laryngis.
Epiglottis.	Two Cuneiform.

The **thyroid** (*θυρεός, a shield*) is the largest cartilage of the larynx. It consists of two lateral lamellæ or alæ, united at an acute angle in front, forming a vertical projection in the middle line which is prominent above, and called the *pomum Adami*. This projection is subcutaneous, more distinct in the male than in the female, and occasionally separated from the integument by a bursa mucosa.

Each lamella is quadrilateral in form. Its *outer surface* presents an oblique ridge, which passes downward and forward from a tubercle, situated near the root of the superior cornu, to a small tubercle near the anterior part of the lower border. This ridge gives attachment to the Sterno-thyroid and Thyro-hyoid muscles, and the portion of cartilage included between it and the posterior border to part of the Inferior constrictor muscle.

The *inner surface* of each ala is smooth, slightly concave, and covered by mucous membrane above and behind; but in front, in the receding angle formed by their junction, are attached the epiglottis, the true and false vocal cords, the Thyro-arytenoid and Thyro-epiglottidean muscles, and the thyro-epiglottidean ligament.

The *upper border of the thyroid cartilage* is sinuously curved, being concave at its posterior part, just in front of the superior cornu, then rising into a convex outline, which dips in front to form the sides of a notch, the *thyroid notch*, in the middle line, immediately above the pomum Adami. This border gives attachment throughout its whole extent to the thyro-hyoid membrane.

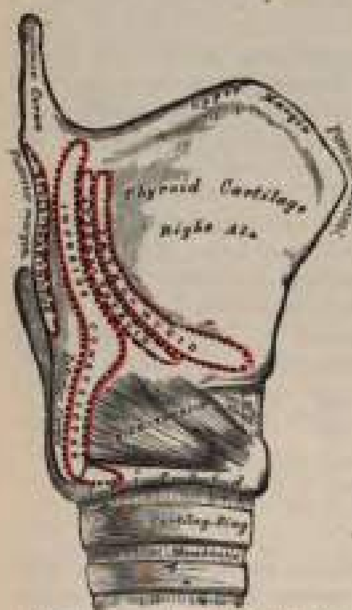


FIG. 527.—Side view of the thyroid and cricoid cartilages.

The *lower border* is nearly straight in front, but behind, close to the cornu, is concave. It is connected to the cricoid cartilage, in and near the median line, by the middle portion of the crico-thyroid membrane; and, on each side, by the Crico-thyroid muscle.

The *posterior borders*, thick and rounded, terminate, above, in the *superior cornua*, and below, in the *inferior cornua*. The two superior cornua are long and narrow, directed upward, backward, and inward, and terminate in conical extremities, which give attachment to the lateral thyro-hyoid ligament. The two inferior cornua are short and thick; they pass downward, with a slight inclination forward and inward, and present, on their inner surfaces, a small oval articular facet for articulation with the side of the cricoid cartilage. The posterior border receives the insertion of the Stylo-pharyngeus and Palato-pharyngeus muscles on each side.

During infancy the alæ of the thyroid cartilage are joined to each other by a narrow, lozenge-shaped strip, named the *intra-thyroid cartilage*. This strip extends from the upper to the lower border of the cartilage in the middle line, and is distinguished from the alæ by being more transparent and more flexible.

The **cricoid cartilage** is so called from its resemblance to a signet ring (*κρίκος, a ring*). It is smaller, but thicker and stronger than the thyroid cartilage, and forms the lower and back part of the cavity of the larynx. It consists of two parts: a quadrate portion, situated behind, and a narrow ring or arch, one-fourth or one-fifth the depth of the posterior part, situated in front. The posterior square portion rapidly narrows at the sides of the cartilage, at the expense of the upper border, into the anterior portion.

Its *posterior portion* is very deep and broad, and measures from above downward about an inch (2–3 cm.); it presents, on its posterior surface, in the middle line, a vertical ridge for the attachment of the longitudinal fibres of the œsophagus; and on either side a broad depression for the Crico-arytenoideus posticus muscle.

Its *anterior portion* is narrow and convex, and measures vertically about one-fourth or one-fifth of an inch (5–7 cm.); it affords attachment externally in front and at the sides to the Crico-thyroid muscles, and behind, to part of the Inferior constrictor.

At the point of junction of the posterior quadrate portion with the rest of the cartilage is a small round elevation, for articulation with the inferior cornu of the thyroid cartilage.

The *lower border* of the cricoid cartilage is horizontal, and connected to the upper ring of the trachea by fibrous membrane.

Its *upper border* is directed obliquely upward and backward, owing to the great depth of the posterior surface. It gives attachment, in front, to the middle portion of the crico-thyroid membrane; at the sides, to the lateral portion of the same membrane and to the lateral Crico-arytenoid muscle; behind, it presents, in the middle, a shallow notch, and on each side of this is a smooth, oval surface, directed upward and outward, for articulation with the arytenoid cartilage.

The *inner surface* of the cricoid cartilage is smooth, and lined by mucous membrane.

The **arytenoid cartilages** are so called from the resemblance they bear, when approximated, to the mouth of a pitcher (*ἀρύταινα, a pitcher*). They are two in number, and situated at the upper border of the cricoid cartilage, at the back of the larynx. Each cartilage is pyramidal in form, and presents for examination three surfaces, a base, and an apex.

The *posterior surface* is triangular, smooth, concave, and gives attachment to the Arytenoid muscle.

The *anterior or external surface* is somewhat convex and rough. It presents rather below its centre a transverse ridge, to the inner extremity of which is attached the false vocal cord, and to the outer part, as well as the surfaces above and below, is attached the Thyro-arytenoid muscle.

The *internal surface* is narrow, smooth, and flattened, covered by mucous membrane, and forms the lateral boundary of the respiratory part of the glottis.

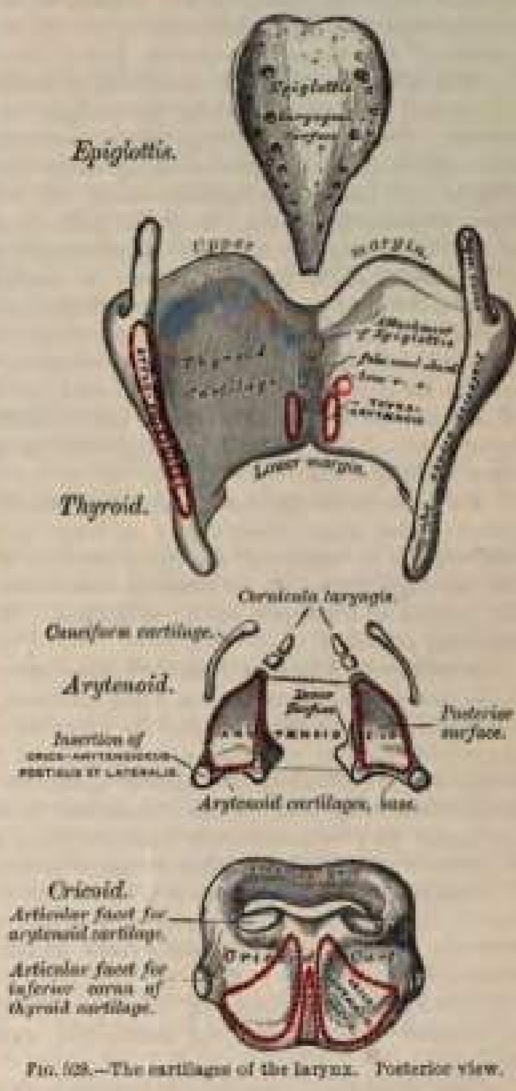


Fig. 528.—The cartilages of the larynx. Posterior view.

The *base* of each cartilage is broad, and presents a concave smooth surface, for articulation with the cricoid cartilage. Two of its angles require special mention: the *external*, which is short, rounded, and prominent, projects backward and outward, and is termed the *muscular process*, from receiving the insertion of the Posterior and Lateral crico-arytenoid muscles. The *anterior angle*, also prominent, but more pointed, projects horizontally forward, and gives attachment to the true vocal cord. This angle is called the *vocal process*.

The *apex* of each cartilage is pointed, curved backward and inward, and surmounted by a small conical, cartilaginous nodule, the *corniculum laryngis*.

The **cornicula laryngis** (*cartilages of Santorini*) are two small conical nodules, consisting of white fibro-cartilage, which articulate with the summit of the arytenoid cartilages and serve to prolong them backward and inward. To them are attached the aryteno-epiglottidean folds. They are sometimes united to the arytenoid cartilages.

The **cuneiform cartilages** (*cartilages of Wrisberg*) are two small, elongated, cartilaginous bodies, placed one on each side, in the fold of mucous membrane which extends from the apex of the arytenoid cartilage to the side of the epiglottis (*aryteno-epiglottidean fold*); they give rise to small whitish elevations on the inner surface of the mucous membrane, just in front of the arytenoid cartilages.

The **epiglottis** is a thin lamella of fibro-cartilage, of a yellowish color, shaped like a leaf, and placed behind the tongue in front of the superior opening of the larynx. Its free extremity is broad and rounded; its attached part is long, narrow, and connected to the receding angle between the two alæ of the thyroid cartilage, just below the median notch, by a long, narrow ligamentous band, the *thyro-epiglottic ligament*. It is also connected to the posterior surface of the body of the hyoid bone by an elastic ligamentous band, the *hyo-epiglottic ligament*.

Its *anterior* or *lingual surface* is curved forward, toward the tongue, and covered at its upper, free part by mucous membrane, which is reflected on to the sides and base of the organ, forming a median and two lateral folds, the *glosso-epiglottidean folds*. The depressions between the epiglottis and the base of the tongue, on either side of the median fold, are named the *valleculæ*. The lower part of its anterior surface lies behind the hyoid bone, the thyro-hyoid membrane, and upper part of the thyroid cartilage, but is separated from these structures by a mass of fatty tissue.

Its *posterior* or *laryngeal surface* is smooth, concave from side to side, concavo-convex from above downward; its lower part projects backward as an elevation, the *tubercle* or *cushion*; when the mucous membrane is removed, the surface of the cartilage is seen to be studded with a number of small mucous glands, which are lodged in little pits upon its surface. To its sides the aryteno-epiglottidean folds are attached.

Structure.—The cuneiform cartilages, the epiglottis, and the apices of the arytenoids are composed of yellow fibro-cartilage, which shows little tendency to calcification; on the other hand, the thyroid, cricoid, and the greater part of the arytenoids consist of hyaline cartilage, and become more or less ossified as age advances. Ossification commences about the twenty-fifth year in the thyroid cartilage, somewhat later in the cricoid and arytenoids; by the sixty-fifth year these cartilages may be completely converted into bone. The cornicula laryngis consist of white fibro-cartilage, which becomes osseous about the seventieth year.

Ligaments.—The ligaments of the larynx are *extrinsic*—*i. e.*, those connecting the thyroid cartilage and epiglottis with the hyoid bone, and the cricoid cartilage with the trachea; and *intrinsic*, those which connect the several cartilages of the larynx to each other.

The ligaments connecting the thyroid cartilage with the hyoid bone are three in number—the thyro-hyoid membrane, and the two lateral thyro-hyoid ligaments.

The *thyro-hyoid membrane*, or *middle thyro-hyoid ligament*, is a broad, fibro-elastic, membranous layer, attached below to the upper border of the thyroid cartilage, and above to the posterior border of the body and greater cornua of the hyoid bone, thus passing behind the postero-inferior surface of the hyoid, and being separated from it by a synovial bursa, which facilitates the upward movement of the larynx during deglutition. It is thicker in the middle line than at either side, and is pierced, in the latter situation, by the superior laryngeal vessels and the internal branch of the superior laryngeal nerve. Its anterior surface is in relation with the Thyro-hyoid, Sterno-hyoid, and Omo-hyoid muscles, and with the body of the hyoid bone.

The *two lateral thyro-hyoid ligaments* are rounded, elastic cords, which pass between the superior cornua of the thyroid cartilage and the extremities of the greater cornua of the hyoid bone. A small cartilaginous nodule (*cartilago triticea*), sometimes bony, is frequently found in each.

The ligament connecting the epiglottis with the hyoid bone is the *hyo-epiglottic*. In addition to this extrinsic ligament, the epiglottis is connected to the tongue by the three glosso-epiglottidean folds of mucous membrane, which may also be considered as extrinsic ligaments of the epiglottis.

The *hyo-epiglottic ligament* is an elastic band, which extends from the anterior surface of the epiglottis, near its apex, to the upper border of the body of the hyoid bone.

The ligaments connecting the thyroid cartilage to the cricoid are also three in number—the crico-thyroid membrane, and the capsular ligaments.

The *crico-thyroid membrane* is composed mainly of yellow elastic tissue. It consists of three parts, a central, triangular portion and two lateral portions. The central part is thick and strong, narrow above and broadening out below. It connects together the contiguous margins of the thyroid and cricoid cartilages. It is convex, concealed on each side by the Crico-thyroid muscle, but subcutaneous in the middle line; it is crossed horizontally by a small anastomotic arterial arch, formed by the junction of the two crico-thyroid arteries. The lateral portions are thinner and lie close under the mucous membrane of the larynx. They extend from the superior border of the cricoid cartilage to the inferior margin of the true vocal cords, with which they are continuous.

The lateral portions are lined internally by mucous membrane, and covered by the lateral Crico-arytenoid and Thyro-arytenoid muscles.

A *capsular ligament* encloses the articulation of the inferior cornu of the thyroid with the cricoid cartilage on each side. The articulation is lined by synovial membrane.

The ligaments connecting the arytenoid cartilages to the cricoid are two *capsular ligaments* and two *posterior crico-arytenoid ligaments*. The *capsular ligaments* are thin and loose capsules attached to the margin of the articular surfaces; they are lined internally by synovial membrane. The *posterior crico-arytenoid ligaments* extend from the cricoid to the inner and back part of the base of the arytenoid cartilage.

The ligament connecting the epiglottis with the thyroid cartilage is the thyro-epiglottic.

The *thyro-epiglottic ligament* is a long, slender, elastic cord which connects the apex of the epiglottis with the receding angle of the thyroid cartilage, immediately beneath the median notch, above the attachment of the vocal cords.

The *crico-tracheal ligament* connects the cricoid cartilage with the first ring of the trachea. It resembles the fibrous membrane which connects the cartilaginous rings of the trachea to each other.

Interior of the Larynx.—The *cavity of the larynx* extends from its superior aperture to the lower border of the cricoid cartilage. It is divided into two parts by the projection inward of the true vocal cords, between which is a narrow triangular fissure or chink, the *rima glottidis*. The portion of the cavity of the larynx above the true vocal cords, sometimes called the *vestibule*, is broad and triangular in shape, and corresponds to the interval between the alæ of the thyroid cartilage; it contains the false vocal cords, and between these and the true vocal cords are the ventricles of the larynx. The portion below the true vocal cords widens out, and is at first of an elliptical and lower down of a circular form, and is continuous with the tube of the trachea.

The *superior aperture of the larynx* (Fig. 529) is a triangular or cordiform opening, wide in front, narrow behind, and sloping obliquely downward and backward. It is bounded, in front, by the epiglottis; behind, by the apices of the arytenoid cartilages and the cornicula laryngis; and laterally, by a fold of mucous membrane, enclosing ligamentous and muscular fibres, stretched between the sides of the epiglottis and the apices of the arytenoid cartilages: these are the *arytenoepiglottidean folds*, on the margins of which the cuneiform cartilages form more or less distinct whitish prominences.

The *rima glottidis* is the elongated fissure or chink between the inferior or true vocal cords in front, and between the bases and vocal processes of the arytenoid cartilages behind. It is therefore frequently subdivided into an anterior interligamentous or *vocal* portion (*glottis vocalis*) and a posterior intercartilaginous or *respiratory* part (*glottis respiratoria*). Posteriorly it is limited by the mucous membrane passing between the arytenoid cartilages. The vocal portion averages about three-fifths of the length of the entire aperture. It is the narrowest part of

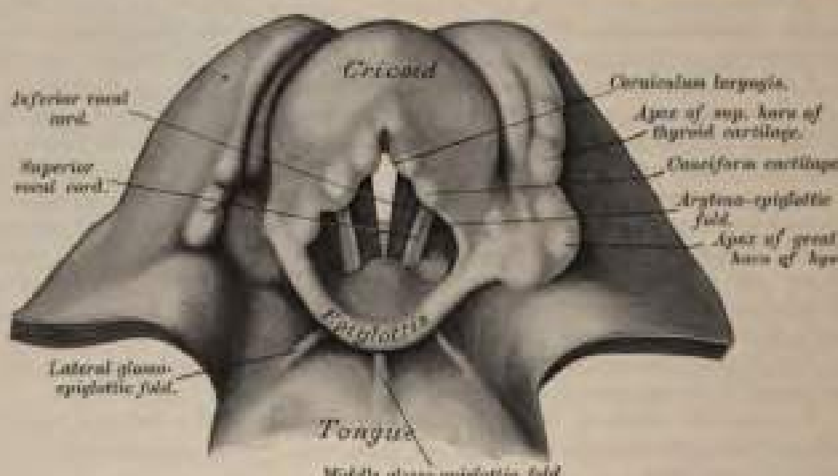


FIG. 529.—Larynx, viewed from above. (Testut.)

the cavity of the larynx, and its level corresponds to the bases of the arytenoid cartilages. Its length, in the male, measures rather less than an inch (20–25 mm.); in the female it is shorter by 5 or 6 mm., or three lines. The width and shape of the rima glottidis vary with the movements of the vocal cords and arytenoid cartilages during respiration and phonation. In the condition of rest—*i. e.*, when these structures are uninfluenced by muscular action, as in quiet respiration—the glottis vocalis is triangular, with its apex in front and its base behind, the latter being represented by a line about 8 mm. long, connecting the anterior extremities of the vocal processes, while the inner surfaces of the arytenoids are parallel to each other, and hence the glottis respiratoria is rectangular. During extreme adduction of the cords, as in the emission of a high note, the glottis vocalis is reduced to a linear slit by the apposition of the cords, while the glottis respiratoria is triangular, its apex corresponding to the anterior extremities of the vocal processes of the arytenoids, which are approximated by the inward rotation of the cartilages. Conversely in extreme abduction of the cords, as in forced inspiration, the arytenoids and their vocal processes are rotated outward, and the glottis respiratoria is triangular in shape, but with its apex directed backward. In this condition the entire glottis is somewhat lozenge-shaped, the sides of the glottis vocalis diverging from before backward, those of the glottis respiratoria diverging from behind forward, the widest part of the aperture corresponding with the attachment of the cords to the vocal processes.[1]

The *superior* or *false vocal cords*, so called because they are not directly concerned in the production of the voice, are two thick folds of mucous membrane, enclosing a narrow band of fibrous tissue, the *superior thyro-arytenoid ligament*, which is attached in front to the angle of the thyroid cartilage immediately below the attachment of the epiglottis, and behind to the anterior surface of the arytenoid cartilage. The lower border of this ligament, enclosed in mucous membrane, forms a free crescentic margin, which constitutes the upper boundary of the ventricle of the larynx.

[1] On the shape of the rima glottidis, in the various conditions of breathing and speaking, see Czermak, *On the Laryngoscope*, translated for the New Sydenham Society.

The *inferior* or *true vocal cords*, so called from their being concerned in the production of sound, are two strong bands (*inferior thyro-arytenoid ligaments*), covered on their surface by a thin layer of mucous membrane. Each ligament consists of a band of yellow elastic tissue, attached in front to the depression between the two alæ of the thyroid cartilage, and behind to the anterior angle (vocal process) of the base of the arytenoid. Its lower border is continuous with the thin lateral part of the crico-thyroid membrane. Its upper border forms the lower boundary of the ventricle of the larynx. Externally, the Thyro-arytenoideus muscle lies parallel with it. It is covered internally by mucous membrane, which is extremely thin, and closely adherent to its surface.

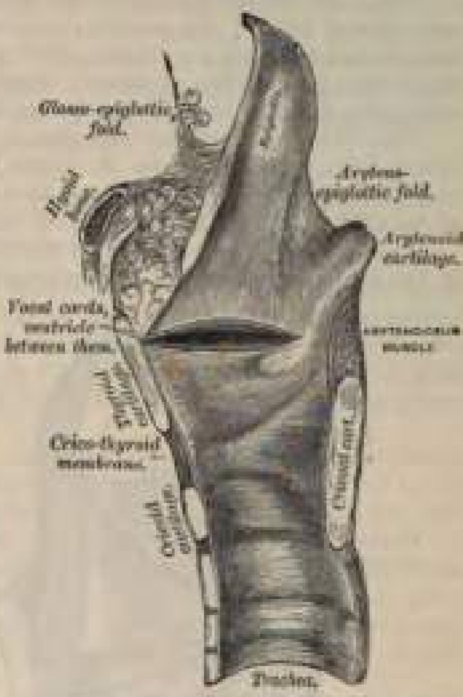


Fig. [illegible].—Vertical section of the larynx and upper part of the trachea.

The *ventricle of the larynx* is an oblong fossa, situated between the superior and inferior vocal cords on each side, and extending nearly their entire length. This fossa is bounded, above, by the free crescentic edge of the superior vocal cord; below, by the straight margin of the true vocal cord; externally, by the mucous membrane covering the corresponding Thyro-arytenoideus muscle. The anterior part of the ventricle leads up by a narrow opening into a cæcal pouch of mucous membrane of variable size, called the *laryngeal pouch*.

The *sacculus laryngis*, or laryngeal pouch, is a membranous sac, placed between the superior vocal cord and the inner surface of the thyroid cartilage, occasionally extending as far as its upper border or even higher; it is conical in form, and curved slightly backward. On the surface of its mucous membrane are the openings of sixty or seventy mucous glands, which are lodged in the submucous areolar tissue. This sac is enclosed in a fibrous capsule, continuous below with the superior thyro-arytenoid ligament: its laryngeal surface is covered by the Aryteno-epiglottideus inferior muscle (*Compressor sacculi laryngis*, Hilton); while its exterior is covered by the Thyro-arytenoideus and Thyro-epiglottideus muscles. These muscles compress the sacculus laryngis, and discharge the secretion it contains upon the chordæ vocales, the surfaces of which it is intended to lubricate.

Muscles.—The intrinsic muscles of the larynx are eight in number, five of which are the muscles of the vocal cords and rima glottidis, and three are connected with the epiglottis.

The five muscles of the vocal cords and rima glottidis are the—

Crico-thyroid.	Crico-arytenoideus lateralis.
Crico-arytenoideus posticus.	Arytenoideus.

Thyro-arytenoideus.

The *Crico-thyroid* is triangular in form, and situated at the fore part and side of the cricoid cartilage. It arises from the front and lateral part of the cricoid cartilage; its fibres diverge, passing obliquely upward and outward to be inserted into the lower border of the thyroid cartilage and into the anterior border of the lower cornua.

The inner borders of these two muscles are separated in the middle line by a triangular interval occupied by the central part of the crico-thyroid membrane.

The *Crico-arytenoideus posticus* arises from the broad depression occupying each lateral half of the posterior surface of the cricoid cartilage; its fibres pass upward and outward, converging to be inserted into the outer angle (muscular process) of the base of the arytenoid cartilage. The upper fibres are nearly horizontal, the middle oblique, and the lower almost vertical.[1]

The *Crico-arytenoideus lateralis* is smaller than the preceding, and of an oblong form. It arises from the upper border of the side of the cricoid cartilage, and, passing obliquely upward and backward, is inserted into the muscular process of the arytenoid cartilage in front of the preceding muscle.

The *Arytenoideus* is a single muscle filling up the posterior concave surface of the arytenoid cartilages. It arises from the posterior surface and outer border of one arytenoid cartilage, and is inserted into the corresponding parts of the opposite cartilage. It consists of three planes of fibres, two oblique and one transverse. The *oblique fibres*, the most superficial, form two fasciculi, which pass from the base of one cartilage to the apex of the opposite one. The *transverse fibres*, the deepest and most numerous, pass transversely across between the two cartilages; hence the Arytenoideus was formerly considered as three muscles, the transverse and the two oblique. A few of the oblique fibres are occasionally continued round the outer margin of the cartilage, and blend with the Thyro-arytenoid or the Aryteno-epiglottideus muscle.

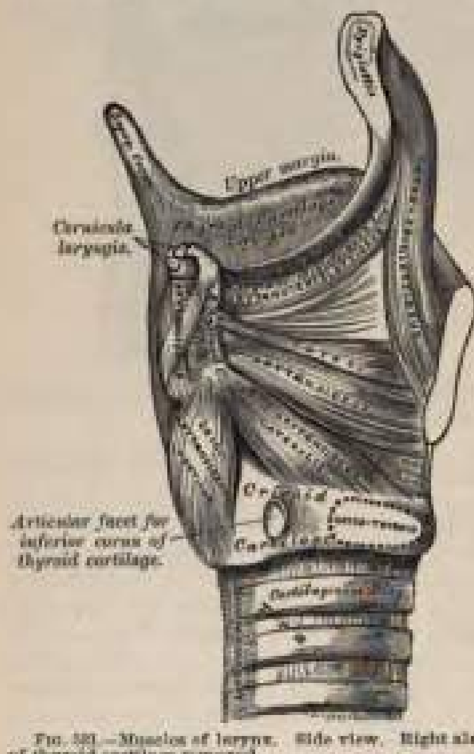


FIG. 381.—Muscles of larynx. Side view. Right ala of thyroid cartilage removed.

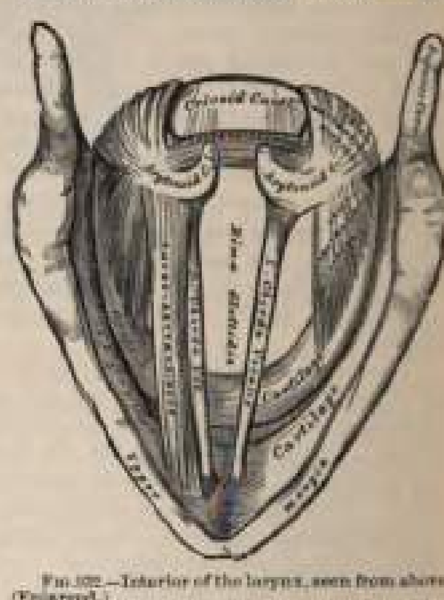


FIG. 382.—Interior of the larynx, seen from above. (Enlarged.)

The *Thyro-arytenoideus* is a broad, flat muscle, which lies parallel with the outer side of the true vocal cord. It arises in front from the lower half of the receding angle of the thyroid cartilage, and from the crico-thyroid membrane. Its

[1] Merkel, of Leipsic, has described a muscular slip which occasionally extends between the outer border of the posterior surface of the cricoid cartilage and the posterior margin of the inferior cornu of the thyroid; this he calls the "Musculus kerato-cricoideus." It is not found in every larynx, and when present exists usually only on one side, but is occasionally found on both sides. Sir William Turner (*Edinburgh Medical Journal*, Feb., 1860) states that it is found in about one case in five. Its action is to fix the lower horn of the thyroid cartilage backward and downward, opposing in some measure the part of the Crico-thyroid muscle, which is connected to the anterior margin of the horn.

fibres pass backward and outward, to be inserted into the base and anterior surface of the arytenoid cartilage. This muscle consists of two fasciculi.[1] The *inner or inferior portion*, the thicker, is inserted into the vocal process of the arytenoid cartilage, and into the adjacent portion of its anterior surface; it lies parallel with the true vocal cord, to which it is adherent. The *outer or superior fasciculus*, the thinner, is inserted into the anterior surface and outer border of the arytenoid cartilage above the preceding fibres; it lies on the outer side of the sacculus laryngis, immediately beneath the mucous membrane.[2]

The muscles of the epiglottis are the—

Thyro-epiglottideus. Aryteno-epiglottideus superior.
Aryteno-epiglottideus inferior.

The *Thyro-epiglottideus* is a delicate fasciculus, which arises from the inner surface of the thyroid cartilage, just external to the origin of the Thyro-arytenoid muscle, of which it is sometimes described as a part, and spreads over the outer surface of the sacculus laryngis; some of its fibres are lost in the aryteno-epiglottidean fold, while the others are continued forward to the margin of the epiglottis (*Depressor epiglottidis*).

The *Aryteno-epiglottideus superior* consists of a few delicate muscular fasciculi, which arise from the apex of the arytenoid cartilages, and become lost in the fold of mucous membrane extending between the arytenoid cartilage and the side of the epiglottis (*aryteno-epiglottidean fold*).

The *Aryteno-epiglottideus inferior* (*Compressor sacculi laryngis*, Hilton) arises from the arytenoid cartilage, just above the attachment of the superior vocal cord; passing forward and upward, it spreads out upon the anterior surface of the epiglottis. This muscle is separated from the preceding by an indistinct areolar interval.[3]

Actions.—In considering the action of the muscles of the larynx, they may be conveniently divided into two groups, viz.: 1. Those which open and close the glottis. 2. Those which regulate the degree of tension of the vocal cords.

1. The muscles which open the glottis are the Crico-arytenoidei postici; and those which close it are the Arytenoideus and the Crico-arytenoidei laterales. 2. The muscles which regulate the tension of the vocal cords are the Crico-thyroidei, which tense and elongate them; and the Thyro-arytenoidei, which relax and shorten them. The Thyro-epiglottideus is a depressor of the epiglottis, and the Aryteno-epiglottidei constrict the superior aperture of the larynx, compress the sacculi laryngis, and empty them of their contents.

The *Crico-arytenoidei postici* separate the chordæ vocales, and consequently open the glottis, by rotating the arytenoid cartilages outward around a vertical axis passing through the crico-arytenoid joints, so that their vocal processes and the vocal cords attached to them become widely separated.

The *Crico-arytenoidei laterales* close the glottis by rotating the arytenoid cartilages inward so as to approximate their vocal processes.

The *Arytenoideus muscles* approximate the arytenoid cartilages, and thus close the opening of the glottis, especially at its back part.

The *Crico-thyroid muscles* produce tension and elongation of the vocal cords. This is effected as follows: the thyroid cartilage is fixed by its extrinsic muscles; then the Crico-thyroid muscles, when they act, draw upward the front of the cricoid cartilage, and so depress

[1] Henle describes these two portions as separate muscles, under the names of External and Internal thyro-arytenoid.

[2] Luschka has described a small but fairly constant muscle as the *Arytenoideus rectus*. It is attached below to the posterior concave surface of the arytenoid cartilage, beneath the Arytenoideus muscle, and, passing upward, emerges at the upper border of this muscle, and is inserted into the posterior surface of the cartilage of Santorini (*Anatomy*, by Hyrtl, page 718).

[3] Musculus tritriceo-glossus. Bochdalek, jun. (*Prager Vierteljahrsschrift*, 2d part, 1866), describes a muscle hitherto entirely overlooked, except a brief statement in Henle's *Anatomy*, which arises from the nodule of cartilage (*corpus triticeum*) in the posterior thyro-hyoid ligament, and passes forward and upward to enter the tongue along with the Hyo-glossus muscle. He met with this muscle eight times in twenty-two subjects. It occurred in both sexes, sometimes on both sides, at others on one only.

the posterior portion, which carries with it the arytenoid cartilages, and thus elongate the vocal cords.

The *Thyro-arytenoidei muscles*, consisting of two parts having different attachments and different directions, are rather complicated as regards their action. Their main use is to draw the arytenoid cartilages forward toward the thyroid, and thus shorten and relax the vocal cords. But, owing to the connection of the inner portion with the vocal cord, this part, if acting separately, is supposed to modify its elasticity and tension, and the outer portion, being inserted into the outer part of the anterior surface of the arytenoid cartilage, may rotate it inward, and thus narrow the rima glottidis by bringing the two cords together.

The *Thyro-epiglottidei* may depress the epiglottis; they assist in compressing the sacculi laryngis. The Aryteno-epiglottideus superior constricts the superior aperture of the larynx, when it is drawn upward, during deglutition. The *Aryteno-epiglottideus inferior*, together with some fibres of the Thyro-arytenoidei, compress the sacculus laryngis.

The **Mucous Membrane of the Larynx** is continuous above with that lining the mouth and pharynx, and it is prolonged through the trachea and bronchi into the lungs. It lines the posterior surface and the anterior part of the upper surface of the epiglottis, to which it is closely adherent, and forms the aryteno-epiglottidean folds which form the laterial boundaries of the superior aperture of the larynx. It lines the whole of the cavity of the larynx; forms, by its reduplication, the chief part of the superior or false vocal cord; and, from the ventricle, is continued into the sacculus laryngis. It is then reflected over the true vocal cords, where it is thin and very intimately adherent; covers the inner surface of the crico-thyroid membrane and cricoid cartilage; and is ultimately continuous with the lining membrane of the trachea. The fore part of the anterior surface and the upper half of the posterior surface of the epiglottis, the upper part of the aryteno-epiglottidean folds, and the true vocal cords are covered by stratified squamous epithelium; all the rest of the laryngeal mucous membrane is covered by columnar ciliated cells.

Glands.—The mucous membrane of the larynx is furnished with numerous muciparous glands, the orifices of which are found in nearly every part; they are very numerous upon the epiglottis, being lodged in little pits in its substance; they are also found in large numbers along the posterior margin of the aryteno-epiglottidean fold, in front of the arytenoid cartilages, where they are termed the *arytenoid glands.* They exist also in large numbers upon the inner surface of the sacculus laryngis. None are found on the free edges of the vocal cords.

Vessels and Nerves.—The *arteries of the larynx* are the laryngeal branches derived from the superior and inferior thyroid. The *veins* accompany the arteries: those accompanying the superior laryngeal artery join the superior thyroid vein which opens into the internal jugular vein; while those accompanying the inferior laryngeal artery join the inferior thyroid vein which opens into the innominate vein. The *lymphatics* consist of two sets, superior and inferior. The former accompany the superior laryngeal artery and pierce the thyro-hyoid membrane, to terminate in the glands situated near the bifurcation of the common carotid artery. The latter pass through the crico-thyroid membrane, and open into one or two glands lying either in front of that membrane or to the side of the cricoid cartilage. The nerves are derived from the internal and external laryngeal branches of the superior laryngeal nerve, from the inferior or recurrent laryngeal, and from the sympathetic. The internal laryngeal nerve is almost entirely sensory, but some motor filaments are said to be carried by it to the Arytenoideus muscle. It divides into a branch which is distributed to both surfaces of the epiglottis, a second to the aryteno-epiglottidean folds, and a third, the largest, which supplies the mucous membrane over the back of the larynx and communicates with the recurrent laryngeal. The external laryngeal nerve supplies the Crico-thyroid muscle. The recurrent laryngeal passes upward under the lower border of the Inferior constrictor, and enters the larynx between the cricoid and thyroid cartilages. It supplies all the muscles of the larynx except the Crico-thyroid and part of the Arytenoideus. The sensory branches of the laryngeal nerves form subepithelial plexuses, from which fibres ascend to end between the cells covering the mucous membrane.

Over the posterior surface of the epiglottis, in the aryteno-epiglottidean folds, and less regularly in some other parts, taste-buds, similar to those in the tongue, are found.

THE TRACHEA (Fig. 583).

The **trachea, or windpipe,** is a cartilaginous and membranous cylindrical tube, flattened posteriorly, which extends from the lower part of the larynx, on a level with the sixth cervical vertebra, to opposite the fourth, or sometimes the fifth,

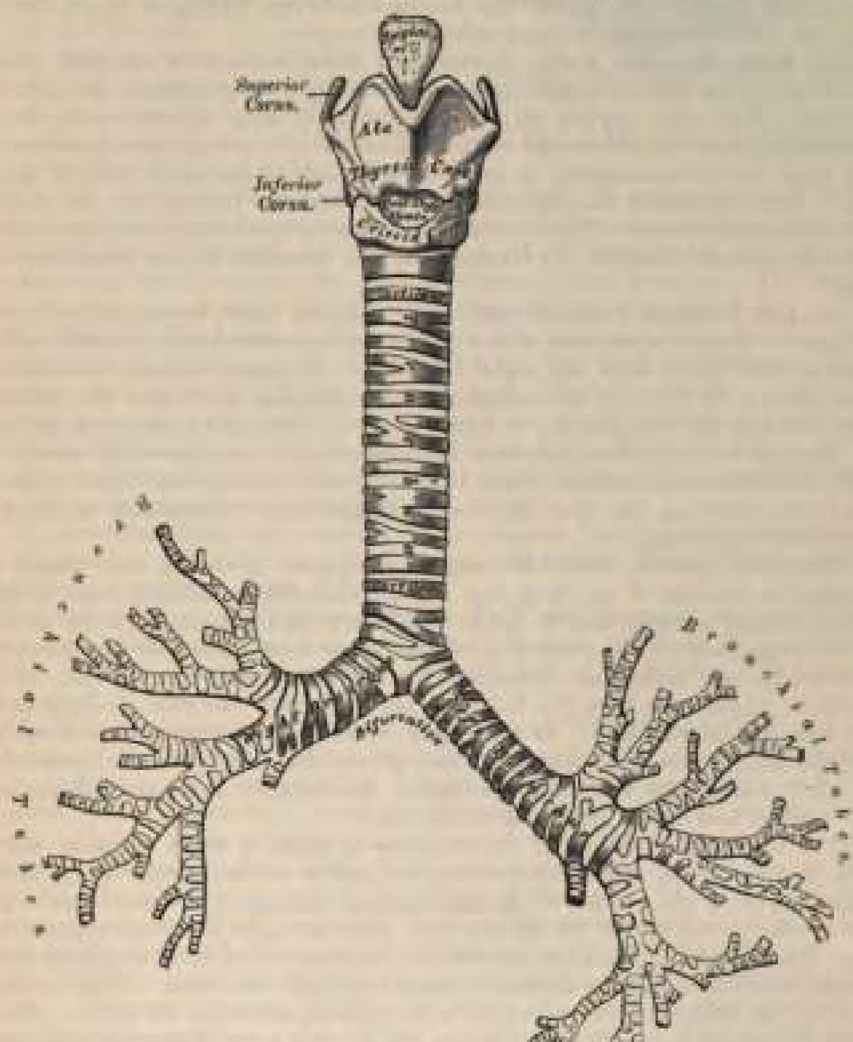


FIG. 583.—Front view of cartilages of larynx; the trachea and bronchi.

dorsal vertebra, where it divides into two bronchi, one for each lung. The trachea measures about four inches and a half in length; its diameter, from side to side, is from three-quarters of an inch to an inch, being always greater in the male than in the female.

Relations.—The anterior surface of the trachea is convex, and covered *in the neck,* from above downward, by the isthmus of the thyroid gland, the inferior thyroid veins, the arteria thyroidea ima (when that vessel exists), the Sterno-hyoid and Sterno-thyroid muscles, the cervical fascia, and more superficially, by the anastomosing branches between the anterior jugular veins: *in the thorax* it is covered from before backward by the first piece of the sternum, the remains of the thymus gland, the left innominate vein, the arch of the aorta, the innominate and left common carotid arteries, and the deep cardiac plexus. Posteriorly, it is in relation with the œsophagus: laterally, *in the neck*, it is in relation with the common carotid arteries, the lateral lobes of the thyroid gland, the inferior thyroid arteries, and recurrent laryngeal nerves; and, *in the thorax*, it lies in the upper part of the interpleural space (superior mediastinum), and is in relation on the right to the pleura and right vagus, and near the root of the neck to the innominate artery; on its left side are the recurrent laryngeal nerve, the aortic arch, the left common carotid and subclavian arteries.

The **Right Bronchus**, wider, shorter, and more vertical in direction than the left, is about an inch in length, and enters the right lung opposite the fifth dorsal vertebra. The vena azygos major arches over it from behind; and the right pulmonary artery lies below and then in front of it. About three-quarters of an inch from its commencement it gives off a branch to the upper lobe of the right lung. This is termed the *eparterial* branch, because it is given off above the right pulmonary artery. The bronchus now passes below the artery, and is known as the *hyparterial* branch. It divides into two branches for the middle and lower lobes.

The **Left Bronchus** is smaller and longer than the right, being nearly two inches in length. It enters the root of the left lung, opposite the sixth dorsal vertebra, about an inch lower than the right bronchus. It passes beneath the arch of the aorta, crosses in front of the œsophagus, the thoracic duct, and the descending aorta, and has the left pulmonary artery lying at first above, and then in front of it. The left bronchus has no branch corresponding to the eparterial branch of the right bronchus, and therefore it has been supposed by some that there is no upper lobe to the left lung, but that the so-called upper lobe corresponds to the middle lobe of the right lung.

When the bronchi enter the lung they appear to divide into nearly equal branches at the root of the lung, but a somewhat similar arrangement to what is found in many animals may be made out where each bronchus passes downward and backward toward the extremity of the lower lobe, giving off four branches at intervals in two directions, dorsally and ventrally, and, in addition, accessory branches, which arise from the front of the bronchus and pass mesially and dorsally into the inferior lobe. In the right bronchus the *first ventral* branch supplies the middle lobe, the other three and all the dorsal going to the lower lobe; in the left bronchus, the *first ventral* supplies the superior lobe, and all the others, both ventral and dorsal, go to the lower lobe.

If a transverse section of the trachea is made a short distance above its point of bifurcation, and a bird's-eye view taken of its interior (Fig. 534), the septum placed at the bottom of the trachea and separating the two bronchi will be seen to occupy the left of the median line, and the right bronchus appears to be a more direct continuation than the left, so that any solid body dropping into the trachea would naturally be directed toward the right bronchus. This tendency is aided by the larger size of the right tube as compared with its fellow. This fact serves to explain why a foreign body in the trachea more frequently falls into the right bronchus.[1]

Structure.—The trachea is composed of imperfect cartilaginous rings, fibrous membrane, muscular fibres, mucous membrane, and glands.

The **cartilages** vary from sixteen to twenty in number: each forms an imperfect ring, which surrounds about two-thirds of the cylinder of the trachea, being imperfect behind, where the tube is completed by fibrous membrane. The cartilages are placed horizontally above each other, separated by narrow membranous intervals. They measure about two lines in depth, and half a line in thickness. Their outer surfaces are flattened, but internally they are convex.

[1] Reigel asserts that the entry of a foreign body into the *left* bronchus is by no means so infrequent as is generally supposed. See also *Med.-Chir. Trans.*, vol. lxxi., p. 121.

from being thicker in the middle than at the margins. Two or more of the cartilages often unite, partially or completely, and are sometimes bifurcated at their extremities. They are highly elastic, but sometimes become calcified in advanced life. In the right bronchus the cartilages vary in number from six to eight; in the left, from nine to twelve. They are shorter and narrower than those of the trachea. The peculiar cartilages are the first and the last.

FIG. [illegible].—Transverse section of the trachea, just above its bifurcation, with a bird's-eye view of the interior.

The *first cartilage* is broader than the rest, and sometimes divided at one end; it is connected by fibrous membrane with the lower border of the cricoid cartilage, with which or with the succeeding cartilage it is sometimes blended.

The *last cartilage* is thick and broad in the middle, in consequence of its lower border being prolonged into a triangular hook-shaped process which curves downward and backward between the two bronchi. It terminates on each side in an imperfect ring which encloses the commencement of the bronchi. The cartilage above the last is somewhat broader than the rest at its centre.

The Fibrous Membrane.—The cartilages are enclosed in an elastic fibrous membrane which forms a double layer, one layer, the thicker of the two, passing over the outer surface of the ring, the other over the inner surface; at the upper and lower margins of the cartilages these two layers blend together to form a single membrane, which connects the rings one with another. They are thus, as it were, imbedded in the membrane. In the space behind, between the extremities of the rings, the membrane forms a single distinct layer.

The **muscular fibres** are disposed in two layers, longitudinal and transverse. The *longitudinal fibres* are the most external, and consist merely of a few scattered longitudinal bundles of fibres.

The *transverse fibres* (Trachealis muscle, Todd and Bowman), the most internal, form a thin layer, which extends transversely between the ends of the cartilages and the intervals between them at the posterior part of the trachea. The muscular fibres are of the unstriped variety.

The **Mucous membrane** is continuous above with that of the larynx, and below with that of the bronchi. Microscopically, it consists of areolar and lymphoid tissue, and presents a well-marked basement-membrane, supporting a layer of columnar, ciliated epithelium, between the deeper ends of which are smaller triangular cells, the bases of which, often branched, are attached to the basement-membrane. These triangular cells are mucus-secreting, and may be seen as goblet- or chalice-cells when their contents have been discharged. In the deepest part of the mucous membrane, and especially between the mucous and submucous layers, longitudinally arranged fibres are very abundant and form a distinct layer.

The **Tracheal glands** are found in great abundance at the posterior part of the trachea. They are racemose glands, and consist of a basement-membrane lined by columnar mucus-secreting cells. They are situated at the back of the trachea, outside the layer of muscular tissue, between it and the outer fibrous layer. Their excretory ducts pierce the muscular and inner fibrous layers, and pass through the submucous and mucous layers to open on the surface of the mucous membrane. Some glands of smaller size are also found at the sides of the trachea, between the layers of fibrous tissue connecting the rings, and others immediately beneath the mucous coat. The secretion from these glands serves to lubricate the inner surface of the trachea.

Vessels and Nerves.—The trachea is supplied with blood by the inferior thyroid arteries. The *veins* terminate in the thyroid venous plexus. The *nerves* are derived from the pneumogastric and its recurrent branches and from the sympathetic.

Surface Form.—In the middle line of the neck some of the cartilages of the larynx can be readily distinguished. In the receding angle below the chin the hyoid bone can easily be made out (see page 126), and a finger's breadth below it is the pomum Adami, the prominence between the upper borders of the two alæ of the thyroid cartilage. About an inch below this, in the middle line, is a depression corresponding to the crico-thyroid space, in which the operation of laryngotomy is performed. This depression is bounded below by a prominent arch, the anterior ring of the cricoid cartilage, below which the trachea can be felt, though it is only in the emaciated adult that the separate rings can be distinguished. The lower part of the trachea is not easily made out, for as it descends in the neck it takes a deeper position, and is farther removed from the surface. The level of the vocal cords corresponds to the middle of the anterior margin of the thyroid cartilage.

With the laryngoscope, the following structures can be seen: The base of the tongue and the upper surface of the epiglottis, with the glosso-epiglottic ligaments; the superior aperture of the larynx, bounded on either side by the aryteno-epiglottidean folds, in which may be seen two rounded eminences corresponding to the cornicula and cuneiform cartilages. Beneath those, the true and false vocal cords, with the ventricle between them. Still deeper, the cricoid cartilage and some of the anterior parts of the rings of the trachea, and sometimes, in deep inspiration, the bifurcation of the trachea.

Surgical Anatomy.—*Foreign bodies* often find their way into the air-passages. These may be either large soft substances, as a piece of meat, which may become lodged in the upper aperture of the larynx or in the rima glottidis, and cause speedy suffocation unless rapidly got rid of, or unless an opening is made into the air-passages below, so as to enable the patient to breathe. Smaller bodies, frequently of a hard nature, such as cherry or plum stones, small pieces of bone, buttons, etc., may find their way through the rima glottidis into the trachea or bronchus, or may become lodged in the ventricle of the larynx. The dangers then depend not so much upon the mechanical obstruction as upon the spasm of the glottis which they excite from reflex irritation. When lodged in the ventricle of the larynx, they may produce very few symptoms beyond sudden loss of voice or alteration in the voice sounds, immediately following the inhalation of the foreign body. When, however, they are situated in the trachea, they are constantly striking against the vocal cords during expiratory efforts, and produce attacks of dyspnœa from spasm of the glottis. When lodged in the bronchus, they usually become fixed there, and, occluding the lumen of the tube, cause a loss of the respiratory murmur on the affected side, which is, as stated above, more often the right.

Beneath the mucous membrane of the upper part of the air-passages there is a considerable amount of submucous tissue which is liable to become much swollen from effusion in inflammatory affections, constituting the disease known as "œdema of the glottis." This effusion does not extend below the level of the vocal cords, on account of the fact that the mucous membrane is closely adherent to these structures, without the intervention of any submucous tissue. So that, in cases of this disease in which it is necessary to open the air-passages to prevent suffocation, the operation of laryngotomy is sufficient.

Chronic laryngitis is an inflammation of the mucous glands of the larynx, which occurs in those who speak much in public, and is known as "clergyman's sore throat." It is due to the dryness induced by the large amount of cold air drawn into the air-passages during prolonged speaking, which incites increased activity in the mucous glands to keep the parts moist, and this eventually terminates in inflammation of these structures.

Ulceration of the larynx may occur from syphilis, either as a superficial ulceration, or from the softening of a gumma; from tuberculous disease (laryngeal phthisis), or from malignant disease (epithelioma).

The air-passages may be opened in two different situations: through the crico-thyroid membrane (*laryngotomy*), or in some part of the trachea (*tracheotomy*); and to these some surgeons have added a third method, by opening the crico-thyroid membrane and dividing the cricoid cartilage with the upper ring of the trachea (*laryngo-tracheotomy*).

Laryngotomy is anatomically the more simple operation: it can readily be performed, and should be employed in those cases where the air-passages require opening in an emergency for the relief of some sudden obstruction to respiration. The crico-thyroid membrane is very superficial, being covered only in the middle line by the skin, superficial fascia, and the deep fascia. On each side of the middle line it is also covered by the Sterno-hyoid and Sterno-thyroid muscles, which diverge from each other at their upper parts, leaving a slight interval between them. On these muscles rest the anterior jugular veins. The only vessel of any importance in connection with this operation is the crico-thyroid artery, which crosses the crico-thyroid membrane, and which may be wounded, but rarely gives rise to any trouble. The operation is performed thus: the head being thrown back and steadied by an assistant, the finger is passed over the front of the neck, and the crico-thyroid depression felt for. A vertical incision is then made through the skin, in the middle line over this spot, and carried down through the fascia until the crico-thyroid membrane is exposed. A cross cut is then made through the membrane, close to the upper border of the cricoid cartilage, so as to avoid, if possible, the crico-thyroid artery, and a tracheotomy tube introduced. It has been recommended, as a more rapid way of performing the operation, to make a transverse instead of a longitudinal cut, through the superficial structures, and thus to open at once the air-passages. It will be seen, however, that in operating in this way the anterior jugular veins would be in danger of being wounded.

Tracheotomy may be performed either above or below the isthmus of the thyroid body, or this structure may be divided and the trachea opened behind it.

The isthmus of the thyroid gland usually crosses the second and third rings of the trachea; along its upper border is frequently to be found a large transverse communicating branch between the superior thyroid veins; and the isthmus itself is covered by a venous plexus formed between the thyroid veins of the opposite sides. Theoretically, therefore, it is advisable to avoid dividing this structure in opening the trachea.

Above the isthmus the trachea is comparatively superficial, being covered by the skin, superficial fascia, deep fascia, Sterno-hyoid and Sterno-thyroid muscles, and a second layer of the deep fascia, which, attached above to the lower border of the hyoid bone, descends beneath the muscles to the thyroid body, where it divides into two layers and encloses the isthmus.

Below the isthmus the trachea lies much more deeply, and is covered by the Sterno-hyoid and the Sterno-thyroid muscles and a quantity of loose areolar tissue in which is a plexus of veins, some of them of large size; they converge to two trunks, the inferior thyroid veins, which descend on either side of the median line on the front of the trachea and open into the innominate veins. In the infant the thymus gland ascends a variable distance along the front of the trachea, and opposite the episternal notch the windpipe is crossed by the left innominate vein. Occasionally also, in young subjects, the innominate artery crosses the tube obliquely above the level of the sternum. The thyroidea ima artery, when that vessel exists, passes from below upward along the front of the trachea.

From these observations it must be evident that the trachea can be more readily opened above than below the isthmus of the thyroid body.

Tracheotomy above the isthmus is performed thus: the patient should, if possible, be laid on his back on a table in a good light. A pillow is to be placed under the shoulders and the head thrown back and steadied by an assistant. The surgeon standing on the right side of his patient makes an incision from an inch and a half to two inches in length in the median line of the neck from the top of the cricoid cartilage. The incision must be made exactly in the middle line, so as to avoid the anterior jugular veins, and after the superficial structures have been divided the interval between the Sterno-hyoid muscles must be found, the raphe divided, and the muscles drawn apart. The lower border of the cricoid cartilage must now be felt for, and the upper part of the trachea exposed from this point downward in the middle line. Bose has recommended that the layer of fascia in front of the trachea should be divided transversely at the level of the lower border of the cricoid cartilage, and, having been seized with a pair of forceps pressed downward with the handle of the scalpel. By this means the isthmus of the thyroid gland is depressed, and is saved from all danger of being wounded, and the trachea cleanly exposed. The trachea is now transfixed with a sharp hook and drawn forward in order to steady it, and is then opened by inserting the knife into it and dividing the two or three upper rings from below upward. If the trachea is to be opened below the isthmus, the incision must be made from a little below the cricoid cartilage to the top of the sternum.

In the child the trachea is smaller, more deeply placed, and more movable than in the adult. In fat or short-necked people, or in those in whom the muscles of the neck are prominently developed, the trachea is more deeply placed than in the opposite conditions.

A portion of the larynx or the whole of it has been removed for malignant disease, *laryngectomy*. The results which have been obtained from the removal of the whole of it have not been very satisfactory, and the cases in which the operation is justifiable are very few. It may be removed by a median incision through the soft parts, freeing the cartilage from the muscles and other structures in front, separating the larynx from the trachea below, and dissecting off the deeper structure from below upward.

THE PLEURÆ.

Each lung is invested, upon its external surface, by an exceedingly delicate serous membrane, the **pleura,** which encloses the organ as far as its root, and is then reflected upon the inner surface of the thorax. The portion of the serous membrane investing the surface of the lung and dipping into the fissures between its lobes, is called the *pleura pulmonalis* (visceral layer of pleura), while that which lines the inner surface of the chest is called the *pleura costalis* (parietal layer of pleura). The space between these two layers is called the *cavity of the pleura,* but it must be borne in mind that in the healthy condition the two layers are in contact, and there is no real cavity until the lung becomes collapsed and a separation of it from the wall of the chest takes place. Each pleura is therefore a shut sac, one occupying the right, the other the left half of the thorax, and they are perfectly separate from each other. The two pleuræ do not meet in the middle line of the chest, excepting anteriorly opposite the second and third pieces of the sternum—a space being left between them, which contains all the viscera of the thorax excepting the lungs: this is the *mediastinum.*

Reflections of the Pleura (Fig. 535).—Commencing at the sternum, the pleura passes outward, lines the costal cartilages, the inner surface of the ribs and

Intercostal muscles, and at the back part of the thorax passes over the thoracic ganglia and their branches, and is reflected upon the sides of the bodies of the

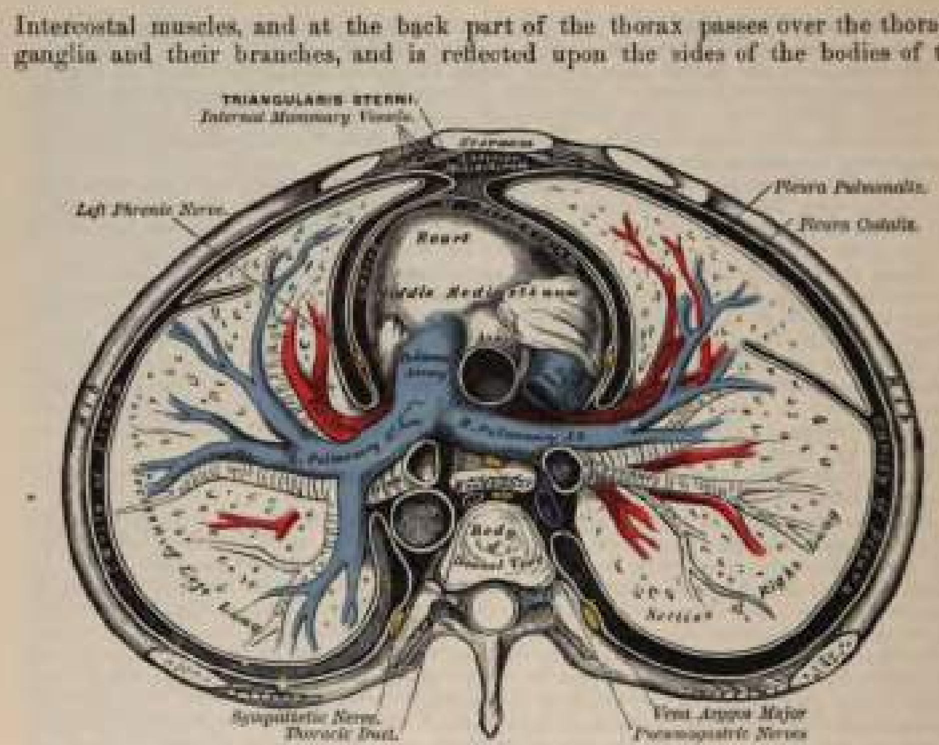


FIG. [illegible].—A transverse section of the thorax, showing the relative position of the viscera and the reflections of the pleuræ.

vertebræ, where it is separated by a narrow interval, the *posterior mediastinum*, from the opposite pleura. From the vertebral column the pleura passes to the side of the pericardium, which it covers to a slight extent; it then covers the back part of the root of the lung, from the lower border of which a triangular fold descends vertically by the side of the posterior mediastinum to the Diaphragm. This fold is the broad ligament of the lung, the *ligamentum latum pulmonis*, and serves to retain the lower part of that organ in position. *From the root* the pleura may be traced over the convex surface of the lung, the summit and base, and also over the sides of the fissures between the lobes on to its inner surface and the front part of its root; from this it is reflected on to the pericardium, and from it to the back of the sternum. *Below*, it covers the upper surface of the Diaphragm, and extends in front as low as the costal cartilage of the seventh rib: at the side of the chest, to the lower border of the tenth rib on the left side, and to the upper border of the same rib on the right side; and behind, it reaches as low as the twelfth rib, and sometimes even as low as the transverse process of the first lumbar vertebra. *Above*, its apex projects, in the form of a *cul-de-sac*, through the superior opening of the thorax into the neck, extending from one to two inches above the margin of the first rib, and receives the summit of the corresponding lung; this sac is strengthened, according to Sibson, by a dome-like expansion of fascia, attached in front to the posterior border of the first rib, and behind to the anterior border of the transverse process of the seventh cervical vertebra. This is covered and strengthened by a few spreading muscular fibres derived from the Scaleni muscles.

In the front of the chest, where the parietal layer of the pleura is reflected backward to the pericardium, the two pleural sacs are in contact for a considerable extent. At the upper part of the chest, behind the manubrium, they are not in contact; the point of reflection being represented by a line drawn from the sterno-clavicular articulation to the mid-point of the junction of the manubrium to the body of the sternum. From this point the two pleuræ descend in close contact to the level of the fourth costal cartilage. Here the line of reflection on the right side is continued onward in nearly a straight line to the lower end of the gladiolus and then turns outward, while on the left side the line of reflection diverges outward, so that opposite the seventh cartilage it is about three-quarters of an inch from the left border of the sternum. It, however, always extends considerably farther over the pericardium than the corresponding lung. The lower limit of the pleura is on a considerably lower level than the lower limit of the lung, but does not extend to the attachment of the Diaphragm, so that below the line of reflection of the pleura from the chest wall on to the Diaphragm the latter is in direct contact with the rib cartilages and the Internal intercostal muscles. Moreover, in ordinary inspiration the thin margin of the base of the lung does not extend as low as the line of pleural reflection, with the result that the costal and diaphragmatic pleura are here in contact, the narrow slit between the two being termed the *phrenico-costal sinus.* A similar condition exists behind the sternum and rib cartilages, where the anterior thin margin of the lung falls short of the line of pleural reflection, and where the slit-like cavity between the two layers of pleura forms what is sometimes called the *costo-mediastinal sinus.*

The inner surface of the pleura is smooth, polished, and moistened by a serous fluid; its outer surface is intimately adherent to the surface of the lung, and to the pulmonary vessels as they emerge from the pericardium; it is also adherent to the upper surface of the Diaphragm: throughout the rest of its extent it is somewhat thicker, and may be separated from the adjacent parts with extreme facility.

The right pleural sac is shorter, wider, and reaches higher in the neck than the left.

Vessels and Nerves.—The *arteries of the pleura* are derived from the intercostal, the internal mammary, the musculo-phrenic, thymic, pericardiac, and bronchial. The *veins* correspond to the arteries. The *lymphatics* are very numerous. The *nerves* are derived from the phrenic and sympathetic (Luschka). Kölliker states that nerves accompany the ramification of the bronchial arteries in the pleura pulmonalis.

Surgical Anatomy.—In operations upon the kidney it must be borne in mind that the pleura may sometimes extend below the level of the last rib, and may therefore be opened in these operations, especially when the last rib is removed in order to give more room.

THE MEDIASTINUM.

The **Mediastinum** is the space left in the median portion of the chest by the non-approximation of the two pleuræ. It extends from the sternum in front to the spine behind, and contains all the viscera in the thorax excepting the lungs. The mediastinum may be divided for purposes of description into two parts—an upper portion, above the upper level of the pericardium, which is named the *Superior mediastinum* (Struthers); and a lower portion, below the upper level of the pericardium. This lower portion is again subdivided into three—that part which contains the pericardium and its contents, the *middle mediastinum;* that part which is in front of the pericardium, the *anterior mediastinum;* and that part which is behind the pericardium, the *posterior mediastinum.*

The **superior mediastinum** is that portion of the interpleural space which lies above the upper level of the pericardium, between the manubrium sterni in front and the upper dorsal vertebræ behind. It is bounded below by a plane passing backward from the junction of the manubrium and gladiolus sterni to the lower part of the body of the fourth dorsal vertebra, and laterally by the lungs and pleuræ. It contains the origins of the Sterno-hyoid and Sterno-thyroid muscles and the lower ends of the Longi colli muscles; the arch of the aorta; the innominate, the thoracic portion of the left carotid and subclavian arteries; the upper half of the superior vena cava and the innominate veins, and the left superior intercostal vein; the pneumogastric, cardiac, phrenic, and left recurrent laryngeal nerves; the trachea, œsophagus, and thoracic duct; the remains of the thymus gland and some lymphatic glands.

The **anterior mediastinum** is bounded in front by the sternum, on each side by the pleura, and behind by the pericardium. It is narrow above, but widens out a little below, and, owing to the oblique course taken by the left pleura, it is directed from above obliquely downward and to the left. Its anterior wall is formed by the left Triangularis sterni muscle and the fifth, sixth, and seventh left

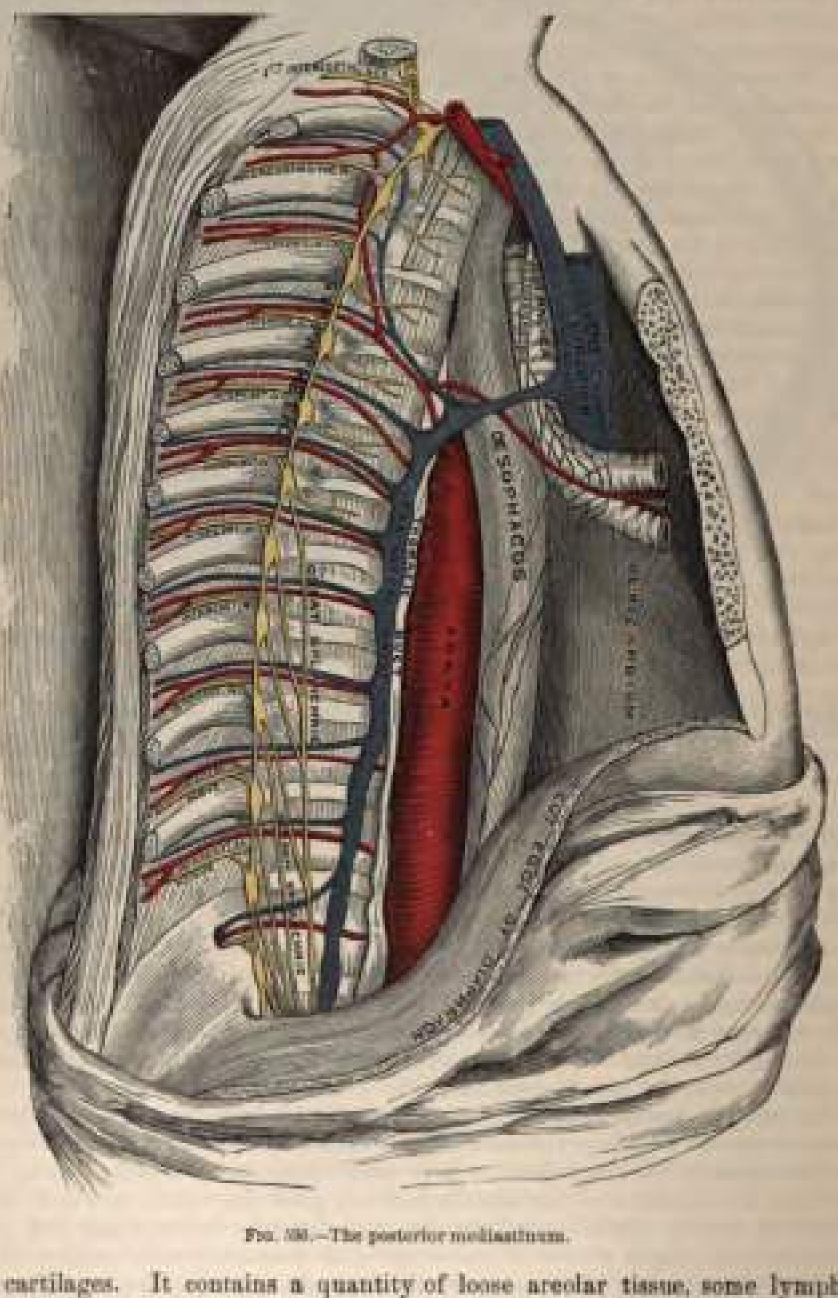


Fig. 586.—The posterior mediastinum.

costal cartilages. It contains a quantity of loose areolar tissue, some lymphatic vessels which ascend from the convex surface of the liver, two or three lymphatic glands (anterior mediastinal glands), and the small mediastinal branches of the internal mammary artery.

The **middle mediastinum** is the broadest part of the interpleural space. It contains the heart enclosed in the pericardium, the ascending aorta, the lower half of the superior vena cava, with the vena azygos major opening into it, the bifurcation of the trachea and the two bronchi, the pulmonary artery dividing into its two branches and the right and left pulmonary veins, the phrenic nerves, and some bronchial lymphatic glands.

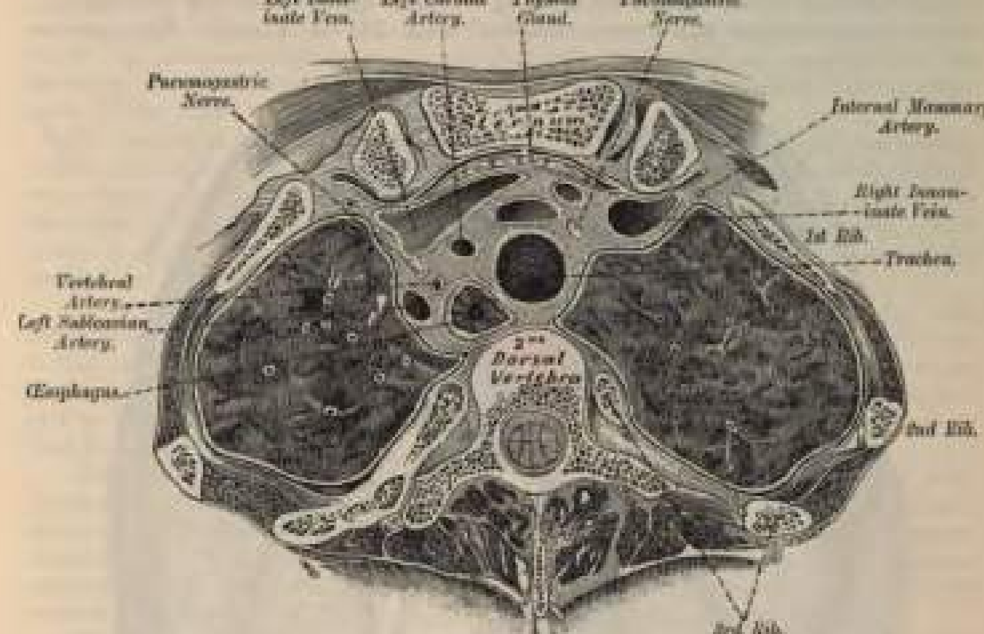


Fig. 537.—Transverse section through the upper margin of the third dorsal vertebra. (Braune.)

The **posterior mediastinum** (Fig. 536) is an irregular triangular space running parallel with the vertebral column; it is bounded in front by the pericardium and roots of the lungs, behind by the vertebral column from the lower border of the fourth dorsal vertebra, and on either side by the pleura. It contains the descending thoracic aorta, the greater and lesser azygos veins, the pneumogastric and splanchnic nerves, the œsophagus, thoracic duct, and some lymphatic glands.

THE LUNGS.

The **Lungs** are the essential organs of respiration; they are two in number, placed one on each side of the chest, separated from each other by the heart and other contents of the mediastinum. Each lung is conical in shape, and presents for examination an apex, a base, two borders, and two surfaces (Fig. 538).

The *apex* forms a tapering cone which extends into the root of the neck about an inch to an inch and a half above the level of the first rib.

The *base* is broad, concave, and rests upon the convex surface of the Diaphragm, which separates the right lung from the upper surface of the right lobe of the liver and the left lung from the upper surface of the left lobe of the liver, the stomach, and spleen; its circumference is thin, and projects for some distance into the phrenico-costal sinus of the pleura, between the lower ribs and the costal attachment of the Diaphragm, extending lower down externally and behind than in front.

The *external* or *thoracic surface* is smooth, convex, of considerable extent, and corresponds to the form of the cavity of the chest, being deeper behind than in front.

The *inner surface* is concave. It presents in front a depression corresponding to the convex surface of the pericardium, and behind a deep fissure (the hilum pulmonis) which gives attachment to the root of the lung.

The *posterior border* is rounded and broad, and is received into the deep concavity on either side of the spinal column. It is much longer than the anterior border, and projects, below, into the phrenico-costal sinus.

The *anterior border* is thin and sharp, overlaps the front of the pericardium, and is projected into the costo-mediastinal sinus of the pleura. The anterior

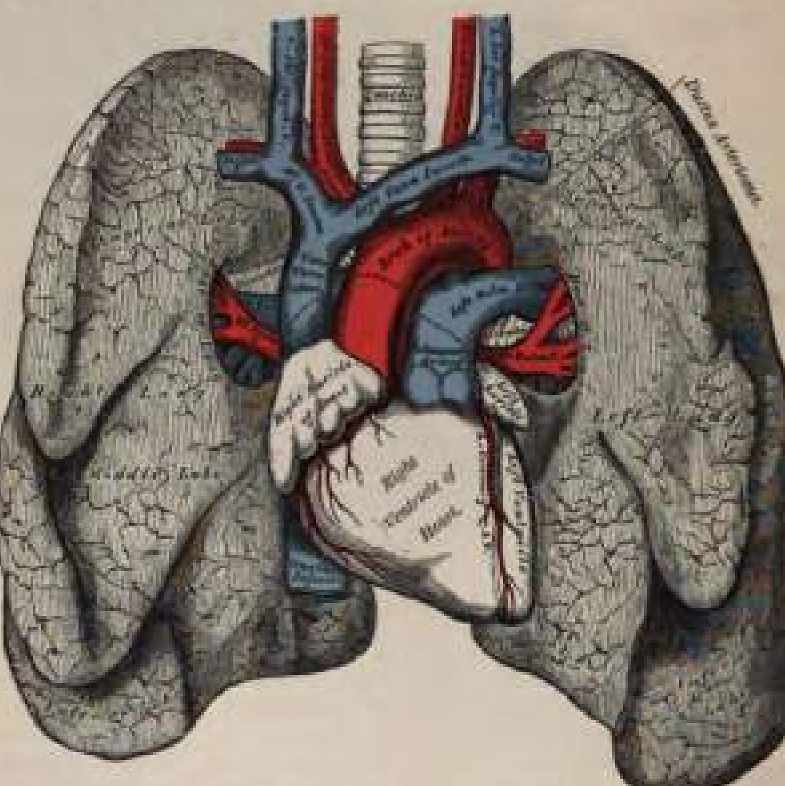


FIG. [illegible].—Front view of the heart and lungs.

border of the right lung is almost vertical; that of the left presents, below, an angular notch, the *incisura cardiaca*, into which the heart and pericardium are received.

Each lung is divided into two lobes, an upper and a lower, by a long and deep fissure, which extends from the upper part of the posterior border of the organ about three inches from its apex, downward and forward to the lower part of its anterior border. This fissure penetrates nearly to the root. In the right lung the upper lobe is partially subdivided by a second and shorter fissure, which extends almost horizontally forward from the middle of the preceding to the anterior margin of the organ, marking off a small triangular portion, the middle lobe.

The *right lung* is the larger and heavier; it is broader than the left, owing to the inclination of the heart to the left side; it is also shorter by an inch, in consequence of the Diaphragm rising higher on the right side to accommodate the liver.

The Root of the Lungs.—A little above the middle of the inner surface of each lung, and nearer its posterior than its anterior border, is its root, by which the lung is connected to the heart and the trachea. The root is formed by the bronchial tube, the pulmonary artery, the pulmonary veins, the bronchial arteries and veins, the pulmonary plexus of nerves, lymphatics, bronchial glands, and areolar tissue, all of which are enclosed by a reflection of the pleura. The root of the right lung lies behind the superior vena cava and ascending portion of the aorta and below the vena azygos major. That of the left lung passes beneath the arch of the aorta and in front of the descending aorta; the phrenic nerve and the anterior pulmonary plexus lie in front of each, and the pneumogastric and posterior pulmonary plexus behind each.

The chief structures composing the root of each lung are arranged in a similar manner from before backward on both sides—viz., the two pulmonary veins in front; the pulmonary artery in the middle; and the bronchus, together with the bronchial vessels, behind. From above downward, on the two sides, their arrangement differs, thus:

On the right side their position is—bronchus, pulmonary artery, pulmonary veins; but on the left side their position is—pulmonary artery, bronchus, pulmonary veins. It should be noted that the entire right bronchus does not lie above the right pulmonary artery, but only its eparterial branch (*see* page 966), which passes to the upper lobe of the right lung; the divisions of the bronchus for the middle and lower lobes lie below the artery.

The *weight* of both lungs together is about forty-two ounces, the right lung being two ounces heavier than the left; but much variation is met with according to the amount of blood or serous fluid they may contain. The lungs are heavier in the male than in the female, their proportion to the body being in the former as 1 to 37, in the latter as 1 to 43. The specific gravity of the lung-tissue varies from 0.345 to 0.746, water being 1000.

The *color* of the lungs at birth is a pinkish-white; in adult life a dark slate-color, mottled in patches; and as age advances this mottling assumes a black color. The coloring matter consists of granules of a carbonaceous substance deposited in the areolar tissue near the surface of the organ. It increases in quantity as age advances, and is more abundant in males than in females. The posterior border of the lung is usually darker than the anterior.

The *surface* of the lung is smooth, shining, and marked out into numerous polyhedral spaces, indicating the lobules of the organ; the area of each of these spaces is crossed by numerous lighter lines.

The *substance* of the lung is of a light, porous, spongy texture; it floats in water and crepitates when handled, owing to the presence of air in the tissue; it is also highly elastic; hence the collapsed state of these organs when they are removed from the closed cavity of the thorax.

Structure.—The lungs are composed of an external serous coat, a subserous areolar tissue, and the pulmonary substance or parenchyma.

The *serous coat* is derived from the pleura; it is thin, transparent, and invests the entire organ as far as the root.

The *subserous areolar tissue* contains a large proportion of elastic fibres; it invests the entire surface of the lung, and extends inward between the lobules.

The *parenchyma* is composed of lobules which, although closely connected together by an interlobular areolar tissue, are quite distinct from one another, and may be teased asunder without much difficulty in the fœtus. The lobules vary in size; those on the surface are large, of pyramidal form, the base turned toward the surface; those in the interior, smaller and of various forms. Each lobule is composed of one of the ramifications of a bronchial tube and its terminal air-cells, and of the ramifications of the pulmonary and bronchial vessels, lymphatics, and nerves, all of these structures being connected together by areolar tissue.

The *bronchus*, upon entering the substance of the lung, divides and subdivides bipinnately, throughout the entire organ. Sometimes three branches arise together, and occasionally small lateral branches are given off from the sides of a main trunk. Each of the smaller subdivisions of the bronchi enters a pulmonary lobule, and is termed a *lobular bronchial tube* or *bronchiole*. Its wall now begins to present irregular dilatations, *air-cells or alveoli*, at first sparingly and on one side of the tube only, but as it proceeds onward these dilatations become more numerous and surround the tube on all sides, so that it loses its cylindrical character. The bronchiole now becomes enlarged, and is termed the *atrium* or *alveolar passage*; from it are given off, on all sides, ramifications, called *infundibula*, which are closely beset in all directions by *alveoli* or *air-cells*. Within the lungs the bronchial tubes are circular, not flattened, and present certain peculiarities of structure.

Changes in the Structure of the Bronchi in the Lungs.—1. *In the Lobes of the Lungs.*—In the lobes of the lungs the following changes take place. The *cartilages* are not imperfect rings, but consist of thin laminæ, of varied form and size, scattered irregularly along the sides of the tube, being most distinct at the points of division of the bronchi. They may be traced into tubes, the diameter of which is only one-fourth of a line. Beyond this point the tubes are wholly membranous. The fibrous coat is continued into the smallest ramifications of the bronchi. The muscular coat is disposed in the form of a continuous layer of annular fibres, which may be traced upon the smallest bronchial tubes, and consists of the unstriped variety of muscular tissue. The mucous membrane lines the bronchi and its ramifications throughout, and is covered with columnar ciliated epithelium.

In the Lobules of the Lung.—In the lobular bronchial tubes and in the infundibula the following changes take place: The muscular tissue begins to disappear, so that in the infundibula there is scarcely a trace of it. The fibrous coat becomes thinner, and degenerates into areolar tissue. The epithelium becomes non-ciliated and flattened. This occurs gradually; thus, in the lobular bronchioles patches of non-ciliated flattened epithelium may be found scattered among the columnar ciliated epithelium; then these patches of non-ciliated flattened epithelium become more and more numerous, until in the infundibula and air-cells all the epithelium is of the non-ciliated pavement variety. In addition to these flattened cells, there are small polygonal granular cells in the air-sacs, in clusters of two or three, between the others.

The air-cells are small, polyhedral recesses composed of a fibrillated connective tissue and surrounded by a few involuntary muscular and elastic fibres. Free in their cavity are to be seen under the microscope granular, rounded, amœboid cells (eosinophile leucocytes), often containing carbonaceous particles. The air-cells are well seen on the surface of the lung, and vary from $\frac{1}{200}$th to $\frac{1}{70}$th of an inch in diameter, being largest on the surface at the thin borders and at the apex, and smallest in the interior.

The *pulmonary artery* conveys the venous blood to the lungs; it divides into branches which accompany the bronchial tubes, and terminates in a dense capillary network upon the walls of the intercellular passages and air-cells. In the lung the branches of the pulmonary artery are usually above and in front of a bronchial tube, the vein below.

The *pulmonary capillaries* form plexuses which lie immediately beneath the mucous membrane in the walls and septa of the air-cells and of the infundibula. In the septa between the air-cells the capillary network forms a single layer. The capillaries form a very minute network, the meshes of which are smaller than the vessels themselves;[1] their walls are also exceedingly thin. The arteries of neighboring lobules are independent of each other, but the veins freely anastomose together.

The *pulmonary veins* commence in the pulmonary capillaries, the radicles coalescing into larger branches, which run along through the substance of the lung, independently from the minute arteries and bronchi. After freely communicating with other branches they form large vessels, which ultimately come into relation with the arteries and bronchial tubes, and accompany them to the hilum of the organ. Finally they open into the left auricle of the heart, conveying oxygenated blood to be eventually distributed to all parts of the body by the aorta.

The *bronchial arteries* supply blood for the nutrition of the lung; they are derived from the thoracic aorta or from the upper aortic intercostal arteries, and,

[1] The meshes are only 0.002''' to 0.008''' in width, while the vessels are 0.002''' to 0.005''' (Kölliker, *Human Microscopic Anatomy*).

accompanying the bronchial tubes, are distributed to the bronchial glands, and upon the walls of the larger bronchial tubes and pulmonary vessels. Those supplying the bronchial tubes form a capillary plexus in the muscular coat, from which branches are given off to form a second plexus in the mucous coat. This plexus communicates with branches of the pulmonary artery, and empties itself into the pulmonary vein. Others are distributed in the interlobular areolar tissue, and terminate partly in the deep, partly in the superficial, bronchial veins. Lastly, some ramify upon the surface of the lung beneath the pleura, where they form a capillary network.

The *bronchial vein* is formed at the root of the lung, receiving superficial and deep veins corresponding to branches of the bronchial artery. It does not, however, receive all the blood supplied by the artery, as some of it passes into the pulmonary vein. It terminates on the right side in the vena azygos major, and on the left side in the superior intercostal or left upper azygos vein.

The **lymphatics** consist of a superficial and deep set: they terminate at the root of the lung, in the bronchial glands.

Nerves.—The lungs are supplied from the anterior and posterior pulmonary plexuses, formed chiefly by branches from the sympathetic and pneumogastric. The filaments from these plexuses accompany the bronchial tubes, upon which they are lost. Small ganglia are found upon these nerves.

Surface Form.—The apex of the lung is situated in the neck, behind the interval between the two heads of origin of the Sterno-mastoid. The height to which it rises above the clavicle varies very considerably, but is generally about one inch. It may, however, extend as much as an inch and a half or an inch and three-quarters, or, on the other hand, it may scarcely project above the level of this bone. In order to mark out the anterior margin of the lung, a line is to be drawn from the apex-point, one inch above the level of the clavicle, and rather nearer the posterior than the anterior border of the Sterno-mastoid muscle, downward and inward across the sterno-clavicular articulation and first piece of the sternum until it meets, or almost meets, its fellow of the other side opposite the articulation of the manubrium and gladiolus. From this point the two lines are to be drawn downward, one on either side of the mesial line and close to it, as far as the level of the articulation of the fourth costal cartilages to the sternum. From here the two lines diverge; the left is to be drawn at first passing outward with a slight inclination downward, and then taking a bend downward with a slight inclination outward to the apex of the heart, and thence to the sixth costo-chondral articulation. The direction of the anterior border of this part of the left lung is denoted with sufficient accuracy by a curved line with its convexity directed upward and outward from the articulation of the fourth right costal cartilage of the sternum to the fifth intercostal space, an inch and a half below and three-quarters of an inch internal to the left nipple. The continuation of the anterior border of the right lung is marked by a prolongation of its line from the level of the fourth costal cartilages vertically downward as far as the sixth, when it slopes off along the line of the sixth costal cartilage to its articulation with the rib.

The lower border of the lung is marked out by a slightly curved line with its convexity downward from the articulation of the sixth costal cartilage to its rib to the spinous process of the tenth dorsal vertebra. If vertical lines are drawn downward from the nipple, the mid-axillary line, and the apex of the scapula, while the arms are raised from the sides, they should intersect this convex line, the first at the sixth, the second at the eighth, and the third at the tenth rib. It will thus be seen that the pleura (see page 971) extends farther down than the lung, so that it may be wounded, and a wound pass through its cavity into the Diaphragm, and even injure the abdominal viscera, without the lung being involved.

The posterior border of the lung is indicated by a line drawn from the level of the spinous process of the seventh cervical vertebra, down either side of the spine, corresponding to the costo-vertebral joints as low as the spinous process of the tenth dorsal vertebra. The trachea bifurcates opposite the spinous process of the fourth dorsal vertebra, and from this point the two bronchi are directed outward.

The position of the great fissure in the right lung may be indicated by a line drawn from the fourth dorsal vertebra round the side of the chest to the anterior margin of the lung opposite the seventh rib, and the smaller or secondary fissure by a line drawn from the preceding where it bisects the mid-axillary line to the junction of the fourth costal cartilage to the sternum. The great fissure in the left lung is a little higher, extending from the third dorsal vertebra round the side of the chest to reach the anterior margin of the lung opposite the sixth costal cartilage.

Surgical Anatomy.—The lungs may be wounded or torn in three ways: (1) By compression of the chest, without any injury to the ribs. (2) By a fractured rib penetrating the lung. (3) By stabs, gunshot wounds, etc.

The first form, where the lung is ruptured by external compression without any fracture of the ribs, is very rare, and usually occurs in young children, and affects the root of the lung—

i.e., the most fixed part—and thus, implicating the great vessels, is frequently fatal. It would seem *a priori* a most unusual injury, and its exact mode of causation is difficult to interpret. The probable explanation is that immediately before the compression is applied a deep inspiration is taken and the lungs are fully inflated; owing then to spasm of the glottis at the moment

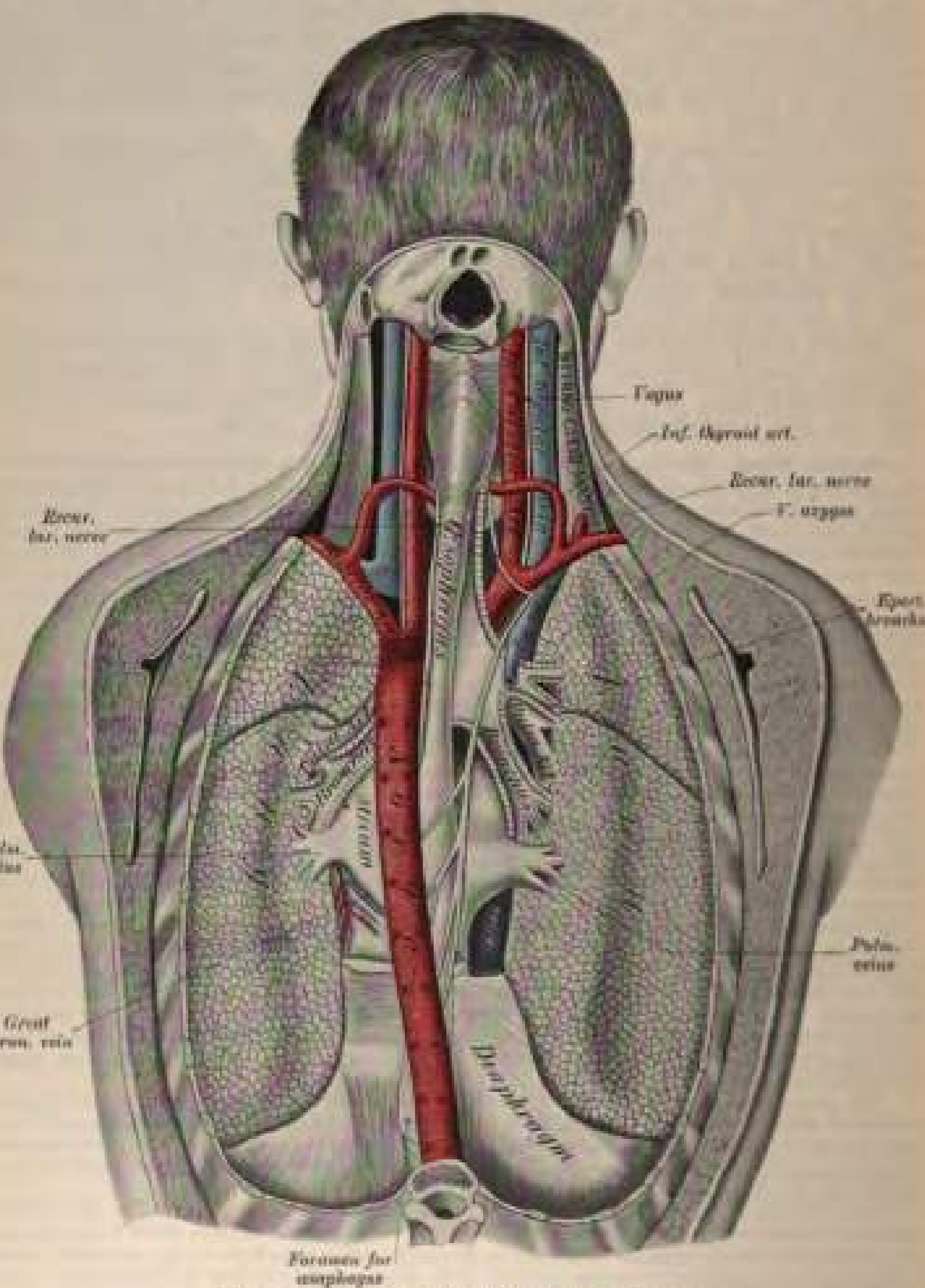


Fig. 599.—Thoracic contents seen from behind. (Jossel.)

of compression, the air is unable to escape from the lung, which is not able to recede, and consequently gives way.

In the second variety, when the wound in the lung is produced by the penetration of a broken rib, both the pleura costalis and pulmonalis must necessarily be injured, and consequently the air taken into the wounded air-cells may find its way through these wounds into the cellular tissue of the parietes of the chest. This it may do without collecting in the pleural cavity; the two layers of the pleura are so intimately in contact that the air passes straight through from the wounded lung into the subcutaneous tissue. Emphysema constitutes, therefore, the most important sign of injury to the lung in cases of fracture of the ribs. Pneumothorax, or air in the pleural cavity, is much more likely to occur in injuries to the lung of the third variety; that is to say, from external wounds, from stabs, gunshot injuries, and such like, in which cases air passes either from the wound of the lung or from an external wound into the cavity of the pleura during the respiratory movements. In these cases there is generally no emphysema of the subcutaneous tissue unless the external wound is small and valvular, so that the air drawn into the wound during inspiration is then forced into the cellular tissue around during expiration because it cannot escape from the external wound. Occasionally in wounds of the parietes of the chest no air finds its way into the cavity of the pleura, because the lung at the time of the accident protrudes through the wound and blocks the opening. This occurs where the wound is large, and constitutes one form of *hernia* of the lung. Another form of hernia of the lung occurs, though very rarely, after wounds of the chest wall, when the wound has healed and the cicatrix subsequently yields from the pressure of the viscus behind. It forms a globular, elastic, crepitating swelling, which enlarges during expiratory efforts, falls in during inspiration, and disappears on holding the breath.

THE THYROID GLAND.

The **thyroid gland** is classified with the thymus, suprarenal capsules, and spleen, under the head of *ductless glands*—*i. e.*, glands which do not possess an excretory duct. From its situation in connection with the trachea and larynx, the thyroid body is usually described with those organs, although it takes no part in the function of respiration. It is situated at the front and sides of the neck, and consists of two lateral lobes connected across the middle line by a narrow transverse portion, the *isthmus*.

The weight of the gland is somewhat variable, but is usually about one ounce. It is somewhat heavier in the female, in whom it becomes enlarged during menstruation and pregnancy.

The lobes are conical in shape, the apex of each being directed upward and outward as far as the junction of the middle with the lower third of the thyroid cartilage; the base looks downward, and is on a level with the fifth or sixth tracheal ring.

The *external* or *superficial surface* is convex, and covered by the skin, the superficial and deep fascia, the Sterno-mastoid, the anterior belly of the Omohyoid, the Sterno-hyoid and Sterno-thyroid muscles, and beneath the last muscle by the pre-tracheal layer of the deep fascia, which forms a capsule for the gland.

The *deep* or *internal surface* is moulded over the underlying structures, viz., the thyroid and cricoid cartilages, the trachea, the inferior constrictor and posterior part of the Crico-thyroid muscles, the œsophagus (particularly on the left side of the neck), the superior and inferior thyroid arteries, and the recurrent laryngeal nerves.

Its *anterior border* is thin, and inclines obliquely from above downward and inward toward the middle line of the neck, while the *posterior border* is thick and overlaps the common carotid artery. Each lobe is about two inches in length, its greatest width is about one inch and a quarter, and its thickness about three quarters of an inch.

The *isthmus* connects the lower third of the two lateral lobes; it measures about half an inch in breadth and the same in depth, and usually covers the second and third rings of the trachea. Its situation presents, however, many variations, a point of importance in the operation of tracheotomy. In the middle line of the neck it is covered by the skin and fascia, and close to the middle line, on either side, by the Sterno-hyoid. Across its upper border runs a branch of the superior thyroid artery; at its lower border are the inferior thyroid veins. Sometimes the isthmus is altogether wanting.

A third lobe, of conical shape, called the *pyramid*, occasionally arises from the upper part of the isthmus, or from the adjacent portion of either lobe, but most commonly the left, and ascends as high as the hyoid bone. It is occasionally quite detached, or divided into two or more parts, or altogether wanting.

A few muscular bands are occasionally found attached, above, to the body of the hyoid bone, and below to the isthmus of the gland or its pyramidal process. These form a muscle, which was named by Sommerring the *Levator glandulæ thyroidæ*.

Small detached portions of thyroid tissue (*accessory thyroid*) are sometimes found above the isthmus, and their presence is readily explained by a reference to the manner in which the gland is developed. They represent isolated portions of the median thyroid rudiment. (See section on Embryology.)

Structure.—The thyroid body is invested by a thin capsule of connective tissue which projects into its substance and imperfectly divides it into masses of irregular form and size. When the organ is cut into, it is of a brownish-red color, and is seen to be made up of a number of closed vesicles containing a yellow glairy fluid and separated from each other by intermediate connective tissue.

According to Baber, who has published some important observations on the minute structure of the thyroid,[1] the vesicles of the thyroid of the adult animal are generally closed cavities; but in some young animals (*e. g.*, young

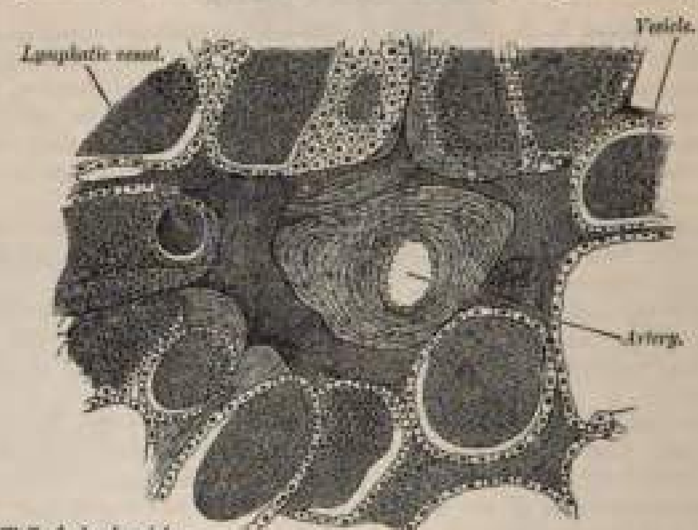


Fig. 540.—Minute structure of thyroid. From a transverse section of the thyroid of a dog. (Semi-diagrammatic.) (Baber.)

dogs) the vesicles are more or less tubular and branched. This appearance he supposes to be due to the mode of growth of the gland, and merely indicating that an increase in the number of vesicles is taking place. Each vesicle is lined by a single layer of epithelium, the cells of which, though differing somewhat in shape in different animals, have always a tendency to assume a columnar form. Between the epithelial cells exists a delicate reticulum. The vesicles are of various sizes and shapes, and contain as a normal product a viscid, homogeneous, semi-fluid, slightly yellowish material which frequently contains blood, the red corpuscles of which are found in it in various stages of disintegration and decolorization, the yellow tinge being probably due to the hæmoglobin, which is thus set free from the colored corpuscles. Baber has also described in the thyroid gland of the dog large round cells ("parenchymatous cells"), each provided with a single oval-shaped nucleus, which migrate into the interior of the gland-vesicles.

The capillary blood-vessels form a dense plexus in the connective tissue around the vesicles, between the epithelium of the vesicles and the endothelium of the lymph-spaces, which latter surround a greater or smaller part of the circumference of the vesicle. These lymph-spaces empty themselves into lymphatic vessels which run in the interlobular connective tissue, not uncommonly surrounding the

[1] "Researches on the Minute Structure of the Thyroid Glands," *Phil. Trans.*, part iii., 1881.

arteries which they accompany, and communicates with a network in the capsule of the gland. Baber has found in the lymphatics of the thyroid a viscid material which is morphologically identical with the normal constituent of the vesicle.

Vessels and Nerves.—The *arteries* supplying the thyroid are the superior and inferior thyroid, and sometimes an additional branch (thyroidea media or ima) from the innominate artery or the arch of the aorta, which ascends upon the front of the trachea. The arteries are remarkable for their large size and frequent anastomoses. The *veins* form a plexus on the surface of the gland and on the front of the trachea, from which arise the superior, middle, and inferior thyroid veins, the two former terminating in the internal jugular, the latter in the innominate vein. The *lymphatics* are numerous, of large size, and terminate in the thoracic and right lymphatic ducts. The *nerves* are derived from the middle and inferior cervical ganglia of the sympathetic.

Surgical Anatomy.—The thyroid gland is subject to enlargement, which is called goitre. This may be due to hypertrophy of any of the constituents of the gland. The simplest (parenchymatous goitre) is due to an enlargement of the follicles. The *fibroid* is due to increase of the interstitial connective tissue. The *cystic* is that form in which one or more large cysts are formed from dilatation and possibly coalescence of adjacent follicles. The *pulsating goitre* is where the vascular changes predominate over the parenchymatous, and the vessels of the gland are especially enlarged. Finally, there is *exophthalmic goitre* (Graves's disease), where there is great vascularity and often pulsation, accompanied by exophthalmos, palpitation, and rapid pulse.

For the relief of these growths various operations have been resorted to, such as injection of tincture of iodine or perchloride of iron, especially applicable to the cystic form of the disease, ligature of the thyroid arteries, excision of the isthmus, and extirpation of the whole or a part of the gland. This latter operation is one of difficulty, and when the entire gland has been removed the operation has been followed by a condition resembling myxœdema. In removing the organ great care must be taken to avoid tearing the capsule, as if this happens the gland-tissue bleeds profusely. The thyroid arteries should be ligatured before an attempt is made to remove the mass, and in ligaturing the inferior thyroids the position of the recurrent laryngeal nerve must be borne in mind, so as not to include it in the ligature. A large number of cases of what were formerly supposed to be goitre are now known to be cases of adenomatous enlargement, where an adenoma, starting in one part of the gland, gradually spreads and involves the whole organ.

Parathyroids.—These are small rounded, brownish-red bodies, with an average diameter of about a quarter of an inch, situated in or near the thyroid gland, from which, however, they differ in structure, being composed of masses of cells arranged in a more or less columnar fashion with numerous intervening capillaries. They are divided from their situation into *external* and *internal*. The former, usually two in number, are situated, one on each side, in relation to the postero-internal surface of the lateral lobe; sometimes they are duplicated. The latter, also usually two in number, are placed one in each lateral lobe, generally near its mesial surface.

THE THYMUS GLANDS.

The **thymus gland** is a temporary organ, attaining its full size at the end of the second year, when it ceases to grow, and gradually dwindles, until at puberty it has almost disappeared. If examined when its growth is most active, it will be found to consist of two lateral lobes placed in close contact along the middle line, situated partly in the superior mediastinum, partly in the neck, and extending from the fourth costal cartilage upward as high as the lower border of the thyroid gland. It is covered by the sternum and by the origins of the Sterno-hyoid and Sterno-thyroid muscles. Below, it rests upon the pericardium, being separated from the arch of the aorta and great vessels by a layer of fascia. In the neck it lies on the front and sides of the trachea, behind the Sterno-hyoid and Sterno-thyroid muscles. The two lobes generally differ in size; they are occasionally united so as to form a single mass, and sometimes separated by an intermediate lobe. The thymus is of a pinkish-gray color, soft, and lobulated on its surfaces. It is about two inches in length, one and a half in breadth below, and about three or four lines in thickness. At birth it weighs about half an ounce.

Structure.—Each lateral lobe is composed of numerous lobules held together by delicate areolar tissue, the entire gland being enclosed in an investing capsule of a similar but denser structure. The primary lobules vary in size from a pin's head to a small pea, and are made up of a number of small nodules or follicles which are irregular in shape and are more or less fused together, especially toward the interior of the gland. Each follicle consists of a medullary and cortical portion, which differ in many essential particulars from each other. The *cortical portion* is mainly composed of lymphoid cells supported by a delicate reticulum. In addition to this reticulum, of which traces only are found in the medullary portion, there is also a network of finely branched cells which is continuous with a similar network in the medullary portion. This network forms an adventitia to the blood-vessels. In the *medullary portion* there are but few lymphoid cells, but there are, especially toward the centre, granular cells and concentric corpuscles. The granular cells are rounded or flask-shaped masses attached (often by fibrillated extremities) to blood-vessels and to newly formed connective tissue. The concentric corpuscles are composed of a central mass consisting of one or more granular cells, and of a capsule which is formed of epithelioid cells which are continuous with the branched cells forming the network mentioned above.

Each follicle is surrounded by a capillary plexus from which vessels pass into the interior and radiate from the periphery toward the centre, and form a second zone just within the margin of the medullary portion. In the centre of the medulla there are very few vessels, and they are of minute size.

Watney has recently made the important observation that hæmoglobin is found in the thymus either in cysts or in cells situated near to or forming part

FIG. 541.—Minute structure of thymus gland. Upper portion of the thymus of a fœtal pig of 2" in length, showing the bud-like lobuli and glandular elements. 2. Cells of the thymus, mostly from a man. *a.* Free nuclei. *b.* Small cells. *c.* Larger. *d.* Larger, with oil-globules, from the ox. *e, f.* Cells completely filled with fat, at *f* without a nucleus. *g, h.* Concentric bodies. *g.* An encapsulated nucleated cell. *h.* A composite structure of a similar nature.

of the concentric corpuscles. This hæmoglobin varies from granules to masses exactly resembling colored blood-corpuscles, oval in the bird, reptile, and fish; circular in all mammals except in the camel. Dr. Watney has also discovered in the lymph issuing from the thymus similar cells to those found in the gland, and, like them, containing hæmoglobin either in the form of granules or masses. From these facts he arrives at the physiological conclusion that the thymus is one source of the colored blood-corpuscles.

Vessels and Nerves.—The *arteries* supplying the thymus are derived from the internal mammary and from the superior and inferior thyroid. The *veins* terminate in the left innominate vein and in the thyroid veins. The *lymphatics* are of large size, arise in the substance of the gland, and are said to terminate in the internal jugular vein. The *nerves* are exceedingly minute; they are derived

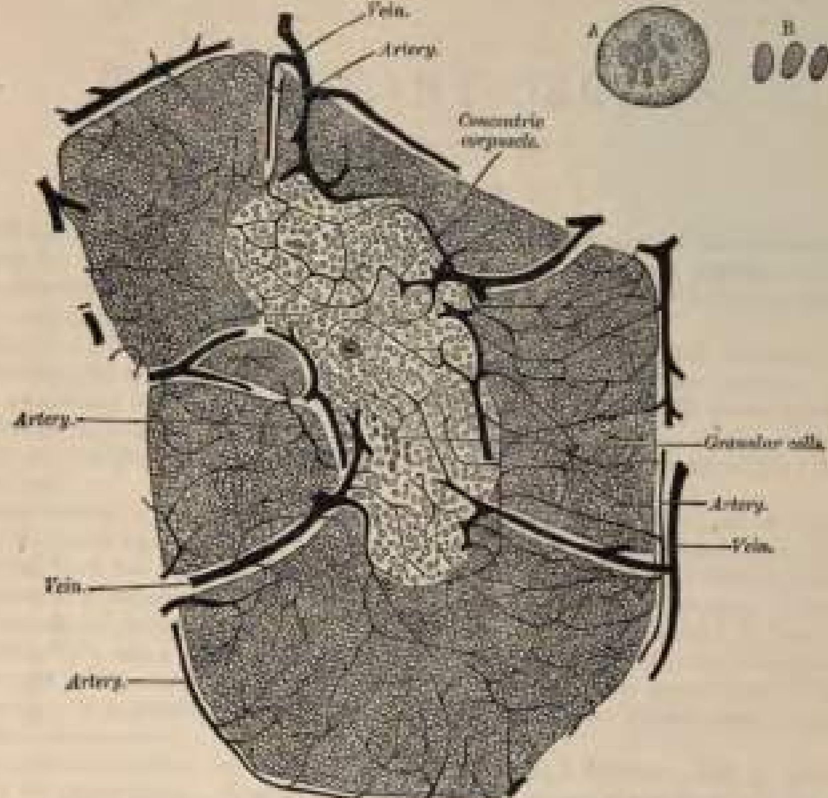


FIG. 542.—Minute structure of the thymus gland. Follicle of injected thymus from calf, four days old, slightly diagrammatic, magnified about 50 diameters. The large vessels are disposed in two rings, one of which surrounds the follicle, the other lies just within the margin of the medulla. (Watney.) A and B. From thymus of camel, examined without addition of any reagent. Magnified about 400 diameters. A. Large colorless cell containing small oval masses of hæmoglobin. Similar cells are found in the lymph-glands, spleen, and medulla of bone. B. Colored blood-corpuscles.

from the pneumogastric and sympathetic. Branches from the descendens hypoglossi and phrenic reach the investing capsule, but do not penetrate into the substance of the gland.

THE URINARY ORGANS.

THE KIDNEYS.

THE Kidneys, two in number, are situated in the back part of the abdomen, and are for the purpose of separating from the blood certain materials which, when dissolved in a quantity of water, also separated from the blood by the kidneys, constitute the urine.

They are placed in the loins, one on each side of the vertebral column, behind the peritoneum, and surrounded by a mass of fat and loose areolar tissue. Their upper extremity is on a level with the upper border of the twelfth dorsal vertebra, their lower extremity on a level with the third lumbar. The right kidney is usually on a slightly lower level than the left, probably on account of the vicinity of the liver.

Each kidney is about four inches in length, two to two and a half in breadth, and rather more than one inch in thickness. The left is somewhat longer, though narrower, than the right. The weight of the kidney in the adult male varies from $4\frac{1}{2}$ ounces to 6 ounces; in the adult female, from 4 ounces to $5\frac{1}{2}$ ounces. The combined weight of the two kidneys in proportion to the body is about 1 in 240.

The kidney has a characteristic form. It is flattened on its sides and presents at one part of its circumference a hollow. It is larger at its upper than its lower extremity. It presents for examination two surfaces, two borders, and an upper and lower extremity.

Its *anterior surface* is convex, looks forward and outward, and is partially covered by peritoneum. The right kidney in its upper three-fourths is in contact with the posterior part of the under surface of the right lobe of the liver, on which it produces a concave impression, the *impressio renalis* (page 918). Toward its inner border it is covered by the second part of the duodenum, while its lower and outer part is in relation with the hepatic flexure of the colon. The relation of the second part of the duodenum to the front of the right kidney is a varying one. The left kidney is covered above by the posterior surface of the stomach, below the stomach by the pancreas, behind which are the splenic vessels. Its lower half is in contact with some of the coils of the small intestine and sometimes with the third part of the duodenum. Near its outer border the anterior surface lies behind the spleen and the splenic flexure of the colon.

The kidneys are partly covered in front by peritoneum and partly uncovered. On the right kidney, the *hepatic area*, that is to say that portion of the kidney which produces the renal impression on the liver, is covered by peritoneum, which therefore separates the kidney from the liver: the *duodenal* and *colic areas* are not peritoneal, and these structures are connected to the kidney by loose connective tissue; at the lower and inner extremity is a small area, the *mesocolic area*, which is covered by a layer of peritoneum of the greater sac and by the colic vessels. On the left kidney, the *gastric area* is covered by the peritoneum of the lesser sac; the *pancreatic* and *colic areas* are non-peritoneal: while, as on the right side, at the lower and inner extremity, is an area, *mesocolic*, which is covered by the peritoneum of the greater sac and by the colic vessels.

The posterior surface of the kidney is flatter than the anterior and is directed backward and inward. It is entirely devoid of peritoneal covering, being imbedded in areolar and fatty tissue. It lies upon the Diaphragm, the anterior layer of the lumbar aponeurosis, the external and internal arcuate ligaments, the Psoas and Transversalis muscles, one or two of the upper lumbar arteries, the last dorsal, ilio-hypogastric, and ilio-inguinal nerves. The right kidney rests upon the twelfth rib, the left usually on the eleventh and twelfth. The Diaphragm separates the kidney from the pleura as it dips down to form the phrenico-costal sinus, but frequently the muscular fibres of the Diaphragm are defective or absent over a triangular area immediately above the external arcuate ligament, and when this is the case the perirenal areolar tissue is in immediate apposition with the diaphragmatic pleura.

The *external border* is convex, and is directed outward and backward, toward the postero-lateral wall of the abdomen. On the left side it is in contact, at its upper part, with the spleen.

The *internal border* is concave, and is directed forward and a little downward. It presents a deep longitudinal fissure, bounded by a prominent overhanging anterior and posterior lip. This fissure is named the *hilum*, and allows of the passage of the vessels, nerves, and ureter into and out of the kidney.

The *superior extremity*, directly slightly inward as well as upward, is thick and rounded, and is surmounted by the suprarenal capsule, which covers also a small portion of the anterior surface.

The *inferior extremity*, directed a little outward as well as downward, is smaller and thinner than the superior. It extends to within two inches of the crest of the ilium.

At the hilum of the kidney the relative position of the main structures passing into and out of the kidney is as follows: the vein is in front, the artery in the middle, and the duct or ureter behind and toward the lower part. By a knowledge of these relations the student may distinguish between the right and left kidney. The kidney is to be laid on the table before the student on its posterior surface, with its lower extremity toward the observer—that is to say, with the ureter *behind* and *below* the other vessels; the hilum will then be directed to the side to which the kidney belongs.

Fig. 543.—Vertical section of kidney.

General Structure of the Kidney.—The kidney is surrounded by a distinct investment of fibrous tissue which forms a firm, smooth covering to the organ. It closely invests it, but can be easily stripped off, in doing which, however, numerous fine processes of connective tissue and small blood-vessels are torn through. Beneath this coat a thin wide-meshed network of unstriped muscular fibre forms an incomplete covering to the organ. When the fibrous coat is stripped off, the surface of the kidney is found to be smooth and even and of a deep-red color.

In infants fissures extending for some depth may be seen on the surface of the organ, a remnant of the lobular construction of the gland. The kidney is dense in texture, but is easily lacerable by mechanical force. In order to obtain a knowledge of the structure of the gland, a vertical section must be made from its convex to its concave border, and the loose tissue and fat removed around the vessels and the excretory duct (Fig. 543). It will be then seen that the kidney consists of a central cavity surrounded at all parts but one by the proper kidney-substance. This central cavity is called the *sinus*, and is lined by a prolongation of the fibrous coat of the kidney, which enters through a longitudinal fissure, the *hilum* (before mentioned), which is situated at that part of the cavity which is not surrounded by kidney-structure. Through this fissure the blood-vessels of the kidney and its excretory duct pass, and therefore these structures, upon entering the kidney, are contained within the sinus. The excretory duct, or *ureter*, after entering, dilates into a wide, funnel-shaped sac named the *pelvis*. This divides into two or three tubular divisions, which subdivide into several short, truncated branches named *calices* or *infundibula*, all of which are contained in the central cavity of the kidney. The blood-vessels of the kidney, after passing through the hilum, are contained in the sinus or central cavity, lying between its lining membrane and the excretory apparatus, before entering the kidney-substance.

This central cavity, as before mentioned, is surrounded on all sides except at the hilum by the substance of the kidney, which is at once seen to consist of two parts—viz. of an external granular investing part, which is called the *cortical portion*; and of an internal part, the *medullary portion*, made up of a number of dark-colored pyramidal masses, with their bases resting on the cortical part and their apices converging toward the centre, where they form prominent papillæ which project into the interior of the calices.

The cortical substance is of a bright reddish-brown color, soft, granular, and easily lacerable. It is found everywhere immediately beneath the capsule, and is seen to extend in an arched form over the base of each medullary pyramid. The part separating the sides of any two pyramids through which the arteries and nerves enter, and the veins and lymphatics emerge, from the kidney, is called a *cortical column* or *column of Bertin* (A, A′, Fig. 543); while that portion which stretches from one cortical column to the next, and intervenes between the base of the pyramid and the capsule (marked by the dotted line extending from A to A′ in Fig. 543), is called a *cortical arch*, the depth of which varies from a third to half an inch.

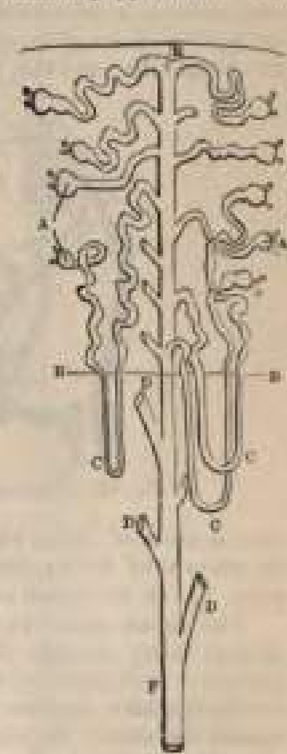


FIG. 544.—Plan of uriniferous tubes. A, A. Malpighian bodies. B, B. Margin of medullary structure. C, C, C. Loops of Henle. D, D, D. Straight tubes cut off. E. Commencing straight tubes. F. Termination of straight tube.

The *medullary substance*, as before stated, is seen to consist of red-colored, striated, conical masses, the *pyramids of Malpighi*, the number of which, varying from eight to eighteen, corresponds to the number of lobes of which the organ in the fœtal state is composed. The base of each pyramid is surrounded by a cortical arch, and directed toward the circumference of the kidney; the sides are contiguous with the cortical columns; while the apex, known as the *papilla* or *mammilla* of the kidney, projects into one of the calices of the ureter, each calyx receiving two or three papillæ.

These two parts, *cortical* and *medullary*, so dissimilar in appearance, are very similar in structure, being made up of urinary tubes and blood-vessels united and bound together by a connecting matrix or stroma.

Minute Anatomy.—The *tubuli uriniferi*, of which the kidney is for the most part made up, commence in the cortical portion of the kidney, and, after pursuing a very circuitous course through the cortical and medullary parts of the kidney, finally terminate at the apices of the Malpighian pyramids by open mouths (Fig. 544), so that the fluid which they contain is emptied into the dilated extremity of the ureter contained in the sinus of the kidney. If the surface of one of the papillæ is examined with a lens, it will be seen to be studded over with a number of small depressions, from sixteen to twenty in number, and in a fresh kidney, upon pressure being made, fluid will be seen to exude from these depressions. They are the orifices of the tubuli uriniferi, which terminate in this situation. They commence in the cortical portion of the kidney as the *Malpighian* *bodies*, which are small rounded masses, varying in size, but average about $\frac{1}{120}$ of an inch in diameter. They are of a deep-red color, and are found only in the cortical portion of the kidney. Each of these little bodies is composed of two parts—a central glomerulus of vessels, called a *Malpighian tuft*, and a membranous envelope, the *Malpighian capsule*, or *capsule of Bowman*, which latter is a small pouch-like commencement of a uriniferous tubule.

The *Malpighian tuft*, or vascular glomerulus, is a network of convoluted capillary blood-vessels held together by scanty connective tissue and grouped into from two to five lobules. This capillary network is derived from a small arterial twig, the *afferent vessel*, which pierces the wall of the capsule, generally at a point opposite that at which the latter is connected with the tube; and the resulting vein, the *efferent vessel*, emerges from the capsule at the same point. The afferent vessel is usually the larger of the two (Fig. 545). The *Malpighian* or *Bowman's capsule*, which surrounds the glomerulus, is formed of a hyaline membrane supported by a small amount of connective tissue which is continuous with the connective tissue of the tube. It is lined on its inner surface by a layer of squamous epithelial cells which are reflected from the lining membrane on to the glomerulus at the point of entrance or exit of the afferent and efferent vessels. The whole surface of the glomerulus is covered with a continuous layer of the same cells on a delicate supporting membrane, which with the cells dips in between the lobules of the glomerulus, closely surrounding them (Fig. 546). Thus, between the glomerulus and the capsule a space is left, forming a cavity lined by a con-

FIG. 545.—Minute structure of kidney.

FIG. 546.—Malpighian body.

tinuous layer of cells, which varies in size according to the state of secretion and the amount of fluid present in it. The cells, as above stated, are squamous in the adult, but in the fœtus and young subject they are polyhedral or even columnar.

The *tubuli uriniferi*, commencing in the Malpighian bodies, in their course present many changes in shape and direction, and are contained partly in the medullary and partly in the cortical portions of the organ. At their junction with the Malpighian capsule they present a somewhat constricted portion which is termed the *neck*. Beyond this the tube becomes convoluted, and pursues a considerable course in the cortical structure, constituting the *proximal convoluted tube*. After a time the convolutions disappear, and the tube approaches the medullary portion of the kidney in a more or less spiral manner. This section of the tube has been called the *spiral tube of Schachowa*. Throughout this portion of their course the tubuli uriniferi have been contained entirely in the cortical structure, and have presented a pretty uniform calibre. They now enter the medullary portion, and suddenly become much smaller, quite straight in direction, and dip down for a variable depth into the pyramids, constituting the *descending limb of Henle's loop*. Bending on themselves, they form a kind of loop, the *loop of Henle*, and, reascending, become suddenly enlarged and again spiral in direction, forming the *ascending limb of Henle's loop*, and re-enter the cortical structure. This portion of the tube does not present a uniform calibre, but becomes narrower as it ascends and irregular in outline. As a narrow tube it enters the cortex and ascends for a short distance, when it again becomes dilated, irregular, and angular. This section is termed the *irregular tubule;* it terminates in a convoluted tube which exactly resembles the proximal convoluted tubule; and is called the *distal convoluted tubule.* This again terminates in a narrow *curved tube,* which enters the straight or collecting tube.

Each *straight,* otherwise called a *collecting* or *receiving, tube* commences by a small orifice on the summit of one of the papillæ, thus opening and discharging its contents into the interior of one of the calices. Traced into the substance of the pyramid, these tubes are found to run from apex to base, dividing dichotomously in their course and slightly diverging from each other. Thus dividing and subdividing, they reach the base of the pyramid, and enter the cortical structure greatly increased in number. Upon entering the cortical portion they continue a straight course for a variable distance, and are arranged in groups called *medullary rays,* several of these groups corresponding to a single pyramid. The tubes in the centre of the group are the longest, and reach almost to the surface of the kidney, while the external ones are shorter, and advance only a short distance into the

FIG. 547.—Uriniferous tube. For the sake of clearness the epithelial cells have been represented more highly magnified than the tubes in which they are contained.

cortex. In consequence of this arrangement the cortical portion presents a number of conical masses, the apices of which reach the periphery of the organ, and the bases are applied to the medullary portion. These are termed the *pyramids of Ferrein.* As they run through the cortical portion the straight tubes receive on either side the curved extremity of the convoluted tubes, which, as stated above, commence at the Malpighian bodies.

It will be seen from the above description that there is a continuous series of tubes from their commencement in the Malpighian bodies to their termination at the orifices on the apices of the pyramids of Malpighi, and that the urine, the secretion of which commences in the capsule, finds its way through these tubes into the calices of the kidney, and so into the ureter. To recapitulate: the tube first presents a constricted portion, (1) the *neck*. 2. It forms a wide convoluted tube, the *proximal convoluted tube*. 3. It becomes spiral, the *spiral tubule of Schachowa*. 4. It enters the medullary structure as a narrow, straight tube, the *descending limb of Henle's loop*. 5. Forming a loop and becoming dilated, it ascends somewhat spirally, and, gradually diminishing in calibre, again enters the cortical structure, the *ascending limb of Henle's loop*. 6. It now becomes irregular and angular in outline, the *irregular tubule*. 7. It then becomes convoluted, the *distal convoluted tubule*. 8. Diminishing in size, it forms a curve, the *curved tubule*. 9. Finally, it joins a straight tube, the *straight collecting tube*, which is continued downward through the medullary substance to open at the apex of a pyramid.

The Tubuli Uriniferi: their Structure.—The tubuli uriniferi consist of basement membrane lined with epithelium. The epithelium varies considerably in different sections of the uriniferous tubes. In the neck the epithelium is continuous with that lining the Malpighian capsule, and, like it, consists of flattened cells with an oval nucleus (Fig. 547 A). The cells are, however, very indistinct and difficult to trace, and the tube has here the appearance of a simple basement membrane unlined by epithelium. In the proximal convoluted tubule and the spiral tubule of Schachowa the epithelium is polyhedral in shape, the sides of the cells not being straight, but fitting into each other, and in some animals so fused

FIG. 548.[1]—Longitudinal section of Henle's descending limb. *a*. Membrana propria. *b*. Epithelium.

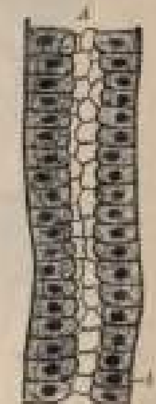


FIG. 549.—Longitudinal section of straight tube. *a*. Cylindrical or cubical epithelium. *b*. Membrana propria.

together that it is impossible to make out the lines of junction. In the human kidney the cells often present an angular projection of the surface next the basement membrane. These cells are made up of more or less rod-like fibres, which rest by one extremity on the basement membrane, whilst the other projects toward the lumen of the tube. This gives to the cells the appearance of distinct striation (Heidenhain) (Fig. 547, B). In the descending limb of Henle's loop the epithelium resembles that found in the Malpighian capsule and the commencement of the tube, consisting of flat transparent epithelial plates with an oval nucleus (Figs. 547, A, 548). In the ascending limb, on the other hand, the cells partake more of the character of those described as existing in the proximal convoluted tubule, being polyhedral in shape and presenting the same appearance of striation. The nucleus, however, is not situated in the centre of the cell, but near the lumen (Fig. 547, C). After the ascending limb of Henle's loop becomes narrower upon entering the cortical structure, the striation appears to be confined to the outer part of the cell:

[1] From *Handbook for the Physiological Laboratory*.

at all events, it is much more distinct in this situation, the nucleus, which appears flattened and angular, being still situated near the lumen (Fig. 547, D). In the irregular tubule the cells undergo a still farther change, becoming very angular, and presenting thick bright rods or markings, which render the striation much more distinct than in any other section of the urinary tubules (Fig. 547, E). In

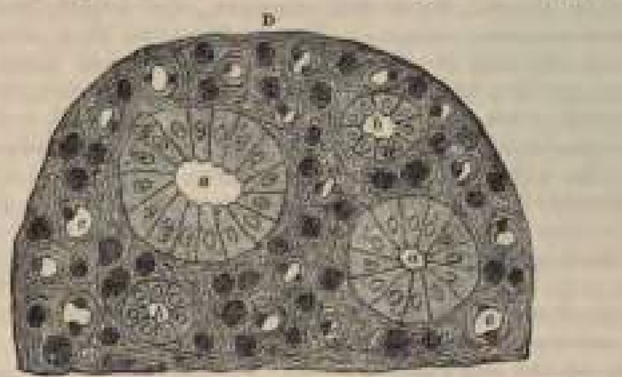
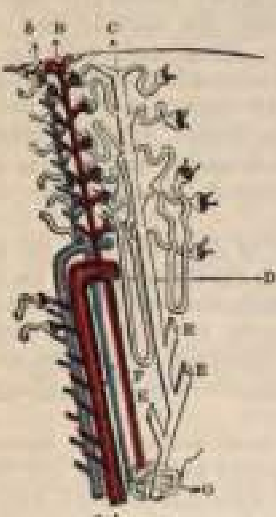


FIG. 550.—Transverse section of pyramidal substance of kidney of pig, the blood-vessels of which are injected. *a*. Large collecting tube cut across, lined with cylindrical epithelium. *b*. Branch of collecting tube cut across, lined with epithelium with shorter cylinders. *c* and *d*. Henle's loops cut across. *e*. Blood-vessels cut across. D. Connective-tissue ground-substance.

the distal convoluted tubule the epithelium appears to be somewhat similar to that which has been described as existing in the proximal convoluted tubule, but presents a peculiar refractive appearance (Fig. 547, D). In the curved tubule, just before its entrance into the straight collecting tube, the epithelium varies greatly



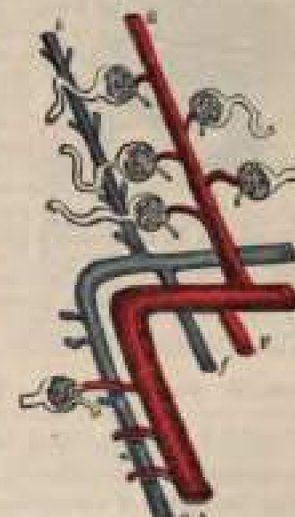


FIG. 551.—Diagrammatical sketch of the blood-vessels of kidney.

FIG. 552.—A portion of Fig. 551 enlarged. (The references are the same.)

A, a. Proper renal artery and vein, the *former* giving off the renal afferents, the latter receiving the renal efferents. B, *b*. Interlobular artery and vein, the latter commencing from the stellate veins, and receiving branches from the plexus around the tubuli contorti, the former giving off renal afferents. C. Straight tube, surrounded by tubuli contorti, with which it communicates, as more fully shown in Fig. 548. D. Margin of medullary substance. E, E, E. Receiving tubes cut off. F, *f*. Arteriolæ et venæ rectæ, the latter arising from (G) the plexus at the medullary apex.

as regards the shape of the cells, some being angular with short processes, others spindle-shaped, others polyhedral (Fig. 547, E).

In the straight tubes the epithelium is more or less columnar; in its papillary portion the cells are distinctly columnar and transparent (Figs. 549, 550), but as the tube approaches the cortex the cells are less uniform in shape; some are polyhedral, and others angular with short processes (Fig. 547, F and G).

The Renal Blood-vessels.—The kidney is plentifully supplied with blood by the renal artery, a large offset of the abdominal aorta. Previously to entering the kidney, each artery divides into four or five branches, which are distributed to its substance. At the hilum these branches lie between the renal vein and ureter, the vein being in front, the ureter behind. Each vessel gives off some small branches to the suprarenal capsules, the ureter, and the surrounding cellular tissue and muscles. Frequently there is a second renal artery, which is given off from the abdominal aorta at a lower level, and supplies the lower portion of the kidney. It is termed the *inferior renal artery*. The branches of the renal artery whilst in the sinus give off a few twigs for the nutrition of the surrounding tissues, and terminate in the *arteriæ propriæ renales*, which enter the kidney proper in the columns of Bertin. Two of these pass to each pyramid of Malpighi and run along its sides for its entire length, giving off as they advance the afferent vessels of the Malpighian bodies in the columns. Having arrived at the bases of the pyramids, they make a bend in their course, so as to lie between the bases of the pyramids and the cortical arches, where they break up into two distinct sets of branches devoted to the supply of the remaining portions of the kidney.

The *first set*, the *interlobular arteries* (Figs. 551, 552, B), are given off at right angles from the side of the arteriæ propriæ renales looking toward the cortical substance, and, passing directly outward between the pyramids of Ferrein, they reach the capsule, where they terminate in the capillary network of this part. In their outward course they give off lateral branches; these are the *afferent vessels* for the Malpighian bodies (see page 988), and, having pierced the capsule, end in the Malpighian tufts. From each tuft the corresponding renal efferent arises, and, having made its egress from the capsule near to the point where the afferent vessel entered, breaks up into a number of branches which form a dense *venous plexus* around the adjacent urinary tubes (Fig. 553).

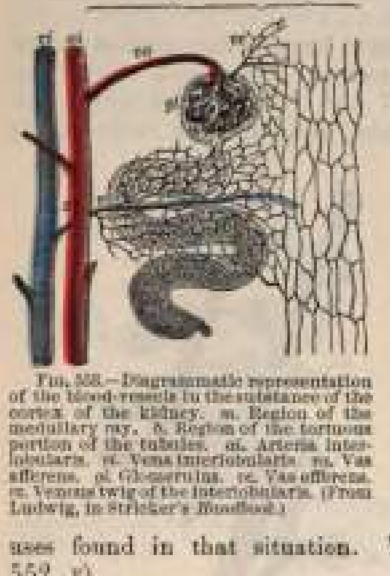


FIG. 553.—Diagrammatic representation of the blood-vessels in the substance of the cortex of the kidney. m. Region of the medullary ray. b. Region of the tortuous portion of the tubules. ai. Arteria interlobularis. vi. Vena interlobularis. va. Vas afferens. gl. Glomerulus. ve. Vas efferens. vi. Venous twig of the interlobularis. (From Ludwig, in Stricker's *Handbook*.)

The *second set of branches* from the arteriæ propriæ renales are for the supply of the medullary pyramids, which they enter at their bases; and, passing straight through their substance to their apices, terminate in the venous plexuses found in that situation. They are called the *arteriolæ rectæ* (Figs. 551, 552, F).

The *renal veins* arise from *three sources*—the veins beneath the capsule, the plexuses around the convoluted tubules in the cortical arches, and the plexuses situated at the apices of the pyramids of Malpighi. The veins beneath the capsule are stellate in arrangement, and are derived from the capillary network of the capsule, into which the terminal branches of the interlobular arteries break up. These join to form the *venæ interlobulares*, which pass inward *between* the pyramids of Ferrein, receive branches from the plexuses around the convoluted tubules, and, having arrived at the bases of the Malpighian pyramids, join with the venæ rectæ, next to be described (Figs. 551, 552, *b*).

The *Venæ Rectæ* are branches from the plexuses at the apices of the medullary pyramids, formed by the terminations of the arteriolæ rectæ. They pass outward in a straight course between the tubes of the medullary structure, and joining, as above stated, the venæ interlobulares, form the proper renal veins (Figs. 551, 552, *f*).

These vessels, *Venæ Propriæ Renales*, accompany the arteries of the same name, running along the entire length of the sides of the pyramids; and, having received in their course the efferent vessels from the Malpighian bodies in the cortical structure adjacent, quit the kidney substance to enter the sinus. In this cavity they inosculate with the corresponding veins from the other pyramids to form the *renal vein*, which emerges from the kidney at the hilum and opens into the inferior vena cava, the left being longer than the right, from having to cross in front of the abdominal aorta.

Nerves of the Kidney.—The nerves of the kidney, although small, are about fifteen in number. They have small ganglia developed upon them, and are derived from the renal plexus, which is formed by branches from the solar plexus, the lower and outer part of the semilunar ganglion and aortic plexus, and from the lesser and smallest splanchnic nerves. They communicate with the spermatic plexus, a circumstance which may explain the occurrence of pain in the testicle in affections of the kidney. So far as they have been traced, they seem to accompany the renal artery and its branches, but their exact mode of termination is not known.

The *lymphatics* consist of a superficial and deep set which terminate in the lumbar glands.

Connective Tissue, or Intertubular Stroma.—Although the tubules and vessels are closely packed, a certain small amount of connective tissue, continuous with the capsule, binds them firmly together. This tissue was first described by Goodsir, and subsequently by Bowman. Ludwig and Zawarykin have observed distinct fibres passing around the Malpighian bodies, and Henle has seen them between the straight tubes composing the medullary structure.

Surface Form.—The kidneys, being situated at the back part of the abdominal cavity and deeply placed, cannot be felt unless enlarged or misplaced. They are situated on the confines of the epigastric and umbilical regions internally, with the hypochondriac and lumbar regions externally. The left is somewhat higher than the right. According to Morris, the position of the kidney may be thus defined: *Anteriorly*: "1. A horizontal line through the umbilicus is below the lower edge of each kidney. 2. A vertical line carried upward to the costal arch from the middle of Poupart's ligament has one-third of the kidney to its outer side and two-thirds to its inner side—*i. e.* between this line and the median line of the body." In adopting these lines it must be borne in mind that the axes of the kidneys are not vertical, but oblique, and if continued upward would meet about the ninth dorsal vertebra. *Posteriorly*: The upper end of the left kidney would be defined by a line drawn horizontally outward from the spinous process of the eleventh dorsal vertebra, and its lower end by a point two inches above the iliac crest. The right kidney would be half to three-quarters of an inch lower. Morris lays down the following rules for indicating the position of the kidney on the posterior surface of the body: "1. A line parallel with, and one inch from, the spine, between the lower edge of the tip of the spinous process of the eleventh dorsal vertebra and the lower edge of the spinous process of the third lumbar vertebra. 2. A line from the top of this first line outward at right angles to it for 2¾ inches. 3. A line from the lower end of the first transversely outward for 2¾ inches. 4. A line parallel to the first and connecting the outer extremities of the second and third lines just described."

The hilum of the kidney lies about two inches from the middle line of the back, at the level of the spinous process of the first lumbar vertebra.

Surgical Anatomy.—Malformations of the kidney are not uncommon. There may be an entire absence of one kidney, though, according to Morris, the number of these cases is "excessively small": or there may be congenital atrophy of one kidney, when the kidney is very small, but usually healthy in structure. These cases are of great importance, and must be duly taken into account, when nephrectomy is contemplated. A more common malformation is where the two kidneys are fused together. They may be only joined together at their lower ends by means of a thick mass of renal tissue, so as to form a horseshoe-shaped body or they may be completely united, forming a disc-like kidney, from which two ureters descend into the bladder. These fused kidneys are generally situated in the middle line of the abdomen, but may be misplaced as well.

One or both kidneys may be misplaced as a congenital condition, and remain fixed in this abnormal position. They are then very often misshapen. They may be situated higher or lower than normal or removed farther from the spine than usual or they may be displaced into the iliac fossa, over the sacro-iliac joint, on to the promontory of the sacrum, or into the pelvis between the rectum and bladder or by the side of the uterus. In these latter cases they may give rise to very serious trouble. The kidney may also be misplaced as a congenital condition, but may not be fixed. It is then known as a *floating kidney*. It is believed to be due to the fact that the kidney is completely enveloped by peritoneum which then passes backward to the spine as a double layer, forming a mesonephron, which permits of movement taking place. The kidney may also be misplaced as an acquired condition; in these cases the kidney is mobile in the tissues by which it is surrounded, either moving in its capsule or else moving with the capsule in the perinephric tissues. This condition is known as *movable kidney*, and is more common in the female than the male. Other malformations are the persistence of the fœtal lobulation; the presence of two pelves or two ureters to the one kidney. In some rare instances a third kidney may be present.

The kidney is imbedded in a large quantity of loose fatty tissue, and is but partially covered by peritoneum; hence rupture of this organ is not nearly so serious an accident as rupture of the liver or spleen, since the extravasation of blood and urine which follows is, in the majority of cases, outside the peritoneal cavity. Occasionally the kidney may be bruised by blows in the loin or by being compressed between the lower ribs and the ilium when the body is violently bent forward. This is followed by a little transient hæmaturia, which, however, speedily passes off. Occasionally, when rupture involves the pelvis of the kidney or the commencement of the ureter, this duct may become blocked, and hydronephrosis follow.

The loose cellular tissue around the kidney may be the seat of suppuration, constituting *perinephritic abscess*. This may be due to injury, to disease of the kidney itself, or to extension of inflammation from neighboring parts. The abscess may burst into the pleura, constituting empyema; into the colon or bladder; or may point externally in the groin or loin. Tumors of the kidney, of which, perhaps, sarcoma in children is the most common, may be recognized by their position and fixity; by the resonant colon lying in front of it; by their not moving with respiration; and by their rounded outline, not presenting a notched anterior margin like the spleen, with which they are most likely to be confounded. The examination of the kidney should be bimanual; that is to say, one hand should be placed in the flank and firm pressure made forward, while the other hand is buried in the abdominal wall, over the situation of the organ. Manipulation of the kidney frequently produces a peculiar sickening sensation, with sometimes faintness.

The kidney is mainly held in position by the mass of fatty matter in which it is embedded. If this fatty matter is loose or lax or is absorbed, the kidney may become movable and may give rise to great pain. This condition occurs, therefore, in badly nourished people or in those who have become emaciated from any cause, and is more common in women than in men. It must not be confounded with the *floating kidney*: this is a congenital condition due to the development of a mesonephron, which permits the organ to move more or less freely. The two conditions cannot, however, be distinguished until the abdomen is opened or the kidney explored from the loin.

The kidney has, of late years, been frequently the seat of surgical interference. It may be exposed for exploration or the evacuation of pus (nephrotomy); it may be incised for the removal of stone (nephro-lithotomy); it may be sutured when movable or floating (nephrorraphy); or it may be removed (nephrectomy).

The kidney may be exposed either by a lumbar or abdominal incision. The operation is best performed by a lumbar incision, except in cases of very large tumors or of wandering kidneys with a loose mesonephron, on account of the advantages which it possesses of not opening the peritoneum and of affording admirable drainage. It may be performed either by an oblique, a vertical, or a transverse incision. Perhaps the preferable, as affording the best means for exploring the whole surface of the kidney, is an incision from the tip of the last rib backward to the edge of the Erector spinæ. This incision must not be quite parallel to the rib, but its posterior end must be at least three-quarters of an inch below it, lest the pleura be wounded. This cut is quite sufficient for an exploration of the organ. Should it require removal, a vertical incision can be made downward to the crest of the ilium, along the outer border of the Quadratus lumborum. The structures divided are the skin, the superficial fascia with the cutaneous nerves, the deep fascia, the posterior border of the External oblique muscle of the abdomen, and the outer border of the Latissimus dorsi; the Internal oblique and the posterior aponeurosis of the Transversalis muscle; the outer border of the Quadratus lumborum, and the deep layer of the lumbar fascia, and the transversalis fascia. The fatty tissue around the kidney is now exposed to view, and must be separated by the fingers or a director in order to reach the kidney.

The abdominal operation is best performed by an incision in the linea semilunaris on the side of the kidney to be removed, as recommended by Langenbuch; the kidney is then reached from the outer side of the colon, ascending or descending, as the case may be, and the vessels of the colon are not interfered with. If the incision is made in the linea alba, the kidney is reached from the inner side of the colon, and the vessels running to supply it must necessarily be interfered with. The incision is made of varying length according to the size of the kidney, commencing just below the costal arch. The abdominal cavity is opened. The intestines are held aside, and the outer layer of the mesocolon incised, so that the fingers can be introduced behind the peritoneum and the renal vessels sought for. These are then to be ligatured; if tied separately, care must be taken to ligature the artery first. The kidney must now be enucleated, and the vessels and the ureter divided, and the latter tied, or if thought necessary, stitched to the edge of the wound.

THE URETERS.

The **Ureters** are the two tubes which conduct the urine from the kidneys into the bladder. They commence within the sinus of the kidney by a number of short truncated branches, the *calices* or *infundibula*, which unite either directly or indirectly to form a dilated pouch, the *pelvis*, from which the ureter, after passing through the hilum of the kidney, descends to the bladder. The *calices* are cup-like tubes encircling the apices of the Malpighian pyramids; but inasmuch as one calyx may include two or even more papillæ, their number is generally less than the pyramids themselves, the former being from seven to thirteen, whilst the latter vary from eight to eighteen. These calices converge into two or three tubular divisions which by their junction form the *pelvis* or dilated portion of the ureter. The portion last mentioned, where the pelvis merges into the ureter proper, is found opposite the spinous process of the first lumbar vertebra, in which situation it is accessible behind the peritoneum (see Fig. 507, page 924).

The *ureter proper* is a cylindrical membranous tube, about sixteen inches in length and of the diameter of a goosequill, extending from the pelvis of the kidney to the bladder. Its course is obliquely downward and inward through the lumbar region into the cavity of the pelvis where it passes downward, forward, and inward across that cavity to the base of the bladder, into which it then opens by a constricted orifice, after having passed obliquely for nearly an inch between its muscular and mucous coats.

Relations.—In its course it rests upon the Psoas muscle, being covered by the peritoneum, and crossed obliquely, from within outward, by the spermatic vessels; the right is crossed by the branches of the mesenteric arteries, which are distributed to the ascending, and the left by those for the descending colon; the right ureter lying close to the outer side of the inferior vena cava. Opposite the first piece of the sacrum it crosses either the common or external iliac artery, lying behind the ileum on the *right* side and the sigmoid flexure of the colon on the *left*. In the pelvis it enters the posterior false ligament of the bladder, below the obliterated hypogastric artery, the vas deferens in the male passing between it and the bladder. In the female the ureter passes along the side of the neck of the uterus and upper part of the vagina. At the base of the bladder it is situated about two inches from its fellow: lying, in the male, about an inch and a half from the vesical orifice of the urethra, at one of the posterior angles of the trigone.

Structure.—The *ureter* is composed of three coats—a fibrous, muscular, and mucous.

The *fibrous coat* is the same throughout the entire length of the duct, being continuous at one end with the capsule of the kidney at the floor of the sinus, while at the other it is lost in the fibrous structure of the bladder.

In the pelvis of the kidney the muscular coat consists of two layers, longitudinal and circular: the longitudinal fibres become lost upon the sides of the papillæ at the extremities of the calices; the circular fibres may be traced surrounding the medullary structure in the same situation. In the ureter proper the muscular fibres are very distinct, and are arranged in three layers—an external longitudinal, a middle circular, and an internal layer, less distinct than the other two, but having a general longitudinal direction. According to Kölliker, this internal layer is only found in the neighborhood of the bladder.

The *mucous coat* is smooth, and presents a few longitudinal folds which become effaced by distension. It is continuous with the mucous membrane of the bladder below, whilst it is prolonged over the papillæ of the kidney above. Its epithelium is of a peculiar character, and resembles that found in the bladder. It is known by the name of "transitional" epithelium. It consists of several layers of cells, of which the innermost—that is to say, the cells in contact with the urine—are quadrilateral in shape, with a concave margin on their outer surface, into which fits the rounded end of the cells of the second layer. These, the intermediate cells, more or less resemble columnar epithelium, and are pear-shaped, with a rounded internal extremity which fits into the concavity of the cells of the first layer, and a narrow external extremity which is wedged in between the cells of the third layer. The external or third layer consists of conical or oval cells varying in number in different parts, and presenting processes which extend down into the basement membrane.

The *arteries* supplying the ureter are branches from the renal, spermatic, internal iliac, and inferior vesical.

The *nerves* are derived from the inferior mesenteric, spermatic, and pelvic plexuses.

Surgical Anatomy.—Subcutaneous rupture of the ureter is not a common accident, but occasionally occurs from a sharp, direct blow on the abdomen, as from the kick of a horse. It may be either torn completely across or only partially divided, and, as a rule, the peritoneum escapes injury. If torn completely across, the urine collects in the retroperitoneal tissues; if it is not completely divided, the lumen of the tube may become obstructed and hydro-nephrosis or pyo-nephrosis result. The ureter may be accidentally wounded in some abdominal operations; if this should happen, the divided ends must be sutured together, or, failing to accomplish this, the upper end must be implanted into the bladder or the intestine.

THE SUPRARENAL CAPSULES.

The **Suprarenal Capsules** belong to the class of ductless glands. They are two small flattened bodies, of a yellowish color, situated at the back part of the abdomen, behind the peritoneum, and immediately above and in front of the upper end of each kidney; hence their name. The right one is somewhat triangular in shape, bearing a resemblance to a cocked hat; the left is more semilunar, usually larger and placed at a higher level than the right. They vary in size in different individuals, being sometimes so small as to be scarcely detected: their usual size is from an inch and a quarter to nearly two inches in length, rather less in width, and from two to three lines in thickness. Their average weight is from one to one and a half drachms each.

Fig. 554.—Vertical section of the suprarenal capsule. From Eberth, in Stricker's *Manual*.

Fig. 555.—Minute structure of suprarenal capsule.

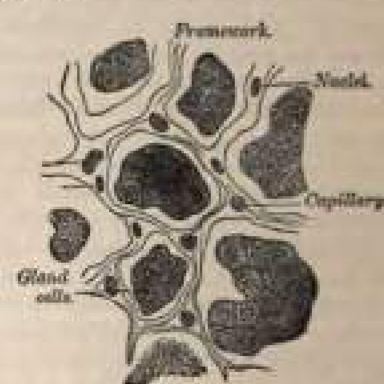


Fig. 556.—Minute structure of suprarenal capsule.

Relations.—The relations of the suprarenal capsules differ on the two sides of the body. The *right suprarenal* is roughly triangular in shape, its angles pointing upward, downward, and outward. It presents two surfaces for examination, an anterior and a posterior. The *anterior surface* presents two areas, separated by a furrow, the *hilum*: one area occupying about one-third of the whole surface, is situated above and internally; it is depressed, uncovered by peritoneum, and is in contact in front with the posterior surface of the right lobe of the liver, and along its inner border with the inferior vena cava; the remaining area is elevated, and is divided into a non-peritoneal portion, in contact with the hepatic flexure of the duodenum, and a portion covered by peritoneum forming the hepato-renal fold. The *posterior surface* is slightly convex, and rests upon the Diaphragm. The *base* is concave, and is in contact with the upper end and the adjacent part of the anterior surface of the kidney. The *left suprarenal* is crescentic in shape, its concavity being adapted to the upper end of the left kidney. It presents an inner border which is convex, and an outer which is concave; its upper border is narrow, and its lower rounded. Its *anterior surface* presents two areas: an upper one, covered by the peritoneum forming the lesser sac, which separates it from the cardiac end of the stomach and to a small extent from the superior extremity of the spleen; and a lower one, which is in contact with the pancreas and splenic artery, and is therefore not covered by the peritoneum. Its *posterior surface* presents a vertical ridge, which divides it into two areas. The ridge lies in the sulcus between the kidney and crus of the Diaphragm, while the area on either side of it lies on these parts respectively; the outer area, which is thin, resting on the kidney, and the inner and smaller area resting on the left crus of the Diaphragm. The surface of the suprarenal gland is surrounded by areolar tissue containing much fat, and closely invested by a thin fibrous coat, which is difficult to remove, on account of numerous fibrous processes and vessels which enter the organ through the furrows on its anterior surface and base.

Small accessory suprarenals are often to be found in the connective tissue around the suprarenals. The smaller of these, on section, show a uniform surface, but in some of the larger a distinct medulla can be made out.

Structure.—On making a perpendicular section, the gland is seen to consist of two substances—external or cortical, and internal or medullary. The former, which constitutes the chief part of the organ, is of a deep yellow color. The medullary substance is soft, pulpy, and of a dark brown or black color, whence the name *atrabiliary capsules* formerly given to these organs. In the centre is often seen a space, not natural, but formed by breaking down after death of the medullary substance.

The **cortical portion** consists chiefly of narrow columnar masses placed perpendicularly to the surface. This arrangement is due to the disposition of the capsule, which sends into the interior of the gland processes passing in vertically and communicating with each other by transverse bands so as to form spaces which open into each other. These spaces are of slight depth near the surface of the organ, so that there the section somewhat resembles a net; this is termed the *zona glomerulosa*; but they become much deeper or longer farther in, so as to resemble pipes or tubes placed endwise, the *zona fasciculata*. Still deeper down, near the medullary part, the spaces become again of small extent; this is named the *zona reticularis*. These processes or trabeculæ, derived from the capsule and forming the framework of the spaces, are composed of fibrous connective tissue with longitudinal bundles of unstriped muscular fibres. Within the interior of the spaces are contained groups of polyhedral cells, which are finely granular in appearance, and contain a spherical nucleus, and not infrequently fat-globules. These groups of cells do not entirely fill the spaces in which they are contained, but between them and the trabeculæ of the framework is a channel which is believed to be a lymph-path or sinus, and which communicates with certain passages between the cells composing the group. The lymph-path is supposed to open into a plexus of efferent lymphatic vessels which are contained in the capsule.

In the **medullary portion** the fibrous stroma seems to be collected together into a much closer arrangement, and forms bundles of connective tissue which are loosely applied to the large plexus of veins of which this part of the organ mainly consists. In the interstices lie a number of cells compared by Frey to those of columnar epithelium. They are coarsely granular, do not contain any fat-molecules, and some of them are branched. Luschka has affirmed that these branches are connected with the nerve-fibres of a very intricate plexus which is found in the medulla: this statement has not been verified by other observers, for the tissue of the medullary substance is less easy to make out than that of the cortical, owing to its rapid decomposition.

The numerous arteries which enter the suprarenal bodies from the sources mentioned below penetrate the cortical part of the gland, where they break up into capillaries in the fibrous septa, and these converge to the very numerous veins of the medullary portion, which are collected together into the suprarenal vein, which usually emerges as a single vessel from the centre of the gland.

The *arteries* supplying the suprarenal capsules are numerous and of large size; they are derived from the aorta, the phrenic, and the renal; they subdivide into numerous minute branches previous to entering the substance of the gland.

The *suprarenal vein* returns the blood from the medullary venous plexus, and receives several branches from the cortical substance; it opens on the right side into the inferior vena cava, on the left side into the renal vein.

The *lymphatics* terminate in the lumbar glands.

The *nerves* are exceedingly numerous, and are derived from the solar and renal plexuses, and, according to Bergmann, form the phrenic and pneumogastric nerves. They enter the lower and inner part of the capsule, traverse the cortex, and terminate round the cells of the medulla. They have numerous small ganglia developed upon them, from which circumstance the organ has been conjectured to have some function in connection with the sympathetic nervous system.

THE CAVITY OF THE PELVIS.

The **cavity of the pelvis** is that part of the general abdominal cavity which is below the level of the linea ilio-pectinea and the promontory of the sacrum.

Boundaries.—It is bounded behind by the sacrum, the coccyx, the Pyriformis muscle, and the great sacro-sciatic ligaments; in front and at the sides by the ossa pubis and ischia, covered by the Obturator muscles; above, it communicates with the cavity of the abdomen; and below, the outlet is closed by the triangular ligament, the Levatores ani and Coccygei muscles, and the visceral layer of the pelvic fascia, which is reflected from the wall of the pelvis on to the viscera.

Contents.—The viscera contained in this cavity are—the urinary bladder, the rectum, and some of the generative organs peculiar to each sex, and some convolutions of the small intestines; they are partially covered by the peritoneum, and supplied with blood-vessels, lymphatics, and nerves.

THE BLADDER.

The **bladder** is the reservoir for the urine. It is a musculo-membranous sac situated in the pelvis, behind the pubes, and in front of the rectum in the male, the cervix uteri and vagina intervening between it and that intestine in the female. The shape, position, and relations of the bladder are greatly influenced by age, sex, and the degree of distention of the organ. *During infancy* it is conical in shape, and projects above the upper border of the ossa pubis into the hypogastric region. *In the adult*, when quite empty and contracted, it is cup-shaped, and on vertical median section its cavity, with the adjacent portion of the urethra, presents a Y-shaped cleft, the stem of the Y corresponding to the urethra. It is placed deeply in the pelvis, flattened from before backward, and reaches as high as the upper border of the symphysis pubis. When slightly distended, it has a rounded form, and is still contained within the pelvic cavity; and when greatly distended it is ovoid in shape, rising into the abdominal cavity, and often extending nearly as high as the umbilicus. It is larger in its vertical diameter than from side to side, and its long axis is directed from above obliquely downward and backward, in a line directed from some point between the symphysis pubis and umbilicus (according to its distention) to the end of the coccyx. The bladder, when distended, is slightly curved forward toward the anterior wall of the abdomen, so as to be more convex behind than in front. In the female it is larger in the transverse than in the vertical diameter, and its capacity is said to be greater

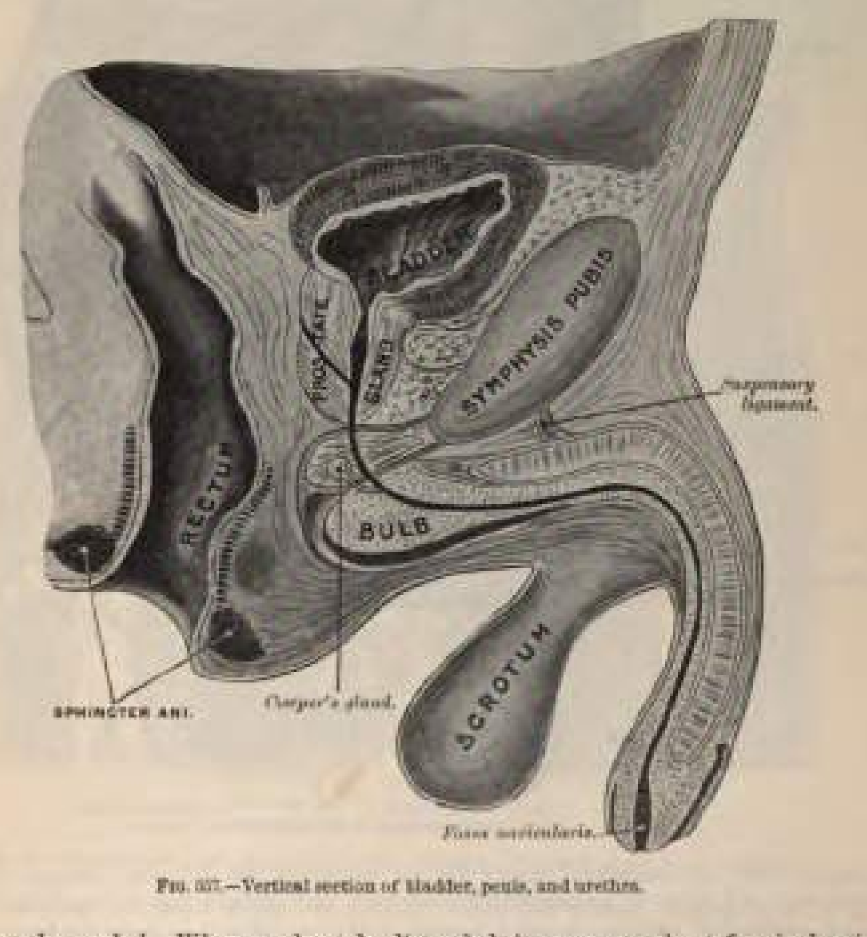


Fig. 557.—Vertical section of bladder, penis, and urethra.

than in the male.[1] When moderately distended, it measures about five inches in length, and three inches across, and the ordinary amount which it contains is about a pint.

The bladder is divided for purposes of description into a superior, an antero-inferior, and two lateral surfaces, a base or fundus and a summit or apex.

The **superior** or **abdominal surface** is entirely free, and is covered throughout by peritoneum. It looks almost directly upward into the abdominal cavity, and extends in an antero-posterior direction from the apex to the base of the bladder. It is in relation with the small intestine and sometimes with the sigmoid flexure, and in the female, with the uterus. On each side, in the male, a portion of the

[1] According to Henle, the bladder is considerably smaller in the female than in the male.

vas deferens is in contact with the hinder part of this surface, lying beneath the peritoneum.

The **antero-inferior** or **pubic surface** looks downward and forward. In the undistended condition it is uncovered by peritoneum, and is in relation with the Obturator internus muscle on each side, with the recto-vesical fascia, and anterior true ligaments of the bladder. It is separated from the body of the pubis by a triangular interval, the *space of Retzius*, occupied by fatty tissue. As the bladder

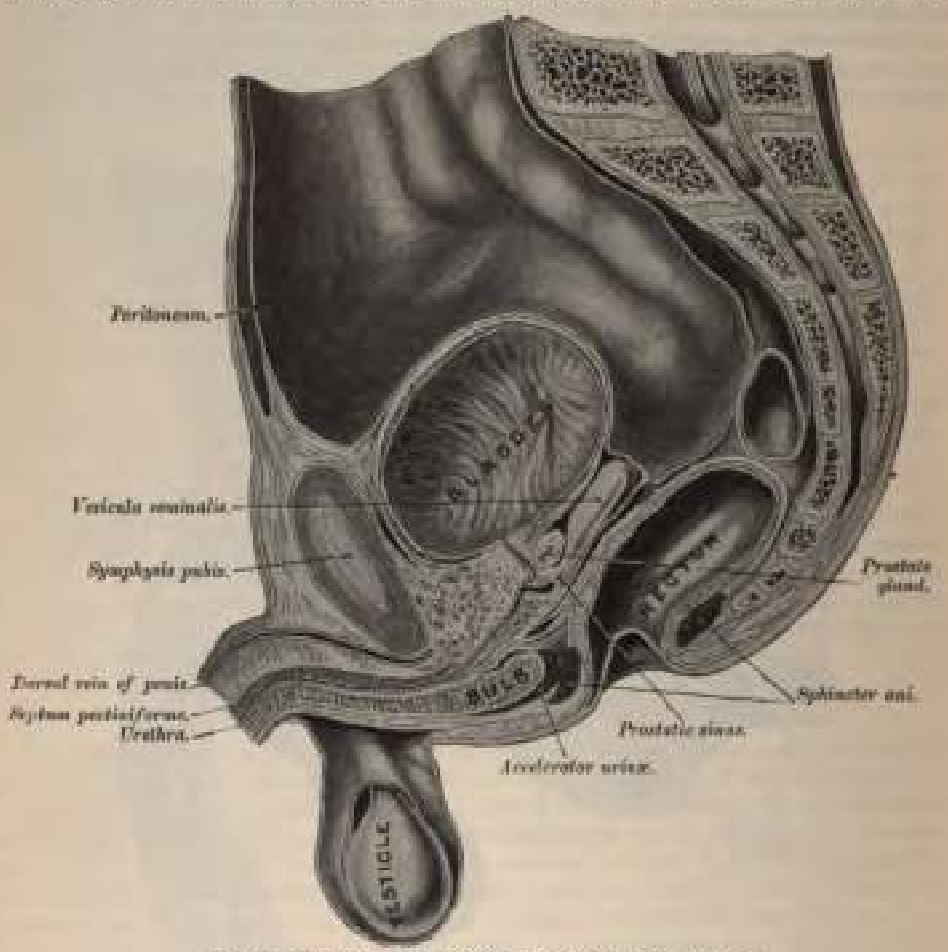


FIG. 558.—Vertical median section of the male pelvis. (Henle.)

ascends into the abdominal cavity during distention the distance between its apex and the umbilicus is necessarily diminished, and the urachus is thus relaxed; so that, instead of passing directly upward to the umbilicus, it descends first on the upper part of the anterior surface of the bladder, and then, curving upward, ascends on the back of the abdominal wall. The peritoneum, which follows the urachus, thus comes to form a pouch of varying depth between the anterior surface of the viscus and the abdominal wall. Thus, when the bladder is distended, the upper part of its anterior surface is in relation to the urachus and is covered by peritoneum. The lower part of its anterior surface, a distance of about two inches above the symphysis pubis, is devoid of peritoneum, and is in contact with the abdominal wall.

The **lateral surfaces** are covered behind and above by peritoneum, which extends as low as the level of the obliterated hypogastric artery; below and in front of this, these surfaces are uncovered by peritoneum, and are separated from the Levatores ani muscles and walls of the pelvis by a quantity of loose areolar tissue containing fat. In front this surface is connected to the recto-vesical fascia by a broad expansion on either side, the *lateral true ligaments*. The vas deferens crosses the hinder part of the lateral surface obliquely, and passes between the ureter and the bladder.

The **fundus** or **base** is directed downward and backward, and is partly covered by peritoneum and partly uncovered. In the male the upper portion, to within about an inch and a half of the prostate, is covered by the recto-vesical pouch of peritoneum. The lower part is in direct contact with the anterior wall of the second part of the rectum and the vesiculæ seminales and vasa deferentia. The ureters enter the bladder at the upper part of its base, about two inches above the prostate gland.

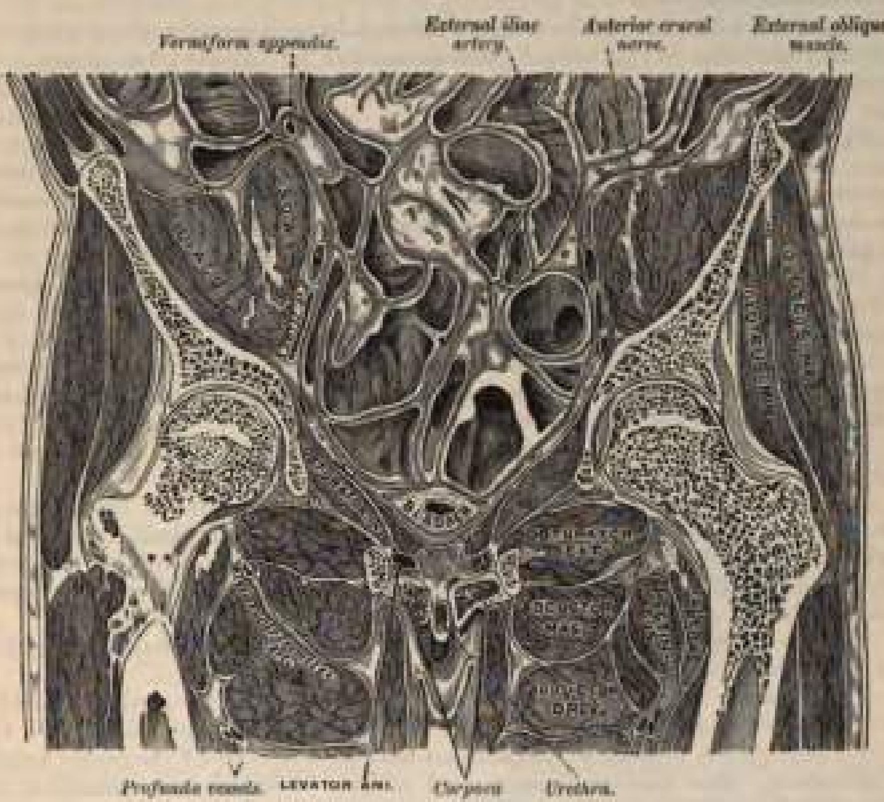


Fig. 559.—Frontal section of the lower part of the abdomen. Viewed from the front. (Braune.)

The portion of the bladder in relation with the rectum corresponds to a triangular space, bounded, below, by the prostate gland; above, by the recto-vesical fold of the peritoneum; and on each side, by the vesicula seminalis and vas deferens. It is separated from direct contact with the rectum by the recto-vesical fascia. When the bladder is very full, the peritoneal fold is raised with it, and the distance between its reflection and the anus is about four inches; but this distance is much diminished when the bladder is empty and contracted. *In the female*, the base of the bladder is connected to the anterior aspect of the cervix uteri by areolar tissue, and is adherent to the anterior wall of the vagina. Its upper surface is separated from the anterior surface of the body of the uterus by the utero-vesical pouch of peritoneum.

The so-called *neck* (*cervix*) *of the bladder* is the point of commencement of the urethra; there is, however, no tapering part, which would constitute a true neck, but the bladder suddenly contracts to the opening of the urethra. In the male its direction is oblique in the erect posture, and it is surrounded by the prostate gland. In the female its direction is obliquely downward and forward.

The **urachus** is the obliterated remains of the tubular canal of the *allantois*, which exists in the embryo, and a portion of which becomes expanded to form the bladder (see section on Embryology). It passes upward, from the apex of the bladder, between the transversalis fascia and peritoneum, to the umbilicus, becoming thinner as it ascends. It is composed of fibrous tissue, mixed with plain muscular fibres. On each side of it is placed a fibrous cord, the obliterated portion of the hypogastric artery, which, passing upward from the side of the bladder, approaches the urachus above its summit. In the infant, at birth, it is occasionally found pervious, so that the urine escapes at the umbilicus, and calculi have been found in its canal.

Ligaments.—The bladder is retained in its place by ligaments, which are divided into true and false. The true ligaments are five in number: two anterior, two lateral, and the urachus. The false ligaments, also five in number, are formed by folds of the peritoneum.

The *anterior true ligaments* (*pubo-prostatic*) extend from the back of the ossa pubis, one on each side of the symphysis, to the front of the neck of the bladder, over the anterior surface of the prostate gland. These ligaments are formed by the recto-vesical fascia, and contain a few muscular fibres prolonged from the bladder.

The *lateral true ligaments*, also formed by the recto-vesical fascia, are broader and thinner than the preceding. They are attached to the lateral parts of the prostate and to the sides of the base of the bladder.

The *urachus* is the fibro-muscular cord already mentioned, extending between the summit of the bladder and the umbilicus. It is broad below, at its attachment to the bladder, and becomes narrower as it ascends.

The *false ligaments of the bladder* are two posterior, two lateral, and one superior.

The *two posterior* pass forward, in the male, from the sides of the rectum; in the female, from the sides of the uterus, to the posterior and lateral aspect of the bladder: they form the lateral boundaries of the recto-vesical fold of the peritoneum, and contain the obliterated hypogastric arteries, and the ureters, together with vessels and nerves.

The *two lateral ligaments* are reflections of the peritoneum, from the iliac fossæ and lateral walls of the pelvis to the sides of the bladder.

The *superior ligament* (*ligamentum suspensorium*) is the prominent fold of peritoneum extending from the summit of the bladder to the umbilicus. It is carried off from the bladder by the urachus and the obliterated hypogastric arteries.

Structure.—The bladder is composed of four coats—serous, muscular, submucous, and mucous.

The *serous coat* is partial, and derived from the peritoneum. It invests the superior surface and the upper part of the lateral surfaces and base, and is reflected from these parts on to the abdominal and pelvic walls.

The *muscular coat* consists of three layers of unstriped muscular fibre: an external layer, composed of fibres having for the most part a longitudinal arrangement; a middle layer, in which the fibres are arranged, more or less, in a circular manner; and an internal layer, in which the fibres have a general longitudinal arrangement.

The *fibres of the external longitudinal layer* arise from the posterior surface of the body of the os pubis in both sexes (*musculi pubo-vesicalis*), and in the male from the adjacent part of the prostate gland and its capsule. They pass, in a more or less longitudinal manner, up the anterior surface of the bladder, over its apex, and then descend along its posterior surface to its base, where they become attached to the prostate in the male and to the front of the vagina in the female.

At the sides of the bladder the fibres are arranged obliquely and intersect one another. This layer has been named the *detrusor urinæ muscle*.

The *middle circular layers* are very thinly and irregularly scattered on the body of the organ, and, though to some extent placed transversely to the long axis of the bladder, are for the most part arranged obliquely. Toward the lower part of the bladder, round the cervix and commencement of the urethra, they are disposed in a thick circular layer, forming the *sphincter vesicæ*, which is continuous with the muscular fibres of the prostate gland.

The *internal longitudinal layer* is thin, and its fasciculi have a reticular arrangement, but with a tendency to assume for the most part a longitudinal direction.

Two bands of oblique fibres, originating behind the orifices of the ureters, converge to the back part of the prostate gland, and are inserted, by means of a fibrous process, into the middle lobe of that organ. They are the *muscles of the ureters*, described by Sir C. Bell, who supposed that during the contraction of the bladder they served to retain the oblique direction of the ureters, and so prevent the reflux of the urine into them.

The *submucous coat* consists of a layer of areolar tissue connecting together the muscular and mucous coats, and intimately united to the latter.

The *mucous coat* is thin, smooth, and of a pale rose color. It is continuous above through the ureters with the lining membrane of the uriniferous tubes, and below with that of the urethra. It is connected loosely to the muscular coat by a layer of areolar tissue, and is therefore thrown into folds or *rugæ* when the bladder is empty. The epithelium covering it is of the transitional variety, consisting of a superficial layer of polyhedral flattened cells, each with one, two, or three nuclei; beneath these, a stratum of large club-shaped cells with the narrow extremity directed downward and wedged in between smaller spindle-shaped cells, containing an oval nucleus (Figs. 560, 561). There are no true glands in the mucous mem-

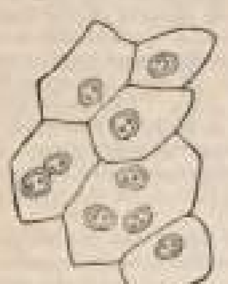


FIG. 560.—Superficial layer of the epithelium of the bladder. Composed of polyhedral cells of various sizes, each with one, two, or three nuclei. (Klein and Noble Smith.)

FIG. 561.—Deep layers of epithelium of bladder, showing large club-shaped cells above, and smaller, more spindle-shaped cells below, each with an oval nucleus. (Klein and Noble Smith.)

brane of the bladder, though certain mucous follicles which exist, especially near the neck of the bladder, have been regarded as such.

Objects seen on the Inner Surface.—Upon the inner surface of the bladder are seen the orifices of the ureters, the trigone, and the commencement of the urethra.

The Orifices of the Ureters.—These are situated at the base of the trigone, being distant from each other about two inches; they are about an inch and a half from the base of the prostate and the commencement of the urethra.

The *trigonum vesicæ*, or *trigone vesical*, is a triangular smooth surface, with the apex directed forward, situated at the base of the bladder, immediately behind the urethral orifice. It is paler in color than the rest of the interior, and never presents any rugæ, even in the collapsed condition of the organ, owing to the intimate adhesion of its mucous membrane to the subjacent tissue. It is bounded at each posterior angle by the orifice of the ureter, and in front by the orifice of the urethra.

Projecting from the lower and anterior part of the bladder, and reaching to the orifice of the urethra, is a slight elevation of mucous membrane, called the *uvula vesicæ*. It is formed by a thickening of the submucous tissue.

The *arteries* supplying the bladder are the superior, middle, and inferior vesical in the male, with additional branches from the uterine and vaginal in the female. They are all derived from the anterior trunk of the internal iliac. The obturator and sciatic arteries also supply small visceral branches to the bladder.

The *veins* form a complicated plexus round the neck, sides, and base of the bladder, and terminate in the internal iliac vein.

The *lymphatics* form two plexuses, one in the muscular and another in the submucous coat; they are most numerous in the neighborhood of the trigone. They accompany the blood-vessels, and ultimately terminate in the internal iliac glands.

The *nerves* are derived from the pelvic plexus of the sympathetic and from the third and the fourth sacral nerves; the former supplying the upper part of the organ, the latter its base and neck. According to F. Darwin, the sympathetic fibres have ganglia connected with them, which send branches to the vessels and muscular coat.

Surface Form.—The surface form of the bladder varies with its degree of distention and under other circumstances. In the young child it is represented by a conical figure, the apex of which, even when the viscus is empty, is situated in the hypogastric region, about an inch above the level of the symphysis pubis. In the adult, when the bladder is empty, its apex does not reach above the level of the upper border of the symphysis pubis, and the whole organ is situated in the pelvis; the neck, in the male, corresponding to a line drawn horizontally backward through the symphysis a little below its middle. As the bladder becomes distended, it gradually rises out of the pelvis into the abdomen, and forms a swelling in the hypogastric region which is perceptible to the hand as well as to percussion. In extreme distention it reaches into the umbilical region. Under these circumstances the lower part of its anterior surface, for a distance of about two inches above the symphysis pubis, is closely applied to the abdominal wall, without the intervention of peritoneum, so that it can be tapped by an opening in the middle line just above the symphysis pubis, without any fear of wounding the serous membrane. When the rectum is distended, the prostatic portion of the urethra is elongated and the bladder lifted out of the pelvis and the peritoneum pushed upward. Advantage is taken of this by some surgeons in performing the operation of suprapubic cystotomy. The rectum is distended by an India-rubber bag, which is introduced into this cavity empty, and then filled with ten or twelve ounces of water. If now the bladder is injected with about half a pint of some antiseptic fluid, it will appear above the pubes plainly perceptible to the sight and touch. The peritoneum will be pushed out of the way, and an incision three inches long may be made in the linea alba, from the symphysis pubis upward, without any great risk of wounding the peritoneum. Other surgeons object to the employment of this bag, as its use is not unattended with risk, and because it causes pressure on the prostatic sinuses and produces congestion of the vessels over the bladder and a good deal of venous hemorrhage.

When distended, the bladder can be felt in the male, from the rectum, behind the prostate, and fluctuation can be perceived by a bimanual examination, one finger being introduced into the rectum and the distended bladder tapped on the front of the abdomen with the finger of the other hand. This portion of the bladder—that is, the portion felt in the rectum by the finger—is also uncovered by peritoneum, and the bladder may here be punctured from the rectum, in the middle line, without risk of wounding the serous membrane.

Surgical Anatomy.—A defect of development in which the bladder is implicated is known under the name of *extroversion of the bladder*. In this condition the lower part of the abdominal wall and the anterior wall of the bladder are wanting, so that the posterior surface of the bladder presents on the abdominal surface, and is pushed forward by the pressure of the viscera within the abdomen, forming a red, vascular tumor, on which the openings of the ureters are visible. The penis, except the glans, is rudimentary and is cleft on its dorsal surface, exposing the floor of the urethra—a condition known as *epispadias*. The pelvic bones are also arrested in development (see page 183).

The bladder may be ruptured by violence applied to the abdominal wall when the viscus is distended without any injury to the bony pelvis, or it may be torn in cases of fracture of the pelvis. The rupture may be either intraperitoneal or extraperitoneal—that is, may implicate the superior surface of the bladder in the former case, or one of the other surfaces in the latter. Rupture of the antero-inferior surface alone is, however, very rare. Until recently intraperitoneal rupture was uniformly fatal, but now abdominal section and suturing the rent with Lembert's suture are resorted to, with a very considerable amount of success. The sutures are inserted only through the peritoneal and muscular coats in such a way as to bring the serous surfaces at the margins of the wound into apposition, and one is inserted just beyond each end of the wound. The bladder should be tested as to whether it is water-tight before closing the external incision.

The muscular coat of the bladder undergoes hypertrophy in cases in which there is any obstruction to the flow of urine. Under these circumstances the bundles of which the muscular coat consists become much increased in size, and, interlacing in all directions, give rise to what is known as the *fasciculated bladder*. Between these bundles of muscular fibres the mucous membrane may bulge out, forming sacculi, constituting the *sacculated bladder*, and in these little pouches phosphatic concretions may collect, forming *encysted calculi*. The mucous membrane is very loose and lax, except over the trigone, to allow of the distention of the viscus.

Various forms of tumors have been found springing from the wall of the bladder. The innocent tumors are the papilloma and the mucous polypus, arising from the mucous membrane; the fibrous, from the submucous tissue; and the myoma, originating in the muscular tissue; and, very rarely, dermoid tumors, the exact origin of which it is difficult to explain. Of the malignant tumors, epithelioma is the most common, but sarcomata are occasionally found in the bladder of children.

Puncture of the bladder may be performed either above the pubes or through the rectum, in both cases without wounding the peritoneum. The former plan is generally to be preferred, since in puncture by the rectum a permanent fistula may be left from abscess forming between the rectum and the bladder; or pelvic cellulitis may be set up; moreover, it is exceedingly inconvenient to keep a cannula in the rectum. In some cases in performing this operation the recto-vesical pouch of peritoneum has been wounded, inducing fatal peritonitis. The operation, therefore, has been almost completely abandoned.

THE MALE URETHRA.

The **urethra in the male** extends from the neck of the bladder to the meatus urinarius at the end of the penis. It presents a double curve in the flaccid state of the penis (Fig. 557), but in the erect state of this organ it forms only a single curve, the concavity of which is directed upward. Its length varies from eight to nine inches; and it is divided into three portions, the *prostatic*, *membranous*, and *spongy*, the structure and relations of which are essentially different. Except during the passage of the urine or semen, the urethra is a more transverse cleft or slit, with its upper and under surfaces in contact. At the meatus urinarius the slit is vertical, and in the prostatic portion somewhat arched.

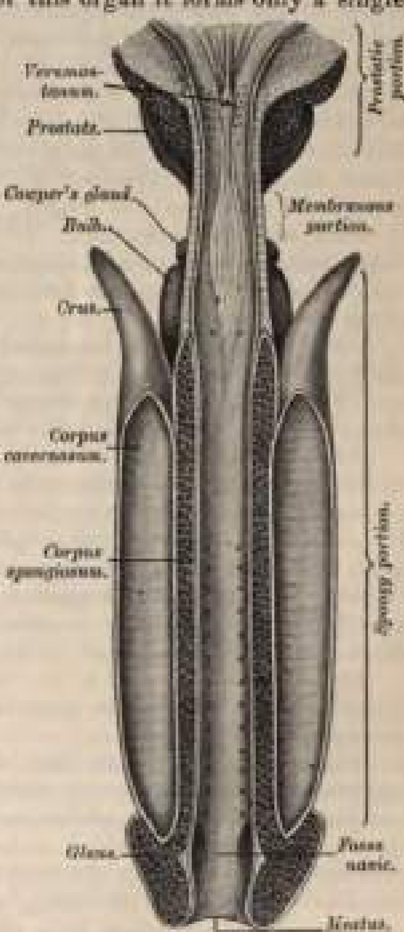


FIG. 562.—The male urethra, laid open on its anterior (upper) surface. (Testut.)

The **Prostatic Portion** is the widest and most dilatable part of the canal. It passes through the prostate gland, from its base to the apex, lying nearer its anterior than its posterior surface. It is about an inch and a quarter in length; the form of the canal is spindle-shaped, being wider in the middle than at either extremity, and narrowest below, where it joins the membranous portion. A transverse section of the canal as it lies in the prostate is horse-shoe in shape, the convexity being directed forward (Fig. 563), since the direction of the canal is nearly vertical.

Upon the floor of the canal is a narrow longitudinal ridge, the *verumontanum*, or *caput gallinaginis*, formed by an elevation of the mucous membrane and its subjacent tissue. It is eight or nine lines in length, and a line and a half in height; and contains, according to Kobelt, muscular and erectile tissues. When distended, it may serve to prevent the passage of the semen backward into the bladder. On each side of the verumontanum is a slightly depressed fossa, the *prostatic sinus*, the floor of which is perforated by numerous apertures, the *orifices of the prostatic ducts* from the lateral lobes of the gland; the ducts of the middle lobe open behind the verumontanum. At the fore part of the verumontanum, in the middle line, is a depression, the *sinus pocularis* (*vesicula prostatica*); and upon or within its margins are the slit-like openings of the ejaculatory ducts. The sinus pocularis forms a *cul-de-sac* about a quarter of an inch in length, which runs upward and backward in the substance of the prostate behind the middle lobe; its prominent anterior wall partly forms the verumontanum. Its walls are composed of fibrous tissue, muscular fibres, and mucous membrane, and numerous small glands open on its inner surface. It has been called by Weber, who discovered it, the *uterus masculinus*, from its being developed from the united lower ends of the atrophied Müllerian ducts, and therefore homologous with the uterus and vagina in the female.

The **Membranous Portion of the Urethra** extends between the apex of the prostate and the bulb of the corpus spongiosum. It is the narrowest part of the canal (excepting the meatus), and measures three-quarters of an inch along its upper, and half an inch along its lower, surface, in consequence of the bulb projecting backward beneath it. Its anterior concave surface is placed about an inch below and behind the pubic arch, from which it is separated by the dorsal vessels and nerves of the penis, and some muscular fibres. Its posterior convex surface is separated from the rectum by a triangular space, which constitutes the perineum. The membranous portion of the urethra lies between the inferior and superior layers of the triangular ligament. As it pierces the inferior layer, the fibres around the opening are prolonged over the tube. It is also surrounded by the Compressor urethræ muscle.

The **Spongy Portion** is the longest part of the urethra, and is contained in the corpus spongiosum. It is about six inches in length, and extends from the termination of the membranous portion of the meatus urinarius. Commencing just below the triangular ligament, it inclines downward for a short distance; it next ascends for about half its length, and then, in the flaccid condition of the penis, it bends suddenly downward. It is narrow, and of uniform size in the body of the penis, measuring about a quarter of an inch in diameter; being dilated behind, within the bulb; and again anteriorly within the glans penis, where it forms the *fossa navicularis*.

The *Bulbous portion* is a name given, in some descriptions of the urethra, to the posterior part of the spongy portion contained within the bulb.

The *meatus urinarius* is the most contracted part of the urethra; it is a vertical slit, about three lines in length, bounded on each side by two small labia.

The inner surface of the lining membrane of the urethra, especially on the floor of the spongy portion, presents the orifices of numerous mucous glands and follicles situated in the submucous tissue, and named the *glands of Littre*. They vary in size, and their orifices are directed forward, so that they may easily intercept the point of a catheter in its passage along the canal. One of these lacunæ, larger than the rest, is situated in the upper surface of the fossa navicularis, about an inch and a half from the orifice; it is called the *lacuna magna*. Into the bulbous portion are found opening the ducts of Cowper's glands.

Structure.—The urethra is composed of a continuous mucous membrane, supported by a submucous tissue which connects it with the various structures through which it passes.

The *mucous coat* forms part of the genito-urinary mucous membrane. It is continuous with the mucous membrane of the bladder, ureters, and kidneys; externally with the integument covering the glans penis; and is prolonged into the ducts of the glands which open into the urethra—viz. Cowper's glands and the prostate gland—and into the vasa deferentia and vesiculæ seminales through the ejaculatory ducts. In the spongy and membranous portions the mucous membrane is arranged in longitudinal folds when the tube is empty. Small papillæ are found upon it near the orifice, and its epithelial lining is of the columnar variety, excepting near the meatus, where it is squamous.

The *submucous tissue* consists of a vascular erectile layer, outside which is a layer of unstriped muscular fibres, arranged in a circular direction, which separates the mucous membrane and submucous tissue from the tissue of the corpus spongiosum.

Surgical Anatomy.—The urethra may be ruptured by the patient falling astride of any hard substance and striking his perinæum, so that the urethra is crushed against the pubic arch. Bleeding will at once take place from the urethra, and this, together with the bruising in the perinæum and the history of the accident, will at once point to the nature of the injury.

The surgical anatomy of the urethra is of considerable importance in connection with the passage of instruments into the bladder. Otis was the first to point out that the urethra is capable of great dilatability, so that, excepting through the external meatus, an instrument corresponding to 18 English gauge (29 French) can usually be passed without damage. The orifice of the urethra is not so dilatable, and therefore frequently requires slitting. A recognition of this dilatability caused Bigelow to very considerably modify the operation of lithotrity and introduce that of litholapaxy. In passing catheters, especially fine ones, the point of the instrument should be kept as far as possible along the upper wall of the canal, as the point is otherwise very liable to enter one of the lacunæ. Stricture of the urethra is a disease of very common occurrence, and is generally situated in the spongy portion of the urethra, most commonly in the bulbous portion, just in front of the membranous urethra, but in a very considerable number of cases in the penile or ante-scrotal part of the canal.

THE FEMALE BLADDER AND URETHRA.

The **Bladder** is situated at the anterior part of the pelvis. It is in relation, *in front*, with the symphysis pubis; *behind*, with the utero-vesical pouch of peritoneum, which separates it from the body of the uterus; its *base* lies in contact with the connective tissue in front of the cervix and upper part of the vagina. *Laterally*, is the recto-vesical fascia. The bladder is said by some anatomists to be larger in the female than in the male. At any rate, it does not rise above the symphysis pubis till more distended than in the male, but this is perhaps owing to the more capacious pelvis rather than to its being of actually larger size.

THE URETHRA.

The **Urethra** is a narrow membranous canal, about an inch and a half in length, extending from the neck of the bladder to the meatus urinarius. It is placed beneath the symphysis pubis, imbedded in the anterior wall of the vagina; and its direction is obliquely downward and forward, its course being slightly curved, the concavity directed forward and upward. Its diameter when undilated is about a quarter of an inch. The urethra perforates the triangular ligament, and its external orifice is situated directly in front of the vaginal opening and about an inch behind the glans clitoridis.

Structure.—The urethra consists of three coats: muscular, erectile, and mucous.

The *muscular coat* is continuous with that of the bladder; it extends the whole length of the tube, and consists of a circular stratum of muscular fibres. In addition to this, between the two layers of the triangular ligament, the female urethra is surrounded by the Compressor urethræ, as in the male.

A *thin layer of spongy erectile tissue*, containing a plexus of large veins intermixed with bundles of unstriped muscular fibre, lies immediately beneath the mucous coat.

The *mucous coat* is pale, continuous externally with that of the vulva, and internally with that of the bladder. It is thrown into longitudinal folds, one of which, placed along the floor of the canal, resembles the verumontanum in the male urethra. It is lined by laminated epithelium, which becomes transitional near the bladder. Its external orifice is surrounded by a few mucous follicles.

The urethra, from not being surrounded by dense resisting structures, as in the male, admits of considerable dilatation, which enables the surgeon to remove with considerable facility calculi or other foreign bodies from the cavity of the bladder.

THE MALE ORGANS OF GENERATION.

THE PROSTATE GLAND.

THE **Prostate Gland** (*προΐστημι, to stand before*) is a pale, firm, partly glandular and partly muscular body, which is placed immediately below the neck of the bladder and around the commencement of the urethra. It is placed in the pelvic cavity, behind the lower part of the symphysis pubis, and above the deep layer of the triangular ligament, and rests upon the rectum, through which it may be distinctly felt, especially when enlarged. In shape and size it resembles a chestnut.

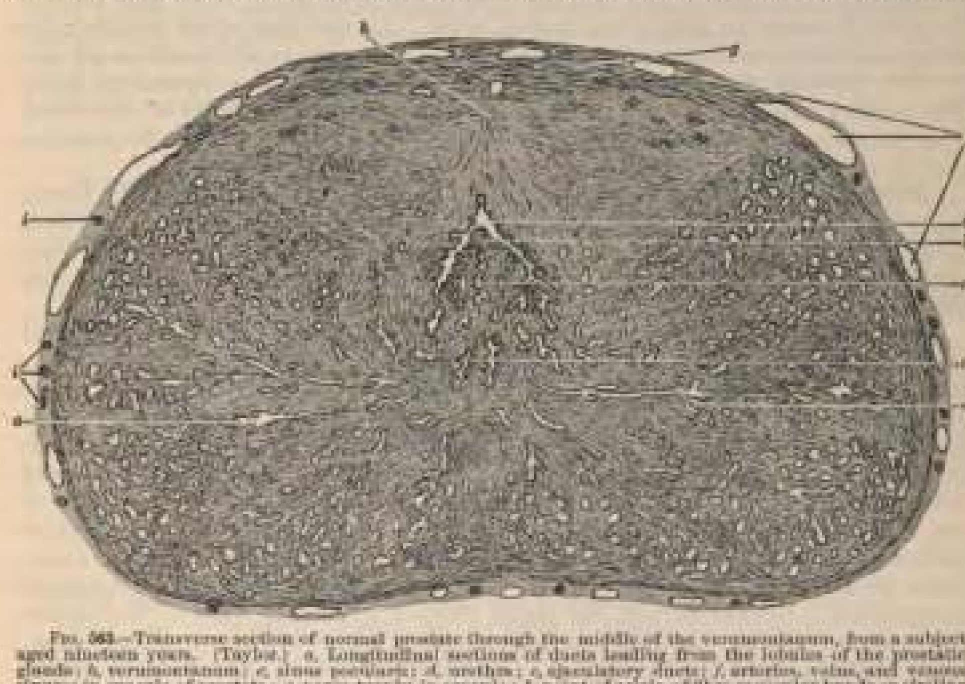


FIG. 563.—Transverse section of normal prostate through the middle of the verumontanum, from a subject aged nineteen years. (Taylor.) *a*, Longitudinal sections of ducts leading from the lobules of the prostatic glands; *b*, verumontanum; *c*, sinus pocularis; *d*, urethra; *e*, ejaculatory ducts; *f*, arteries, veins, and venous sinuses in capsule of prostate; *g*, nerve trunks in capsule; *h*, point of origin of fibro-muscular bands encircling urethra; *i*, zone of striated voluntary muscle on superior surface. (Drawn from Edinger projection apparatus.)

Its *base* is directed upward, and is situated immediately below the neck of the bladder.

Its *apex* is directed downward to the deep layer of the triangular ligament, which it touches.

Its *posterior surface* is flattened, marked by a slight longitudinal furrow, and rests on the second part of the rectum, and is distant about one inch and a half from the anus.

Its *anterior surface* is convex, and placed about three-quarters of an inch behind the pubic symphysis, from which it is separated by a plexus of veins and a quantity of loose fat. It is connected to the pubic bone on either side by the pubo-prostatic ligaments.

The *lateral surfaces* are prominent, and are covered by the anterior portions of the Levatores ani muscles, which are, however, separated from the gland by a plexus of veins.

The prostate measures about an inch and a half transversely at the base, an inch in its antero-posterior diameter, and an inch and a quarter in its vertical diameter. Its weight is about four and a half drachms. It is held in position by the anterior ligaments of the bladder (*pubo-prostatic*); by the deep layer of the triangular ligament, which invests the commencement of the membranous portion of the urethra and prostate gland; and by the anterior portions of the Levatores ani muscles, which pass backward from the os pubis and embrace the sides of the prostate. These portions of the Levatores ani, from the support they afford to the prostate, are named the *Levator prostatæ*.

The prostate consists of two lateral lobes and a middle lobe.

The *two lateral lobes* are of equal size, separated by a deep notch behind, and by a slight furrow upon the anterior and posterior surfaces of the gland, which indicates the bilobed condition of the organ in some animals.

The third, or *middle lobe*, is a small transverse band, occasionally a rounded or triangular prominence, placed between the two lateral lobes at the posterior part of the organ. It lies immediately beneath the neck of the bladder, behind the commencement of the urethra, and above the ejaculatory ducts, which pass through the gland between its middle and lateral lobes. Its existence is not constant, but it is occasionally found at an early period of life, as well as in adults and in old age.

The prostate gland is perforated by the urethra and the ejaculatory ducts. The urethra usually lies along the junction of its anterior with its middle third. The ejaculatory ducts pass obliquely downward and forward through the posterior part of the prostate, and open into the prostatic portion of the urethra.

Structure.—The prostate is immediately enveloped by a thin but firm fibrous capsule, distinct from that derived from the recto-vesical fascia, and separated from it by a plexus of veins. Its substance is of a pale reddish-gray color, of great density and not easily torn. It consists of glandular substance and muscular tissue.

The muscular tissue, according to Kölliker, constitutes the proper stroma of the prostate, the connective tissue being very scanty, and simply forming thin trabeculæ between the muscular fibres, in which the vessels and nerves of the gland ramify. The muscular tissue is arranged as follows: immediately beneath the fibrous capsule is a dense layer which forms an investing sheath for the gland; secondly, around the urethra as it lies in the prostate, is another dense layer of circular fibres, continuous above with the internal layer of the muscular coat of the bladder, and below blending with the fibres surrounding the membranous portion of the urethra. Between these two layers strong bands of muscular tissue, which decussate freely, form meshes in which the glandular structure of the organ is imbedded. In that part of the gland which is situated in front of the urethra the muscular tissue is especially dense, and there is here little or no gland tissue; while in that part which is behind the urethra the muscular tissue presents a wide-meshed structure, which is densest at the base of the gland—that is, near the bladder—becoming looser and more sponge-like toward the apex of the organ.

The *glandular substance* is composed of numerous follicular pouches, opening into elongated canals, which join to form from twelve to twenty small excretory ducts. The follicles are connected together by areolar tissue, supported by prolongations from the fibrous capsule and muscular stroma, and enclosed in a delicate capillary plexus. The epithelium lining of both the canals and the terminal vesicles is of the columnar variety. The prostatic ducts open into the floor of the prostatic portion of the urethra.

Vessels and Nerves.—The *arteries* supplying the prostate are derived from the internal pudic, vesical, and hæmorrhoidal. Its *veins* form a plexus around the sides and base of the gland; they receive in front the dorsal vein of the penis, and terminate in the internal iliac vein. The *nerves* are derived from the pelvic plexus.

Surgical Anatomy.—The relation of the prostate to the rectum should be noted: by means of the finger introduced into the gut the surgeon detects enlargement or other disease of this organ; he can feel the apex of the gland, which is the guide to Cock's operation for stricture; he is enabled also by the same means to direct the point of a catheter when its introduction is attended with difficulty either from injury or disease of the membranous or prostatic portions of the urethra. When the finger is introduced into the bowel the surgeon may, in some cases, especially in boys, learn the position, as well as the size and weight, of a calculus in the bladder; and in the operation for its removal, if, as is not unfrequently the case, it should be lodged behind an enlarged prostate, it may be displaced from its position by pressing upward the base of the bladder from the rectum. The prostate gland is occasionally the seat of suppuration, either due to injury, gonorrhœa, or tuberculous disease. The gland, being enveloped in a dense unyielding capsule, determines the course of the abscess, and also explains the great pain which is present in the acute form of the disease. The abscess most frequently bursts into the urethra, the direction in which there is least resistance, but may occasionally burst into the rectum, or more rarely in the perinæum. In advanced life the prostate becomes considerably enlarged, and projects into the bladder so as to impede the passage of the urine. According to Dr. Messer's researches, conducted at Greenwich Hospital, it would seem that such obstruction exists in 20 per cent. of all men over sixty years of age. In some cases the enlargement affects principally the lateral lobes, which may undergo considerable enlargement without causing much inconvenience. In other cases it would seem that the middle lobe enlarges most, and even a small enlargement of this lobe may act injuriously, by forming a sort of valve over the urethral orifice, preventing the passage of the urine, and the more the patient strains, the more completely will it block the opening into the urethra. In consequence of the enlargement of the prostate a pouch is formed at the base of the bladder behind the projection, in which water collects and cannot entirely be expelled. It becomes decomposed and ammoniacal, and leads to cystitis. For this condition "prostatectomy" is sometimes done. The bladder is opened by an incision above the symphysis pubis, the mucous membrane incised, and the enlarged and projecting middle lobe enucleated.

COWPER'S GLANDS.

Cowper's Glands are two small, rounded, and somewhat lobulated bodies of a yellow color, about the size of peas, placed behind the fore part of the membranous portion of the urethra, between the two layers of the triangular ligament. They lie close above the bulb, and are enclosed by the transverse fibres of the Compressor urethræ muscle. Their existence is said to be constant: they gradually diminish in size as age advances.

Structure.—Each gland consists of several lobules held together by a fibrous investment. Each lobule consists of a number of acini lined by columnar epithelial cells, opening into one duct, which, joining with the ducts of other lobules outside the gland, form a single excretory duct. The excretory duct of each gland, nearly an inch in length, passes obliquely forward beneath the mucous membrane, and opens by a minute orifice on the floor of the bulbous portion of the urethra.

THE PENIS.

The **Penis** consists of a root, body, and extremity or *glans penis*.

The *root* is firmly connected to the rami of the os pubis and ischium by two strong tapering, fibrous processes, the *crura*, and to the front of the symphysis pubis by the *suspensory ligament*, a strong band of fibrous tissue which passes downward from the front of the symphysis pubis to the upper surface of the root of the penis, where it splits into two portions and blends with the fascial sheath of the organ.

The *extremity* or *glans penis*, presents the form of an obtuse cone, flattened from above downward. At its summit is a vertical fissure, the orifice of the urethra (*meatus urinarius*). The base of the glans forms a rounded projecting border, the *corona glandis*, and behind the corona is a deep constriction, the *cervix*. Upon both of these parts numerous small sebaceous glands are found, the *glandulæ Tysonii odoriferæ*. They secrete a sebaceous matter of very peculiar odor, which probably contains caseine and becomes easily decomposed.

[1] Stieda (*Comptes rendus du XII Congrès International de Médecine*, Moscow, 1897) asserts that Tyson's glands are never found on the corona glandis, and that what have hitherto been mistaken for glands are really large papillæ.

The *body of the penis* is the part between the root and extremity. In the flaccid condition of the organ it is cylindrical, but when erect has a triangular prismatic form with rounded angles, the broadest side being turned upward, and called the *dorsum*. The body is covered by integument, and contains in its interior a large portion of the urethra. The integument covering the penis is remarkable for its thinness, its dark color, its looseness of connection with the deeper parts of the organ, and its containing no adipose tissue. At the root of the penis the integument is continuous with that upon the pubes and scrotum, and at the neck of the glans it leaves the surface and becomes folded upon itself to form the *prepuce*.

The internal layer of the prepuce is attached behind to the cervix, and approaches in character to a mucous membrane; from the cervix it is reflected over the glans penis, and at the meatus urinarius is continuous with the mucous lining of the urethra.

The integument covering the glans penis contains no sebaceous glands, but projecting from its free surface are a number of small, highly sensitive papillæ. At the back part of the meatus urinarius a fold of mucous membrane passes backward to the bottom of a depressed raphé, where it is continuous with the prepuce; this fold is termed the *frænum præputii*.

Structure of the Penis.—The penis is composed of a mass of erectile tissue enclosed in three cylindrical fibrous compartments. Of these, two, the *corpora cavernosa*, are placed side by side along the upper part of the organ; the third, or *corpus spongiosum*, encloses the urethra and is placed below.

The **Corpora Cavernosa** form the chief part of the body of the penis. They consist of two fibrous cylindrical tubes, placed side by side, and intimately connected along the median line for their anterior three-fourths, whilst at their back part they separate from each other to form the *crura*, which are two strong tapering fibrous processes firmly connected to the rami of the os pubis and ischium. Each crus commences by a blunt-pointed process in front of the tuberosity of the ischium, and before its junction with its fellow to form the body of the penis it presents a slight enlargement, named by Kobelt the *bulb of the corpus cavernosum*. Just beyond this point they become constricted, and retain an equal diameter to their anterior extremity, where they form a single rounded end which is received into a fossa in the base of the glans penis. A median groove on the upper surface lodges the dorsal vein of the penis, and the groove on the under surface receives the corpus spongiosum. The root of the penis is connected to the symphysis pubis by the suspensory ligament.

Structure.—The corpora cavernosa are surrounded by a strong fibrous envelope, consisting of two sets of fibres—the one, longitudinal in direction, being common to the two corpora cavernosa, and investing them in a common covering; the other, internal, circular in direction, and being proper to each corpus cavernosum. The internal circular fibres of the two corpora cavernosa form, by their junction in the mesial plane, an incomplete partition or septum between the two bodies.

The *septum* between the two corpora cavernosa is thick and complete behind, but in front it is incomplete, and consists of a number of vertical bands, which are arranged like the teeth of a comb, whence the name which it has received, *septum pectiniforme*. These bands extend between the dorsal and the urethral surface of the corpora cavernosa. This fibrous investment is extremely dense, of considerable thickness, and consists of bundles of shining white fibres, with an admixture of well-developed elastic fibre, so that it is possessed of great elasticity.

From the internal surface of the fibrous envelope, as well as from the sides of the septum, are given off a number of bands or cords which cross the interior of the corpora cavernosa in all directions, subdividing them into a number of separate compartments, and giving the entire structure a spongy appearance. These bands and cords are called *trabeculæ*, and consist of white fibrous tissue, elastic fibres, and plain muscular fibres. In them are contained numerous arteries and nerves.

The component fibres of which the trabeculæ are composed are larger and stronger round the circumference than at the centre of the corpora cavernosa; they are also thicker behind than in front. The interspaces, on the contrary, are larger at the centre than at the circumference, their long diameter being directed transversely; they are largest anteriorly. They are occupied by venous blood, and are lined by a layer of flattened cells similar to the endothelial lining of veins.

The whole of the structure of the corpora cavernosa contained within the fibrous sheath consists, therefore, of a sponge-like tissue of areolar spaces freely communicating with each other and filled with venous blood. The spaces may therefore be regarded as large cavernous veins.

The arteries bringing the blood to these spaces are the arteries of the corpora cavernosa and branches from the dorsal artery of the penis, which perforate the fibrous capsule, along the upper surface, especially near the fore part of the organ.

These arteries on entering the cavernous structure divide into branches which are supported and enclosed by the trabeculæ. Some of these terminate in a capillary network, the branches of which open directly into the cavernous spaces; others assume a tendril-like appearance, and form convoluted and somewhat dilated vessels, which were named by Müller *helicine arteries*. They project into the spaces, and from them are given off small capillary branches to supply the trabecular structure. They are bound down in the spaces by fine fibrous processes, and are more abundant in the back part of the corpora cavernosa (Fig. 564).

The blood from the cavernous spaces is returned by a series of vessels, some of which emerge in considerable numbers from the base of the glans penis and

FIG. 564.—From the peripheral portion of the corpus cavernosum penis under a low magnifying power. (Copied from Langer.) 1. a. Capillary network. b. Cavernous spaces. 2. Connection of the arterial twigs (a) with the cavernous spaces.

converge on the dorsum of the organ to form the dorsal vein; others pass out on the upper surface of the corpora cavernosa and join the dorsal vein; some emerge from the under surface of the corpora cavernosa, and, receiving branches from the corpus spongiosum, wind round the sides of the penis to terminate in the dorsal vein; but the greater number pass out at the root of the penis and join the prostatic plexus.

The **Corpus Spongiosum** encloses the urethra, and is situated in the groove on the under surface of the corpora cavernosa. It commences posteriorly below the superficial layer of the triangular ligament of the urethra, between the diverging crura of the corpora cavernosa, where it forms a rounded enlargement, the *bulb*, and terminates anteriorly in another expansion, the *glans penis*, which overlaps the anterior rounded extremity of the corpora cavernosa. The central portion, or body of the corpus spongiosum, is cylindrical, and tapers slightly from behind forward.

The *bulb* varies in size in different subjects; it receives a fibrous investment from the superficial layer of the triangular ligament, and is surrounded by the Accelerator urinæ muscle. The urethra enters the bulb nearer its upper than its lower surface, being surrounded by a layer of erectile tissue, a thin prolongation of which is continued backward round the membranous and prostatic portions of the canal to the neck of the bladder, lying between the two layers of muscular tissue. The portion of the bulb below the urethra presents a partial division into two lobes, being marked externally by a linear raphé, whilst internally there projects, for a short distance, a thin fibrous septum, which is more distinct in early life.

Structure.—The corpus spongiosum consists of a strong fibrous envelope, enclosing a trabecular structure, which contains in its meshes erectile tissue. The fibrous envelope is thinner, whiter in color, and more elastic than that of the corpora cavernosa. The trabeculæ are more delicate, nearly uniform in size, and the meshes between them smaller than in the corpora cavernosa, their long diameter, for the most part, corresponding with that of the penis. The external envelope or outer coat of the corpus spongiosum is formed partly of unstriped muscular fibre, and a layer of the same tissue immediately surrounds the canal of the urethra.

The *lymphatics of the penis* consist of a superficial and deep set; the former are derived from a dense network on the skin of the glans and prepuce and from the mucous membrane of the urethra, and terminate in the superficial inguinal glands; the latter emerge from the corpora cavernosa and corpus spongiosum, and, passing beneath the pubic arch, join the deep lymphatics of the pelvis.

The *nerves* are derived from the internal pudic nerve and the pelvic plexus. On the glans and bulb some filaments of the cutaneous nerves have Pacinian bodies connected with them, and, according to Krause, many of them terminate in a peculiar form of end-bulb.

Surgical Anatomy.—The penis occasionally requires removal for malignant disease. Usually, removal of the ante-scrotal portion is all that is necessary, but sometimes it is requisite to remove the whole organ from its attachment to the rami of the ossa pubis and ischia. The former operation is performed either by cutting off the whole of the anterior part of the penis with one sweep of the knife, or, what is better, cutting through the corpora cavernosa from the dorsum, and then separating the corpus spongiosum from them, dividing it at a level nearer the glans penis. The mucous membrane of the urethra is then slit up, and the edges of the flap attached to the external skin, in order to prevent contraction of the orifice, which would otherwise take place. The vessels which require ligature are the two dorsal arteries of the penis, the arteries of the corpora cavernosa, and the artery of the septum. When the entire organ requires removal the patient is placed in the lithotomy position, and an incision is made through the skin and subcutaneous tissue round the root of the penis, and carried down the median line of the scrotum as far as the perineum. The two halves of the scrotum are then separated from each other, and a catheter having been introduced into the bladder as a guide, the spongy portion of the urethra below the triangular ligament is separated from the corpora cavernosa and divided, the catheter having been withdrawn just behind the bulb. The suspensory ligament is now severed, and the crura separated from the bone with a periosteum scraper, and the whole penis removed. The membranous portion of the urethra, which has not been removed, is now to be attached to the skin at the posterior extremity of the incision in the perineum. The remainder of the wound is to be brought together, free drainage being provided for.

THE TESTES AND THEIR COVERINGS (Fig. 565).

The **Testes** are two glandular organs, which secrete the semen; they are situated in the scrotum, being suspended by the spermatic cords. At an early period of fœtal life the testes are contained in the abdominal cavity, behind the peritoneum. Before birth they descend to the inguinal canal, along which they pass with the spermatic cord, and, emerging at the external abdominal ring, they descend into the scrotum, becoming invested in their course by numerous coverings derived from the serous, muscular, and fibrous layers of the abdominal parietes, as well as by the scrotum. The coverings of the testes are—the

Skin } Scrotum.
Dartos }
Intercolumnar, or External spermatic fascia.
Cremasteric fascia.
Infundibuliform, or Fascia propria (Internal spermatic fascia).
Tunica vaginalis.

The **Scrotum** is a cutaneous pouch which contains the testes and part of the spermatic cords. It is divided on its surface into two lateral portions by a median line, or *raphé*, which is continued forward to the under surface of the penis and backward along the middle line of the perineum to the anus. Of these two lateral portions, the left is longer than the right, and corresponds with the greater length of the spermatic cord on the left side. Its external aspect varies under different circumstances: thus under the influence of warmth and in old and debilitated persons it becomes elongated and flaccid, but under the influence of cold and in the young and robust it is short, corrugated, and closely applied to the testes.

The scrotum consists of two layers, the integument and the dartos.

The **integument** is very thin, of a brownish color, and generally thrown into folds or rugæ. It is provided with sebaceous follicles, the secretion of which has a peculiar odor, and is beset with thinly-scattered, crisp hairs, the roots of which are seen through the skin.

The **dartos** is a thin layer of loose reddish tissue, endowed with contractility: it forms the proper tunic of the scrotum, is continuous, around the base of the scrotum, with the two layers of the superficial fascia of the groin and perinæum,

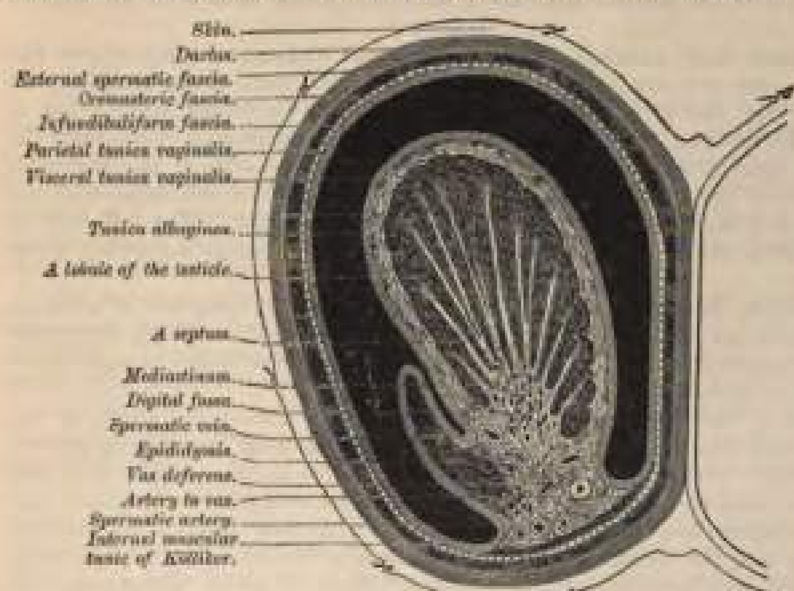


FIG. 565.—Transverse section through the left side of the scrotum and the left testicle. The sac of the tunica vaginalis represented in a distended condition. (Delépine.)

and sends inward a distinct septum, *septum scroti*, which divides it into two cavities for the two testes, the septum extending between the raphe and the under surface of the penis as far as its root.

The dartos is closely united to the skin externally, but connected with the subjacent parts by delicate areolar tissue, upon which it glides with the greatest facility. The dartos is very vascular, and consists of a loose areolar tissue containing unstriped muscular fibre, but no fat. Its contractility is slow, and excited by cold and mechanical stimuli, but not by electricity.

The **intercolumnar fascia** is a thin membrane derived from the margin of the pillars of the external abdominal ring, during the descent of the testes in the fœtus, which is prolonged downward around the surface of the cord and testis. It is separated from the dartos by loose areolar tissue, which allows of considerable movement of the latter upon it, but is intimately connected with the succeeding layers.

The **cremasteric fascia** consists of scattered bundles of muscular fibres (*Cremaster muscle*) connected together into a continuous covering by intermediate areolar tissue. The muscular fibres are continuous with the lower border of the Internal oblique muscle (see page 369).

The **infundibuliform fascia** is a thin membranous layer, which loosely invests the surface of the cord. It is a continuation downward of the fascia transversalis. Beneath it is a quantity of loose connective tissue which connects this layer of fascia with the spermatic cord and posterior part of the testicle. This connective tissue is continuous above with the subserous areolar tissue of the abdomen. These two layers, the infundibuliform fascia and the tissue beneath it, are known collectively as the *fascia propria*.

The **tunica vaginalis** is described with the testis.

Vessels and Nerves.—The *arteries* supplying the coverings of the testis are: the superficial and deep external pudic, from the femoral; the superficial perineal branch of the internal pudic; and the cremasteric branch from the epigastric. The *veins* follow the course of the corresponding arteries. The *lymphatics* terminate in the inguinal glands. The *nerves* are: the ilio-inguinal branch of the lumbar plexus, the two superficial perineal branches of the internal pudic nerve, the inferior pudendal branch of the small sciatic nerve, and the genital branch of the genito-crural nerve.

The **Spermatic Cord** extends from the internal abdominal ring, where the structures of which it is composed converge, to the back part of the testicle. In the abdominal wall the cord passes obliquely along the inguinal canal, lying at first between the Internal oblique and upon the fascia transversalis; but nearer the pubes it rests upon Poupart's ligament, having the aponeurosis of the External oblique in front of it and the conjoined tendon behind it. It then escapes at the external ring, and descends nearly vertically into the scrotum. The left cord is rather longer than the right, consequently the left testis hangs somewhat lower than its fellow.

Structure of the Spermatic Cord.—The spermatic cord is composed of arteries, veins, lymphatics, nerves, and the excretory duct of the testicle. These structures are connected together by areolar tissue, and invested by the layers brought down by the testicle in its descent.

The *arteries of the cord* are: the spermatic, from the aorta; the artery of the vas deferens, from the superior vesical; the cremasteric, from the deep epigastric.

The *spermatic artery*, a branch of the abdominal aorta, escapes from the abdomen at the internal or deep abdominal ring, and accompanies the other constituents of the spermatic cord along the inguinal canal and through the external abdominal ring into the scrotum. It then descends to the testicle, and, becoming tortuous, divides into several branches, two or three of which accompany the vas deferens and supply the epididymis, anastomosing with the artery of the vas deferens; others pierce the back of the tunica albuginea and supply the substance of the testis.

The *cremasteric artery* is a branch of the deep epigastric artery. It accompanies the spermatic cord and supplies the Cremaster muscle and other coverings of the cord, anastomosing with the spermatic artery.

The *artery of the vas deferens*, a branch of the superior vesical, is a long slender vessel which accompanies the vas deferens, ramifying upon the coats of that duct, and anastomosing with the spermatic artery near the testis.

The spermatic veins emerge from the back of the testis and receive tributaries from the epididymis; they unite and form a convoluted plexus (*plexus pampiniformis*), which forms the chief mass of the cord; the vessels composing this plexus are very numerous, and ascend along the cord in front of the vas deferens; below the external or superficial abdominal ring they unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the internal or deep abdominal ring, coalesce to form two veins. These again unite to form a single vein, which opens on the right side into the inferior vena cava at an acute angle, and on the left side into the renal vein at a right angle.

The *lymphatic vessels* terminate in the lumbar glands.

The *nerves* are the spermatic plexus from the sympathetic, joined by filaments from the pelvic plexus which accompany the artery of the vas deferens.

Surgical Anatomy.—The scrotum forms an admirable covering for the protection of the testicle. This body, lying suspended and loose in the cavity of the scrotum and surrounded by a serous membrane, is capable of great mobility, and can therefore easily slip about within the scrotum, and thus avoid injuries from blows or squeezes. The skin of the scrotum is very elastic and capable of great distension, and on account of the looseness and amount of subcutaneous tissue the scrotum becomes greatly enlarged in cases of œdema, to which this part is especially liable on account of its dependent position. The scrotum is frequently the seat of epithelioma; this is no doubt due to the rugæ on its surface, which favor the lodgment of dirt, and this, causing irritation, is the exciting cause of the disease, which is especially common in chimney-sweeps from the lodgment of soot. The scrotum is also the part most frequently affected by elephantiasis.

On account of the looseness of the subcutaneous tissue considerable extravasations of blood may take place from very slight injuries. It is therefore generally recommended never to apply leeches to the scrotum, since they may lead to considerable ecchymosis, but rather to puncture one or more of the superficial veins of the scrotum in cases where local bloodletting from this part is judged to be desirable. The muscular fibre in the dartos causes contraction and considerable diminution in the size of a wound of the scrotum, as after the operation of castration, and is of assistance in keeping the edges together and covering the exposed parts.

THE TESTES.

The **Testes** are suspended in the scrotum by the spermatic cords. As the left spermatic cord is rather longer than the right one, the left testicle hangs somewhat lower than its fellow. Each gland is of an oval form, compressed laterally, and having an oblique position in the scrotum, the upper extremity being directed forward and a little outward, the lower, backward and a little inward; the anterior convex border looks forward and downward; the posterior or straight border, to which the cord is attached, backward and upward.

The anterior border and lateral surfaces, as well as both extremities of the organ, are convex, free, smooth, and invested by the visceral layer of the tunica vaginalis. The posterior border, to which the cord is attached, receives only a partial investment from that membrane. Lying upon the outer edge of this posterior border is a long, narrow, flattened body, named from its relation to the testis, the epididymis (δίδυμος, testis). It consists of a central portion, or *body*; an upper enlarged extremity, the head, or *globus major*; and a lower pointed extremity, the tail, or *globus minor*. The globus major is intimately connected with the upper end of the testicle by means of its efferent ducts, and the globus minor is connected with its lower end by cellular tissue and a reflection of the tunica vaginalis. The outer surface and upper and lower ends of the epididymis are free and covered by serous membrane; the body is also completely invested by it, excepting along its posterior border, and between the body and the testicle is a pouch or *cul-de-sac*, named the *digital fossa*. The epididymis is connected to the back of the testis by a fold of the serous membrane. Attached to the upper end of the testis, close to the globus major, are two small pedunculated bodies. One of them is pear-shaped, and attached by its narrow stalk; the other is small and sessile; they are believed to be the remains of the upper extremity of the Müllerian duct, and are termed the *hydatids of Morgagni*; some observers, however, regard the stalked hydatid as being a rudiment of the pronephros. When the testicle is removed from the body, the position of the vas deferens, on the posterior surface of the testicle and inner side of the epididymis, marks the side to which the gland has belonged.

Size and Weight.—The average dimensions of this gland are from one and a half to two inches in length, one inch in breadth, and an inch and a quarter in the antero-posterior diameter, and the weight varies from six to eight drachms, the left testicle being a little the larger.

The testis is invested by three tunics—the tunica vaginalis, tunica albuginea, and tunica vasculosa.

The **Tunica Vaginalis** is the serous covering of the testis. It is a pouch of serous membrane, derived from the peritoneum during the descent of the testis in the fœtus from the abdomen into the scrotum. After its descent that portion of the pouch which extends from the internal ring to near the upper part of the gland becomes obliterated, the lower portion remaining as a shut sac, which invests the outer surface of the testis, and is reflected on to the internal surface of the scrotum; hence it may be described as consisting of a visceral and parietal portion.

The *visceral portion of the tunica vaginalis* covers the outer surface of the testis, as well as the epididymis, connecting the latter to the testis by means of a distinct fold. From the posterior border of the gland it is reflected on to the internal surface of the scrotum.

The *parietal portion of the tunica vaginalis* is far more extensive than the visceral portion, extending upward for some distance in front and on the inner side of the cord, and reaching below the testis. The inner surface of the tunica vaginalis is free, smooth, and covered by a layer of endothelial cells. The interval between the visceral and parietal layers of this membrane constitutes the cavity of the tunica vaginalis.

The obliterated portion of the pouch may generally be seen as a fibro-cellular thread lying in the loose areolar tissue around the spermatic cord; sometimes this may be traced as a distinct band from the upper end of the inguinal canal, where it is connected with the peritoneum, down to the tunica vaginalis; sometimes it gradually becomes lost on the spermatic cord. Occasionally no trace of it can be detected. In some cases it happens that the pouch of peritoneum does not become obliterated, but the sac of the peritoneum communicates with the tunica vaginalis. This may give rise to one of the varieties of oblique inguinal hernia (page 1049). Or in other cases the pouch may contract, but not become entirely obliterated; it then forms a minute canal leading from the peritoneum to the tunica vaginalis.[1]

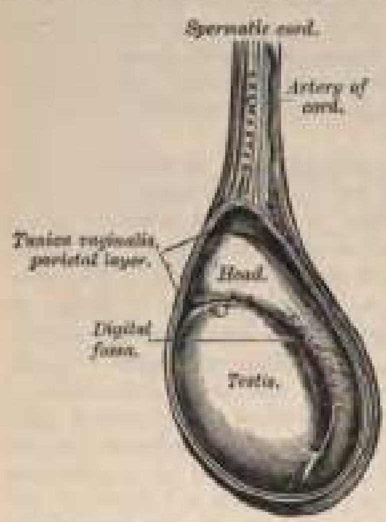


FIG. 566.—The testis *in situ*, the tunica vaginalis having been laid open.

The **Tunica Albuginea** is the fibrous covering of the testis. It is a dense fibrous membrane, of a bluish-white color, composed of bundles of white fibrous tissue, which interlace in every direction. Its outer surface is covered by the tunica vaginalis, except at the points of attachment of the epididymis to the testicle, and along its posterior border, where the spermatic vessels enter the gland. This membrane surrounds the glandular structure of the testicle, and at its posterior border is reflected into the interior of the gland, forming an incomplete vertical septum, called the *mediastinum testis* (*corpus Highmorianum*).

The *mediastinum testis* extends from the upper, nearly to the lower, extremity

[1] It is recorded that in the post-mortem examination of Sir Astley Cooper this minute canal was found on both sides of the body. Sir Astley Cooper states that when a student he suffered from inguinal hernia; probably this was of the congenital variety, and the canal found after death was the remains of the one down which the hernia travelled (*Lancet*, 1824, vol. ii., p. 116).

of the gland, and is wider above than below. From the front and sides of this septum numerous slender fibrous cords and imperfect septa (*trabeculæ*) are given off, which radiate toward the surface of the organ, and are attached to the inner surface of the tunica albuginea. They therefore divide the anterior of the organ into a number of incomplete spaces, which are somewhat cone-shaped, being broad at their bases at the surface of the gland, and becoming narrower as they converge to the mediastinum. The mediastinum supports the vessels and ducts of the testis in their passage to and from the substance of the gland.

The **Tunica Vasculosa** is the vascular layer of the testis, consisting of a plexus of blood-vessels held together by a delicate areolar tissue. It covers the inner surface of the tunica albuginea and the different septa in the interior of the gland, and therefore forms an internal investment to all the spaces of which the gland is composed.

Structure.—The glandular structure of the testis consists of numerous lobules (*lobuli testis*). Their number, in a single testis, is estimated by Berres at 250, and by Krause at 400. They differ in size according to their position, those in the middle of the gland being larger and longer. The lobules are conical in shape, the base being directed toward the circumference of the organ, the apex toward the mediastinum. Each lobule is contained in one of the intervals between the fibrous cords and vascular processes which extend between the mediastinum testis and the tunica albuginea, and consists of from one to three or more minute convoluted tubes, the *tubuli seminiferi*. The tubes may be separately unravelled by careful dissection under water, and may be seen to commence either by free cæcal ends or by anastomotic loops. The total number of tubes is considered by Munro to be about 300, and the length of each about sixteen feet; by Lauth their number is estimated at 840, and their average length two feet and a quarter. The diameter varies from $\frac{1}{200}$ to $\frac{1}{150}$ of an inch. The tubuli are pale in color in early life, but in old age they acquire a deep yellow tinge from containing much fatty matter. Each tube consists of a basement layer, formed of epithelioid cells united edge to edge, outside which are other layers of flattened cells arranged in interrupted laminæ, which give to the tube an appearance of striation in cross section. The cells of the outer layers gradually pass into the interstitial tissue. Within the basement-membrane are epithelial cells arranged in several irregular layers, which are not always clearly separated, but which may be arranged in three different groups. Among these cells may be seen the *spermatozoa* in different stages of development. 1. Lining the basement-membrane and forming the outer zone is a layer of cubical cells, with small nuclei; these are known as the *lining cells* or *spermatogonia*. The nucleus of some of them may be seen to be in the process of indirect division (*karyokinesis*), and in consequence of this daughter cells are formed, which constitute the second zone. 2. Within this first layer is to be seen a number of larger cells with clear nuclei, arranged in two or three layers; these are the *intermediate cells* or *spermatocytes*. Most of these cells are in a condition of karyokinetic division, and the cells which result from this division form those of the next layer, the *spermatoblasts* or *spermatids*. 3. The third layer of cells therefore consists of the spermatoblasts or spermatids, and each of these, without further subdivision, becomes a *spermatozoon*. They are ill-defined granular masses of protoplasm, of an elongated form, with a nucleus which becomes the head of the future spermatozoon. In addition to these three layers of cells others are seen, which are termed the *supporting cells*, or *cells of Sertoli*. They are elongated and columnar, and project inward from the basement-membrane toward the lumen of the tube. They give off numerous lateral branches, which form a reticulum for the support of the three groups of cells just described. As development of the spermatozoa proceeds the latter group themselves around the inner extremities of the supporting cells. The nuclear part of the spermatozoon, which is partly imbedded in the supporting cell, is differentiated to form the head of the spermatozoon, while the cell protoplasm becomes lengthened out to form the middle piece and tail, the latter projecting into the lumen of the tube. Ultimately the heads are separated and the spermatozoa are set free.

Spermatogenesis.—The stages in the development of the spermatozoa are as follows: The spermatogonia become enlarged to form the spermatocytes, and each spermatocyte subdivides into two cells, and each of these again divides into two spermatids or young spermatozoa, so that the spermatocyte gives origin to four spermatozoa.

The process of spermatogenesis bears a close relation to that of maturation of the ovum. The spermatocyte is equivalent to the immature ovum. It undergoes subdivision, and ultimately gives origin to four spermatozoa, each of which contains, therefore, only one-fourth of the chromatin elements of the nucleus of the spermatocyte. In the process of maturation of the ovum its nucleus divides, one half being extended as the first polar body. The remaining half of the nucleus again subdivides, one half being extended as the second polar body. The portion of the nucleus which is retained to form the female pronucleus of the now matured ovum contains, therefore, only one-fourth of the chromatin elements of the original nucleus, and thus the spermatozoon and the matured ovum, so far as their nuclear elements are concerned, may be regarded as of the same morphological value.

The tubules are enclosed in a delicate plexus of capillary vessels, and are held together by an intertubular connective tissue, which presents large interstitial spaces lined by endothelium, which are believed to be the rootlets of lymphatic vessels of the testis.

In the apices of the lobules the tubuli become less convoluted, assume a nearly straight course, and unite together to form from twenty to thirty larger ducts, of about $\frac{1}{50}$ of an inch in diameter, and these, from their straight course, are called *vasa recta*.

The *vasa recta* enter the fibrous tissue of the mediastinum, and pass upward and backward, forming, in their ascent, a close network of anastomosing tubes, which are merely channels in the fibrous stroma, lined by flattened epithelium, and having no proper walls; this constitutes the *rete testis*. At the upper end of the mediastinum the vessels of the rete testis terminate in from twelve to fifteen or twenty ducts, the *vasa efferentia;* they perforate the tunica albuginea, and carry the seminal fluid from the testis to the epididymis. Their course is at first straight; they then become enlarged and exceedingly convoluted, and form a series of conical masses, the *coni vasculosi*, which, together, constitute the globus major of the epididymis. Each cone consists of a single convoluted duct from six to eight inches in length, the diameter of which gradually decreases from the testis to the epididymis. Opposite the bases of the cones the efferent vessels open at narrow intervals into a single duct, which constitutes, by its complex convolutions, the body and globus minor of the epididymis. When the convolutions of this tube are unravelled, it measures upward of twenty feet in length, and it increases in diameter and thickness as it approaches the vas deferens. The convolutions are held together by fine areolar tissue and by bands of fibrous tissue.

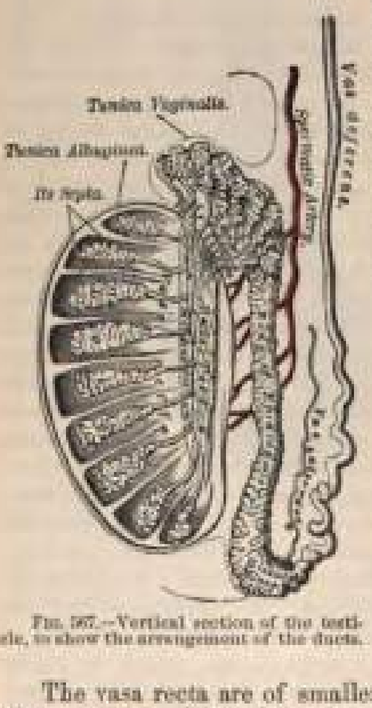


FIG. 567.—Vertical section of the testicle, to show the arrangement of the ducts.

The vasa recta are of smaller diameter than the seminal tubes, and have very thin parietes. They, like the channels of the rete testis, are lined by a single layer of flattened epithelium. The vasa efferentia and the tube of the epididymis have walls of considerable thickness, on account of the presence in them of muscular tissue, which is principally arranged in a circular manner. These tubes are lined by columnar ciliated epithelium.

The **Vas Deferens**, the excretory duct of the testis, is the continuation of the epididymis. Commencing at the lower part of the globus minor, it ascends along the posterior border of the testis and inner side of the epididymis, and along the back part of the spermatic cord, through the inguinal canal to the internal or deep abdominal ring. From the ring it curves round the outer side of the epigastric artery, crosses the external iliac vessels, and descends into the pelvis at the side of the bladder; it arches backward and downward to its base, crossing over the obliterated hypogastric artery and to the inner side of the ureter. At the base of the bladder it lies between that viscus and the rectum, running along the inner border of the vesicula seminalis. In this situation it becomes enlarged and sacculated, forming the *ampulla*, and then, becoming narrowed at the base of the prostate, unites with the duct of the vesicula seminalis to form the ejaculatory duct. The vas deferens presents a hard and cord-like sensation to the fingers; it is about two feet in length, of cylindrical form, and about a line and a quarter in diameter. Its walls are dense, measuring one-third of a line, and its canal is extremely small, measuring about half a line.

Structure.—The vas deferens consists of three coats: 1. An external or areolar coat. 2. A muscular coat, which in the greater part of the tube consists of two layers of unstriped muscular fibre: an outer, longitudinal in direction, and an inner, circular; but in addition to these, at the commencement of the vas deferens, there is a third layer, consisting of longitudinal fibres, placed internal to the circular stratum, between it and the mucous membrane. 3. An internal or mucous coat, which is pale, and arranged in longitudinal folds; its epithelial covering is of the columnar variety.

A long narrow tube, the *vas aberrans of Haller*, is occasionally found connected with the lower part of the canal of the epididymis or with the commencement of the vas deferens. It extends up into the cord for about two or three inches, where it terminates by a blind extremity, which is occasionally bifurcated. Its length varies from an inch and a half to fourteen inches, and sometimes it becomes dilated toward its extremity; more commonly it retains the same diameter throughout. Its structure is similar to that of the vas deferens. Occasionally it is found unconnected with the epididymis.

Organ of Giraldes.—This term is applied to a small collection of convoluted tubules, situated in front of the lower part of the cord or above the globus major of the epididymis. These tubes are lined with columnar ciliated epithelium, and probably represent the remains of a part of the Wolffian body.

Surgical Anatomy.—The testicle frequently requires removal for malignant disease; in tuberculous disease; in cystic disease; in cases of large hernia testis, and in some instances of incompletely descended or misplaced testicles. The operation of castration has also been, during the last few years, performed for enlargement of the prostate; for it has been found that removal of the testicle is followed by very rapid and often considerable diminution in the size of the prostate. The operation is, however, one of severity, and is frequently followed by death in these cases, performed, as it necessarily is, in old men. Reginald Harrison has proposed to substitute for it excision of a portion of the vasa deferentia. The operation of castration is a comparatively simple one. An incision is made into the tunica vaginalis from the external ring to the bottom of the scrotum. The coverings are shelled off the organ, and the mesorchium, stretching between the back of the testicle and the scrotum, divided. The cord is then isolated, and an aneurism needle, armed with a double ligature, passed under it, as high as is thought necessary, and the cord tied in two places, and divided between the ligatures. Sometimes, in cases of malignant disease, it is desirable to open the inguinal canal and tie the cord as near the internal abdominal ring as possible.

Spermatozoa.—The spermatozoa are minute, thread-like bodies, which constitute the essential elements of the semen. Each consists of a *head*, a middle piece or *body*, and an elongated filament or *tail*. The head, on surface view, appears oval in shape, but if seen in profile it is narrow and pointed at its free end. It represents the modified nucleus of the spermatid, and consists chiefly of chromatin, and so stains readily with nuclear reagents; it is covered by a thin cap of protoplasm. The body is a short cylindrical or conical piece, intervening between the head and tail, and is therefore sometimes spoken of as the intermediate segment. The tail is about four times the combined lengths of the head and body; its terminal part is extremely fine, and is named the *end-piece*. Contained within the body and tail is an axial filament, surrounded, except in the end-piece, by a thin layer of protoplasm; this axial filament terminates just below the head in a rounded knob or button. In virtue of their tails, which act as propellers, the spermatozoa, in the fresh condition, are capable of free movement, and if placed in favorable surroundings (*e. g.*, in the female passages) may retain their vitality for some days or even weeks.

VESICULÆ SEMINALES.

The **Seminal Vesicles** are two lobulated membranous pouches placed between the base of the bladder and the rectum, serving as reservoirs for the semen, and secreting a fluid to be added to the secretion of the testicles. Each sac is somewhat pyramidal

Fig. [illegible].—Base of the bladder, with the vasa deferentia and vesiculæ seminales.

in form, the broad end being directed backward and the narrow end forward toward the prostate. They measure about two and a half inches in length, about five lines in breadth, and two or three lines in thickness. They vary, however, in size, not only in different individuals, but also in the same individual on the two sides. Their *upper surface* is in contact with the base of the bladder, extending from near the termination of the ureters to the base of the prostate gland. Their *under surface* rests upon the rectum, from which they are separated by the recto-vesical fascia. Their *posterior extremities* diverge from each other. Their *anterior extremities* are pointed, and converge toward the base of the prostate gland, where each joins with the corresponding vas deferens to form the ejaculatory duct. Along the inner margin of each vesicula runs the enlarged and convoluted vas deferens. The inner border of the vesiculæ and the corresponding vas deferens form the lateral boundaries of a triangular space, limited behind by the recto-vesical peritoneal fold; the portion of the bladder included in this space rests on the rectum.

Each vesicula consists of a single tube, coiled upon itself and giving off several irregular cæcal diverticula, the separate coils, as well as the diverticula, being connected together by fibrous tissue. When uncoiled this tube is about the diameter of a quill, and varies in length from four to six inches; it terminates posteriorly in a *cul-de-sac;* its anterior extremity becomes constricted into a narrow straight duct, which joins with the corresponding vas deferens, and forms the ejaculatory duct.

The **ejaculatory ducts**, two in number, one on each side, are formed by the junction of the ducts of the vesiculæ seminales with the vasa deferentia. Each duct is about three-quarters of an inch in length; it commences at the base of the prostate, and runs forward and downward between its middle and lateral lobes, and along the side of the sinus pocularis, to terminate by a separate slit-like orifice close to or just within the margins of the sinus. The ducts diminish in size and also converge toward their termination.

Structure.—The vesiculæ seminales are composed of three coats: an *external* or *areolar;* a *middle* or *muscular coat*, which is thinner than in the vas deferens, arranged in two layers, an outer, longitudinal, and inner, circular; an *internal* or *mucous coat*, which is pale, of a whitish-brown color, and presents a delicate reticular structure, like that seen in the gall-bladder, but the meshes are finer. The epithelium is columnar.

The coats of the ejaculatory ducts are extremely thin. They are: an *outer fibrous layer*, which is almost entirely lost after their entrance into the prostate; a *layer of muscular fibres*, consisting of an outer thin circular and an inner longitudinal layer; and the *mucous membrane*.

Vessels and Nerves.—The *arteries* supplying the vesiculæ seminales are derived from the middle and inferior vesical and middle hæmorrhoidal. The *veins* and *lymphatics* accompany the arteries. The *nerves* are derived from the pelvic plexus.

Surgical Anatomy.—The vesiculæ seminales are often the seat of an extension of the disease in cases of tuberculous disease of the testicle, and should always be examined from the rectum before coming to a decision with regard to castration in this affection.

THE FEMALE ORGANS OF GENERATION.

EXTERNAL ORGANS.

THE **External Organs of Generation in the Female** are: the mons Veneris, the labia majora and minora, the clitoris, the meatus urinarius, and the orifice of

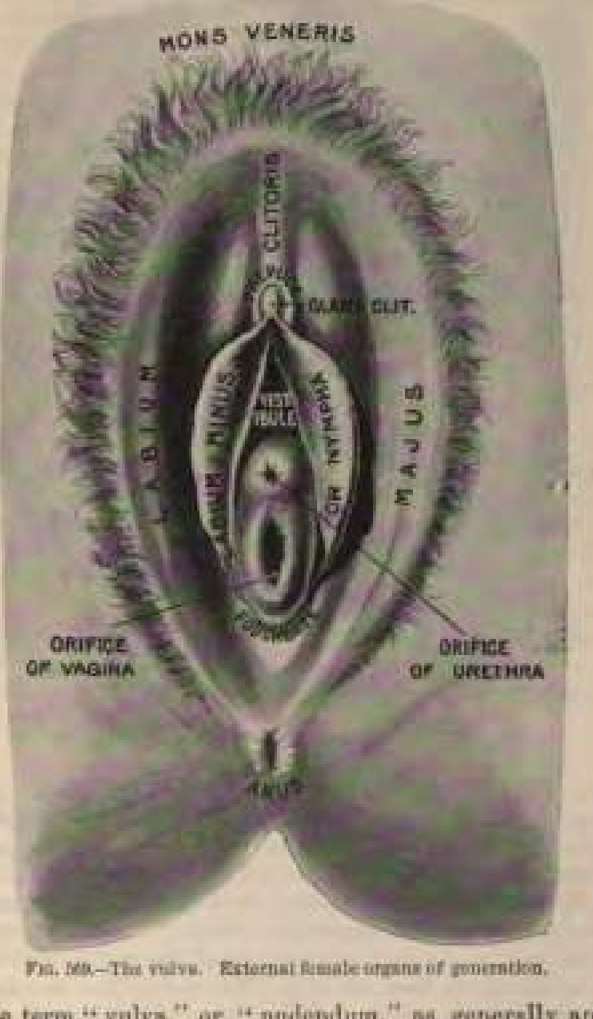


Fig. 569.—The vulva. External female organs of generation.

the vagina. The term "vulva" or "pudendum," as generally applied, includes all these parts.

The **Mons Veneris** is the rounded eminence in front of the pubic symphysis, formed by a collection of fatty tissue beneath the integument. It becomes covered with hair at the time of puberty.

The **Labia Majora** are two prominent longitudinal cutaneous folds extending downward from the mons Veneris to the anterior boundary of the perinæum, and enclosing the common urino-sexual opening. Each labium has two surfaces, an outer, which is pigmented and covered with strong, crisp hairs; and an inner, which is smooth and is beset with large sebaceous follicles and is continuous with the genito-urinary mucous tract; between the two there is a considerable quantity of areolar tissue, fat, and a tissue resembling the dartos of the scrotum, besides vessels, nerves, and glands. The labia are thicker in front, where they form by their meeting the *anterior commissure.* Posteriorly they are not really joined, but appear to become lost in the neighboring integument, terminating close to, and nearly parallel with, each other. Together with the connecting skin between them, they form the posterior commissure or posterior boundary of the vulval orifice. The

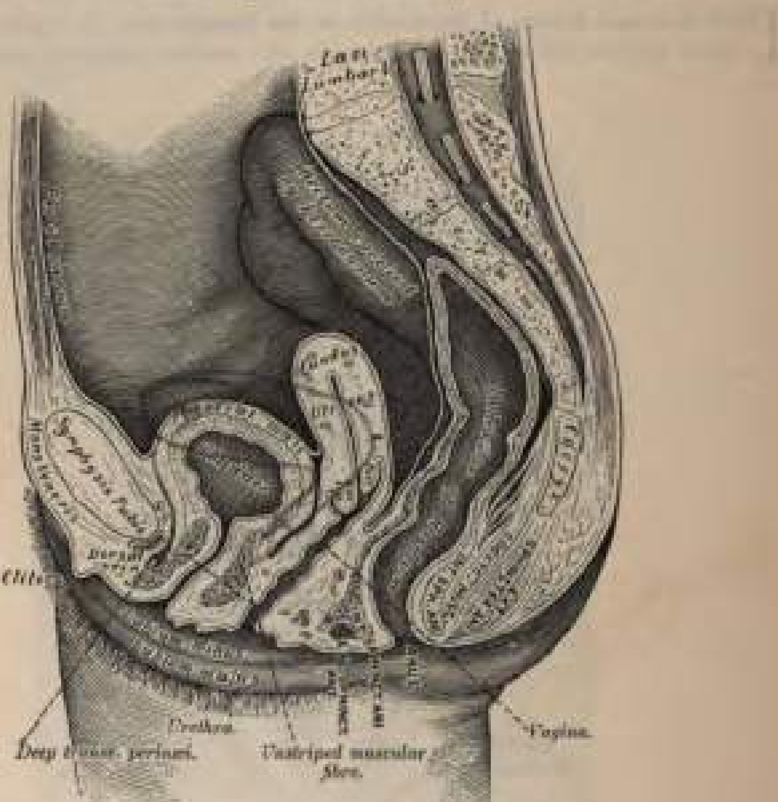


Fig. [illegible].—Vertical median section of the female pelvis.

interval between the posterior commissure and the anus, about an inch to an inch and a quarter in length, constitutes the perinæum. The *fourchette* is the anterior edge of the perineum, and between it and the hymen is a depression, the *fossa navicularis.* The labia correspond to the scrotum in the male.

The **Labia Minora,** or **Nymphæ,** are two small cutaneous folds, situated within the labia majora, and extending from the clitoris obliquely downward, outward, and backward for about an inch and a half on each side of the orifice of the vagina, between which and the labia majora they are lost. Anteriorly, the two labia minora meet and form the *frænum of the clitoris.* The *prepuce* of the clitoris, passing backward on each side, is inserted, as it were, into the labium minora, but is not actually a part of them. The nymphæ are really modified skin. Their internal surfaces have numerous sebaceous follicles.

The **Clitoris** is an erectile structure analogous to the corpora cavernosa of the penis. It is situated beneath the anterior commissure, partially hidden between the anterior extremities of the labia minora. It is connected to the rami of the os pubis and ischium on each side by a crus; the body is short and concealed beneath the labia; the free extremity, or *glans clitoridis*, is a small rounded tubercle, consisting of spongy erectile tissue, and highly sensitive. It is provided, like the penis, with a suspensory ligament, and with two small muscles, the Erectores clitoridis, which are inserted into the crura of the clitoris. The clitoris consists of two corpora cavernosa, composed of erectile tissue enclosed in a dense layer of fibrous membrane, united together along their inner surfaces by an incomplete fibrous pectiniform septum.

Between the clitoris and the entrance of the vagina is a triangular smooth surface, bounded on each side by the nymphæ; this is the *vestibule*.

The orifice of the urethra (**meatus urinarius**) is situated at the back part of the vestibule, about an inch below the clitoris and near the margin of the vagina, surrounded by a prominent elevation of the mucous membrane. Below the meatus urinarius is the orifice of the vagina, more or less closed in the virgin by a membranous fold, the *hymen*.

The **Hymen** varies much in shape. Its commonest form is that of a ring, generally broadest posteriorly: sometimes it is represented by a semilunar fold, with its concave margin turned toward the pubes. A complete septum stretched across the lower part of the vaginal orifice is called "imperforate hymen." Occasionally it is cribriform, or its free margin forms a membranous fringe, or it may be entirely absent. It may persist after copulation, so that it cannot be considered as a test of virginity. After parturition the small rounded elevations known as the *carunculæ myrtiformes* are found as the remains of the hymen.

Glands of Bartholin.—On each side of the commencement of the vagina, and behind the hymen, is a round or oblong body, of a reddish-yellow color, and of the size of a horse-bean, analogous to Cowper's gland in the male. It is called the *gland of Bartholin*. Each gland opens by means of a long single duct immediately external to the hymen, in the angle or groove between it and the nympha.

Bulbi Vestibuli.—Extending from the clitoris, along either side of the vestibule, and lying a little behind the nymphæ, are two large oblong masses, about an inch in length, consisting of a plexus of veins enclosed in a thin layer of fibrous membrane. These bodies are narrow in front, rounded below, and are connected with the crura of the clitoris and rami of the pubes: they are termed by Kobelt the *bulbi vestibuli*, and he considers them analogous to the bulb of the corpus spongiosum in the male. Immediately in front of these bodies is a smaller venous plexus, continuous with the bulbi vestibuli behind and the glans clitoridis in front: it is called by Kobelt the *pars intermedia*, and is considered by him as analogous to that part of the body of the corpus spongiosum which immediately succeeds the bulb.

INTERNAL ORGANS.

The **Internal Organs of Generation** are—the vagina, the uterus and its appendages, the Fallopian tubes, the ovaries and their ligaments.

The **Vagina** extends from the vulva to the uterus. It is situated in the cavity of the pelvis, behind the bladder and in front of the rectum. Its direction is curved upward and backward, at first in the line of the outlet, and afterward in that of the axis of the cavity of the pelvis. Its walls are ordinarily in contact, and its usual shape on transverse section is that of an H, the transverse limb being slightly curved forward or backward, whilst the lateral limbs are somewhat convex toward the median line. Its length is about two and a half inches along its anterior wall, and three and a half inches along its posterior wall. It is constricted at its commencement, and becomes dilated medially, and narrowed near its uterine extremity; it surrounds the vaginal portion of the cervix uteri, a short distance from the os, its attachment extending higher up on the posterior than on the anterior wall of the uterus.

Relations.—Its *anterior surface* is in relation with the base of the bladder and with the urethra. Its *posterior surface* is connected for the lower three-fourths of its extent to the anterior wall of the rectum, the upper fourth being separated from that tube by the recto-vaginal pouch of peritoneum, or pouch of Douglas, between the vagina and rectum. Its sides are enclosed between the Levatores ani muscles.

Structure.—The vagina consists of an internal mucous lining, of a muscular coat, and between the two of a layer of erectile tissue.

The *mucous membrane* is continuous above with that lining the uterus. Its inner surface presents, along the anterior and posterior walls, a longitudinal ridge or raphé, called the *columns of the vagina*, and numerous transverse ridges or rugæ, extending outward from the raphé on either side. These rugæ are divided by furrows of variable depth, giving to the mucous membrane the appearance of being studded over with conical projections or papillæ; they are most numerous near the orifice of the vagina, especially in females before parturition. The epithelium covering the mucous membrane is of the squamous variety. The submucous tissue is very loose and contains numerous large veins, which by their anastomoses form a plexus, together with smooth muscular fibres from the muscular coat; it is regarded by Gussenbauer as an erectile tissue. It contains a number of mucous crypts, but no true glands.

The *muscular coat* consists of two layers: an external longitudinal, which is far the stronger, and an internal circular layer. The longitudinal fibres are continuous with the superficial muscular fibres of the uterus. The strongest fasciculi are those attached to the recto-vesical fascia on each side. The two layers are not distinctly separable from each other, but are connected by oblique decussating fasciculi which pass from the one layer to the other. In addition to this the vagina at its lower end is surrounded by a band of striped muscular fibres, the *sphincter vaginæ* (see page 375).

External to the muscular coat is a layer of connective tissue containing a large plexus of blood-vessels.

The *erectile tissue* consists of a layer of loose connective tissue situated between the mucous membrane and the muscular coat; imbedded in it is a plexus of large veins, and numerous bundles of unstriped muscular fibres derived from the circular muscular layer. The arrangement of the veins is similar to that found in other erectile tissues.

THE UTERUS.

The **Uterus** is the organ of gestation, receiving the fecundated ovum in its cavity, retaining and supporting it during the development of the fœtus, and becoming the principal agent in its expulsion at the time of parturition.

In the virgin state it is pear-shaped, flattened from before backward, and situated in the cavity of the pelvis between the bladder and the rectum; it is retained in its position by the round and broad ligaments on each side, and projects into the upper end of the vagina below. Its upper end, or base, is directed upward and forward; its lower end, or apex, downward and backward, in the line of the axis of the inlet of the pelvis. It therefore forms an angle with the vagina, since the direction of the vagina corresponds to the axis of the cavity and outlet of the pelvis. The uterus measures about three inches in length, two in breadth at its upper part, and nearly an inch in thickness, and it weighs from an ounce to an ounce and a half.

It consists of two parts: (1) the *body*, with its upper broad extremity, the *fundus*; and (2) the *cervix, or neck*, which is partly above the vagina and partly in the vagina. The fundus is placed on a line below the level of the brim of the pelvis, and its direction varies with the condition of the bladder.

The division between the body and cervix is indicated externally by a slight constriction, and by the reflection of the peritoneum from the anterior surface of the uterus on to the bladder, and internally by a narrowing of the canal, called the *internal os*.

The *body* gradually narrows from the fundus to the neck. Its anterior surface is flattened, covered by peritoneum, which becomes separated from it at its union with the cervix, in order to form the utero-vesical pouch, which lies between the uterus and bladder. Its *posterior surface* is convex transversely, covered by peritoneum throughout, and separated from the rectum by some convolutions of the intestine. Its *lateral margins* are concave, and give attachment to the Fallopian tube above, the round ligament below and in front of this, and the ligament of the ovary behind both of these structures.

The *cervix* is the lower constricted segment of the uterus; around its circumference is attached the upper end of the vagina, which extends upward a greater distance behind than in front.

The supravaginal portion is not covered by peritoneum in front; a pad of cellular tissue is interposed between it and the bladder. Behind, the peritoneum is extended over it. The vaginal portion is the rounded lower end projecting into

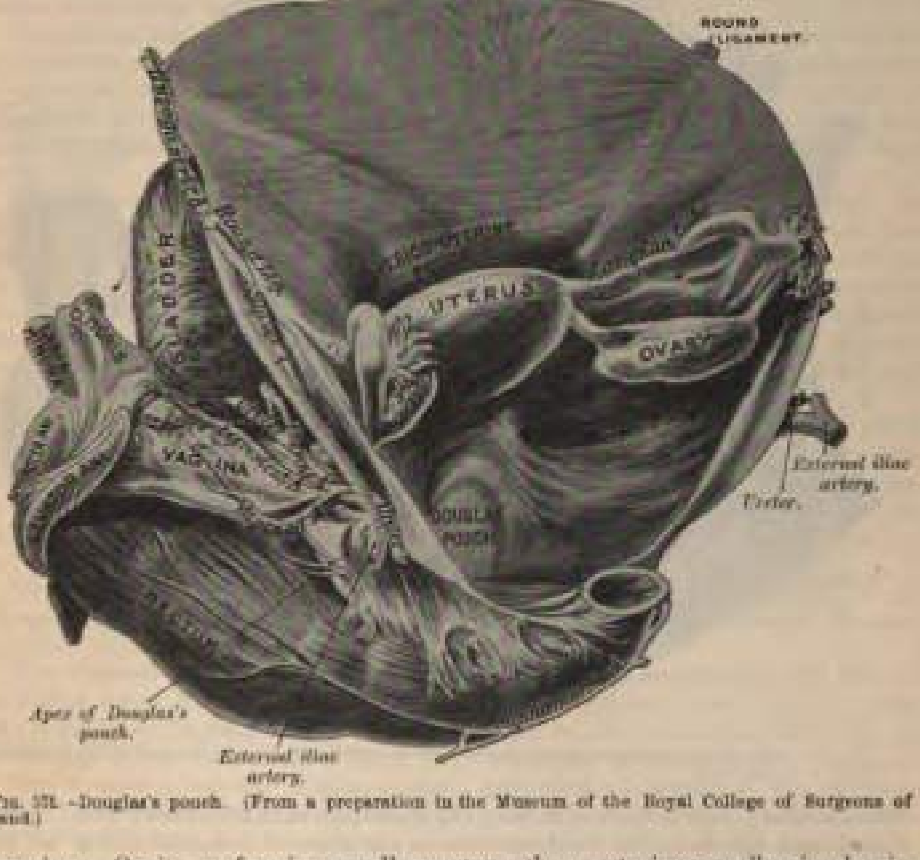


FIG. 571.—Douglas's pouch. (From a preparation in the Museum of the Royal College of Surgeons of England.)

the vagina. On its surface is a small aperture, the *os uteri*, generally circular in shape, but sometimes oval or almost linear. The margin of the opening is, in the absence of past parturition or disease, quite smooth.

Ligaments.—The ligaments of the uterus are eight in number: one anterior; one posterior; two lateral or broad; two sacro-uterine,—all these being formed of peritoneum—and, lastly, two round ligaments.

The *anterior ligament* (vesico-uterine) is reflected on to the bladder from the front of the uterus, at the junction of the cervix and body.

The *posterior ligament* (recto-uterine) passes from the posterior wall of the uterus over the upper fourth of the vagina, and thence on to the rectum and sacrum. It thus forms a pouch called *Douglas's pouch* (Fig. 571), the boundaries of which are, in front, the posterior wall of the uterus, the supravaginal cervix, and the upper fourth of the vagina; behind, the rectum and sacrum; above, the small intestine; and, laterally, the sacro-uterine ligaments.

The *two lateral* or *broad ligaments* pass from the sides of the uterus to the lateral walls of the pelvis, forming a septum across the pelvis, which divides that cavity into two portions. In the anterior part are contained the bladder, urethra, and vagina; in the posterior part, the rectum. Between the two layers of each broad ligament are contained—(1) the Fallopian tubes superiorly; (2) the round ligament; (3) the ovary and its ligament; (4) the parovarium, or organ of

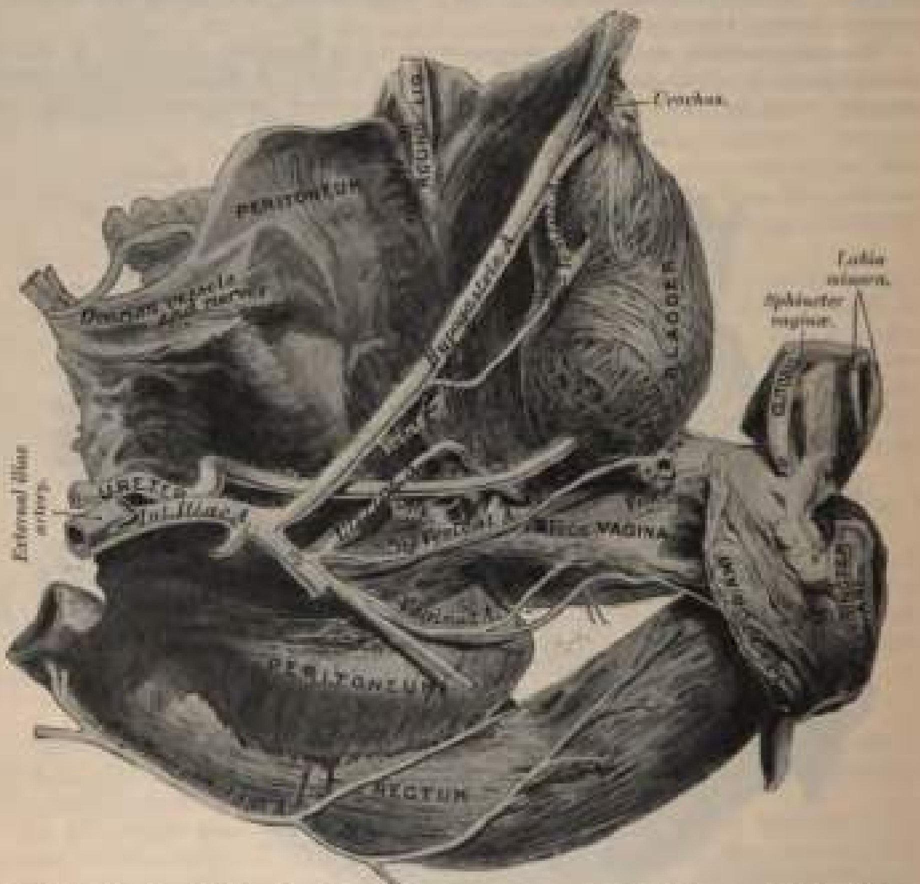


Fig. 572.—Side view of the female pelvic organs. (From a preparation in the Museum of the Royal College of Surgeons of England.)

Rosenmüller; (5) connective tissue; (6) unstriped muscular fibre; and (7) blood-vessels and nerves. The Fallopian tube is contained in a special fold of the broad ligament, which is attached to the part of the ligament near the ovary, and is known by the name of the *mesosalpinx*. Between the fimbriated extremity of the tube and the lower attachment of the broad ligament is a concave rounded margin, called the *infundibulo-pelvic ligament* (Fig. 574).

The *sacro-uterine ligaments* pass from the second and third bones of the sacrum, downward and forward on the lateral aspects of the rectum to be attached one on each side of the uterus at the junction of the supravaginal cervix and the body, this point corresponding internally to the position of the os internum.

The *round ligament* will be described in the sequel.

The **cavity of the uterus** is small in comparison with the size of the organ;

that portion of the cavity which corresponds to the body is triangular, flattened from before backward, so that its walls are closely approximated, and having its base directed upward toward the fundus. At each superior angle is a funnel-shaped cavity, which constitutes the remains of the division of the body of the uterus into two cornua, and at the bottom of each cavity is the minute orifice of the Fallopian tube. At the inferior angle of the uterine cavity is a small constricted opening, the internal orifice (*ostium internum*), which leads into the cavity of the cervix.

The **cavity of the cervix** is somewhat fusiform, flattened from before backward, broader at the middle than at either extremity, and communicates below with the vagina. The wall of the canal presents, anteriorly and posteriorly, a longitudinal column, from which proceed a number of small oblique columns, giving the appearance of branches from the stem of a tree; and hence the name *arbor vitæ uterina* applied to it. These folds usually become very indistinct after the first labor.

Structure.—The uterus is composed of three coats: an external serous coat, a middle or muscular, and an internal mucous coat.

The *serous coat* is derived from the peritoneum; it invests the fundus and the whole of the posterior surface of the uterus; but covers the anterior surface only as far as the junction of the body and cervix. In the lower fourth of the posterior surface the peritoneum, though covering the uterus, is not closely connected with it, being separated from it by a layer of loose cellular tissue and some large veins.

The *muscular coat* forms the chief bulk of the substance of the uterus. In the unimpregnated state it is dense, firm, of a grayish color, and cuts almost like cartilage. It is thick opposite the middle of the body and fundus, and thin at the orifices of the Fallopian tubes. It consists of bundles of unstriped muscular fibres, disposed in layers, intermixed with areolar tissue, blood-vessels, lymphatic vessels, and nerves. In the impregnated state the muscular tissue becomes more prominently developed, and is disposed in three layers—external, middle, and internal.

The external layer is placed beneath the peritoneum, disposed as a thin plane on the anterior and posterior surfaces. It consists of fibres which pass transversely across the fundus, and, converging at each superior angle of the uterus, are continued on the Fallopian tube, the round ligament, the ligament of the ovary: some passing at each side into the broad ligament, and others running backward from the cervix into the sacro-uterine ligaments.

The middle layer of fibres, which is thickest, presents no regularity in its arrangement, being disposed longitudinally, obliquely, and transversely. It contains most blood-vessels.

The internal or deep layer consists of circular fibres arranged in the form of two hollow cones, the apices of which surround the orifices of the Fallopian tubes, their bases intermingling with one another on the middle of the body of the uterus. At the internal os these circular fibres form a distinct sphincter.

The *mucous membrane* is thin, smooth, and closely adherent to the subjacent tissue. It is continuous, through the fimbriated extremity of the Fallopian tubes, with the peritoneum, and through the os uteri with the lining of the vagina.

In the *body* of the uterus it is smooth, soft, of a pale red color lined by columnar ciliated epithelium, and presents, when viewed with a lens, the orifices of numerous tubular follicles arranged perpendicularly to the surface. It is unprovided with any submucosa, but is intimately connected with the innermost layer of the muscular coat, which is regarded as the muscularis mucosæ. In structure its *corium* differs from ordinary mucous membrane, consisting of an embryonic nucleated and highly cellular form of connective tissue in which run numerous large lymphatics. In it are the tube-like *uterine glands*, which are of small size in the unimpregnated uterus, but shortly after impregnation become enlarged, elongated, presenting a contorted or waved appearance toward their closed extremities, which reaches into the muscularis, and may be single or bifid. They consist of a delicate membrane, lined by an epithelium, which becomes ciliated toward the orifices. The changes which take place in the mucous membrane of the impregnated uterus are more fully dealt with in the section on Embryology.

In the *cervix* the mucous membrane is sharply differentiated from that of the uterine cavity. It is thrown into numerous oblique ridges, which diverge from an anterior and posterior longitudinal raphé, presenting an appearance which has received the name of *arbor vitæ*. In the upper two-thirds of the canal the mucous membrane is provided with numerous deep glandular follicles, which secrete a clear viscid alkaline mucus; and in addition, extending through the whole length of the canal, are a variable number of little cysts, presumably follicles, which have become occluded and distended with retained secretion. They are called the *ovula Nabothi*. The mucous membrane covering the lower half of the cervical canal

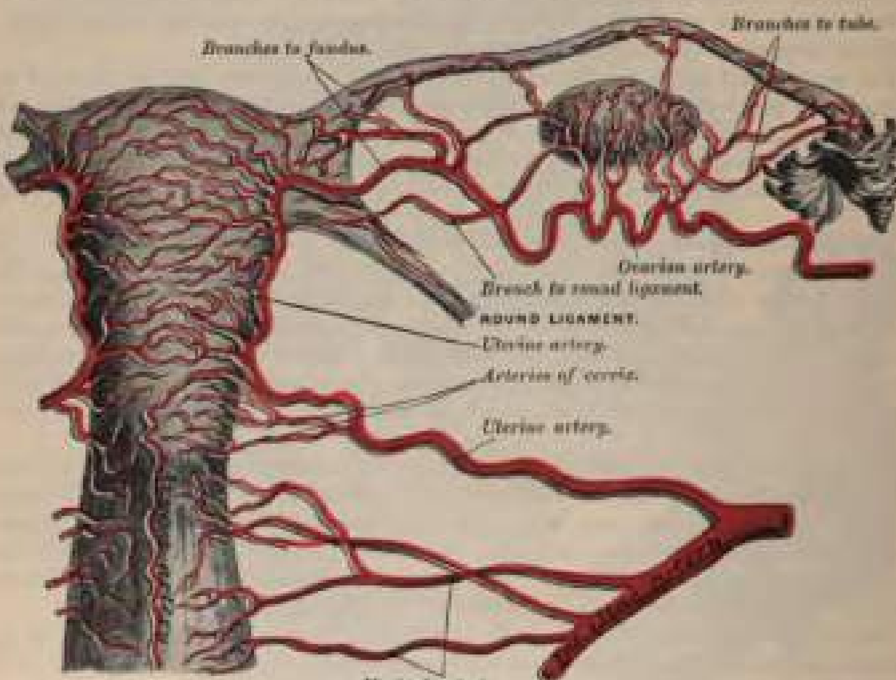


FIG. 672.—The arteries of the internal organs of generation of the female, seen from behind. (After Hyrtl.)

presents numerous papillæ. The epithelium of the upper two-thirds is cylindrical and ciliated, but below this it loses its cilia, and gradually changes to squamous epithelium close to the external os.

Vessels and Nerves.—The *arteries of the uterus* are the uterine, from the internal iliac, and the ovarian, from the aorta. They are remarkable for their tortuous course in the substance of the organ and for their frequent anastomoses. The termination of the ovarian artery meets the termination of the uterine artery, and forms an anastomotic trunk from which branches are given off to supply the uterus, their disposition being, as shown by Sir John Williams, circular. The *veins* are of large size, and correspond with the arteries. In the impregnated uterus these vessels form the *uterine sinuses*, consisting of the lining membrane of the veins adhering to the walls of the canal channelled through the substance of the uterus. They terminate in the uterine plexuses. The *lymphatics* of the body terminate in the lumbar glands, those of the cervix in the pelvic glands. The *nerves* are derived from the inferior hypogastric and ovarian plexuses, and from the third and fourth sacral nerves.

The form, size, and situation of the uterus vary at different periods of life and under different circumstances.

In the fœtus the uterus is contained in the abdominal cavity, projecting beyond the brim of the pelvis. The cervix is considerably larger than the body.

At puberty the uterus is pyriform in shape, and weighs from eight to ten drachms. It has descended into the pelvis, the fundus being just below the level of the brim of this cavity. The arbor vitæ is distinct, and extends to the upper part of the cavity of the organ.

The position of the uterus in the adult is liable to considerable variation, depending chiefly on the condition of the bladder and rectum. When the bladder is empty the entire uterus is directed forward, and is at the same time bent on itself at the junction of the body and cervix, so that the body lies upon the bladder. As the latter fills the uterus gradually becomes more and more erect, until with a fully distended bladder the fundus may be directed backward toward the sacrum.

During menstruation the organ is enlarged and more vascular, its surfaces rounder; the os externum is rounded, its labia swollen, and the lining membrane of the body thickened, softer, and of a darker color. According to Sir J. Williams, at each recurrence of menstruation a molecular disintegration of the mucous membrane takes place, which leads to its complete removal, only the bases of the glands imbedded in the muscle being left. At the cessation of menstruation by a proliferation of the remaining structures a fresh mucous membrane is formed.

During pregnancy the uterus becomes enormously enlarged, and in the ninth month reaches the epigastric region. The increase in size is partly due to growth of pre-existing muscle and partly to development of new fibres.

After parturition the uterus nearly regains its usual size, weighing about an ounce and a half; but its cavity is larger than in the virgin state, the external orifice is more marked, its edges present a fissured surface, its vessels are tortuous, and its muscular layers are more defined.

In old age the uterus becomes atrophied, and paler and denser in texture; a more distinct constriction separates the body and cervix. The ostium internum and, occasionally, the vaginal orifice often become obliterated, and its labia almost entirely disappear.

Surgical Anatomy.—The uterus may require removal in cases of malignant disease or for fibroid tumors. Carcinoma is the most common form of malignant disease of the uterus, though cases of sarcoma do occur. It may show itself either as a columnar carcinoma or as a squamous carcinoma; the former commencing either in the cervix or body of the uterus, the latter always commencing in the epithelial cells of the mucous covering of the vaginal surface of the cervix. The columnar form may be treated in the early stage, before fixation has taken place, by removal of the uterus, either through the vagina or by means of abdominal section. The former operation is the better of the two, and is attended by a much smaller death-rate. Vaginal hysterectomy is performed by placing the patient in the lithotomy position and introducing a large duckbill speculum. The cervix is then seized with a volsellum and pulled down as far as possible and the mucous membrane of the vagina incised around the cervix and as near to it as the disease will allow, especially in front, where the ureters are in danger of being wounded. A pair of dressing forceps are then pushed through into Douglas's pouch and opened sufficiently to allow of the introduction of the two forefingers, by means of which the opening is dilated laterally as far as the sacro-uterine ligaments. A somewhat similar proceeding is adopted in front, but here the bladder has to be separated from the anterior wall of the uterus for about an inch before the vesico-uterine fold of peritoneum can be reached. This is done by carefully burrowing upward with a director and stripping the tissues off the anterior uterine wall. When the vesico-uterine pouch has been opened and the opening dilated laterally, the uterus remains attached only by the broad ligaments, in which are contained the vessels that supply the uterus. Before division of the ligaments, these vessels have to be dealt with. The forefinger of the left hand is introduced into Douglas's pouch and an aneurism needle, armed with a long silk ligature, is inserted into the vesico-uterine pouch, and is pushed through the broad ligament about an inch above its lower level and at some distance from the uterus. One end of the ligature is now pulled through the anterior opening, and in this way we have the lowest inch of the broad ligament, in which is contained the uterine artery (Fig. 573), enclosed in a ligature. This is tied tightly, and the operation is repeated on the other side. The broad ligament is then divided on either side, between the ligature and the uterus, to the extent to which it has been constricted. By traction on the volsellum which grasps the cervix, the uterus can be pulled considerably further down in the vagina, and a second inch of the broad ligament is treated in a similar way. This second ligature will embrace the pampiniform plexus of veins, and, when the broad ligament has been divided on either side, it will be found that a third ligature can be made to pass over the Fallopian tube and top of the broad ligament, after the uterus has been dragged down as far as possible. After the third ligature has been tied and the structures between it and the uterus divided, this organ will be freed from all its connections and can be removed from the vagina. This canal is then sponged out and lightly dressed with gauze; no sutures being used. The gauze may be removed at the end of the second day. In squamous epithelioma, amputation of the cervix is all that is necessary in those cases where the disease is recognized before it has invaded the walls of the vagina or the neighboring broad ligaments. The operation consists in removing a wedge-shaped piece of the uterus, including the cervix, through the vagina and attaching the cut surfaces of the stump to the anterior and posterior vaginal walls, so as to prevent retraction. In the treatment of uterine fibroids which require operative interference, removal of the whole of the uterus together with the tumors through an abdominal incision gives the most satisfactory results; for, if the tumor is large, its size acts as a barrier to its safe delivery through the pelvis and genital passages. After the abdomen has been opened the uterine vessels are secured and the broad ligaments divided in a similar manner to that employed in vaginal hysterectomy, except that the proceeding is commenced from above. When the two first ligatures have been tied, and the broad ligament divided, it will be found that the uterus can be raised out of the pelvis. A transverse incision is now made through the peritoneum, where it is reflected from the anterior surface of the uterus on to the back of the bladder and the serous membrane peeled from the surface of the uterus until the vagina is reached. The anterior wall of this canal is cut across. The uterus is now turned forward and the peritoneum at the bottom of Douglas's pouch incised transversely, and the posterior wall of the vagina cut across until it meets the incision on the anterior wall. The uterus is now almost free, and is held only by the lower part of the broad ligament on either side, containing the uterine artery. A third ligature is made to encircle this, and, after having been tied, the structures are divided between the ligature and the uterus. The organ can now be removed. The vagina is plugged with gauze, and the external wound closed in the usual way. The vagina acts as a drain, and therefore the opening into it is not sutured.

APPENDAGES OF THE UTERUS.

The **appendages of the uterus** are the Fallopian tubes, the ovaries and their ligaments, and the round ligaments. They are placed in the following order: in front is the round ligament; the Fallopian tube occupies the upper margin of the broad ligament; the ovary and its ligament are behind and below both.

THE FALLOPIAN TUBES.

The **Fallopian Tubes,** or **Oviducts**, convey the ova from the ovaries to the cavity of the uterus. They are two in number, one on each side, situated in the upper margin of the broad ligament, extending from each superior angle of the uterus to the sides of the pelvis. Each tube is about four inches in length; and is described as consisting of three portions: (1) the *isthmus*, or inner constricted third; (2) the *ampulla*, or outer dilated portion, which curves over the ovary; and (3) the

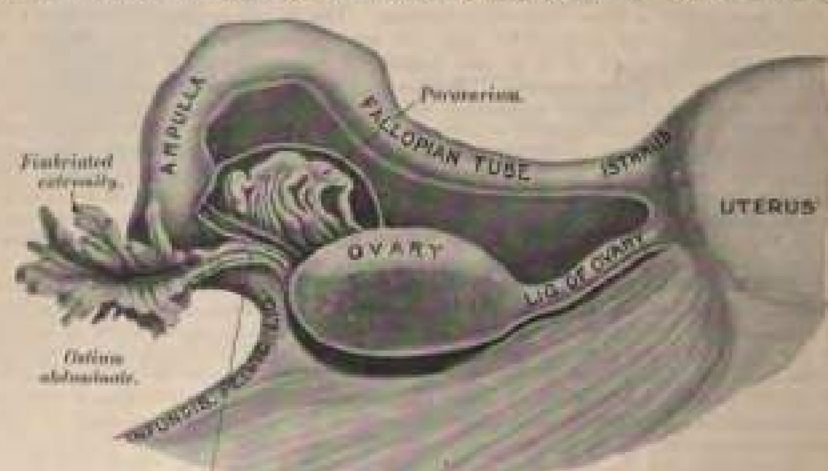


FIG. 574.—Uterine appendages, seen from behind. (Henle.)

infundibulum with its *ostium abdominale*, surrounded by fimbriæ, one of which is attached to the ovary, the *fimbria ovarica*. The general direction of the Fallopian tube is outward, backward and downward. The uterine opening is minute, and will admit only a fine bristle; the abdominal opening is somewhat larger. In connection with the fimbriæ of the Fallopian tube or with the broad ligament close to them there is frequently one or more small vesicles floating on a long stalk of peritoneum. These are termed the *hydatids of Morgagni*.

Structure.—The Fallopian tube consists of three coats—serous, muscular, and mucous.

The *external* or *serous coat* is peritoneal.

The *middle* or *muscular coat* consists of an external longitudinal and an internal circular layer of muscular fibres continuous with those of the uterus.

The *internal* or *mucous coat* is continuous with the mucous lining of the uterus and, at the free extremity of the tube, with the peritoneum. It is thrown into longitudinal folds, which in the outer, larger part of the tube, or ampulla, are much more extensive than in the narrow canal of the isthmus. The lining epithelium is columnar ciliated. This form of epithelium is also found on the inner surface of the fimbriæ, while on the outer or serous surfaces of these processes the epithelium gradually merges into the endothelium of the peritoneum.

THE OVARIES.

The **ovaries** (*testes muliebres*, Galen) are analogous to the testes in the male. They are oval-shaped bodies of an elongated form, flattened from above downward, situated one on each side of the uterus, in the posterior layer of the broad ligament behind and below the Fallopian tubes. Each ovary is connected by its anterior straight margin to the broad ligament; by its lower extremity to the uterus by a proper ligament, the *ligament of the ovary;* and by its upper end to the fimbriated extremity of the Fallopian tube by the ovarian fimbria; its mesial and lateral surfaces and posterior convex border are free. The ovaries are of a grayish-pink color, and present either a smooth or puckered, uneven surface. They are each about an inch and a half in length, three-quarters of an inch in width, and about a third of an inch thick, and weigh from one to two drachms.

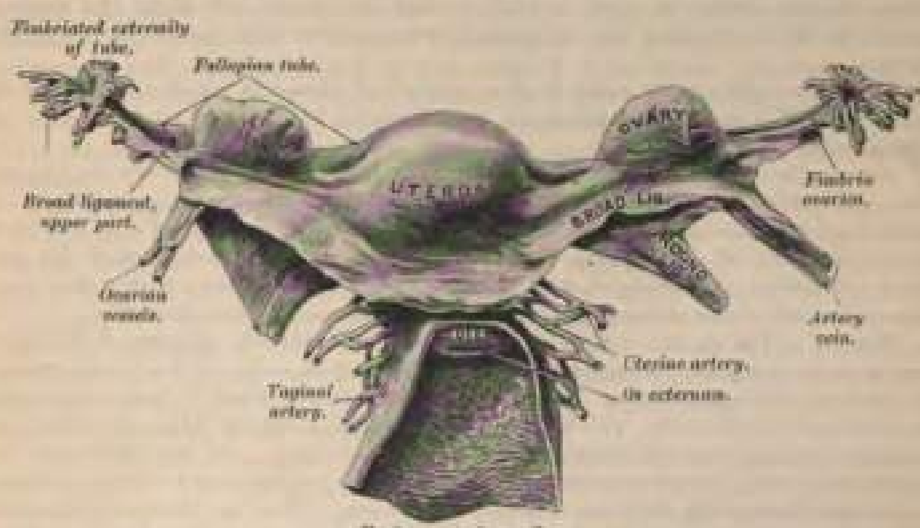


FIG. 575.—The uterus and its appendages. Posterior view. The parts have been somewhat displaced from their proper position in the preparation of the specimen; thus the right ovary has been raised above the Fallopian tube, and the fimbriated extremities of the tubes have been turned upward and outward. (From a preparation in the Museum of the Royal College of Surgeons of England.)

The exact position of the ovary has been the subject of considerable difference of opinion, and writers differ much as to what is to be regarded as the normal position. The fact appears to be that it is differently placed in different individuals. Hasse has described it as being situated with its long axis transverse, or almost transverse, to the pelvic cavity. Schultze, on the other hand, believes that its long axis is antero-posterior. Kölliker asserts that the truth lies between these two views, and that the ovary is placed obliquely in the pelvis, its long axis lying parallel to the external iliac vessels, with its surface directed inward and outward, and its convex free border upward. His has made some important observations on this subject, and his views are largely accepted. He teaches that the uterus rarely lies symmetrically in the middle of the pelvic cavity, but is generally inclined to one or other side, most frequently to the left, in the proportion of three to two. The position of the two ovaries varies according to the inclination of the uterus. When the uterus is inclined to the left, the ovary of this side lies with its long axis vertical and with one side closely applied to the outer wall of the pelvis, while the ovary of the opposite side, being dragged upon by the inclination of the uterus, lies obliquely, its outer extremity being retained in close apposition to the side of the pelvis by the infundibulo-pelvic ligament (page 1030). When, on the other hand, the uterus is inclined to the right, the position of the two ovaries is exactly reversed, the right being vertical and the left oblique. In whichever position the ovary is placed, the Fallopian tube forms a loop around it, the uterine half ascending obliquely over it, and the outer half, including the dilated extremity, descending and bulging freely behind it. From this extremity the fimbriæ pass upward on to the ovary and closely embrace it.

Waldeyer[1] states, as the result of the examination of fifty female subjects, ranging from early childhood to advanced age, that the ovary "lies on the lateral pelvic wall and vertically when the woman takes the erect posture." Its *tubal* extremity is near the external iliac vein; its uterine end is directed downward, while the Fallopian tube overlies it so as to cover it on its medial face entirely or nearly so. Its convex margin looks downward and backward toward the pelvic cavity and rectum, while its straight margin or hilum lies laterally on the pelvic wall attached to the mesosalpinx. He also finds that it lies in a distinct but shallow groove (*fossa ovarii*) limited above by the hypogastric artery and below by the ureter, in such a manner that the ureter lies along the convex margin of the ovary, and the hypogastric artery passes near the hilum or straight margin.

Structure.—The ovary consists of a number of Graafian vesicles imbedded in the meshes of a stroma or framework, and invested by a serous covering derived from the peritoneum.

Serous Covering.—Though the investing membrane of the ovary is derived from the peritoneum, it differs essentially from that structure, inasmuch as its epithelium consists of a single layer of columnar cells, instead of the flattened endothelial cells of other parts of the membrane; this has been termed the *germinal epithelium of Waldeyer*, and gives to the surface of the ovary a dull gray aspect instead of the shining smoothness of serous membranes generally.

Stroma.—The stroma is a peculiar soft tissue, abundantly supplied with blood-vessels, consisting for the most part of spindle-shaped cells, with a small amount of ordinary connective tissue. These cells have been regarded by some anatomists as unstriped muscle-cells, which, indeed, they most resemble (His); by others as connective-tissue cells (Waldeyer, Henle, and Kölliker). On the surface of the organ this tissue is much condensed, and forms a layer composed of short connective-tissue fibres, with fusiform cells between them. This was formerly regarded as a distinct fibrous covering, and was termed the *tunica albuginea*, but is nothing more than a condensed layer of the stroma of the ovary.

Graafian Vesicles.—Upon making a section of an ovary numerous round transparent vesicles of various sizes are to be seen; they are the *Graafian vesicles* or ovisacs containing the ova. Immediately beneath the superficial covering is a layer of stroma, in which are a large number of minute vesicles of uniform size, about $\frac{1}{100}$ of an inch in diameter. These are the Graafian vesicles in their earliest condition, and the layer where they are found has been termed the *cortical layer*. They are especially numerous in the ovary of the young child. After puberty

[1] *Journal of Anatomy and Physiology*, vol. xxxii.

and during the whole of the child-bearing period large and mature, or almost mature, Graafian vesicles are also found in the cortical layer in small numbers, and also "corpora lutea," the remains of vesicles which have burst and are undergoing atrophy and absorption. Beneath this superficial stratum other large and more mature Graafian vesicles are found imbedded in the ovarian stroma.

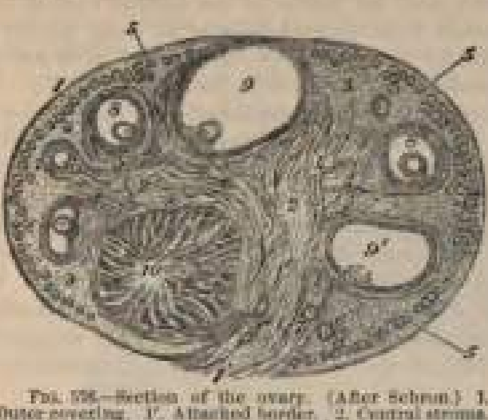


FIG. 576.—Section of the ovary. (After Schrön.) 1. Outer covering. 1'. Attached border. 2. Central stroma. 3. Peripheral stroma. 4. Blood-vessels. 5. Graafian follicles in their earliest stage. 6, 7, 8. More advanced follicles. 9. An almost mature follicle. 9'. Follicle from which the ovum has escaped. 10. Corpus luteum.

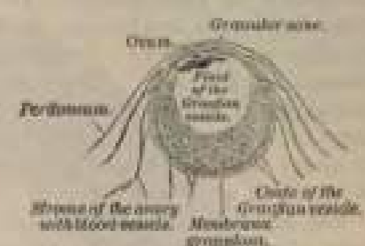


FIG. 577.—Section of the Graafian vesicle. (After Von Baer.)

These increase in size as they recede from the surface toward a highly vascular stroma in the centre of the organ, termed the *medullary substance* (*zona vasculosa*, Waldeyer). This stroma forms the tissue of the hilum by which the ovary is attached, and through which the blood-vessels enter; it does not contain any Graafian vesicles.

The larger *Graafian follicles* consist of an external fibro-vascular coat connected with the surrounding stroma of the ovary by a network of blood-vessels; and an internal coat, named *ovicapsule*, which is lined by a layer of nucleated cells, called the *membrana granulosa*. The fluid contained in the interior of the vesicles is transparent and albuminous, and in it is suspended the ovum. In that part of the mature Graafian vesicle which is nearest the surface of the ovary the cells of the membrana granulosa are collected into a mass which projects into the cavity of the vesicle. This is termed the *discus proligerus*, and in this the ovum is imbedded.[1]

The ova are formed from the germinal epithelium on the surface of the ovary. This becomes thickened, and in it are seen some cells which are larger and more rounded than the rest; these are termed the *primordial ova*. The germinal epithelium grows downward in the form of tubes or columns, termed the *egg tubes* of Pflüger, into the ovarian stroma, which grows outward between the tubes, and ultimately cuts them off from the germinal epithelium. These tubes are further subdivided into rounded *nests* or groups, each containing a primordial ovum which undergoes further development and growth while the surrounding cells of the nest form the epithelium of the Graafian follicle.

The development and maturation of the Graafian vesicles and ova continue uninterruptedly from puberty to the end of the fruitful period of woman's life, while their formation commences before birth. Before puberty the ovaries are small, the Graafian vessels contained in them are disposed in a comparatively thick layer in the cortical substance; here they present the appearance of a large number of minute closed vesicles, constituting the early condition of the Graafian vesicle; many, however, never attain full development, but shrink and disappear. At puberty the ovaries enlarge, and become more vascular, the Graafian vesicles are developed in greater abundance, and their ova are capable of fecundation.

Discharge of the Ovum.—The Graafian vesicles, after gradually approaching the surface of the ovary, burst: the ovum and fluid contents of the vesicles are

[1] For a description of the ovum, see section on Embryology.

liberated, and escape on the exterior of the ovary, passing thence into the Fallopian tube.[1]

In the fœtus the ovaries are situated, like the testes, in the lumbar region, near the kidneys. They may be distinguished from those bodies at an early period by their elongated and flattened form, and by their position, which is at first oblique and then nearly transverse. They gradually descend into the pelvis.

Lying above the ovary in the broad ligament between it and the Fallopian tube is the *organ of Rosenmüller*, called also the *parovarium* or *epoöphoron*. This is the remnant of a fœtal structure, the development of which is described in the section on Embryology. In the adult it consists of a few closed convoluted tubes, lined with epithelium, which converge toward the ovary at one end and at the other are united by a longitudinal tube, which is the homologue of the *duct of Gärtner* in the cow. This duct terminates in a bulbous enlargement. The parovarium is connected at the uterine extremity with the remains of the Wolffian duct. A few scattered rudimentary tubules, best seen in the child, are situated in the broad ligament between the parovarium and the uterus. These constitute the *paroöphoron of Waldeyer*.

The **ligament of the ovary** is a rounded cord, which extends from each superior angle of the uterus to the inner extremity of the ovary; it consists of fibrous tissue and a few muscular fibres derived from the uterus.

The **Round Ligaments** are two rounded cords, between four and five inches in length, situated between the layers of the broad ligament in front of and below the Fallopian tube. Commencing on each side at the superior angle of the uterus, this ligament passes forward, upward, and outward through the internal abdominal ring, along the inguinal canal, to the labia majora, in which it becomes lost. The round ligament consists principally of muscular tissue prolonged from the uterus; also of some fibrous and areolar tissue, besides blood-vessels and nerves, enclosed in a duplicature of peritoneum, which in the fœtus is prolonged in the form of a tubular process for a short distance into the inguinal canal. This process is called the *canal of Nuck*. It is generally obliterated in the adult, but sometimes remains pervious even in advanced life. It is analogous to the peritoneal pouch which precedes the descent of the testis.

Vessels and Nerves.—The *arteries of the ovaries and Fallopian tubes* are the ovarian from the aorta. They enter the attached border, or hilum, of the ovary. The *veins* follow the course of the arteries; they form a plexus near the ovary, the *pampiniform plexus*. The *nerves* are derived from the inferior hypogastric or pelvic plexus, and from the ovarian plexus, the Fallopian tube receiving a branch from one of the uterine nerves.

THE MAMMARY GLANDS.

The **mammæ**, or breasts, secrete the milk, and are accessory glands of the generative system. They exist in the male as well as in the female; but in the former only in the rudimentary state, unless their growth is excited by peculiar circumstances. In the female they are two large hemispherical eminences situated toward the lateral aspect of the pectoral region, corresponding to the intervals between the third and sixth or seventh ribs, and extending from the side of the sternum to the axilla. Their weight and dimensions differ at different periods of life and in different individuals. Before puberty they are of small size, but enlarge as the generative organs become more completely developed. They increase during pregnancy, and especially after delivery, and become atrophied in old age. The left mamma is generally a little larger than the right. Their base is nearly circular, flattened or slightly concave, and has its long diameter directed upward and outward toward the axilla; they are separated from the Pectoral

[1] This is effected either by application of the tube to the ovary, or by a curling upward of the fimbriated extremity, so that the ovum is caught as it falls.

muscles by a layer of fascia. The outer surface of the mamma is convex, and presents, just below the centre, a small conical prominence, the nipple (*mammilla*). The surface of the nipple is dark-colored and surrounded by an areola having a colored tint. In the virgin the areola is of a delicate rosy hue; about the second month after impregnation it enlarges and acquires a darker tinge, which increases as pregnancy advances, becoming in some cases of a dark-brown or even black color. This color diminishes as soon as lactation is over, but is never entirely lost throughout life. These changes in the color of the areola are of importance in forming a conclusion in a case of suspected first pregnancy.

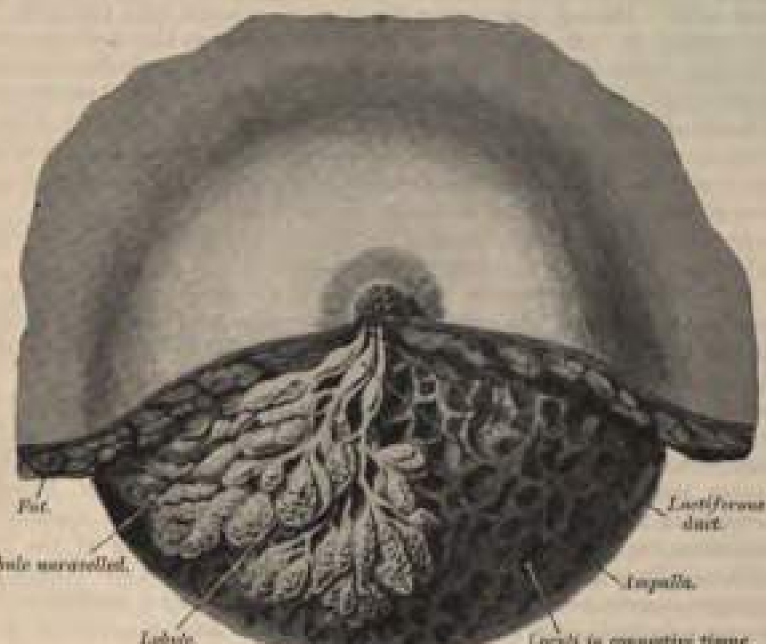


FIG. 578.—Dissection of the lower half of the female breast during the period of lactation. (From Luschka.)

The **nipple** is a cylindrical or conical eminence capable of undergoing a sort of erection from mechanical excitement, a change mainly due to the contraction of its muscular fibres. It is of a pink or brownish hue, its surface wrinkled and provided with papillæ, and it is perforated by numerous orifices, the apertures of the lactiferous ducts. Near the base of the nipple and upon the surface of the areoli are numerous sebaceous glands, which become much enlarged during lactation, and present the appearance of small tubercles beneath the skin. These glands secrete a peculiar fatty substance, which serves as a protection to the integument of the nipple during the act of sucking. The nipple consists of numerous vessels, intermixed with plain muscular fibres, which are principally arranged in a circular manner around the base, some few fibres radiating from base to apex.

Structure.—The mamma consists of gland-tissue; of fibrous tissue, connecting its lobes; and of fatty tissue in the intervals between the lobes. The gland-tissue, when freed from fibrous tissue and fat, is of a pale reddish color, firm in texture, circular in form, flattened from before backward, thicker in the centre than at the circumference, and presenting several inequalities on its surface, especially in front. It consists of numerous lobes, and these are composed of lobules connected together by areolar tissue, blood-vessels, and ducts. The smallest lobules consist of a cluster of rounded alveoli, which open into the smallest branches of the lactiferous ducts; these ducts, uniting, form larger ducts, which terminate in a single canal, corresponding with one of the chief subdivisions of the gland. The number of excretory ducts varies from fifteen to twenty; they are termed the *tubuli lactiferi*, or *galactophori*. They converge toward the areola, beneath which they form dilatations, or *ampullæ*, which serve as reservoirs for the milk, and at the base of the nipple become contracted and pursue a straight course to its summit, perforating it by separate orifices considerably narrower than the ducts themselves. The ducts are composed of areolar tissue, with longitudinal and transverse elastic fibres; muscular fibres are entirely absent; their mucous lining is continuous, at the point of the nipple, with the integument. The epithelium of the mammary gland differs according to the state of activity of the organ. In the gland of a woman who is not pregnant or suckling the alveoli are very small and solid, being filled with a mass of granular polyhedral cells. During pregnancy the alveoli enlarge and the cells undergo rapid multiplication. At the commencement of lactation the cells in the centre of the alveolus undergo fatty degeneration, and are eliminated in the first milk as *colostrum-corpuscles*. The peripheral cells of the alveolus remain, and form a single layer of granular, short columnar cells, with a spherical nucleus, lining the limiting membrana propria. These cells during the state of activity of the gland are capable of forming, in their interior, oil-globules, which are then ejected into the lumen of the alveolus and constitute the milk-globules.

The *fibrous tissue* invests the entire surface of the breast, and sends down septa between its lobes, connecting them together.

The *fatty tissue* surrounds the surface of the gland and occupies the interval between its lobes. It usually exists in considerable abundance, and determines the form and size of the gland. There is no fat immediately beneath the areola and nipple.

Vessels and Nerves.—The *arteries* supplying the mammæ are derived from the thoracic branches of the axillary, the intercostals, and internal mammary. The *veins* describe an anastomotic circle round the base of the nipple, called by Haller the *circulus venosus*. From this large branches transmit the blood to the circumference of the gland and end in the axillary and internal mammary veins. The *lymphatics*, for the most part, run along the lower border of the Pectoralis major to the axillary glands; some few, from the inner side of the breast, perforate the intercostal spaces and empty themselves into the anterior mediastinal glands. The *nerves* are derived from the anterior and lateral cutaneous nerves of the thorax.

THE SURGICAL ANATOMY OF HERNIA.

Dissection (Fig. 217).—For dissection of the parts concerned in inguinal hernia a male subject, free from fat, should always be selected. The body should be placed in the supine position, the abdomen and pelvis raised by means of blocks placed beneath them, and the lower extremities rotated outward, so as to make the parts as tense as possible. If the abdominal walls are flaccid, the cavity of the abdomen should be inflated through an aperture made at the umbilicus. An incision should be made along the middle line from a little below the umbilicus to the symphysis pubis, and continued along the front of the scrotum, and a second incision from the anterior superior spine of the ilium to just below the umbilicus. These incisions should divide the integument, and the triangular-shaped flap included between them should be reflected downward and outward, when the superficial fascia will be exposed.

The Superficial Fascia of the Abdomen.—This, over the greater part of the abdominal wall, consists of a single layer of fascia, which contains a variable amount of fat; but as it approaches the groin it is easily divisible into two layers, between which are found the superficial vessels and nerves and the superficial inguinal lymphatic glands.

The *superficial layer* (*fascia of Camper*), is thick, areolar in texture, containing adipose tissue in its meshes, the quantity of which varies in different subjects. Below, it passes over Poupart's ligament, and is continuous with the outer layer of the superficial fascia of the thigh. In the male this fascia is continued over the penis and over the outer surface of the cord to the scrotum, where it helps to form the dartos. As it passes to the penis and over the cord to the scrotum it changes its character, becoming thin, destitute of adipose tissue, and of a pale reddish color; and in the scrotum it acquires some involuntary muscular fibres. From the scrotum it may be traced backward, to be continuous with the superficial fascia of the perinæum. In the female this fascia is continued into the labia majora.

The *hypogastric branch of the ilio-hypogastric nerve* perforates the aponeurosis of the External oblique muscle about an inch above and a little to the outer side of the external abdominal ring, and is distributed to the integument of the hypogastric region.

The *ilio-inguinal nerve* escapes at the external abdominal ring, and is distributed to the integument of the upper and inner part of the thigh, to the scrotum in the male and to the labium in the female.

The *superficial epigastric artery* arises from the femoral about half an inch below Poupart's ligament, and, passing through the saphenous opening in the fascia lata, ascends on to the abdomen, in the superficial fascia covering the External oblique muscle, nearly as high as the umbilicus. It distributes branches to the superficial inguinal lymphatic glands, the superficial fascia, and the integument, anastomosing with branches of the deep epigastric and internal mammary arteries.

The *superficial circumflex iliac artery*, the smallest of the cutaneous branches, arises close to the preceding, and, piercing the fascia lata, runs outward, parallel with Poupart's ligament, as far as the crest of the ilium, dividing into branches which supply the superficial inguinal lymphatic glands, the superficial fascia, and the integument, anastomosing with the deep circumflex iliac and with the gluteal and external circumflex arteries.

The *superficial external pudic* (*superior*) *artery* arises from the inner side of the femoral artery close to the preceding vessels, and, after passing through the saphenous opening, courses inward across the spermatic cord, to be distributed to the integument on the lower part of the abdomen, the penis and scrotum in the male, and the labium in the female, anastomosing with branches of the internal pudic.

The Superficial Veins.—The veins accompanying these superficial vessels are usually much larger than the arteries; they terminate in the internal saphenous vein.

The *superficial inguinal lymphatic glands* are placed immediately beneath the integument, are of large size, and vary from eight to ten in number. They are divisible into two groups: an upper, disposed irregularly along Poupart's ligament, which receive the lymphatic vessels from the integument of the scrotum, penis, parietes of the abdomen, perineal and gluteal regions, and the mucous membrane of the urethra; and an inferior group, which surround the saphenous opening in the fascia lata, a few being sometimes continued along the saphenous

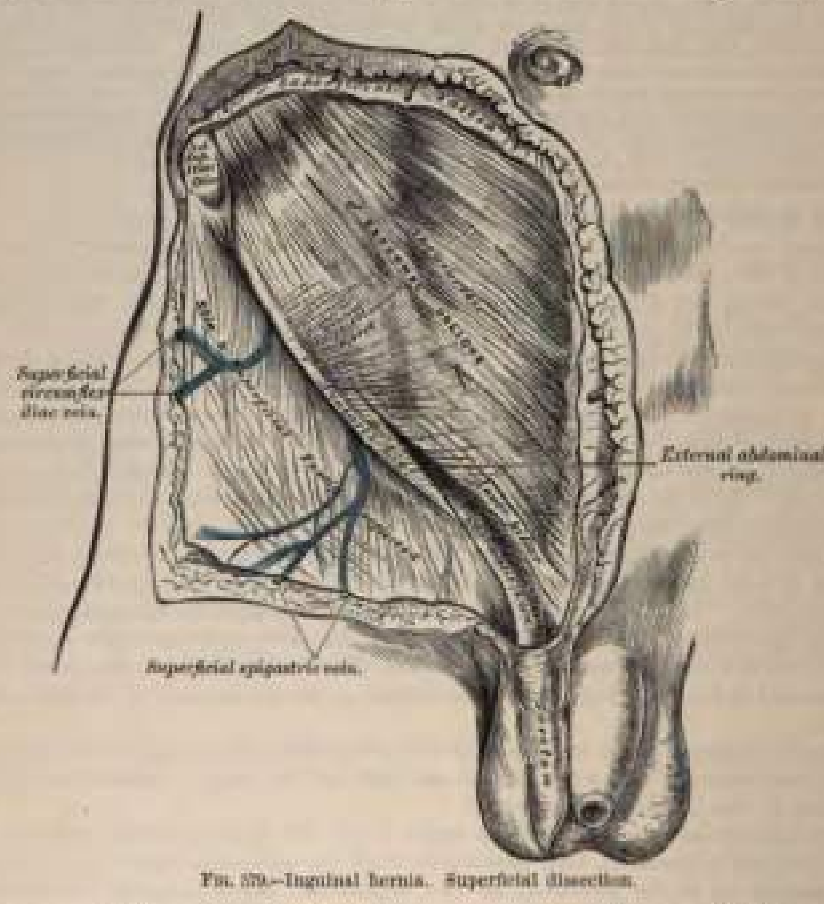


FIG. 579.—Inguinal hernia. Superficial dissection.

vein to a variable extent. This latter group receive the superficial lymphatic vessels from the lower extremity.

The *deep layer of the superficial fascia (fascia of Scarpa)* is thinner and more membranous in character than the superficial layer. In the middle line it is intimately adherent to the linea alba; above, it is continuous with the superficial fascia over the rest of the trunk; below, it blends with the fascia lata of the thigh a little below Poupart's ligament; below and internally, in the male, it is continued over the penis and over the outer surface of the cord to the scrotum, where it helps to form the dartos. From the scrotum it may be traced backward to be continuous with the base of the triangular ligament of the urethra. In the female it is continuous with the labia majora.

The scrotum is a cutaneous pouch which contains the testes and part of the spermatic cords, and into which an inguinal hernia frequently descends (see page 1014).

The Aponeurosis of the External Oblique Muscle.—This is a thin but strong membranous aponeurosis, the fibres of which are directed obliquely downward and inward. That portion of the aponeurosis which extends between the anterior superior spine of the ilium and the spine of the os pubis is a broad band, folded inward and continuous below with the fascia lata; it is called *Poupart's ligament.* The portion which is reflected from Poupart's ligament at the spine of the os pubis, along the pectineal line, is called *Gimbernat's ligament.* From the point of attachment of the latter to the pectineal line a few fibres pass upward and inward, behind the inner pillar of the ring, to the linea alba. They diverge as they ascend, and form a thin, triangular, fibrous band, which is called the *triangular fascia of the abdomen.*

The External or Superficial Abdominal Ring.—Just above and to the outer side of the crest of the os pubis an interval is seen in the aponeurosis of the External oblique, called the *external abdominal ring.* This aperture is oblique in direction, somewhat triangular in form, and corresponds with the course of the fibres of the aponeurosis. It usually measures from base to apex about an inch, and transversely about half an inch. It is bounded below by the crest of the os pubis; above, by a series of curved fibres, the *intercolumnar,* which pass across the upper angle of the ring, so as to increase its strength; and on either side, by the margins of the opening in the aponeurosis, which are called the *columns* or *pillars of the ring.*

The *external pillar,* which at the same time is *inferior* from the obliquity of its direction, is the stronger; it is formed by that portion of Poupart's ligament which is inserted into the spine of the os pubis; it is curved, so as to form a kind of groove, upon which the spermatic cord rests.

The *internal* or *superior pillar* is a broad, thin, flat band, which is attached to the front of the body of the os pubis, interlacing with its fellow of the opposite side in front of the symphysis pubis, that of the right side being superficial.

The external abdominal ring gives passage to the spermatic cord in the male and round ligament in the female; it is much larger in men than in women, on account of the large size of the spermatic cord, and hence the great frequency of inguinal hernia in men.

The *intercolumnar fibres* are a series of curved tendinous fibres which arch across the lower part of the aponeurosis of the External oblique. They have received their name from stretching across between the two pillars of the external ring; they increase the strength of the lower part of the aponeurosis and prevent the divergence of the pillars from one another. They are thickest below, where they are connected to the outer third of Poupart's ligament, and are inserted into the linea alba, describing a curve, with the convexity downward. They are much thicker and stronger at the outer angle of the external ring than internally, and are more strongly developed in the male than in the female. These intercolumnar fibres, as they pass across the external abdominal ring, are themselves connected together by delicate fibrous tissue, thus forming a fascia which, as it is attached to the pillars of the ring, covers it in, and is called the *intercolumnar fascia.* This intercolumnar fascia is continued downward as a tubular prolongation around the outer surface of the cord and testis, and encloses them in a distinct sheath; hence it is also called the *external spermatic fascia.* The sac of an inguinal hernia in passing through the external abdominal ring receives an investment from the intercolumnar fascia.

If the finger is introduced a short distance into the external ring, and then, if the limb is extended and rotated outward, the aponeurosis of the External oblique, together with the iliac portion of the fascia lata, will be felt to become tense and the external ring much contracted; if the limb is, on the contrary, flexed upon the pelvis and rotated inward, this aponeurosis will become lax, and the external ring sufficiently enlarged to admit the finger with comparative ease; hence the patient should always be put in the latter position when the taxis is applied for the reduction of an inguinal hernia, in order that the abdominal walls may be relaxed as much as possible.

The aponeurosis of the External oblique should be removed by dividing it across in the same direction as the external incisions, and reflecting it downward and outward: great care is requisite in separating it from the aponeurosis of the muscle beneath. The lower part of the Internal oblique and the Cremaster are then exposed, together with the inguinal canal, which contains the spermatic cord (Fig. 580). The mode of insertion of Poupart's and Gimbernat's ligaments into the os pubis should also be examined.

Poupart's ligament, or the crural arch, is the lower border of the aponeurosis of the External oblique muscle, which extends from the anterior superior spine of the ilium to the spine of the os pubis. From this latter point it is reflected outward to be attached to the pectineal line for about half an inch, forming

Fig. 580.—Inguinal hernia. Dissection showing the Internal oblique and Cremaster.

Gimbernat's ligament. Its general direction is curved downward toward the thigh, where it is continuous with the fascia lata. Its outer half is rounded and oblique in direction; its inner half gradually widens at its attachment to the os pubis, is more horizontal in direction, and lies beneath the spermatic cord.

Gimbernat's Ligament (Fig. 588) is that portion of the aponeurosis of the External oblique muscle which is reflected upward and outward from the spine of the os pubis to be inserted into the pectineal line. It is about half an inch in length, larger in the male than in the female, almost horizontal in direction in the erect posture, and of a triangular form, with the base directed outward. Its base or outer margin is concave, thin, and sharp, and lies in contact with the femoral sheath, forming the inner boundary of the crural ring (see Fig. 588). Its apex corresponds to the spine of the os pubis. Its posterior margin is attached to the pectineal line, and is continuous with the pubic portion of the fascia lata. Its anterior margin is continuous with Poupart's ligament.

The **triangular fascia of the abdomen** is a band of tendinous fibres, of a triangular shape, which is attached by its apex to the pectineal line, where it is continuous with Gimbernat's ligament. It passes inward beneath the spermatic cord, and expands into a somewhat fan-shaped fascia, lying behind the inner pillar of the external abdominal ring and in front of the conjoined tendon, and interlaces with the ligament of the other side at the linea alba.

The **Internal oblique muscle** has been previously described (page 360). The part which is now exposed is partly muscular and partly tendinous in structure. Those fibres which arise from Poupart's ligament, few in number and paler in color than the rest, arch downward and inward across the spermatic cord, and, becoming tendinous, are inserted, conjointly with those of the Transversalis, into the crest of the os pubis and pectineal line, forming what is known as the conjoined tendon of the Internal oblique and Transversalis. This tendon is inserted immediately behind the inguinal canal and external abdominal ring, serving to protect what would otherwise be a weak point in the abdominal wall. Sometimes this tendon is insufficient to resist the pressure from within, and is carried forward in front of the protrusion through the external ring, forming one of the coverings of direct inguinal hernia, or the hernia forces its way through the fibres of the conjoined tendon.

The **Cremaster** is a thin muscular layer composed of a number of fasciculi which arise from the middle of Poupart's ligament at the inner side of the Internal oblique, being connected with that muscle and also occasionally with the Transversalis. It passes along the outer side of the spermatic cord, descends with it through the external ring upon the front and sides of the cord, and forms a series of loops which differ in thickness and length in different subjects. Those at the upper part of the cord are exceedingly short, but they become in succession longer and longer, the longest reaching down as low as the testicle, where a few are inserted into the tunica vaginalis. These loops are united together by areolar tissue, and form a thin covering over the cord and testis, the *fascia cremasterica*. The fibres ascend along the inner side of the cord, and are inserted by a small pointed tendon into the crest of the os pubis and front of the sheath of the Rectus muscle.

It will be observed that the origin and insertion of the Cremaster is precisely similar to that of the lower fibres of the Internal oblique. This fact affords an easy explanation of the manner in which the testicle and cord are invested by this muscle. At an early period of fœtal life the testis is placed at the lower and back part of the abdominal cavity, but during its descent toward the scrotum, which takes place before birth, it passes beneath the arched border of the Internal oblique. In its passage beneath this muscle some fibres are derived from its lower part which accompany the testicle and cord into the scrotum.

It occasionally happens that the loops of the Cremaster surround the cord, some lying behind as well as in front. It is probable that under these circumstances the testis in its descent passes through, instead of beneath, the fibres of the Internal oblique.

In the descent of an oblique inguinal hernia, which takes the same course as the spermatic cord, the Cremaster muscle forms one of its coverings. This muscle becomes largely developed in cases of hydrocele and large old scrotal herniæ. No such muscle exist in the female, but an analogous structure is developed in those cases where an oblique inguinal hernia descends beneath the margin of the Internal oblique.

The Internal oblique should be detached from Poupart's ligament, separated from the Transversalis to the same extent as in the previous incisions, and reflected inward on to the sheath of the Rectus (Fig. 581). The deep circumflex iliac vessels, which lie between these two muscles, form a valuable guide to their separation.

The **Transversalis muscle** has been previously described (page 362). The part which is now exposed is partly muscular and partly tendinous in structure; it arises from the outer third of Poupart's ligament, its fibres curve downward and inward, and are inserted, together with those of the Internal oblique, into the lower part of the linea alba, into the crest of the os pubis and the pectineal line, forming what is known as the conjoined tendon of the Internal oblique and Transversalis. Between the lower border of this muscle and Poupart's ligament a space is left in which is seen the transversalis fascia.

The **inguinal** or **spermatic canal** contains the spermatic cord in the male and the round ligament in the female. It is an oblique canal, about an inch and a half in length, directed downward and inward and placed parallel with, and a little above, Poupart's ligament. It commences above at the internal or deep abdominal ring, which is the point where the cord enters the inguinal canal, and terminates below at the external or superficial ring. It is bounded, *in front*, by the integument and superficial fascia, by the aponeurosis of the External oblique throughout its whole length, and by the Internal oblique for its outer third; *behind*, by the triangular fascia, the conjoined tendon of the Internal oblique and Transversalis, transversalis fascia, and the subperitoneal fat and peritoneum; *above*, by the arched fibres of the Internal oblique and Transversalis; *below*, by the union of the transversalis fascia with Poupart's ligament. That form of hernia in which the intestine follows the course of the spermatic cord along the inguinal canal is called *oblique inguinal hernia*.

The **transversalis fascia** is a thin aponeurotic membrane which lies between

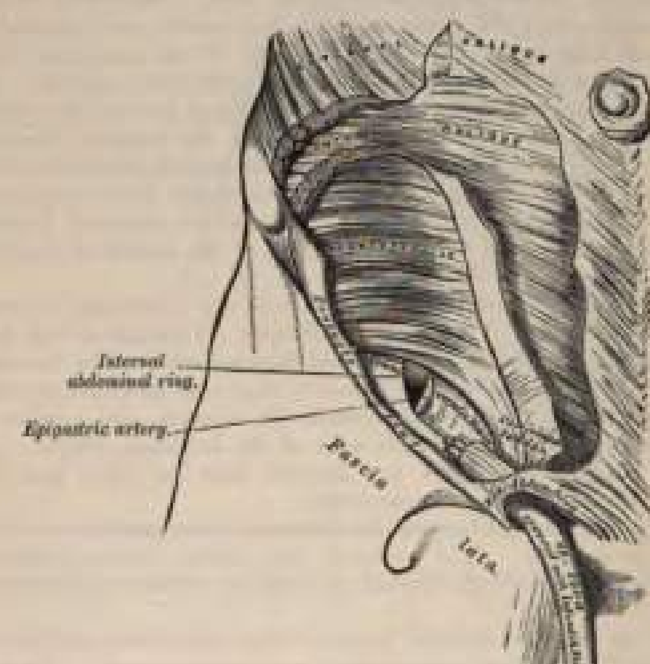


FIG. 581.—Inguinal hernia. Dissection showing the Transversalis muscle, the transversalis fascia, and the internal abdominal ring.

the inner surface of the Transversalis muscle and the peritoneum. It forms part of the general layer of fascia which lines the interior of the abdominal and pelvic cavities, and is directly continuous with the iliac and pelvic fasciæ.

In the inguinal region the transversalis fascia is thick and dense in structure, and joined by fibres from the aponeurosis of the Transversalis muscle; but it becomes thin and cellular as it ascends to the Diaphragm. Below, it has the following attachments: external to the femoral vessels it is connected to the posterior margin of Poupart's ligament, and is there continuous with the iliac fascia. Internal to the vessels it is thin, and attached to the os pubis and pectineal line behind the conjoined tendon, with which it is united; and, corresponding to the points where the femoral vessels pass into the thigh, this fascia descends in front of them, forming the anterior wall of the femoral sheath. The spermatic cord in the male and the round ligament in the female pass through this fascia; the point where they pass through is called the internal or deep abdominal ring. This opening is not visible externally, owing to a prolongation of the transversalis fascia on the structures forming the infundibuliform fascia.

The **internal** or **deep abdominal ring** is situated in the transversalis fascia, midway between the anterior superior spine of the ilium and symphysis pubis, and about half an inch above Poupart's ligament. It is of an oval form, its long diameter being directed upward and downward; it varies in size in different subjects, and is much larger in the male than in the female. It is bounded above and externally by the arched fibres of the Transversalis muscle, below and internally by the deep epigastric vessels. It transmits the spermatic cord in the male and the round ligament in the female. From its circumference, a thin, funnel-shaped membrane, the *infundibuliform fascia*, is continued round the cord and testis, enclosing them in a distinct pouch. When the sac of an oblique inguinal hernia passes through the internal or deep abdominal ring, the infundibuliform fascia constitutes one of its coverings.

The Subperitoneal Areolar Tissue.—Between the transversalis fascia and the peritoneum is a quantity of loose areolar tissue. In some subjects it is of considerable thickness and loaded with adipose tissue. Opposite the internal ring it is continued round the surface of the cord, forming a loose sheath for it.

The *deep epigastric artery* arises from the external iliac artery a few lines above Poupart's ligament. It at first descends to reach this ligament, and then ascends obliquely along the inner margin of the internal or deep abdominal ring, lying between the transversalis fascia and the peritoneum, and passing upward pierces the transversalis fascia and enters the sheath of the Rectus muscle by passing over the semilunar fold of Douglas. Consequently the deep epigastric artery bears a very important relation to the internal abdominal ring as it passes obliquely upward and inward from its origin from the external iliac. In this part of its course it lies along the lower and inner margin of the internal ring and beneath the commencement of the spermatic cord. At its commencement it is crossed by the vas deferens in the male and by the round ligament in the female.

The **peritoneum,** corresponding to the inner surface of the internal ring, presents a well-marked depression, the depth of which varies in different subjects. A thin fibrous band is continued from it along the front of the cord for a variable distance, and becomes ultimately lost. This is the remains of the pouch of peritoneum which, in the fœtus, precedes the cord and testis into the scrotum, the obliteration of which commences soon after birth. In some cases the fibrous band can only be traced a short distance, but occasionally it may be followed, as a fine cord, as far as the upper end of the tunica vaginalis. Sometimes the tube of peritoneum is closed only at intervals and presents a sacculated appearance, or a single pouch may extend along the whole length of the cord, which may be closed above, or the pouch may be directly continuous with the peritoneum by an opening at its upper part.

In the female fœtus the peritoneum is also prolonged in the form of a tubular process for a short distance into the inguinal canal. This process is called the canal of Nuck. It is generally obliterated in the adult, but sometimes it remains pervious even in advanced life.

In order to understand the relation of the peritoneum to inguinal hernia, it is necessary to view the anterior abdominal wall from its internal aspect, when it will be seen as shown in Fig. 582. Between the upper margin of the front of the pelvis and the umbilicus, the peritoneum, when viewed from behind, will be seen to be raised into five vertical folds, with intervening depressions, by more or less prominent bands which converge to the umbilicus. One of these is situated in the median line, and is caused by the urachus, the remnant of the allantois: it extends from the summit of the bladder to the umbilicus. The fold of peritoneum covering it is known as the *plica urachi*. On either side of this is a prominent band, caused by the obliterated hypogastric artery, which extends from the side of the bladder obliquely upward and inward to the umbilicus. This is covered by a fold of peritoneum, which is known as the *plica hypogastrica*. To either side of these three cords is the deep epigastric artery, which ascends obliquely upward and inward from a point midway between the symphysis pubis and the anterior superior spine of the ilium to the semilunar fold of Douglas, in front of which it disappears. It is covered by a fold of peritoneum, which is known as the *plica epigastrica*. Between these raised folds are depressions of the peritoneum, constituting so-called fossæ. The most internal, between the plica urachi and the plica hypogastrica, is known as the *internal inguinal fossa* (fovea supravesicalis). The middle one is situated between the plica hypogastrica and the plica epigastrica, and is termed the *middle inguinal fossa* (fovea inguinalis mesialis). The external one is external to

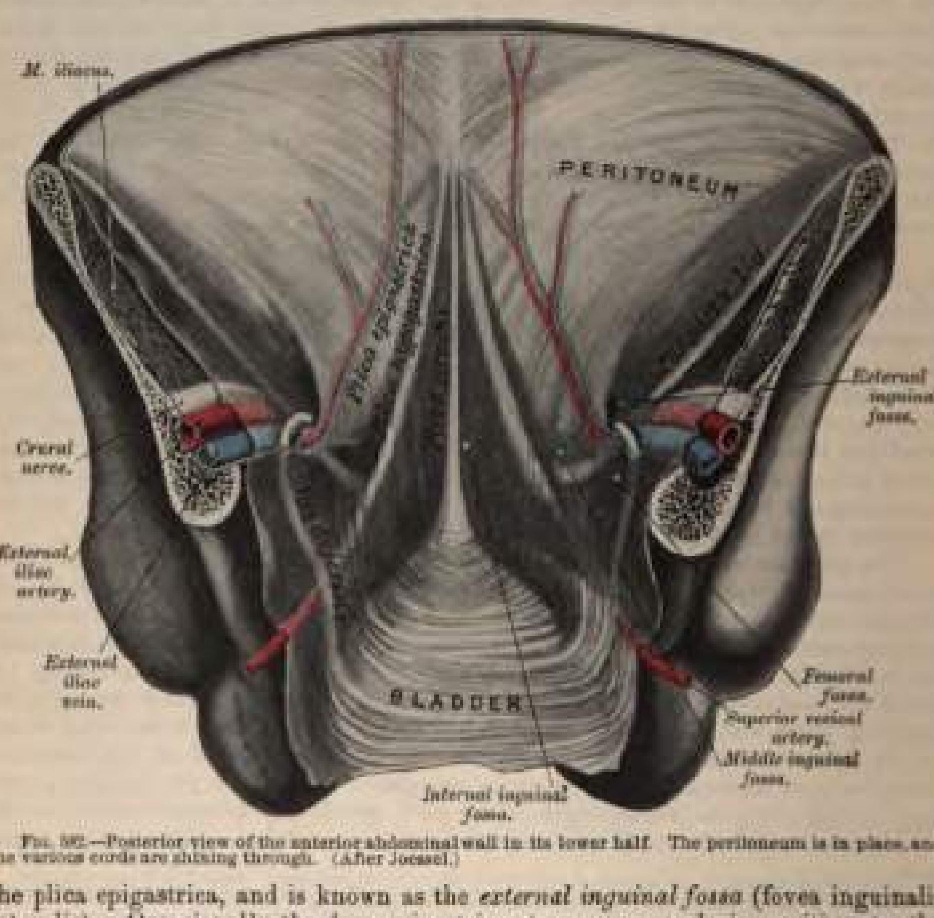


FIG. 582.—Posterior view of the anterior abdominal wall in its lower half. The peritoneum is in place, and the various cords are shining through. (After Joessel.)

the plica epigastrica, and is known as the *external inguinal fossa* (fovea inguinalis lateralis). Occasionally the deep epigastric artery corresponds in position to the obliterated hypogastric artery, and then there is but one fold on each side of the middle line, and the two external fossæ are merged into one. In the usual condition of the parts the floor of the external inguinal fossa corresponds to the internal abdominal ring, and into this fossa an oblique inguinal hernia descends. To the inner side of the plica epigastrica are the two internal fossæ, and through either of these a direct hernia may descend, as will be explained in the sequel (page 1052). The whole of this space, that is to say, the space between the deep epigastric artery, the margin of the Rectus and Poupart's ligament, is commonly known as *Hesselbach's triangle*. These three depressions or fossæ are situated above the level of Poupart's ligament, and in addition to them is another below the ligament, corresponding to the position of the femoral ring, and into which a femoral hernia descends.

INGUINAL HERNIA.

Inguinal hernia is that form of protrusion which makes its way through the abdomen in the inguinal region.

There are two principal varieties of inguinal hernia—external or oblique, and internal or direct.

External or *oblique inguinal hernia*, the more frequent of the two, takes the same course as the spermatic cord. It is called *external* from the neck of the sac being on the outer or iliac side of the deep epigastric artery.

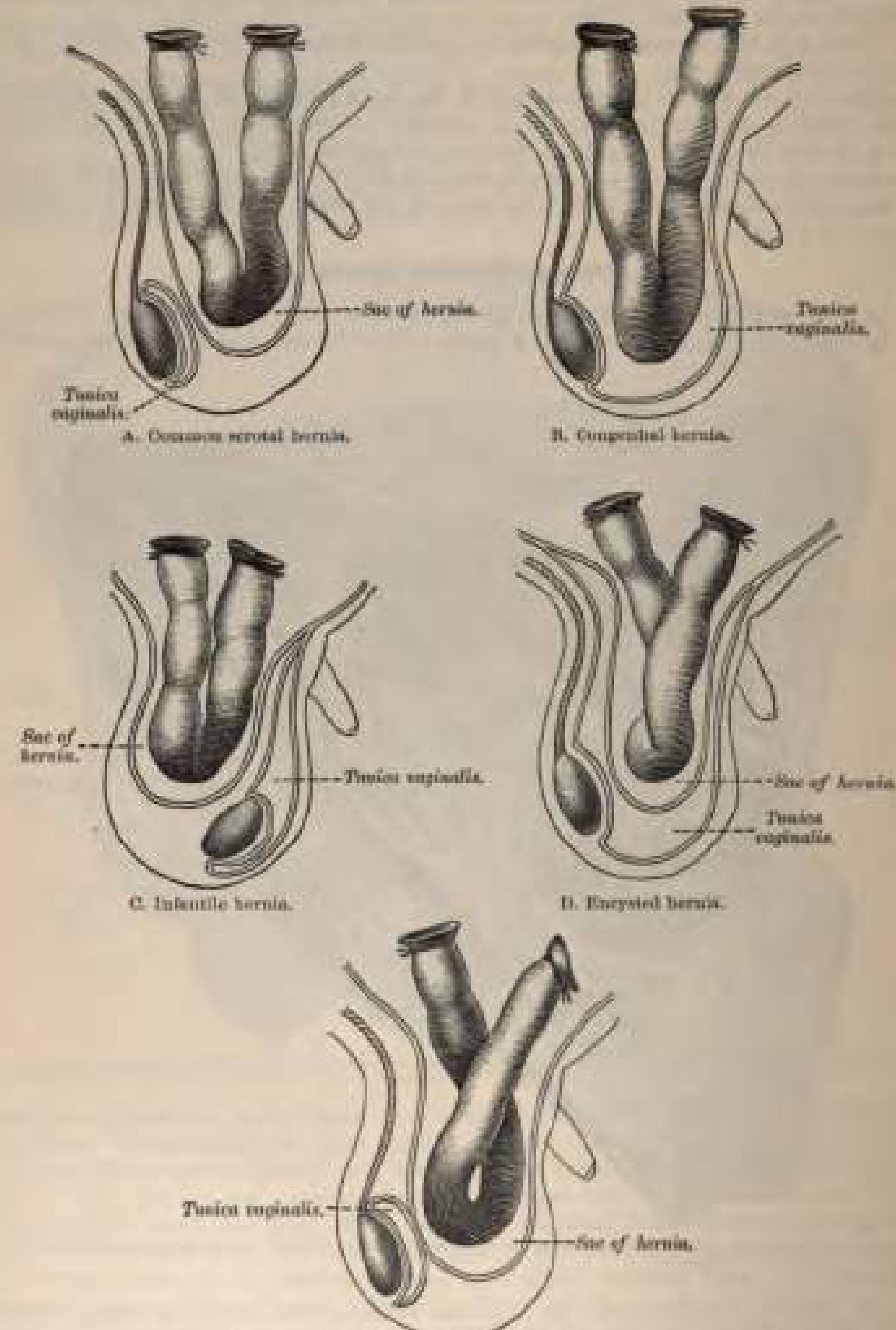
Internal or *direct inguinal hernia* does not follow the same course as the cord, but protrudes through the abdominal wall on the inner or pubic side of the deep epigastric artery.

Oblique Inguinal Hernia.

In **oblique inguinal hernia** the intestine escapes from the abdominal cavity at the internal ring, pushing before it a pouch of peritoneum, which forms the hernial

FIG. [illegible].—Oblique inguinal hernia, showing its various coverings. (From a preparation in the Museum of the Royal College of Surgeons.)

sac (Fig. 584, A). As it enters the inguinal canal it receives an investment from the subserous areolar tissue, and is enclosed in the infundibuliform process of the transversalis fascia. In passing along the inguinal canal it displaces upward the arched fibres of the Transversalis and Internal oblique muscles, and is surrounded by the fibres of the Cremaster. It then passes along the front of the cord, and escapes from the inguinal canal at the external ring, receiving an investment from the intercolumnar fascia. Lastly, it descends into the scrotum, receiving coverings from the superficial fascia and the integument.



E. Hernia into the funicular process.

Fig. 584.—Varieties of oblique inguinal hernia.

The coverings of this form of hernia, after it has passed through the external ring, are, from without inward, the integument, superficial fascia, intercolumnar fascia, Cremaster muscle, infundibuliform fascia, subserous areolar tissue, and peritoneum.

This form of hernia lies in front of the vessels of the spermatic cord and seldom extends below the testis, on account of the intimate adhesion of the coverings of the cord to the tunica vaginalis.

The *seat of stricture* in oblique inguinal hernia is either at the external ring, in the inguinal canal, caused by the fibres of the Internal oblique or Transversalis; or at the internal ring, most frequently in the latter situation. If it is situated at the external ring, the division of a few fibres at one point of its circumference is all that is necessary for the replacement of the hernia. If in the inguinal canal or at the internal ring, it may be necessary to divide the aponeurosis of the External oblique so as to lay open the inguinal canal. In dividing the stricture the direction of the incision should be upward.

When the intestine passes along the inguinal canal and escapes from the external ring into the scrotum, it is called *complete oblique inguinal* or *scrotal hernia*. If the intestine does not escape from the external ring, but is retained in the inguinal canal, it is called *incomplete inguinal hernia*, or *bubonocele*. In each of these cases the coverings which invest it will depend upon the extent to which it descends in the inguinal canal.

There are some other varieties of oblique inguinal hernia depending upon congenital defects in the processus vaginalis. The testicle in its descent from the abdomen into the scrotum is preceded by a pouch of peritoneum, which about the period of birth becomes shut off from the general peritoneal cavity by a closure of that portion of the pouch which extends from the internal abdominal ring to near the upper part of the testicle, the lower portion of the pouch remaining persistent as the tunica vaginalis. It would appear that this closure commences at two points—viz. at the internal abdominal ring and at the top of the epididymis—and gradually extends until, in the normal condition, the whole of the intervening portion is converted into a fibrous cord. From failure in the completion of this process variations in the relation of the hernial protrusion to the testicle and tunica vaginalis are produced, which constitute distinct varieties of inguinal hernia, and which have received separate names and are of surgical importance. These are congenital, infantile, encysted, and hernia of the funicular process.

Congenital Hernia (Fig. 584, B).—Where the pouch of peritoneum which precedes the cord and testis in its descent remains patent throughout and is unclosed at any point, the cavity of the tunica vaginalis communicates directly with the peritoneum. The intestine descends along this pouch into the cavity of the tunica vaginalis, which constitutes the sac of the hernia, and the gut lies in contact with the testicle.

Infantile and Encysted Hernia.—Where the pouch of peritoneum is occluded at the internal ring only, and remains patent throughout the rest of its extent, two varieties of oblique inguinal hernia may be produced, which have received the names of infantile and encysted hernia. In the *infantile* form (Fig. 584, C) the bowel, pressing upon the septum and the peritoneum in its immediate neighborhood, causes it to yield and form a sac, which descends behind the tunica vaginalis, so that in front of the bowel there are three layers of peritoneum, the two layers of the tunica vaginalis and its own sac. In the *encysted* form (Fig. 584, D) pressure in the same position—namely, at the occluded spot in the pouch—causes the septum to yield and form a sac which projects *into* and not *behind* the tunica vaginalis, as in the infantile form, and thus it constitutes a sac within a sac, so that in front of the bowel there are two layers of peritoneum—one layer of the tunica vaginalis and its own sac.

Hernia into the Funicular Process (Fig. 584, E).—Where the pouch of peritoneum is occluded at the lower point only—that is, just above the testicle—the intestine descends into the pouch of peritoneum as far as the testicle, but is prevented from entering the sac of the tunica vaginalis by the septum which has formed between it and the pouch, so that it resembles the congenital form in all respects, except that, instead of enveloping the testicle, that body can be felt below the rupture.

Direct Inguinal Hernia.

In **direct inguinal hernia** the protrusion makes its way through some part of the abdominal wall internal to the epigastric artery.

At the lower part of the abdominal wall is a triangular space (*Hesselbach's triangle*), bounded externally by the deep epigastric artery, internally by the margin of the Rectus muscle, below by Poupart's ligament (Fig. 582). The conjoined tendon is stretched across the inner two-thirds of this space, the remaining portion of the space having only the subperitoneal areolar tissue and the transversalis fascia between the peritoneum and the aponeurosis of the External oblique muscle.

In some cases the hernial protrusion escapes from the abdomen on the outer side of the conjoined tendon, pushing before it the peritoneum, the subserous areolar tissue, and the transversalis fascia. It then enters the inguinal canal, passing along nearly its whole length, and finally emerges from the external ring, receiving an investment from the intercolumnar fascia. The coverings of this form of hernia are precisely similar to those investing the oblique form, with the insignificant difference that the infundibuliform fascia is replaced by a portion derived from the general layer of the transversalis fascia.

In other cases—and this is the more frequent variety—the hernia is either forced through the fibres of the conjoined tendon or the tendon is gradually distended in front of it so as to form a complete investment for it. The intestine then enters the lower end of the inguinal canal, escapes at the external ring lying on the inner side of the cord, and receives additional coverings from the superficial fascia and the integument. This form of hernia has the same coverings as the oblique variety, excepting that the conjoined tendon is substituted for the Cremaster, and the infundibuliform fascia is replaced by a portion derived from the general layer of the transversalis fascia.

The difference between the position of the neck of the sac in these two forms of direct inguinal hernia has been referred, with some probability, to a difference in the relative positions of the obliterated hypogastric artery and the deep epigastric artery. When the course of the obliterated hypogastric artery corresponds pretty nearly with that of the deep epigastric the projection of these arteries toward the cavity of the abdomen produces two fossæ in the peritoneum. The bottom of the external fossa of the peritoneum corresponds to the position of the internal abdominal ring, and a hernia which distends and pushes out the peritoneum lining this fossa is an oblique hernia. When, on the other hand, the obliterated hypogastric artery lies considerably to the inner side of the deep epigastric artery, corresponding to the outer margin of the conjoined tendon, it divides the triangle of Hesselbach into two parts, so that three depressions will be seen on the inner surface of the lower part of the abdominal wall, viz., an external one, on the outer side of the deep epigastric artery; a middle one, between the deep epigastric and the obliterated hypogastric arteries; and an internal one, on the inner side of the obliterated hypogastric artery (see page 1051). In such a case a hernia may distend and push out the peritoneum forming the bottom of either fossa. When the hernia distends and pushes out the peritoneum forming the bottom of the external fossa, it is an oblique or external inguinal hernia. These fossæ are the *inguinal fossæ*.

When the hernia distends and pushes out the peritoneum forming the bottom of either the middle or the internal fossa, it is a direct or internal hernia.

The anatomical difference between these two forms of direct or internal inguinal hernia is that, when the hernia protrudes through the middle fossa—that is, the fossa between the deep epigastric and the obliterated hypogastric arteries—it will enter the upper part of the inguinal canal; consequently its coverings will be the same as those of an oblique hernia, with the insignificant difference that the infundibuliform fascia is replaced by a portion derived from the general layer of the transversalis fascia, whereas when the hernia protrudes through the internal fossa it is either forced through the fibres of the conjoined tendon or the tendon is gradually distended in front of it so as to form a complete investment for it. The intestine then enters the lower part of the inguinal canal, and escapes from the external abdominal ring lying on the inner side of the cord.

This form of hernia has the same coverings as the oblique variety, excepting that the conjoined tendon is substituted for the Cremaster, and the infundibuliform fascia is replaced by a portion derived from the general layer of the fascia transversalis.

The *seat of stricture* in both varieties of direct hernia is most frequently at the neck of the sac or at the external ring. In that form of hernia which perforates the conjoined tendon it not unfrequently occurs at the edges of the fissure through which the gut passes. In dividing the stricture the incision should in all cases be directed upward.[1]

If the hernial protrusion passes into the inguinal canal, but does not escape from the external abdominal ring, it forms what is called *incomplete direct hernia*. This form of hernia is usually of small size, and in corpulent persons very difficult of detection.

Direct inguinal hernia is of much less frequent occurrence than the oblique, their comparative frequency being, according to Cloquet, as one to five. It occurs far more frequently in men than in women, on account of the larger size of the external ring in the former sex. It differs from the oblique in its smaller size and globular form, dependent most probably on the resistance offered to its progress by the transversalis fascia and conjoined tendon. It differs also in its position, being placed over the os pubis and not in the course of the inguinal canal. The deep epigastric artery runs on the outer or iliac side of the neck of the sac, and the spermatic cord along its external and posterior side, not directly behind it, as in oblique inguinal hernia.

FEMORAL HERNIA.

The dissection of the parts comprised in the anatomy of femoral hernia should be performed, if possible, upon a female subject free from fat. The subject should lie upon its back; a block is first placed under the pelvis, the thigh everted, and the knee slightly bent and retained in this position. An incision should then be made from the anterior superior spinous process of the ilium along Poupart's ligament to the symphysis pubis; a second incision should be carried transversely across the thigh about six inches beneath the preceding; and these are to be connected together by a vertical one carried along the inner side of the thigh. These several incisions should divide merely the integument; this is to be reflected outward, when the superficial fascia will be exposed.

The **superficial fascia** forms a continuous layer over the whole of the thigh, consisting of areolar tissue, containing in its meshes much fat, and capable of being separated into two or more layers, between which are found the superficial vessels and nerves. It varies in thickness in different parts of the limb. In the groin it is thick, and the two layers are separated from one another by the superficial inguinal lymphatic glands, the internal saphenous vein, and several smaller vessels. One of these layers, the superficial, is continuous with the superficial fascia of the abdomen.

The superficial layer should be detached by dividing it across in the same direction as the external incisions; its removal will be facilitated by commencing at the lower and inner angle of the space, detaching it at first from the front of the internal saphenous vein, and dissecting it off from the anterior surface of that vessel and its tributaries; it should then be reflected out-

[1] In all cases of inguinal hernia, whether oblique or direct, it is proper to divide the stricture directly upward: the reason of this is obvious, for by cutting in this direction the incision is made parallel to the deep epigastric artery—either external to it in the oblique variety, or internal to it in the direct form of hernia—and thus all chance of wounding the vessel is avoided. If the incision was made outward, the artery might be divided if the hernia was direct; and if made inward, it would stand an equal chance of injury if the case was one of oblique inguinal hernia.

ward in the same manner as the integument. The cutaneous vessels and nerves and superficial inguinal glands are then exposed, lying upon the deep layer of the superficial fascia. These are the internal saphenous vein and the superficial epigastric, superficial circumflex iliac, and superficial external pudic vessels, as well as numerous lymphatics, ascending with the saphenous vein to the inguinal glands.

The *internal* or *long saphenous vein* ascends along the inner side of the thigh, and, passing through the saphenous opening in the fascia lata, terminates in the femoral vein about an inch and a half below Poupart's ligament. This vein receives at the saphenous opening the superficial epigastric, the superficial circumflex iliac, and the superficial external pudic veins.

The *superficial external pudic artery* (superior) arises from the inner side of the femoral artery, and, after passing through the saphenous opening, courses inward across the spermatic cord, to be distributed to the integument on the lower part of the abdomen, the penis and scrotum in the male and the labium in the female, anastomosing with branches of the internal pudic.

The *superficial epigastric artery* arises from the femoral about half an inch below Poupart's ligament, and, passing through the saphenous opening in the fascia lata, ascends on to the abdomen, in the superficial fascia covering the

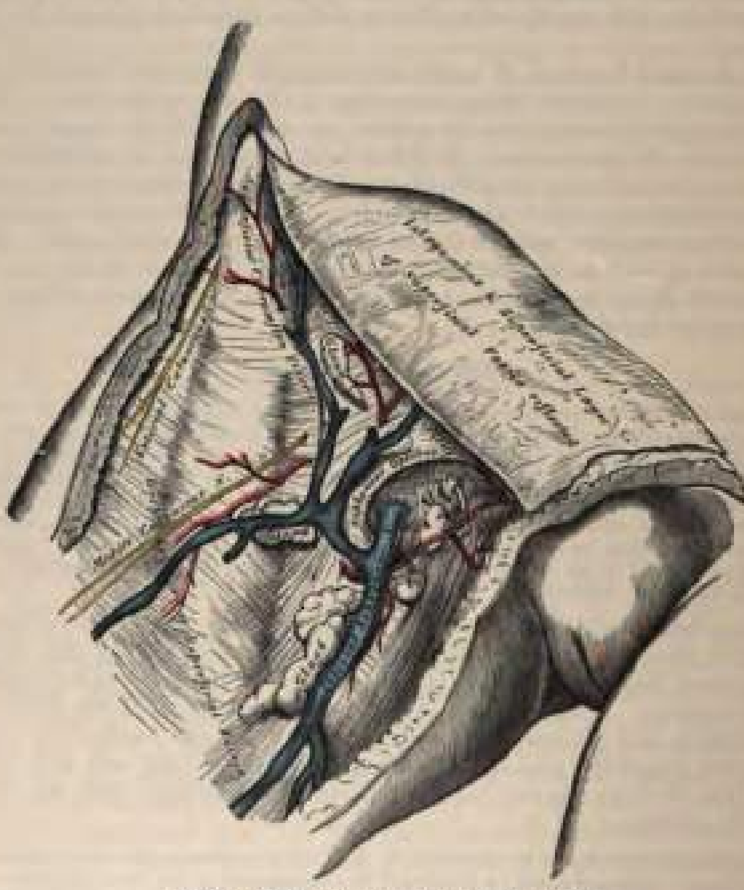


FIG. 585.—Femoral hernia. Superficial dissection.

External oblique muscle, nearly as high as the umbilicus. It distributes branches to the superficial inguinal lymphatic glands, the superficial fascia, and the integument, anastomosing with branches of the deep epigastric and internal mammary arteries.

The *superficial circumflex iliac artery*, the smallest of the cutaneous branches, arises close to the preceding, and, piercing the fascia lata, runs outward, parallel with Poupart's ligament, as far as the crest of the ilium, dividing into branches which supply the superficial inguinal lymphatic glands, the superficial fascia, and the integument of the groin, anastomosing with the deep circumflex iliac, and with the gluteal and external circumflex arteries.

The Superficial Veins.—The veins accompanying these superficial arteries are usually much larger than the arteries: they terminate in the internal or long saphenous vein at the saphenous opening.

The *superficial inguinal lymphatic glands*, placed immediately beneath the integument, are of large size and vary from eight to ten in number. They are divisible into two groups: an upper, disposed irregularly along Poupart's ligament, which receive the lymphatic vessels from the integument of the scrotum, penis, parietes of the abdomen, perineal and gluteal regions, and the mucous membrane of the urethra; and an inferior group, which surround the saphenous opening in the fascia lata, a few being sometimes continued along the saphenous vein to a variable extent. This latter group receive the superficial lymphatic vessels from the lower extremity.

The *ilio-inguinal nerve* arises from the first lumbar nerve. It escapes at the external abdominal ring, and is distributed to the integument of the upper and inner part of the thigh—to the scrotum in the male and to the labium in the female. The size of this nerve is in inverse proportion to that of the ilio-hypogastric. Occasionally it is very small, and ends by joining the ilio-hypogastric: in such cases a branch of the ilio-hypogastric takes the place of the ilio-inguinal, or the latter nerve may be altogether absent. The *crural branch of the genito-crural nerve* passes along the inner margin of the Psoas muscle, beneath Poupart's ligament, into the thigh, entering the sheath of the femoral vessels, and lying superficial and a little external to the femoral artery. It pierces the anterior layer of the sheath of the vessels, and, becoming superficial by passing through the fascia lata, it supplies the skin of the anterior aspect of the thigh as far as midway between the pelvis and knee. On the front of the thigh it communicates with the outer branch of the middle cutaneous nerve, derived from the anterior crural.

The *deep layer of the superficial fascia* is a very thin fibrous layer, best marked on the inner side of the long saphenous vein and below Poupart's ligament. It is placed beneath the subcutaneous vessels and nerves, and upon the surface of the fascia lata, to which it is intimately adherent at the lower margin of Poupart's ligament. It covers the saphenous opening in the fascia lata, is closely united to its circumference, and is connected to the sheath of the femoral vessels corresponding to its under surface. The portion of fascia covering this aperture is perforated by the internal saphenous vein and by numerous blood- and lymphatic vessels; hence it has been termed the *cribriform fascia*, the openings for these vessels having been likened to the holes in a sieve. The cribriform fascia adheres closely both to the superficial fascia and to the fascia lata, so that it is described by some anatomists as a part of the fascia lata, but it is usually considered (as in this work) as belonging to the superficial fascia. It is not till the cribriform fascia has been cleared away that the saphenous opening is seen, so that this opening does not in ordinary cases exist naturally, but is the result of dissection. A femoral hernia in passing through the saphenous opening receives the cribriform fascia as one of its coverings.

The deep layer of superficial fascia, together with the cribriform fascia, having been removed, the fascia lata is exposed.

The **Fascia Lata** has been already described with the muscles of the front of the thigh (page 419). At the upper and inner part of the thigh, a little below Poupart's ligament, a large oval-shaped aperture is observed after the superficial fascia has been cleared away; it transmits the internal saphenous vein and other smaller vessels, and is called the *saphenous opening*. In order the more correctly to consider the mode of formation of this aperture, the fascia lata in this part of the thigh is described as consisting of two portions, an iliac portion and a pubic portion.

The *iliac portion* is all that part of the fascia lata on the outer side of the saphenous opening. It is attached externally to the crest of the ilium and its anterior superior spine; to the whole length of Poupart's ligament; and to the pectineal line in conjunction with Gimbernat's ligament. From the spine of the os pubis it is reflected downward and outward, forming an arched margin, the outer boundary or falciform process or superior cornu of the saphenous opening. This margin overlies and is adherent to the anterior layer of the sheath of the femoral vessels; to its edge is attached the cribriform fascia, and below it is continuous with the pubic portion of the fascia lata.

The *pubic portion of the fascia lata* is situated at the inner side of the saphenous opening: at the lower margin of this aperture it is continuous with the iliac portion: traced upward, it covers the surface of the Pectineus, Adductor longus, and Gracilis muscles; and, passing behind the sheath of the femoral vessels, to which it is closely united, is continuous with the sheath of the Psoas and Iliacus muscles, and is attached above to the ilio-pectineal line, where it becomes continuous with the fascia covering the Iliacus muscle. From this description it may be observed that the iliac portion of the fascia lata passes in front of the femoral vessels and the pubic portion behind them, so that an apparent aperture

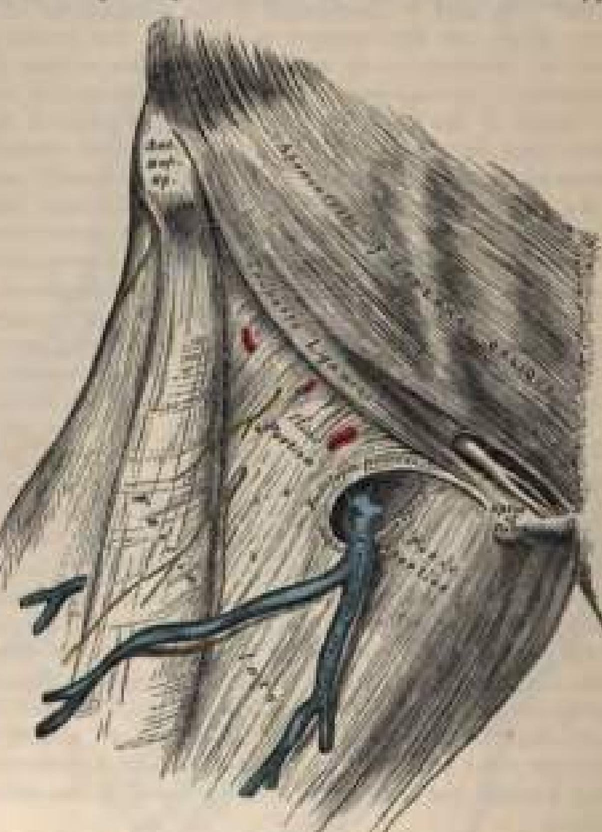


FIG. [illegible].—Femoral hernia, showing fascia lata and saphenous opening.

consequently exists between the two, through which the internal saphenous joins the femoral vein.

The **Saphenous Opening** is an oval-shaped aperture measuring about an inch and a half in length and half an inch in width. It is situated at the upper and inner part of the front of the thigh, below Poupart's ligament, and is directed obliquely downward and outward.

Its *outer margin* is of a semilunar form, thin, strong, sharply defined, and lies on a plane considerably anterior to the inner margin. If this edge is traced upward, it will be seen to form a curved elongated process, the *falciform process* or *superior cornu*, which ascends in front of the femoral vessels, and, curving inward, is attached to Poupart's ligament and to the spine of the os pubis and pectineal line, where it is continuous with the pubic portion. If traced downward, it is found continuous with another curved margin, the concavity of which is directed upward and inward: this is the inferior cornu of the saphenous opening, and is blended with the pubic portion of the fascia lata covering the Pectineus muscle.

The *inner boundary of the opening* is on a plane posterior to the outer margin and behind the level of the femoral vessels; it is much less prominent and defined than the outer, from being stretched over the subjacent Pectineus muscle. It is through the saphenous opening that a femoral hernia passes after descending along the crural canal.

If the finger is introduced into the saphenous opening while the limb is moved in different directions, the aperture will be found to be greatly constricted on extending the limb or rotating it outward, and to be relaxed on flexing the limb

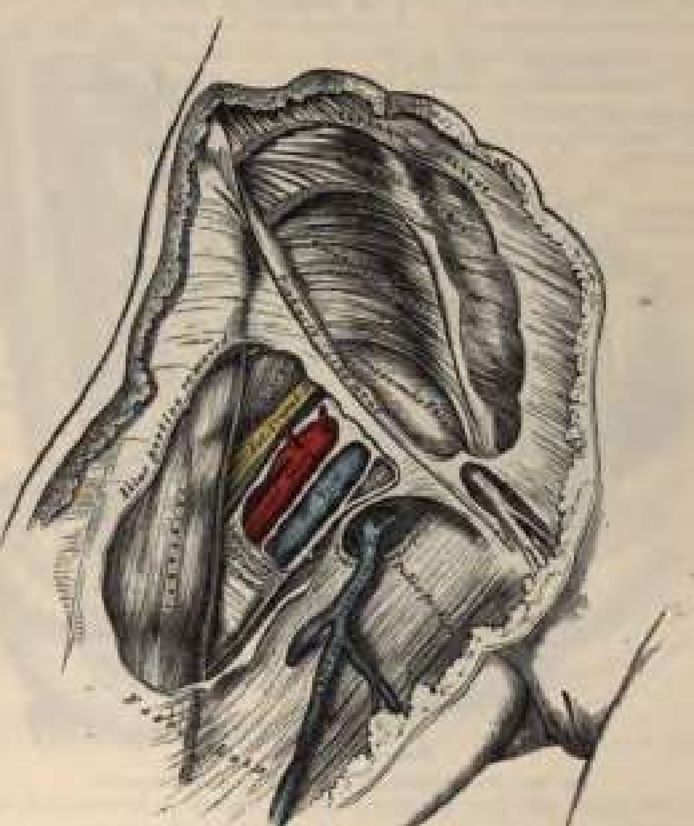


FIG. 587.—Femoral hernia. Iliac portion of fascia lata removed, and sheath of femoral vessels and femoral canal exposed.

and inverting it: hence the necessity for placing the limb in the latter position in employing the taxis for the reduction of a femoral hernia.

The iliac portion of the fascia lata, but not its falciform process, should now be removed by detaching it from the lower margin of Poupart's ligament, carefully dissecting it from the subjacent structures, and turning it inward, when the sheath of the femoral vessels is exposed, descending beneath Poupart's ligament (Fig. 587).

Poupart's Ligament, or the **Crural Arch**, is the lower border of the aponeurosis of the External oblique muscle, which extends from the anterior superior spine of

THE SURGICAL ANATOMY OF HERNIA

the ilium to the spine of the os pubis. From this latter point it is reflected outward, to be attached to the pectineal line for about half an inch, forming Gimbernat's ligament. Its general direction is curved downward toward the thigh, where it is continuous with the fascia lata. Its outer half is rounded and oblique in direction. Its inner half gradually widens at its attachment to the os pubis, is more horizontal in direction, and lies beneath the spermatic cord. Nearly the whole of the space included between the crural arch and innominate bone is filled in by the parts which descend from the abdomen into the thigh (Fig. 588). The outer half of the space is occupied by the Iliacus and Psoas muscles, together with the external cutaneous and anterior crural nerves. The pubic half of the space is occupied by the femoral vessels included in their sheath, a small oval-shaped interval existing between the femoral vein and the inner wall of the sheath, which is occupied merely by a little loose areolar tissue, a few lymphatic vessels,

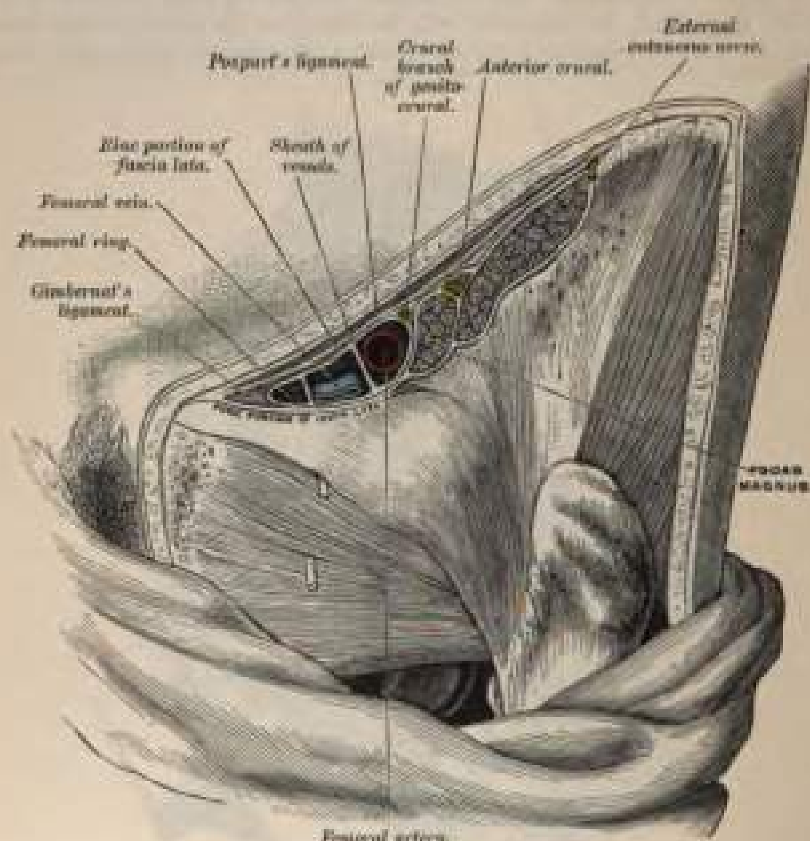


Fig. 589.—Structures which pass beneath the crural arch.

and occasionally by a small lymphatic gland; this is the femoral ring, through which the gut descends in femoral hernia.

Gimbernat's Ligament (Figs. 588, 589) is that part of the aponeurosis of the External oblique muscle which is reflected backward and outward from the spine of the os pubis, to be inserted into the pectineal line. It is about half an inch in length, larger in the male than in the female, almost horizontal in direction in the erect posture, and of a triangular form, with the base directed outward. Its *base*, or outer margin, is concave, thin, and sharp, and lies in contact with the femoral sheath. Its *apex* corresponds to the spine of the os pubis. Its *posterior margin* is attached to the pectineal line, and is continuous with the pubic portion of the fascia lata. Its *anterior margin* is continuous with Poupart's ligament.

Femoral Sheath.—The femoral or crural sheath is a continuation downward of the fasciæ that line the abdomen, the transversalis fascia passing down in front of the femoral vessels, and the iliac fascia descending behind them; these fasciæ are directly continuous on the iliac side of the femoral artery, but a small space exists between the femoral vein and the point where they are continuous on the pubic side of that vessel, which constitutes the femoral or crural canal. The femoral sheath is closely adherent to the contained vessels about an inch below the saphenous opening, being blended with the areolar sheath of the vessels, but opposite Poupart's ligament it is much larger than is required to contain them; hence the funnel-shaped form which it presents. The outer border of the sheath is perforated by the genito-crural nerve. Its inner border is pierced by the internal saphenous vein and numerous lymphatic vessels. In front it is covered by the iliac portion of the fascia lata; and behind it is the pubic portion of the same fascia.

If the anterior wall of the sheath is removed, the femoral artery and vein are seen lying side by side, a thin septum separating the two vessels, while another septum may be seen lying just internal to the vein, and cutting off a small space between the vein and the inner wall of the sheath. The septa are stretched between the anterior and posterior walls of the sheath, so that each vessel is enclosed in a separate compartment. The interval left between the vein and the inner wall of the sheath is not filled up by any structure, excepting a little loose areolar tissue, a few lymphatic vessels, and occasionally by a small lymphatic

FIG. 589.—Hernia. The relations of the femoral and internal abdominal rings, seen from within the abdomen. Right side.

gland: this is the femoral or crural canal, through which the intestine descends in femoral hernia.

Deep Crural Arch.—Passing across the front of the femoral sheath on the abdominal side of Poupart's ligament, and closely connected with it, is a thickened band of fibres called the *deep crural arch.* It is apparently a thickening of the transversalis fascia, joining externally to the centre of Poupart's ligament, and arching across the front of the crural sheath, to be inserted by a broad attachment into the pectineal line behind the conjoined tendon. In some subjects this structure is not very prominently marked, and not infrequently it is altogether wanting.

The **crural canal** is the narrow interval between the femoral vein and the inner wall of the femoral sheath. It exists as a distinct canal only when the sheath has been separated from the vein by dissection or by the pressure of a hernia or tumor. Its length is from a quarter to half an inch, and it extends from Gimbernat's ligament to the upper part of the saphenous opening.

Its *anterior wall* is very narrow, and formed by a continuation downward of the transversalis fascia, under Poupart's ligament, covered by the falciform process of the fascia lata.

Its *posterior wall* is formed by a continuation downward of the iliac fascia covering the pubic portion of the fascia lata.

Its *outer wall* is formed by the fibrous septum separating it from the inner side of the femoral vein.

Its *inner wall* is formed by the junction of the processes of the transversalis and iliac fasciæ, which form the inner side of the femoral sheath, and lies in contact at its commencement with the outer edge of Gimbernat's ligament.

This canal has two orifices—an upper one, the *femoral* or *crural ring*, closed by the septum crurale; and a lower one, the *saphenous opening*, closed by the cribriform fascia.

The **femoral** or **crural ring** (Fig. 589) is the upper opening of the femoral canal, and leads into the cavity of the abdomen. It is bounded in front by Poupart's ligament and the deep crural arch; behind, by the os pubis, covered by the Pectineus muscle and the pubic portion of the fascia lata; internally, by the base of Gimbernat's ligament, the conjoined tendon, the transversalis fascia, and the deep crural arch; externally, by the fibrous septum lying on the inner side of the femoral vein. The femoral ring is of an oval form; its long diameter, directed transversely, measures about half an inch, and it is larger in the female than in the male, which is one of the reasons of the greater frequency of femoral hernia in the former sex.

Position of Parts around the Ring.—The spermatic cord in the male and round ligament in the female lie immediately above the anterior margin of the femoral ring, and may be divided in an operation for femoral hernia if the incision for the relief of the stricture is not of limited extent. In the female this is of little importance, but in the male the spermatic artery and vas deferens may be divided.

The *femoral vein* lies on the outer side of the ring.

The *deep epigastric artery* in its passage upward and inward from the external iliac artery passes across the upper and outer angle of the crural ring, and is consequently in danger of being wounded if the stricture is divided in a direction upward and outward.

The *communicating branch* between the deep epigastric and obturator lies in front of the ring.

The circumference of the ring is thus seen to be bounded by vessels in every part, excepting internally and behind. It is in the former position that the stricture is divided in cases of strangulated femoral hernia.

The *obturator artery*, when it arises by a common trunk with the deep epigastric, which occurs once in every three subjects and a half, bears a very important relation to the crural ring. In most cases it descends on the inner side of the external iliac vein to the obturator foramen, and will consequently lie on the outer side of the crural ring, where there is no danger of its being wounded in the operation for dividing the stricture in femoral hernia (see Fig. 314, page 565, fig. A). Occasionally, however, the obturator artery curves along the free margin of Gimbernat's ligament in its passage to the obturator foramen: it would consequently skirt along the greater part of the circumference of the crural ring, and could hardly avoid being wounded in the operation (see Fig. 314, page 565, fig. B).

Septum Crurale.—The femoral ring is closed by a layer of condensed areolar tissue called, by J. Cloquet, the *septum crurale*. This serves as a barrier to the protrusion of a hernia through this part. Its upper surface is slightly concave, and supports a small lymphatic gland by which it is separated from the subserous areolar tissue and peritoneum. Its under surface is turned toward the femoral canal. The septum crurale is perforated by numerous apertures for the passage of lymphatic vessels connecting the deep inguinal lymphatic glands with those surrounding the external iliac artery.

The size of the femoral canal, the degree of tension of its orifices, and consequently the degree of constriction of a hernia, vary according to the position of the limb. If the leg and thigh are extended, abducted, or everted, the femoral canal and its orifices are rendered tense from the traction on these parts by Poupart's ligament and the fascia lata, as may be ascertained by passing the finger along the canal. If, on the contrary, the thigh is flexed upon the pelvis, and at the same time adducted and rotated inward, the femoral canal and its orifices become considerably relaxed; for this reason the limb should always be placed in the latter position when the application of the taxis is made in attempting the reduction of a femoral hernia.

The *subperitoneal areolar tissue* is continuous with the subserous areolar tissue of surrounding parts. It is usually thickest and most fibrous where the iliac vessels leave the abdominal cavity. It covers over the small interval (crural ring) on the inner side of the femoral vein. In some subjects it contains a considerable amount of adipose tissue. In such cases, where it is protruded forward in front of the sac of a femoral hernia, it may be mistaken for a portion of omentum. The peritoneum lining the portion of the abdominal wall between Poupart's ligament and the brim of the pelvis is similar to that lining any other portion of the abdominal wall, being very thin. It has here no natural aperture for the escape of intestine.

Descent of the Hernia.—From the preceding description it follows that the femoral ring must be a weak point in the abdominal wall: hence it is that when violent or long-continued pressure is made upon the abdominal viscera a portion of intestine may be forced into it, constituting a femoral hernia; and the changes in the tissues of the abdomen which are produced by pregnancy, together with the larger size of this aperture in the female, serve to explain the frequency of this form of hernia in women.

When a portion of the intestine is forced through the femoral ring, it carries before it a pouch of peritoneum, which forms what is called the *hernial sac*; it receives an investment from the subserous areolar tissue and from the septum crurale, and descends vertically along the crural canal in the inner compartment of the sheath of the femoral vessels as far as the saphenous opening; at this point it changes its course, being prevented from extending farther down the sheath on account of the narrowing of the sheath and its close contact with the vessels, and also from the close attachment of the superficial fascia and crural sheath to the lower part of the circumference of the saphenous opening; the tumor is consequently directed forward, pushing before it the cribriform fascia, and then curves upward on to the falciform process of the fascia lata and lower part of the tendon of the External oblique, being covered by the superficial fascia and integument. While the hernia is contained in the femoral canal it is usually of small size, owing to the resisting nature of the surrounding parts; but when it has escaped from the saphenous opening into the loose areolar tissue of the groin, it becomes considerably enlarged. The direction taken by a femoral hernia in its descent is at first downward, then forward and upward; this should be borne in mind, as in the application of the taxis for the reduction of a femoral hernia pressure should be directed in the reverse order.

Coverings of the Hernia.—The coverings of a femoral hernia, from within outward, are—peritoneum, subserous areolar tissue, the septum crurale, crural sheath, cribriform fascia, superficial fascia, and integument.[1]

[1] Sir Astley Cooper has described an investment for femoral hernia, under the name of "fascia propria," lying immediately external to the peritoneal sac, but frequently separated from it by more or less adipose tissue. Surgically, it is important to remember the existence (at any rate, the occasional existence) of this layer, on account of the ease with which an inexperienced operator may mistake the fascia for the peritoneal sac and the contained fat for omentum. Anatomically, this fascia appears identical with what is called in the text "subserous areolar tissue," the areolar tissue being thickened and caused to assume a membranous appearance by the pressure of the hernia.

Varieties of Femoral Hernia.—If the intestine descends along the femoral canal only as far as the saphenous opening, and does not escape from this aperture, it is called *incomplete femoral hernia.* The small size of the protrusion in this form of hernia, on account of the firm and resisting nature of the canal in which it is contained, renders it an exceedingly dangerous variety of the disease, from the extreme difficulty of detecting the existence of the swelling, especially in corpulent subjects. The coverings of an incomplete femoral hernia would be, from without inward, integument, superficial fascia, falciform process of fascia lata, crural sheath, septum crurale, subserous areolar tissue, and peritoneum. When, however, the hernial tumor protrudes through the saphenous opening and directs itself forward and upward, it forms a *complete femoral hernia.* Occasionally the hernial sac descends on the iliac side of the femoral vessels or in front of these vessels, or even sometimes behind them.

The *seat of stricture of a femoral hernia* varies: it may be in the peritoneum at the neck of the hernial sac; in the greater number of cases it would appear to be at the point of junction of the falciform process of the fascia lata with the lunated edge of Gimbernat's ligament, or at the margin of the saphenous opening in the thigh. The stricture should in every case be divided in a direction upward and inward, and the extent necessary in the majority of cases is about two or three lines. By these means all vessels or other structures of importance in relation with the neck of the hernial sac will be avoided.

SURGICAL ANATOMY OF THE PERINÆUM.

Dissection.—The student should select a well-developed muscular subject, free from fat, and the dissection should be commenced early, in order that the parts may be examined in as recent a state as possible. A staff having been introduced into the bladder and the subject placed in the position shown in Fig. 500, the scrotum should be raised upward, and retained in that position, and the rectum moderately distended with tow.

The **Perinæum** corresponds to the inferior aperture or outlet of the pelvis. Its deep boundaries are, in front, the pubic arch and subpubic ligament; behind, the tip of the coccyx; and on each side, the rami of the os pubis and ischium, the tuberosities of the ischium, and great sacro-sciatic ligaments. The space included by these boundaries is somewhat lozenge-shaped, and is limited on the surface of the body by the scrotum in front, by the buttocks behind, and on each side by the inner side of the thighs. A line drawn transversely between the anterior part of the tuberosity of the ischium, on each side, in front of the anus, divides this space into two portions. The anterior portion contains the penis and urethra, and is called the *perinæum proper* or *genito-urinary region*. The posterior portion contains the termination of the rectum, and is called the *ischio-rectal* or *anal region*.

ISCHIO-RECTAL REGION.

The **ischio-rectal region** contains the termination of the rectum and a deep fossa, filled with fat, on each side of the intestine, between it and the tuberosity of the ischium: this is called the *ischio-rectal fossa*.

The **ischio-rectal region** presents in the middle line the *aperture of the anus*: around this orifice the integument is thrown into numerous folds, which are obliterated on distension of the intestine. The integument is of a dark color, continuous with the mucous membrane of the rectum, and provided with numerous follicles, which occasionally inflame and suppurate, and may be mistaken for fistulæ. The veins around the margin of the anus are occasionally much dilated, forming a number of hard pendent masses, of a dark bluish color, covered partly by mucous membrane and partly by the integument. These tumors constitute the disease called *external piles*.

Dissection (Fig. 500).—Make an incision through the integument, along the median line, from the base of the scrotum to the anterior extremity of the anus; carry it round the margins of this aperture to its posterior extremity, and continue it backward to about an inch behind the tip of the coccyx. A transverse incision should now be carried across the base of the scrotum, joining the anterior extremity of the preceding; a second, carried in the same direction, should be made in front of the anus; and a third at the posterior extremity of the first incision. These incisions should be sufficiently extensive to enable the dissector to raise the integument from the inner side of the thighs. The flaps of skin corresponding to the ischio-rectal region should now be removed. In dissecting the integument from this region great care is required, otherwise the Corrugator cutis ani and External sphincter will be removed, as they are intimately adherent to the skin.

The **superficial fascia** is exposed on the removal of the skin: it is very thick, areolar in texture, and contains much fat in its meshes. In it are found ramifying two or three branches of the perforating cutaneous nerve; these turn round the inferior border of the Gluteus maximus and are distributed to the integument around the anus.

In this region, and connected with the lower end of the rectum, are four muscles: the Corrugator cutis ani; the two Sphincters, External and Internal; and the Levator ani.

These muscles have been already described (see page 368).

The **ischio-rectal fossa** is situated between the end of the rectum and the tuberosity of the ischium. It is triangular in shape; its base, directed to the surface of the body, is formed by the integument of the ischio-rectal region; its *apex*, directed upward, corresponds to the point of division of the obturator fascia and the thin membrane given off from it, which covers the outer surface of the Levator ani (ischio-rectal or anal fascia). Its dimensions are about an inch in breadth at the base and about two inches in depth, being deeper behind than in front. It is bounded, *internally*, by the Sphincter ani, Levator ani, and Coccygeus muscles; *externally*, by the tuberosity of the ischium and the obturator fascia, which covers the inner surface of the Obturator internus muscle; *in front*, it is limited by the line of junction of the superficial fascia with the base of the triangular ligament; and *behind*, by the margin of the Gluteus maximus and the great sacro-sciatic ligament. This space is filled with a large mass of adipose tissue, which explains the frequency with which abscesses in the neighborhood of the rectum burrow to a considerable depth.

If the subject has been injected, on placing the finger on the outer wall of this fossa the internal pudic artery, with its accompanying veins and the two divisions of the nerve, will be felt about an inch and a half above the margin of the ischiatic tuberosity, but approaching nearer the surface as they pass forward along the inner margin of the pubic arch. These structures are enclosed in a sheath (canal of Alcock) formed by the obturator fascia, the pudic nerve lying below the artery and the dorsal nerve of the penis above it (Fig. 315). Crossing the space transversely, about its centre are the inferior hemorrhoidal vessels and nerves, which are distributed to the integument of the anus and to the muscles of the lower end of the rectum. These vessels are occasionally of large size, and may give rise to troublesome hemorrhage when divided in the operation of lithotomy or in that for fistula in ano. At the back part of this space, near the coccyx, may be seen a branch of the fourth sacral nerve, and at the fore part of the space the superficial perineal vessels and nerves can be seen for a short distance.

THE PERINÆUM PROPER IN THE MALE.

The perineal space is of a triangular form; its deep boundaries are limited, laterally, by the rami of the pubic bones and ischia, meeting in front at the pubic arch; behind, by an imaginary transverse line extending between the anterior parts of the tuberosities of the ischia. The lateral boundaries are, in the adult, from three inches to three inches and a half in length, and the base from two to three inches and a half in breadth, the average extent of the space being two inches and three-quarters.

The variations in the diameter of this space are of extreme interest in connection with the operation of lithotomy and the extraction of a stone from the cavity of the bladder. In those cases where the tuberosities of the ischia are near together it would be necessary to make the incisions in the lateral operation of lithotomy less oblique than if the tuberosities were widely separated, and the perineal space consequently wider. The perinæum is subdivided by the median raphe into two equal parts. Of these, the left is the one in which the operation of lithotomy is performed.

In the middle line the perinæum is convex, and corresponds to the bulb of the urethra. The skin covering it is of a dark color, thin, freely movable upon the subjacent parts, and covered with sharp crisp hairs, which should be removed before the dissection of the part is commenced. In front of the anus a prominent line commences, the *raphe*, continuous in front with the raphe of the scrotum.

Upon removing the skin and superficial structures from this region, in the manner shown in Fig. 590, a plane of fascia will be exposed, covering in the triangular space and stretching across from one ischio-pubic ramus to the other. This is the *deep layer of the superficial fascia* or *fascia of Colles*. It has already been described (page 370). It is a layer of considerable strength, and encloses and covers a space in which are contained muscles, vessels, and nerves. It is continuous in front with the dartos of the scrotum; on each side it is firmly attached to the margin of the ischio-pubic ramus and to the tuberosity of the ischium; and posteriorly it curves down behind the Transversus perinæi muscles to join the base of the triangular ligament.

It is between this layer of fascia and the triangular ligament of the urethra that extravasation of urine most frequently takes place in cases of rupture of the urethra. The triangular ligament of the urethra (see page 373) is attached to the ischio-pubic rami, and in front to the subpubic ligament. It is clear, therefore, that when extravasation of fluid takes place between these two layers, it cannot pass backward, because the two layers are continuous with each other around the Transversi perinæi muscles: it cannot extend laterally, on account of the connection of both these layers to the rami of the os pubis and ischium; it cannot find its way into the pelvis, because the opening into this cavity is closed by the triangular ligament, and, therefore, so long as these two layers remain intact, the only direction in which the fluid can make its way is forward into the areolar tissue of the scrotum and penis, and then on to the anterior wall of the abdomen.

When the deep layer of the superficial fascia is removed, a space is exposed, between this fascia and the triangular ligament, in which are contained the superficial perineal vessels and nerves and some of the muscles connected with the penis and urethra, viz., in the middle line, the Accelerator urinæ; on each side, the Erector penis; and behind, the transversus perinæi; together with the crura of the corpora cavernosa and the bulb of the corpus spongiosum. Here also is seen the *central tendinous point of the perineum.* This is a fibrous point in the middle line of the perineum between the urethra and the rectum, being about half an inch in front of the anus. At this point four muscles converge and are attached, viz.,

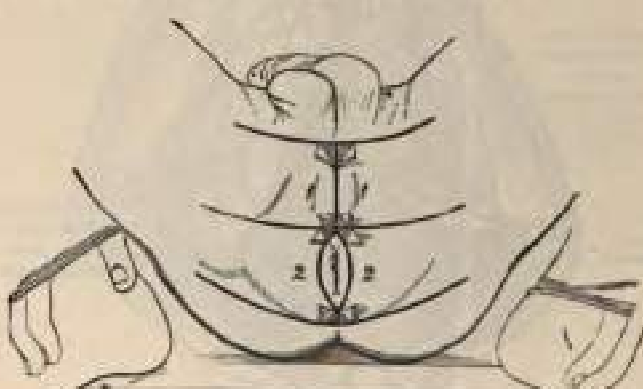


FIG. 190.—Dissection of perinæum and ischio-rectal region.

the External sphincter ani, the Accelerator urinæ, and the two Transversi perinæi muscles; so that by the contraction of these muscles, which extend in opposite directions, it serves as a fixed point of support.

The Accelerator urinæ, the Erector penis, and the Transversus perinæi muscles have been already described (page 371). They form a triangular space, bounded, internally, by the Accelerator urinæ; externally, by the Erector penis; and behind, by the Transversus perinæi. The floor of this space is formed by the triangular ligament of the urethra; and running from behind forward in it are the superficial perineal vessels and nerves, and the transverse perineal artery coursing along the posterior boundary of the space, on the Transversus perinæi muscle.

The Accelerator urinæ and Erector penis should now be removed, when the triangular ligament of the urethra will be exposed, stretching across the front of the outlet of the pelvis. The urethra is seen perforating its centre, just behind the bulb; and on each side is the crus penis, connecting the corpus cavernosum with the rami of the ischium and os pubis.

The **Triangular Ligament**, which has already been described (see page 373), consists of two layers, the inferior superficial layer of which is now exposed.

It is united to the superior or deep layer behind, but is separated in front by a subfascial space in which are contained certain structures.

The *inferior layer of the triangular ligament* consists of a strong fibrous membrane, the fibres of which are disposed transversely, which stretches across from one ischio-pubic ramus to the other and completely fills in the pubic arch; it is attached in front to the subpubic ligament, except just in the centre, where a small interspace is left for the dorsal vein of the penis. In the erect position of the body it is almost horizontal. It is perforated by the urethra in the middle line, and on each side of the urethral opening by the ducts of Cowper's glands and by the arteries of the bulb; in front, and external to this, by the artery of the corpus cavernosum, immediately before this vessel enters the crus penis. Near its apex the ligament is perforated by the termination of the pudic artery and by the dorsal nerve of the penis. The *crura penis* are exposed, lying superficial to this ligament. They will be seen to be attached by blunt-pointed processes to the rami of the os pubis and ischium, in front of the tuberosities, and passing forward and inward, joining to form the body of the penis. In the middle line the bulb and corpus spongiosum are exposed by the removal of the Accelerator urinæ muscle.

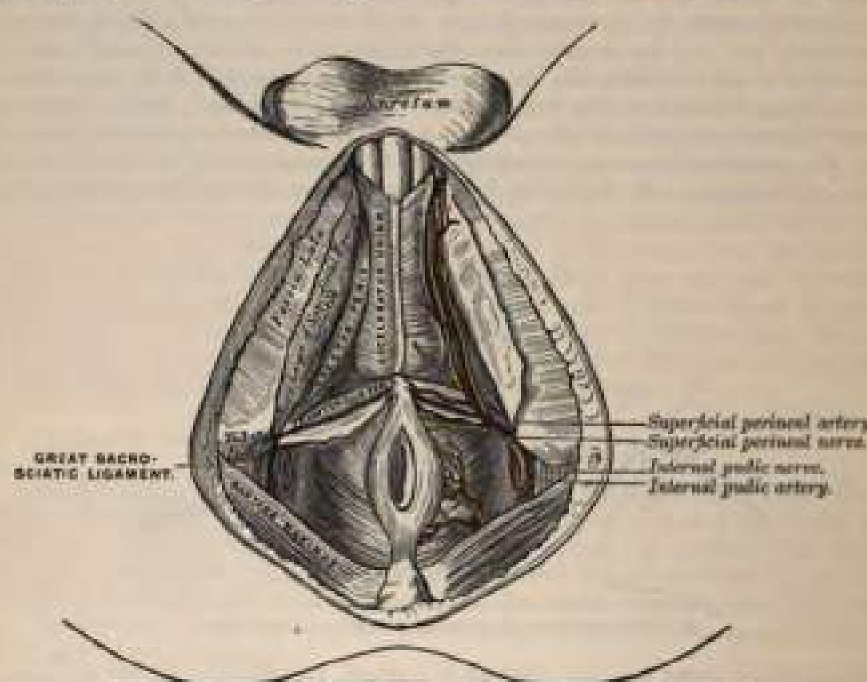


FIG. 591.—The superficial muscles and vessels of the perinæum.

If the superficial layer of the deep perineal fascia is detached on either side, the deep perineal interspace will be exposed and the following parts will be seen between it and the deep layer of the ligament: the subpubic ligament in front, close to the symphysis pubis; the dorsal vein of the penis; the membranous portion of the urethra and the Compressor urethræ muscle; Cowper's glands and their ducts; the pudic vessels and the dorsal nerve of the penis; the artery and nerve of the bulb and a plexus of veins.

The *superior layer of the triangular ligament*, or *deep perineal fascia*, is derived from the obturator fascia, and is continuous with it along the pubic arch. Behind, it joins with the superficial layer of the triangular ligament, and is continuous with the anal fascia. Above it is the prostate gland, supported by the anterior fibres of the Levator ani, which act as a sling for the gland and form the Levator prostatæ muscle. The superior layer of the triangular ligament is continuous round the anterior free edge of this muscle with the recto-vesical layer covering the prostate gland. The superior layer of the triangular ligament is perforated by the urethra. Between the two layers of the triangular ligament are situated the membranous part of the urethra, enveloped by the Compressor urethræ muscle; the ducts of Cowper's glands; the arteries to the bulb; the pudic vessels and the dorsal nerve of the penis. The membranous part of the urethra is about three-quarters of an inch in length, and passes downward and forward behind the symphysis pubis, from which it is distant about an inch. It is the narrowest part of the tube, and is enveloped, as has already been stated, by the Compressor urethræ muscle.

The **Compressor urethræ** has already been described (page 374). In addition to this muscle and immediately beneath it *circular muscular fibres* surround the membranous portion of the urethra from the bulb in front to the prostate behind, and are continuous with the muscular fibres of the bladder. These fibres are involuntary.

Cowper's glands are situated immediately below the membranous portion of the urethra, close behind the bulb, and below the artery of the bulb.

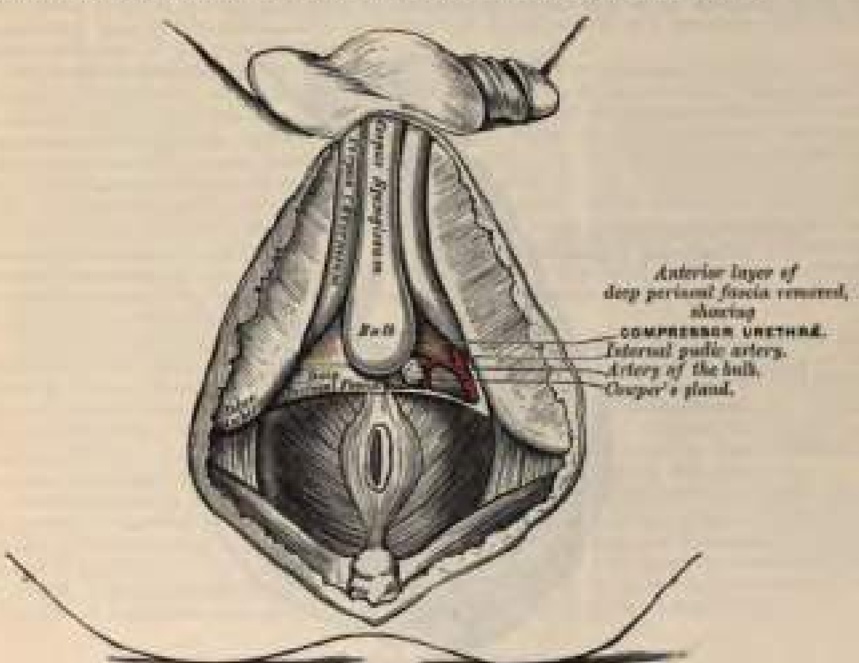


FIG. 592.—Deep perineal fascia. On the left side the anterior layer has been removed.

The **pudic vessels** and **dorsal nerve of the penis** are placed along the inner margin of the pubic arch (pages 565 and 793).

The **artery of the bulb** passes transversely inward, from the internal pudic along the base of the triangular ligament, between its two layers, accompanied by a branch of the pudic nerve (page 567). If the deep layer of the triangular ligament is removed and the crus penis of one side detached from the bone, the under or perineal surface of the Levator ani is brought fully into view. This muscle, with the triangular ligament in front and the Coccygeus and Pyriformis behind, closes the outlet of the pelvis.

The Levator ani and Coccygeus muscles have already been described (page 369).

Position of the Viscera at the Outlet of the Pelvis.—Divide the central tendinous point of the perineum, separate the rectum from its connections by dividing the fibres of the Levator ani, which descend upon the sides of the prostate gland, and draw the gut backward toward the coccyx, when the under surface of the prostate gland, the neck and base of the bladder, the vesiculæ seminales, and the vasa deferentia will be exposed.

The **Prostate Gland** is a pale, firm, glandular body which is p
below the neck of the bladder, around the commencement of t
placed in the pelvic cavity, behind the lower part of the sympl
the deep layer of the triangular ligament, and rests upon the
which it may be distinctly felt, especially when enlarged. In
resembles a chestnut. Its base is directed upward toward the ne
Its apex is directed downward to the deeper layer of the tri
which it touches.

Its posterior surface is smooth, marked by a slight longitudina
on the second part of the rectum, to which it is connected by a
anterior surface is flattened, marked by a slight longitudinal f
about three-quarters of an inch below the pubic symphysis. I
an inch and a half in its transverse diameter at the base, an
posterior diameter, and three-quarters of an inch in depth. E
extent of incision that can be made in it without dividing its sub
across is obliquely backward and outward. This is the direc
incision is made in it in the lateral operation of lithotomy.

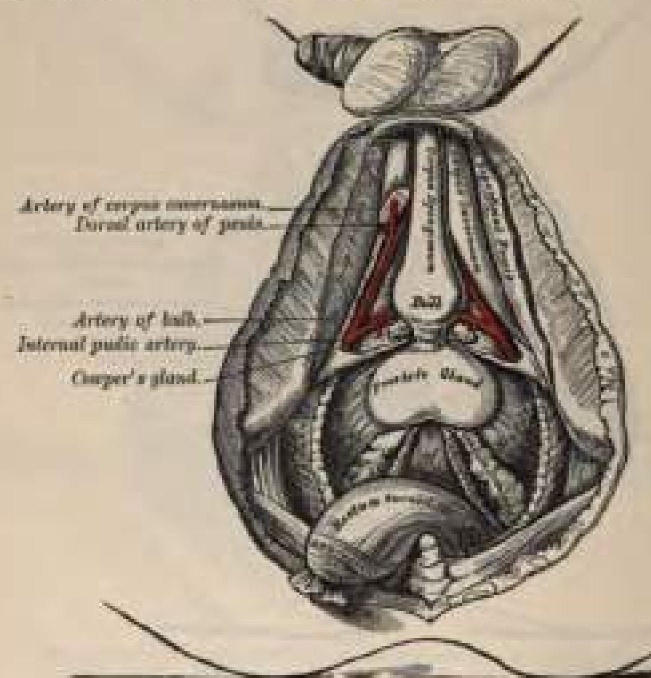


FIG. [illegible].—A view of the position of the viscera at the outlet of the p

Above the prostate a small triangular portion of the bladder
in front and below, by the prostate gland; above, by the recto-
peritoneum; on each side, by the vesicula seminalis and the va
separated from direct contact with the rectum by the recto-ve
relation of this portion of the bladder to the rectum is of extre
surgeon. In cases of retention of urine this portion of the or
jecting into the rectum, between three and four inches from
anus, and may be easily perforated without injury to any imp
portion of the bladder is, consequently, occasionally selected fo
of the operation of tapping the bladder.

Surgical Anatomy.—The student should consider the position of the
ence to the lateral operation of lithotomy. This operation is performed on th
næum, as it is most convenient for the right hand of the operator. A groo

introduced into the bladder, the first incision is commenced midway between the anus and the back of the scrotum (*i. e.* in an ordinary adult perinæum about an inch and a half in front of the anus) a little on the left side of the raphe, and carried obliquely backward and outward to midway between the anus and tuberosity of the ischium. The incision divides the integument and superficial fascia, the inferior hæmorrhoidal vessels and nerves, and the superficial and transverse perineal vessels. If the forefinger of the left hand is thrust upward and forward into the wound, pressing at the same time the rectum inward and backward, the staff may be felt in the membranous portion of the urethra. The finger is fixed upon the staff, and the structures covering it are divided with the point of the knife, which must be directed along the groove toward the bladder, the edge of the knife being turned outward and backward, dividing in its course the membranous portion of the urethra and part of the left lobe of the prostate gland to the extent of about an inch. The knife is then withdrawn, and the forefinger of the left hand passed along the staff into the bladder. The position of the stone having been ascertained, the staff is to be withdrawn, and the forceps is introduced over the finger into the bladder. If the stone is very large, the opposite side of the prostate may be notched before the forceps is introduced: the finger is now withdrawn, and the blades of the forceps opened and made to grasp the stone, which must be extracted by slow and cautious undulating movements.

Parts Divided in the Operation.—The various structures divided in this operation are as follows: the integument, superficial fascia, inferior hæmorrhoidal vessels and nerves, and probably the superficial perineal vessels and nerves, the posterior fibres of the Accelerator urinæ, the Transversus perinæi muscle and artery, the triangular ligament, the anterior fibres of the Levator ani, part of the Compressor urethræ, the membranous and prostatic portions of the urethra, and part of the prostate gland.

Parts to be Avoided in the Operation.—In making the necessary incisions in the perinæum for the extraction of a calculus the following parts should be avoided: The primary incision should not be made too near the middle line, for fear of wounding the bulb of the corpus spongiosum or the rectum; nor too far externally, otherwise the pudic artery may be implicated as it ascends along the inner border of the pubic arch. If the incisions are carried too far forward, the artery of the bulb may be divided; if carried too far backward, the entire breadth of the prostate and neck of the bladder may be cut through, which allows the urine to become infiltrated behind the pelvic fascia into the loose areolar tissue between the bladder and rectum, instead of escaping externally; diffuse inflammation is consequently set up, and peritonitis, from the close proximity of the recto-vesical peritoneal fold, is the result. If, on the contrary, only the anterior part of the prostate is divided, the urine makes its way externally, and there is less danger of infiltration taking place.

During the operation it is of great importance that the finger should be passed into the bladder *before* the staff is removed; if this is neglected, and if the incision made in the prostate and neck of the bladder is too small, great difficulty may be experienced in introducing the finger afterward; and in the child, where the connections of the bladder to the surrounding parts are very loose, the force made in the attempt is sufficient to displace the bladder upward into the abdomen, out of the reach of the operator. Such a proceeding has not unfrequently occurred, producing the most embarrassing results and total failure of the operation.

It is necessary to bear in mind that the arteries in the perinæum occasionally take an abnormal course. Thus the artery of the bulb, when it arises, as sometimes happens, from the pudic opposite the tuber ischii, is liable to be wounded in the operation for lithotomy in its passage forward to the bulb. The accessory pudic may be divided near the posterior border of the prostate gland, if this is completely cut across; and the prostatic veins, especially in people advanced in life, are of large size, and give rise, when divided, to troublesome hæmorrhage.

THE FEMALE PERINÆUM.

The **female perinæum** presents certain differences from that of the male, in consequence of the whole of the structures which constitute it being perforated in the middle line by the vulvo-vaginal passage.

The **superficial fascia**, as in the male, consists of two layers, of which the superficial one is continuous with the superficial fascia over the rest of the body, and the deep layer, corresponding to the fascia of Colles in the male, is like it attached to the ischio-pubic ramus, and in front is continued forward through the labia majora to the inguinal region. It is of less extent than the male, in consequence of being perforated by the aperture of the vulva.

On removing this fascia the muscles of the female perinæum, which have already been described (page 374), are exposed. The Sphincter vaginæ, corresponding to the Accelerator urinæ in the male, consists of an attenuated plane of fibres, forming an orbicular muscle around the orifice of the vagina, instead of being united in a median raphe, as in the male. The Erector clitoridis is proportionately reduced in size, but differs in no other respect, and the Transversus perinæi is similar to the muscle of the same name in the male.

The triangular ligament of the urethra is not strongly marked as in the male. It transmits the urethra and the tube of the vagina.

The **Compressor Urethræ** (*Transversus perinæi profundus*) corresponds with the Compressor urethræ in the male. It arises from the ischio-pubic ramus, and, passing inward, its anterior fibres blend with the muscle of the opposite side, in front of the urethra; its middle fibres, the most numerous, are inserted into the side of the vagina, and the posterior fibres join the central point of the perinæum.

The distribution of the internal pudic artery is the same as in the male (see page 567), and the pudic nerve has also a similar arrangement, the dorsal nerve being, however, very small and supplying the clitoris.

The corpus spongiosum is divided into two lateral halves, which are represented by the *bulbi vestibuli* and *partes intermediales* (see page 1027).

The **perineal body** fills up the interval between the lower part of the vagina and the rectum. Its base is covered by the skin lying between the anus and

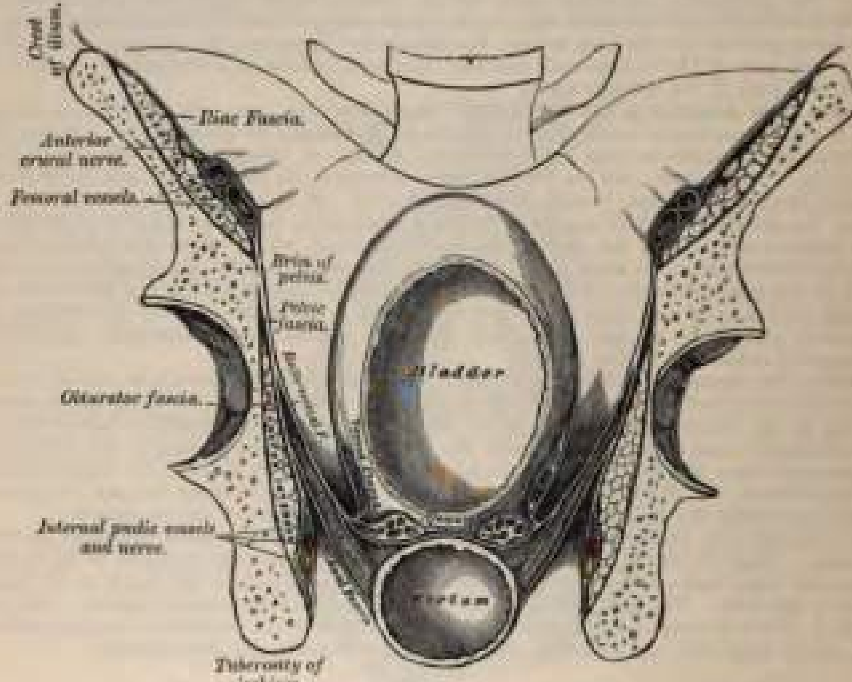


FIG. 594.—A transverse section of the pelvis, showing the pelvic fascia from behind.

vagina on what is called the "perinæum." Its anterior surface lies behind the posterior vaginal wall, and its posterior surface lies in front of the anterior rectal wall and the anus. It measures about an inch and a quarter from before backward, and laterally extends from one tuberosity of the ischium to the other. In it are situated the muscles belonging to the external organs of generation. Through its centre runs the transverse perineal septum, which is of great strength in women, and forms on either side, behind the posterior commissure, a hard, ill-defined body, consisting of connective tissue, with much yellow elastic tissue and interlacing bundles of involuntary muscular fibres, in which the voluntary muscles of the perinæum are inserted.

THE PELVIC FASCIA.

The **Pelvic fascia** (Fig. 595) is a thin membrane which lines the whole of the cavity of the pelvis and is continuous over the back part of the ilio-pectineal line with the iliac fossa. It is attached to the brim of the pelvis, for a short distance, at the side of the cavity, and to the inner surface of the bone round the attachment of the Obturator internus. At the posterior border of this muscle it is continued backward as a very thin membrane in front of the Pyriformis muscle and sacral nerves to the front of the sacrum. In front it follows the attachment of the Obturator internus to the bone, arches beneath the obturator vessels, completing the orifice of the obturator canal, and at the front of the pelvis is attached to the lower part of the symphysis pubis. At the level of a line extending from the lower part of the symphysis pubis to the spine of the ischium is a thickened whitish band, termed the *white line*; this marks the attachment of the Levator ani muscle to the pelvic fascia, and corresponds to its point of division into two layers, the *obturator* and *recto-vesical*.

The **obturator fascia** descends and covers the Obturator internus muscle. It is a direct continuation of the parietal pelvic fascia below the white line above mentioned, and is attached to the pelvic arch, the ischial tuberosities, and to the margin of the great sacro-sciatic ligaments. This fascia forms a canal for the pudic

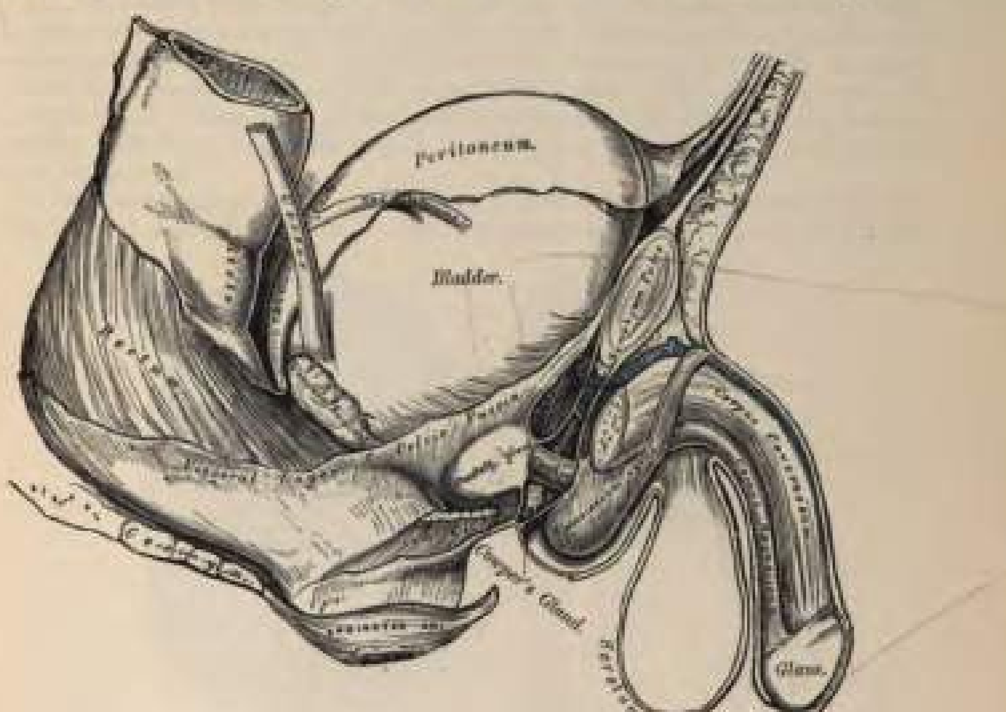


FIG. 595.—Side view of the pelvic viscera of the male subject, showing the pelvic and perineal fasciæ.

vessels and nerve in their passage forward to the perinæum, and gives off a thin membrane which covers the perineal aspect of the Levator ani muscle, called the *ischio-rectal (anal) fossa*. From its attachment to the rami of the os pubis and ischium a process is given off which is continuous with a similar process from the opposite side, so as to close the front part of the outlet of the pelvis, forming the deep layer of the triangular ligament.

The **recto-vesical fascia** (*visceral layer of the pelvic fascia*) descends into the pelvis upon the upper surface of the Levator ani muscle, and invests the prostate, bladder, and rectum. From the inner surface of the symphysis pubis a short rounded band is continued, on each side of the middle line, to the upper surface of the prostate and neck of the bladder, forming the pubo-prostatic or anterior true ligaments of the bladder. At the side this fascia is connected to the side of the prostate, enclosing this gland and the vesico-prostatic plexus of veins, and is continued on to the side of the bladder, forming the lateral true ligaments of the organ. Another prolongation invests the vesiculæ seminales, and passes across between the bladder and rectum, being continuous with the same fascia of the opposite side. Another thin prolongation is reflected round the surface of the lower end of the rectum. The Levator ani muscle arises from the point of division of the pelvic fascia, the visceral layer of the fascia descending upon and being intimately adherent to the upper surface of the muscle, while the under surface of the muscle is covered by a thin layer derived from the obturator fascia, called the *ischio-rectal* or *anal fascia*. In the female the vagina perforates the recto-vesical fascia, and receives a prolongation from it.

GENERAL ANATOMY OR HISTOLOGY.

THE ANIMAL CELL (Fig. 596).

ALL the tissues and organs of which the body is composed were originally developed from a microscopic body (the *ovum*), consisting of a soft gelatinous granular material enclosed in a membrane, and containing a vesicle, or small spherical body, inside which are one or more solid spots. This may be regarded as a perfect cell. Moreover, all the solid tissues can be shown to consist largely of similar bodies or cells, differing, it is true, in external form, but essentially similar to an ovum.

In the higher organisms all such cells may be defined as "nucleated masses of protoplasm of microscopic size." The two essentials, therefore, of an animal

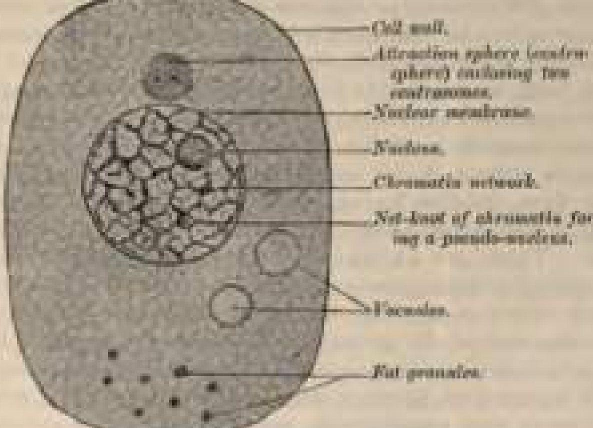


FIG. 596.—Diagram of a cell. (Modified from Wilson.)

cell in the higher organisms are, the presence of a soft gelatinous granular material, similar to that found in the ovum, and which is usually styled *protoplasm*; and a small spherical body imbedded in it, and termed a *nucleus*;[1] the remaining constituents of the ovum—viz., its limiting membrane and the solid spot contained in the nucleus, called the *nucleolus*—are not considered essential to the cell, and in fact many cells exist without them.

Protoplasm (*cytoplasm*) is a material probably of variable constitution, but yielding to the chemist on its disintegration bodies chiefly of proteid nature. Lecithin and cholesterin are constantly found in it, as well as inorganic salts, chief among which are the phosphates and chlorides of the alkali metals and calcium. It is of a semifluid, viscid consistence, and appears either as a hyaline substance, homogeneous and clear, or else it exhibits a granular appearance. This gran-

[1] In certain lower forms of life masses of protoplasm without a nucleus have been described by Huxley and others as cells.

ular appearance, under a high power of the microscope, is seen to be due to the fact that protoplasm consists of a network or honeycombed reticulum, containing in its meshes a homogeneous substance. The former is known as *spongioplasm*, the latter as *hyaloplasm*. The granular appearance is often caused by the knots of the network being mistaken for granules; but, in addition to this, protoplasm often contains true granules, some of which are proteid in nature and probably essential constituents; others are fat- or pigment-granules, and are regarded as adventitious material taken in from without. The size and shape of the meshes of the spongioplasm vary in different cells and in different parts of the same cell. In many fixed cells, *e. g.*, epithelial cells, the external layer becomes denser than the rest, and often altered by the deposition in it of some chemical substance, so as to constitute a membrane which encloses the rest of the protoplasm and forms the *cell-wall*. The relative amount of spongioplasm and hyaloplasm varies in different cells; the latter preponderating in the young cell and the former increasing in amount, at the expense of the hyaloplasm, as the cell grows.

The most striking characteristics of protoplasm are its vital properties of *motion* and *nutrition*. By motion is meant the property which protoplasm has of changing its shape and position by some intrinsic power, which enables it to thrust out from its main body an irregular process, into which the whole of the protoplasmic substance is gradually drawn, so that the mass comes to occupy a new position. This, on account of its resemblance to the movements observed in the Amœba or Proteus animalcule, has been termed "amœboid movement." Ciliary movement, or the vibration of hair-like processes from the surface of any structure, may also be regarded as a variety of the motion with which protoplasm is endowed.

Nutrition is the power which protoplasm has of attracting to itself the materials necessary for its growth and maintenance from surrounding matter. When any foreign particle comes in contact with the protoplasmic substance, it becomes incorporated in it by being enwrapped by one or more processes projected from the parent mass which enclose it. When thus taken up, it may remain in the substance of the protoplasm for some time without change, or may be again extruded.

The **nucleus** is a minute body, imbedded in the protoplasm, and usually of a spherical or oval form, its size having little relation to the size of the cell. It is surrounded by a well-defined wall, the *nuclear membrane*, which encloses the nuclear contents. These are known as the *nuclear substance* (nuclear matrix), which is composed of a homogeneous material and a stroma or network. The former is probably of the same nature as the hyaloplasm of the cell, but the latter, which forms also the wall of the nucleus, differs from the spongioplasm of the cell-substance. It is sometimes known as the *chromoplasm* or *intranuclear network*, and consists of a network of fibres or filaments arranged in a reticular manner. These filaments stain very readily with certain dyes; they are therefore named *chromatin*; while the interstitial substance does not stain readily, and is hence called *achromatin*. In some resting nuclei, *i. e.*, nuclei which are not undergoing subdivision, the nuclear filaments do not form a network, but present the appearance of a convoluted skein, similar to that found in a nucleus about to undergo division, and which will be immediately described.

Within the nuclear matrix are one or more highly refracting bodies, termed *nucleoli*, connected with the nuclear membrane by the nuclear filaments. They are regarded as being of two kinds. Some are mere local condensations of the chromoplasm; these are irregular in shape and are termed *pseudo-nucleoli*; others are distinct bodies differing from the pseudo-nucleoli both in nature and chemical composition; they may be termed *true nucleoli*, and are usually found in resting cells.

The nuclear substance differs chemically from ordinary protoplasm in containing *nuclein*, in its power of resisting the action of acids and alkalies, in its imbibing more intensely the stain of carmine, hæmatoxylin, etc., and in its remaining unstained by some reagents which color ordinary protoplasm.

Recent investigations tend to show that most living cells contain, in addition to their protoplasm and nucleus, a minute particle which, on account of the power it appears to possess of attracting the surrounding protoplasmic granules, is termed the *attraction-particle* or *centrosome;* it usually lies near the nucleus. The spherical arrangement of fibrillar rows of granules surrounding the central particle is termed the *attraction-sphere* or *centrosphere.* These spheres are usually double, and are connected by a spindle-shaped system of delicate fibrils (*achromatic spindle*). They are best seen in young cells which are about to undergo the process of division, a process believed to commence in these bodies.

The process of reproduction of cells is usually described as being brought about by *indirect* or by *direct division. Indirect division* or *karyokinesis* (*karyomitosis*) has been observed in all the tissues—generative cells, epithelial tissue, connective tissue, muscular tissue, and nerve-tissue—and probably it will ultimately be shown that the division of cells always takes place in this way, and that the process of reproduction of cells by direct division is, as is believed by some observers, merely a sort of imperfect or abnormal karyokinesis.

The process of indirect cell-division is characterized by a series of complex changes in the nucleus, leading to its subdivision; this being followed by cleavage of the cell-protoplasm. Starting with the nucleus in the quiescent or *resting* stage, these changes may be briefly grouped under the four following phases:

1. *Prophase.*—The nuclear network of chromatin-filaments assumes the form of a twisted *skein* or *spirem*, while the nuclear membrane and nucleolus disappear. The convoluted skein of chromatin divides into a definite number of V-shaped loops or *chromosomes.* Coincident with or preceding these changes the centrosome, or attraction-particle, which usually lies by the side of the nucleus, undergoes subdivision, and the two resulting centrosomes, each surrounded by a centrosphere, are seen to be connected by a spindle of delicate achromatic fibres, the *achromatic spindle.* These centrosomes move away from each other—one toward each extremity of the nucleus—and the fibrils of the achromatic spindle are correspondingly lengthened. The centrosomes are now situated one at either extremity or pole of the elongated spindle, and each is surrounded by a centrosphere, from which fibrils radiate into the investing protoplasm. A line encircling the spindle midway between its poles is named the *equator*, and around this the V-shaped chromosomes arrange themselves in the form of a star, thus constituting the *mother star* or *monaster.*

2. *Metaphase.*—Each V-shaped chromosome now undergoes longitudinal cleavage into two equal halves or *daughter chromosomes*, the cleavage commencing at the apex of the V and extending along its divergent limbs. The daughter chromosomes, thus separated, travel in opposite directions along the fibrils of the achromatic spindle toward the centrosomes, around which they group themselves, and thus two star-like figures are formed, one at either pole of the achromatic spindle. This is termed the *diaster.*

3. *Anaphase.*—The V-shaped daughter chromosomes now assume the form of a *skein* or *spirem*, and eventually form the network of chromatin which is characteristic of the resting nucleus. The nuclear membrane and nucleolus are also differentiated during this phase. The cell-protoplasm begins to appear constricted around the equator of the achromatic spindle, where double rows of granules are also sometimes seen. The constriction deepens and the original cell gradually becomes divided.

4. *Telophase.*—In this stage the cell is completely divided into two new cells, each with its own nucleus, centrosome, and centrosphere, which assume the ordinary positions occupied by such structures in the resting stage.

In the case of prickle-cells the subdivision of the cell is incomplete; here the achromatic spindle-threads appear to persist and bridge across the intercellular spaces, constituting the prickles.

The series of diagrams (Fig. 597), by Professor S. Delépine, is intended to explain the formation of some of the most important changes observed in nuclei

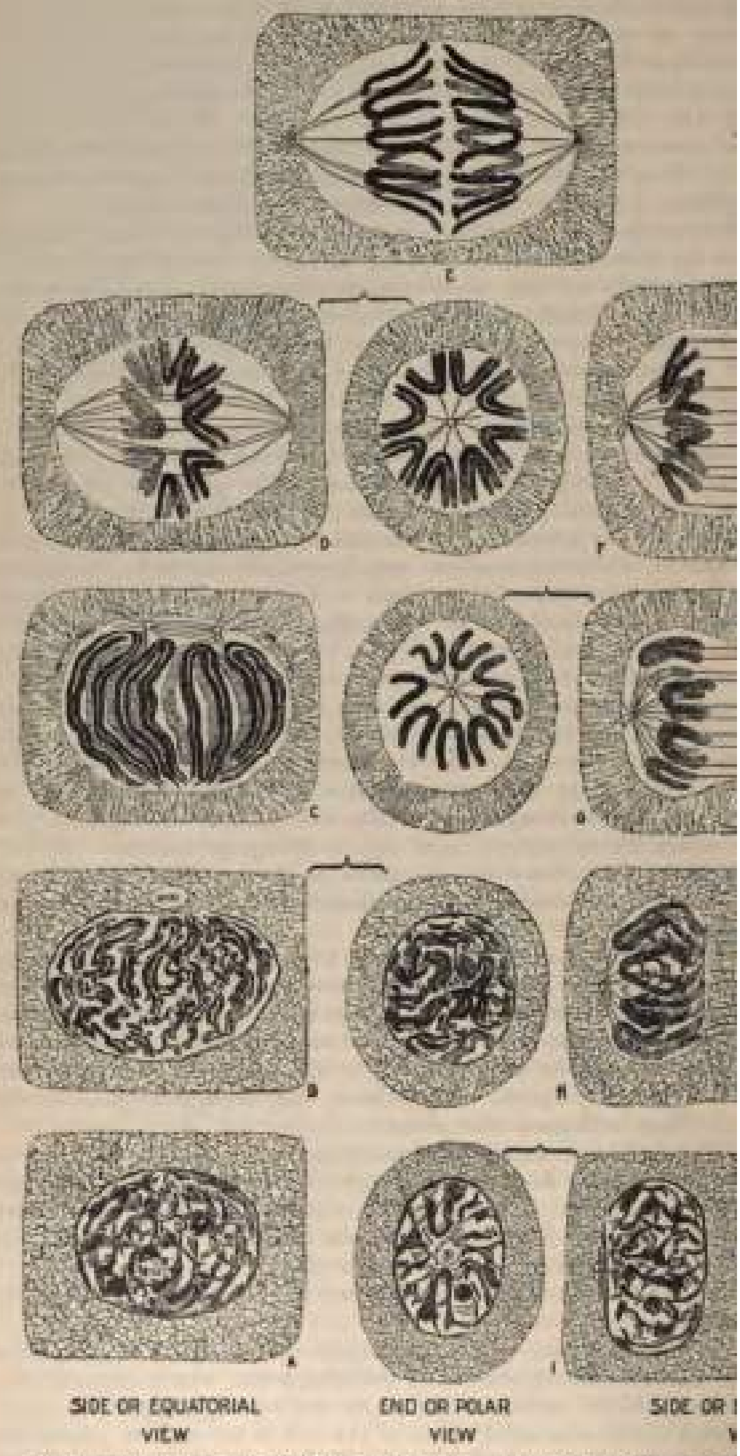


FIG. 597.—Karyokinesis; or indirect cell-division. A. Resting nucleus. B. Ske Skein or spirem, open. D. Mother star, monaster. E. Metaphase. F. Daughter stars skeins or dispirem, beginning to form. H. Daughter skeins or dispirem, formed. I. R

of cells during karyokinesis (mitosis); it is based chiefly on the work of Flemming, Strasburger, E. van Beneden, Rabl, O'Hertwig, Henneguy, etc. A. *Resting nucleus.* Nucleolus and nuclear membrane visible. A centrosome is represented near the nucleus. B and C. *Skein* or *spirem.* Chromatic filaments much convoluted. Evidence of longitudinal splitting begins to be distinct in several parts. The centrosome has divided; the nuclear membrane is becoming indistinct. The two centrosomes are widely separated, and the space between them is occupied by the achromatic spindle. (Two arrows indicate the position which the centrosomes will ultimately occupy; during their passage to these points the achromatic spindle seems to be within the nucleus.) The nuclear membrane has disappeared. D. *Mother star, monaster.* The nuclear segments (chromosomes) resulting from the breaking-up of the chromatic filament into fragments of nearly equal length have moved toward the equator of the spindle, where they now form an equatorial plate. These segments are all split longitudinally. E. *Metaphase.* One half of each chromosome moves toward one pole and the other half toward the other pole, being guided toward the centrosomes by the achromatic filaments. F. *Daughter stars* or *diaster.* G. *Daughter skeins* or *dispirem*, beginning to form. Segments in the form of thick loops not closely packed. H. *Daughter skeins* or *dispirem*, formed. Segments more closely packed and less distinct, owing to the formation of anastomoses. I. *Resting daughter nuclei.* Cell completely divided into two, but bridges remain between them in the region previously occupied by the achromatic filaments, these being specially distinct in certain cells, *e. g.*, prickle-cells. The nucleus has a distinct nuclear membrane and a nucleolus.

In the reproduction of cells by *direct* division the process is brought about either by segmentation or by gemmation. In reproduction by *segmentation* or *fission* the nucleus becomes constricted in its centre, assuming an hour-glass shape, and then divides into two. This leads to a cleavage or division of the whole protoplasmic mass of the cell; and thus two daughter cells are formed, each containing a nucleus. These daughter cells are at first smaller than the original mother cell; but they grow, and the process may be repeated in them, so that multiplication may take place rapidly. In reproduction by *gemmation* a budding-off or separation of a portion of the nucleus and parent-cell takes place, and, becoming separated, forms a new organism.

The **cell-wall**, which is not an essential constituent, and in fact is often absent, is merely the external layer of the protoplasm, firmer than the rest of the cell, and often thickened by the deposit in it of certain chemical substances. It forms a flexible, transparent, finely striated membrane, sometimes furnished with minute pores, so as to be permeable to fluids.

THE NUTRITIVE FLUIDS.

The **circulating fluids** of the body, which subserve its nutrition, are the blood, the lymph, and the chyle.

THE BLOOD.

The blood is an opaque, rather viscid fluid, of a bright-red or scarlet color when it flows from the arteries, of a dark-red or purple color when it flows from the veins. It is salt to the taste, and has a peculiar faint odor and an alkaline reaction. Its specific gravity is about 1.060, and its temperature is generally about 100° F., though varying slightly in different parts of the body.

General Composition of the Blood.—Blood consists of a faintly yellow fluid, the *plasma* or *liquor sanguinis*, in which are suspended numerous minute particles, the *blood-corpuscles*, the majority of which are colored and give to the blood its red tint. If a drop of blood is placed in a thin layer on a glass slide and examined under the microscope, a number of these corpuscles will be seen immersed in the clear fluid plasma.

The **Blood-corpuscles** are chiefly of two kinds: (1) colored corpuscles or erythrocytes, (2) colorless corpuscles or leucocytes. A third variety, the blood-platelets, are of subsidiary importance.

1. Colored or red corpuscles (*erythrocytes*), when examined under the microscope, are seen to be circular disks, biconcave in profile. They have no nuclei, but in consequence of their biconcave shape present, according to the alteration of focus under an ordinary high power, a central part, sometimes bright, sometimes dark, which has the appearance of a nucleus (Fig. 598, *a*). It is to their aggregation that the blood owes its red hue, although when examined by transmitted light their color appears to be only a faint reddish yellow. Their size varies slightly even in the same drop of blood; but it may be stated that their ordinary diameter is about $\frac{1}{3200}$ of an inch, while their thickness is about $\frac{1}{12000}$ of an inch or nearly one-quarter of their diameter. Besides these there are found, especially in disease (*e. g.*, anæmic conditions), certain smaller corpuscles of about one-half or one-third of the size just indicated; these are termed *microcytes*, and are very scarce in human blood. The number of red corpuscles in the blood is enormous; between 4,000,000 and 5,000,000 are contained in a cubic millimetre. Power states that the red corpuscles of an adult would present an aggregate surface of about 3000 square yards. Each corpuscle consists of a colorless elastic spongework or stroma, condensed at the periphery to form an investing membrane, and uniformly diffused throughout this are the colored fluid contents. The stroma is composed mainly of *nucleo-proteid* and of the fatty substances, *lecithin* and *cholesterin*, while the colored material consists chiefly of the respiratory proteid, *hæmoglobin*, which contains a proportion of iron in addition to the ordinary proteid elements. This proteid has a great affinity for oxygen, and when removed from the body crystallizes readily under certain circumstances. It is very soluble in water, the addition of which to a drop of blood speedily dissolves out the hæmoglobin from the corpuscles.

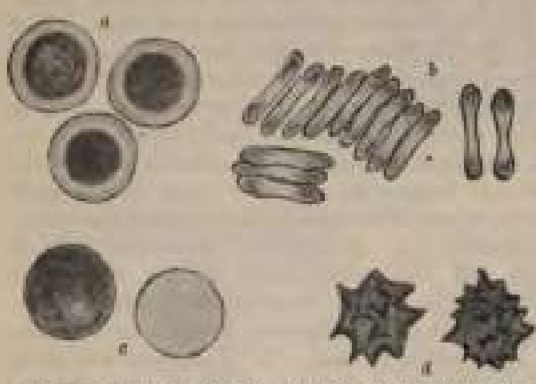


FIG. 598.—Human red blood-corpuscles. Highly magnified. *a.* Seen from the surface. *b.* Seen in profile and forming rouleaux. *c.* Rendered spherical by water. *d.* Rendered crenate by salt solution.

If the web of a frog's foot is spread out and examined under the microscope, the blood is seen to flow in a continuous stream through the vessels, and the corpuscles show no tendency to adhere to each other or to the wall of the vessel. Doubtless the same is the case in the human body; but when the blood is drawn and examined on a slide without reagents, the corpuscles often collect into heaps like rouleaux of coins (Fig. 598, *b*). It has been suggested that this phenomenon may be explained by alteration in surface tension.

During life the red corpuscles may be seen to change their shape under pressure so as to adapt themselves to some extent to the size of the vessel. They are, however, highly elastic, and speedily recover their shape when the pressure is removed. They are soon influenced by the medium in which they are placed, and by the specific gravity of the medium. In water they swell up, lose their shape, and become globular (Fig. 598, *c*). Subsequently the hæmoglobin becomes dissolved out, and the envelope can be barely distinguished as a faint, circular outline. Solutions of salt or sugar, denser than the plasma, give them a stellate or crenated appearance (Fig. 598, *d*); but the usual shape may be restored by diluting the solution to the same specific gravity as the plasma. The crenated outline may be produced as the first effect of the passage of an electric shock; subsequently, if sufficiently strong, the shock ruptures the envelope. A solution of salt or sugar of the same specific gravity as the plasma, merely separates the blood-corpuscles mechanically without changing their shape.

The **colorless corpuscles** (*leucocytes*) are of various sizes, some no larger, others even smaller, than the red corpuscles. In human blood, however, the majority are rather larger than the red corpuscles, and measure about $\frac{1}{2500}$ to $\frac{1}{3000}$ of an inch in diameter. On the average from 10,000 to 12,000 leucocytes are found in each cubic millimetre of blood.

They consist of minute masses of nucleated protoplasm, and exhibit several varieties, which are differentiated from each other chiefly by the occurrence or non-occurrence of granules in their protoplasm and by the staining reactions of these granules when present (Fig. 599). (1) The most numerous and important are spherical in shape, and are characterized by a nucleus, which often consists of two or three parts (multipartite) connected together by fine threads of chromatin. The protoplasm is clear, and contains a number of very fine granules, which stain with acid dyes, as eosin (Fig. 599, 3). (2) A second variety comprises about 2.4 per cent. of the leucocytes; they are larger than the previous kind, and are made up of a coarsely granular protoplasm, the granules being highly refractile and grouped round a single nucleus of horseshoe shape (Fig. 599, 1). These granules stain deeply with eosin, and the cells are therefore often termed *eosinophile corpuscles*. (3) A leucocyte characterized by the presence of a trilobed nucleus, and having in its protoplasm fine granules which stain with basic dyes, such as methylene-blue, is found in small numbers (Fig. 599, 5). (4) The fourth variety is called the *hyaline* cell (Fig. 599, 4). This is usually about the same size as that of the eosinophile cell, and, when at rest, is spherical in shape and contains a single round or oval nucleus. The protoplasm is free from granules, but is not quite transparent, having the appearance of ground glass. (5) The fifth kind of colorless corpuscle is designated the *lymphocyte* (Fig. 599, 2), because it is identical with the lymphoid cell derived from the lymphatic glands, the spleen, tonsil, and thymus. It is the smallest of the leucocytes, and consists chiefly of a spheroidal nucleus with very little surrounding protoplasm of a homogeneous nature; it is regarded as the immature form of the hyaline cell. The fourth and fifth varieties together constitute from 20 to 30 per cent. of the colorless cells, but of these two varieties the lymphocytes are by far the more numerous.

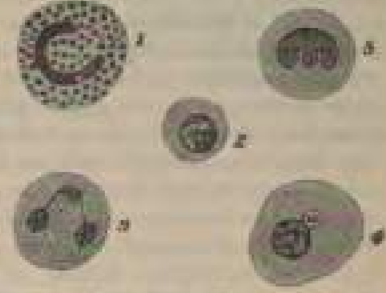


FIG. 599.—Varieties of leucocytes found in human blood. 1. Eosinophile cell with coarse granules and horseshoe-shaped nucleus. 2. Lymphocyte. 3. Polynuclear or finely granular cell. 4. Hyaline cell, showing nucleus with chromatin threads and two centrosomes in clear protoplasm. 5. Finely granular leucocyte; the nucleus is lobed, the granules stain with basic dyes, such as methylene-blue.

The white corpuscles are very various in shape in living blood (Fig. 600), because many of them have the power of constantly changing their form by protruding finger-shaped or filamentous processes of their own substance, by which

FIG. 600.—Human colorless blood-corpuscle, showing its successive changes of outline within ten minutes when kept moist on a warm stage. (Schofield.)

they move, and may take up granules from the surrounding medium. In locomotion the corpuscle pushes out a process of its substance—a *pseudopodium*, as it is called—and then shifts the rest of the body into it. In the same way when any granule or particle comes in its way it wraps a pseudopodium round it, and then withdrawing it, lodges the particle in its own substance. By means of these amœboid properties the cells have the power of wandering or emigrating from the blood-vessels by penetrating their walls and thus finding their way into the extra-vascular spaces. A chemical investigation of the protoplasm of the leucocytes shows the presence of nucleo-proteid and of a globulin. The occurrence of small amounts of fat and glycogen may also be demonstrated.

The **Blood-platelets** are discoid or irregularly shaped, colorless, refractile bodies, much smaller than the red cells. Considerable discussion has arisen as to their significance. In spite of the fact that they have been observed in the blood-vessels during life, there is, at present, a tendency to regard them as products of disintegration of the white cells, or as precipitates, possibly of nucleo-proteid, and not as living elements of the blood.

Origin of the Blood-corpuscles.—In the embryo the red corpuscles are developed from mesoblastic cells in the vascular area of the blastoderm. These cells unite with one another to form a network, their nuclei multiply in number, and around some of the nuclei an aggregation of colored protoplasm takes place. After a time the network becomes hollowed out by an accumulation of fluid, and forms capillary blood-vessels, and in the fluid those nuclei which are surrounded by colored protoplasm float as the first red blood-cells.[1] The embryonic corpuscles are thus nucleated, and, further, they have the power of amœboid movement. These cells disappear in later embryonic life, to be replaced by smaller non-nucleated corpuscles, having all the characters of the adult erythrocyte, which, according to Schäfer, are formed within certain cells of the connective tissue. Small globules of reddish coloring-matter appear in the protoplasm of these cells, and these eventually becoming larger, more uniform in size and disk-shaped, float in a cavity which results from the coalescence of numerous vacuoles. The cells becoming more hollowed join with neighboring cells to form new blood-vessels, and these become connected with previously existing vessels. In post-embryonic life the important source of the red corpuscles is the red marrow in the ends of the long bones and especially in the ribs and sternum. Here are found special, nucleated, colored cells, termed *erythroblasts*, which are probably direct descendants of the nucleated, embryonic red cells. These erythroblasts by atrophy and disappearance of their nuclei (or, as some observers maintain, by their extrusion) and by assumption of the biconcave form are transformed into the adult red corpuscle. Of the white corpuscles of the blood, the lymphocytes are derived from lymphatic tissue generally, and from the lymphatic glands especially, and enter the blood by way of the lymph-stream; the hyaline cells probably develop from the lymphocytes, while the eosinophile cells are believed to originate mainly in the bone-marrow and possibly also in the connective tissues.

The **Plasma** or **Liquor Sanguinis**, the fluid portion of the blood, has a yellowish tint, is alkaline in reaction, and of a specific gravity of 1.028. It contains in solution about 10 per cent. of solids, of which four-fifths are proteid in nature; the remainder being salts, chiefly chlorides, phosphates, and sulphates of the alkali metals; carbohydrates, chiefly sugar; fats and soaps, cholesterin, urea, and other nitrogenous extractives. The proteids are three in number, *serum albumen*, *serum globulin*, and *fibrinogen*. Fibrinogen is a body of the globulin class, but differs from serum globulin in several respects. It is the substance from which the *fibrin*, which plays so important a part in the clotting of the blood, is derived.

Coagulation of the Blood.—When blood is drawn from the body and allowed to stand, it solidifies in the course of a very few minutes into a jelly-like mass or "clot," which has the same appearance and volume as the fluid blood and, like it, looks quite uniform. Soon, however, drops of a transparent yellowish fluid, the "serum," begin to ooze from the surface of the mass and to collect around it. Coincidently the clot begins to contract, so that in the course of about twenty-four hours, having become considerably smaller and firmer than the first formed jelly-like mass, it floats in a quantity of yellowish serum. The clotting of the blood is due to the formation of a fine meshwork of the insoluble material, *fibrin*, which

[1] Recent observations tend to show that the endothelial lining of the vessels and the blood-corpuscles are of hypoblastic origin.

entangles and encloses the blood-corpuscles. It is supposed that when blood is drawn a nucleo-proteid, termed *prothrombin*, appears in the plasma, probably as the result of disintegration of some of the white cells and perhaps also the blood-platelets. This substance interacts with soluble lime salts in the blood, and a fresh body, *thrombin* or *fibrin-ferment*, is the result. The thrombin then acts on the fibrinogen in solution in the plasma, converting it into insoluble fibrin, while at the same time a very small amount of a new proteid of the globulin type passes into solution.

Fibrin may be obtained, practically free from corpuscles, by whipping the blood, after it has been withdrawn from the body, with a bundle of twigs, to which the fibrin adheres as it is formed. By various means the clotting of the blood may be retarded, so that the plasma may be obtained free from corpuscles; from this plasma there may be derived fibrin and serum, without the cellular elements. Fibrin thus obtained is a white or buff-colored stringy substance, and when observed in the course of formation, under the microscope, shows a meshwork of fine fibrils. After exposure to the air for some time it becomes hard, dry, brown, and brittle. It is one of the class of coagulated proteids, insoluble in hot or cold water, saline solution, alcohol, or ether. Under the action of dilute hydrochloric acid it swells up but does not dissolve, but when thus swollen is readily dissolved by a solution of pepsin.

FIG. 601.—Blood-crystals: *A.* Hæmoglobin crystals from human blood. *B.* Hæmin crystals from blood treated with acetic acid. *C.* Hæmatoidin crystals from an old apoplectic clot.

Serum, with the exception of its proteids, has a composition identical with that of plasma. The fibrinogen characteristic of plasma has disappeared, and the fibrin-ferment or thrombin is found instead, together with the serum albumen and serum globulin which are not involved in the process of coagulation.

The relation of the various constituents of the blood to each other may be easily understood by a reference to the subjoined plan:

Blood	Corpuscles		Clot
	Plasma	Fibrin	Clot
		Serum	

Gases of the Blood.—When blood is exposed to the vacuum of an air-pump, 100 volumes are found to yield about 60 volumes of gas. The gases present are carbon dioxide, oxygen, and nitrogen, and they occur in the following proportions in arterial and venous blood:

	Carbon dioxide.	Oxygen.	Nitrogen.
Arterial blood . . .	40 vols.	20 vols.	1 to 2 vols.
Venous blood . . .	46 to 50 vols.	10 to 12 vols.	1 to 2 vols.

The greater quantity of the oxygen is in loose chemical combination with the hæmoglobin of the red corpuscles. The carbon dioxide exists in combination for the most part as sodium bicarbonate and carbonate. The nitrogen is in simple solution in the plasma.

Blood-crystals.—Hæmoglobin, as already stated, readily crystallizes when separated from the blood-corpuscles. In human blood the crystals are elongated prisms (Fig. 601, *A*), and in the majority of animals belong to the rhombic system, though in the squirrel hexagonal plates are met with. Small brown prismatic crystals of *hæmin* (Fig. 601, *B*) may be obtained by mixing dried blood with common salt and boiling with a few drops of glacial acetic acid. A drop of the mixture on a slide will show the characteristic crystals on cooling. *Hæmatoidin* crystals (Fig. 601, *C*) occur sometimes in old blood-clots.

LYMPH AND CHYLE.

Lymph is a transparent, colorless or slightly yellow fluid, which is conveyed by a set of vessels named *lymphatics* into the blood. These vessels arise in nearly all parts of the body as *lymph-capillaries*. They take up the blood-plasma which has exuded from the blood-capillaries into the tissue-spaces where it has nourished the tissue-elements, and return it into the veins close to the heart, there to be mixed with the mass of blood. The greater number of these lymphatics empty themselves into one main duct, the *thoracic duct*, which passes upward along the front of the spine and opens into the large veins on the left side of the root of the neck. The remainder empty themselves into a smaller duct which terminates in the corresponding veins on the right side of the neck.

Lymph, as its name implies, is a watery fluid of sp. gr. about 1.015, closely resembling the blood-plasma, but more dilute and containing only about 5 per cent. of proteids and 1 per cent. of salts and extractives. When examined under the microscope, leucocytes of the lymphocyte class are found floating in the transparent fluid. They are always increased in number after the passage of the lymph through lymphoid tissue, as in lymphatic glands. They are constantly furnishing a fresh supply of colorless corpuscles to the blood.

Chyle is an opaque, milky-white fluid, absorbed by the villi of the small intestine from the food, and carried by a set of vessels similar to the lymphatics, named *lacteals*, to the commencement of the thoracic duct, where it is intermingled with the lymph and poured into the circulation through the same channels. It must be borne in mind that these two sets of vessels, lymphatics and lacteals, though differing in name, are identical in structure, and that the character of the fluid they convey is different only while digestion is going on. At other times the lacteals convey a transparent, nearly colorless lymph.

Chyle exactly resembles lymph in its physical and chemical properties, except that it has, in addition to the other constituents of lymph, a quantity of finely divided fatty particles, the so-called "molecular basis of chyle," to which the milky appearance is due. It contains a little more proteid than lymph, but the chief difference lies in the large quantity of fats, soaps, lecithin, and cholesterin present in the former. Lymph and chyle, containing, as they do, fibrinogen in solution and leucocytes, clot on removal from the body, the coagulum being free from red cells, and presenting a clear or whitish jelly-like appearance.

EPITHELIUM.

All the surfaces of the body—the external surface of the skin, the internal surface of the digestive, respiratory, and genito-urinary tracts, the closed serous cavities, the inner coat of the vessels, and the acini and ducts of all secreting and excreting glands, the ventricles of the brain, and the central canal of the spinal cord—are covered by one or more layers of simple cells, called *epithelium* or *epithelial cells*. These cells are also present in the terminal parts of the organs of special sense, and in some other structures, as the pituitary and thyroid bodies. They serve various purposes, forming in some cases a protective layer, in others acting as agents in secretion and excretion, and again in others being concerned in the elaboration of the organs of special sense. Thus, in the skin, the main purpose served by the epithelium (here called the *epidermis*) is that of protection. As the surface is worn away by the agency of friction or change of temperature new cells are supplied, and thus the surface of the true skin and the vessels and nerves which it contains are defended from damage. In the gastro-intestinal mucous membrane and in the glands the epithelial cells appear to be the principal agents in separating the secretion from the blood or from the alimentary fluids. In other situations (as the nose, fauces, and respiratory passages) the chief office of the epithelial cells appears to be to maintain an equable temperature by the moisture with which they keep the surface always slightly lubricated. In the serous cavities they also keep the opposed layers moist, and thus facilitate their movements on each other. Finally, in all internal parts they insure a perfectly smooth surface.

Of late years there has been a tendency on the part of many histologists to divide these several epithelial structures into two classes: (1) *epithelium*, consisting of nucleated protoplasmic cells, which form continuous masses on the skin and mucous surfaces and the linings of the ducts and alveoli of secreting and excreting glands; and (2) *endothelium*, which is composed of a single layer of flattened transparent squamous cells, joined edge to edge in such a manner as to form a membrane of cells. This is found on the free surfaces of the serous membranes, as the lining membrane of the heart, blood-vessels, and lymphatics; on the surface of the brain and spinal cord, and in the anterior chamber of the eye. Endothelium originates from the embryonic mesoblast, while epithelium arises, as a rule, from the epiblast or hypoblast.

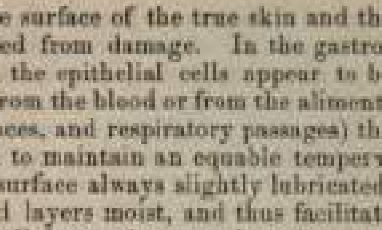


FIG. 602.—Simple pavement epithelium.

Epithelium consists of one or more layers of cells united together by an interstitial cement-substance, supported on a basement-membrane, and is naturally grouped into two classes, according as to whether there is a single layer of cells (*simple epithelium*) or more than one (*stratified epithelium*). A third variety (*transitional epithelium*) is that in which cells in three or four layers are so fitted together that the appearance is not one of distinct stratification. The different varieties of simple epithelium are usually spoken of as squamous or pavement, columnar, glandular or spheroidal, and ciliated.

The *pavement* epithelium (Fig. 602) is composed of flat nucleated scales of various shapes, usually polygonal, and varying in size. These cells fit together by their edges, like the tiles of a mosaic pavement. The nucleus is generally flattened, but may be spheroidal. The flattening depends upon the thinness of the cell. The protoplasm of the cell presents a fine reticulum or honeycombed

FIG. 603.—Columnar epithelium from an intestinal villus.

FIG. 604.—Goblet cells. (From Kirk's *Physiology*.)

network, which gives to the cell the appearance of granulation. This kind of epithelium forms the lining of the air-cells of the lungs. The endothelium, which covers the serous membranes, and which lines the heart, bloodvessels, lymphatics, and the anterior chamber of the eye, is also of the pavement type.

The *columnar* or *cylindrical* epithelium (Fig. 603) is formed of cylindrical or rod-shaped cells set together so as to form a complete layer, resembling, when viewed in profile, a palisade. The cells have a prismatic figure, more or less flattened from mutual pressure, and are set upright on the surface on which they are supported. Their protoplasm is always more or less reticulated, and fine longitudinal striæ may be seen in it. They possess a nucleus which is oval in shape and contains an intranuclear network.

This form of epithelium covers the mucous membrane of nearly the whole gastro-intestinal tract and the glands of that part, the greater part of the

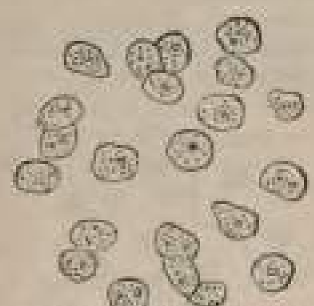


Fig. 605.—Spheroidal epithelium. Magnified 250 times.

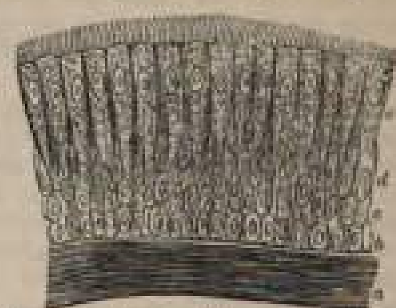


Fig. 606.—Ciliated epithelium from the human trachea. Magnified 250 times. *a.* Innermost layers of the elastic longitudinal fibres. *b.* Homogeneous innermost layer of the mucous membrane. *c.* Deepest round cells. *d.* Middle elongated cells. *e.* Superficial cells, bearing cilia.

urethra, the vas deferens, the prostate, Cowper's glands, Bartholini's glands, and a portion of the uterine mucous membrane. In a modified form it also covers the ovary.

Goblet- or *chalice*-cells are a modification of the columnar cell. They appear to be formed by an alteration in shape of the columnar epithelium (ciliated or otherwise) consequent on the formation of granules which consist of a substance called *mucigen* in the interior of the cell. This distends the upper part of the cell, while the nucleus is pressed down toward its deep part, until the cell bursts and the mucus is discharged on to the surface of the mucous membrane as shown in Fig. 604, the cell then assuming the shape of an open cup or chalice.

The *glandular* or *spheroidal* epithelium (Fig. 605) is composed of spheroidal or polyhedral cells, but the cells may be columnar or cubical in shape in some situ-

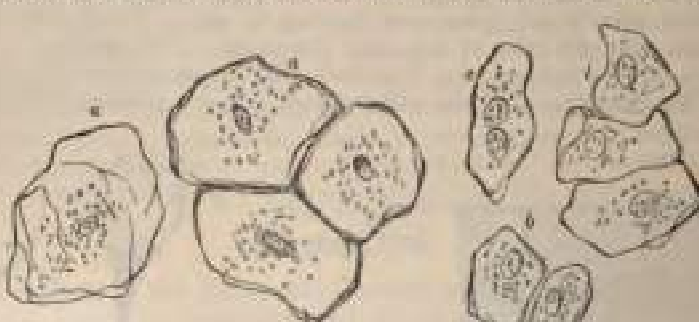


Fig. 607.—Epithelial cells from the oral cavity of man. Magnified 250 times. *a.* Large. *b.* Middle sized. *c.* The same with two nuclei.

ations. Like other forms of epithelial cells, the protoplasm is a fine reticulum, which gives to the cell the appearance of granulation. They are found in the terminal recesses of secreting glands, and the protoplasm of the cells usually contains the materials which the cells secrete.

Ciliated epithelium (Fig. 606) may be of any of the preceding forms, but usually inclines to the columnar shape. It is distinguished by the presence of minute processes, which are direct prolongations of the cell-protoplasm, like hairs or eyelashes (cilia), standing up from the free surface. If the cells are examined during life or immediately on removal from the living body (for which in the human subject the removal of a nasal polypus offers a convenient opportunity) in a weak solution of salt, the cilia will be seen in lashing motion; and if the cells are separate, they will often be seen to be moved about in the field by this motion.

The situations in which ciliated epithelium is found in the human body are: the respiratory tract from the nose downward to the smallest ramifications of the bronchial tube (except a part of the pharynx and the surface of the vocal cords), the tympanum and Eustachian tube, the Fallopian tube and upper portion of the uterus, the vasa efferentia, coni vasculosi, and the first part of the excretory duct of the testicle, and the ventricles of the brain and central canal of the spinal cord.

Stratified epithelium (Fig. 608) consists of several layers of cells superimposed one on the top of the other and varying greatly in shape. The cells of the deepest layer are for the most part columnar in form, and as a rule form a single layer, placed vertically on the supporting membrane; above these are several layers of spheroidal cells, which as they approach the surface become more and more compressed, until the superficial layers are found to consist of flattened scales (Fig. 607), the margins of which overlap one another, so as to present an imbricated appearance. They here undergo a chemical change from the conversion of their protoplasm into a horny substance (*keratin*).

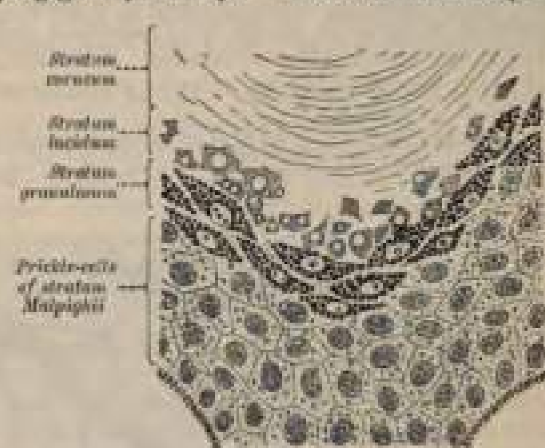


FIG. 608.—Portion of epidermis from a section of the skin of the finger. (Ranvier.) (From Schafer's "Essentials of Histology.")

Certain cells found in the deeper layers of stratified epithelium, and termed *prickle-cells* (Fig. 608), constitute a variety of squamous epithelium. These cells possess short fine fibrils which pass from their margins to those of neighboring cells, serving to connect them together. They are not closely connected together by cement-substance, but are separated from each other by intercellular channels, across which these fine fibrils may be seen bridging; this gives to the cell, when isolated, the appearance of being covered over with a number of short spines, in consequence of the fibrils being broken through. They were first described by Max Schultze and Virchow, and it was believed by them that the cells were dovetailed together. Subsequently this was shown not to be so by Martyn, who pointed out that the prickles were attached to each other by their apices; and recently Delépine has stated that he believes the prickles of prickle-cells are parts of fibrils forming internuclear bundles between the nuclei of the cells of an epithelium in a state of active growth (see Fig. 597).

Transitional epithelium occurs in the ureters and urinary bladder. Here the cells of the most superficial layer are cubical, with depressions on their under surfaces, which fit on to the rounded ends of the cells of the second layer, which are pear-shaped, the apices touching the basement-membrane. Between their tapering points is a third variety of cells, filling in the intervals between them, and of smaller size than those of the other two layers (Fig. 609).

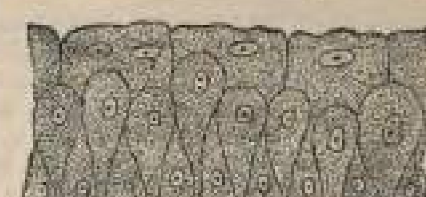


FIG. 609.—Transitional epithelium.

CONNECTIVE TISSUES.

The term **connective tissue** includes a number of tissues which possess this feature in common, viz., that they serve the general purpose in the animal economy of supporting and connecting the tissues of the body. These tissues may differ considerably from each other in appearance, but they present, nevertheless, many points of relationship, and are, moreover, developed from the same layer of the embryo, the mesoblast. They are divided into three great groups: (1) the connective tissues proper, (2) cartilage, and (3) bone. Blood, which has already been described, is, strictly speaking, a form of connective tissue, and is so dealt with by many histologists.

The Connective Tissues Proper.—Several forms or varieties of connective tissue are recognized: (1) Areolar tissue. (2) White fibrous tissue. (3) Yellow elastic tissue. (4) Mucous tissue. (5) Retiform tissue. They are all composed of a homogeneous matrix, in which are imbedded cells and fibres—the latter of two kinds, white and yellow or elastic. The distinction between the different forms of tissue depends upon the relative preponderance of one or other kind of fibre, of cells, or of matrix.

Areolar tissue (Fig. 610) is so called because its meshes are easily distended, and thus separated into areolæ or spaces, which open freely into each other, and are

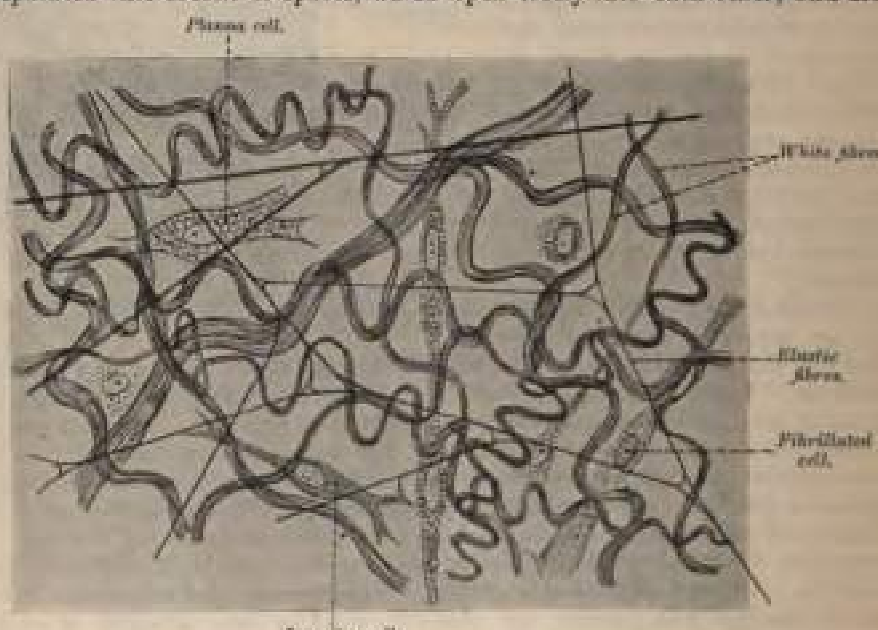


FIG. 610.—Subcutaneous tissue from a young rabbit. Highly magnified. (Schäfer.)

consequently easily blown up with air, or permeated by fluid when injected into any part of the tissue. Such spaces, however, do not exist in the natural condition of the body, but the whole tissue forms one unbroken membrane composed of a number of interlacing fibres, variously superimposed. Hence the term "the cellular membrane" is in many parts of the body more appropriate than its more modern equivalent. The chief use of the areolar tissue is to bind parts together, while by the laxity of its fibres and the permeability of its areolæ it allows them to move on each other, and affords a ready exit for inflammatory and other effused fluids. It is one of the most extensively distributed of all the tissues. It is found beneath the skin in a continuous layer all over the body, connecting it to the subjacent parts. In the same way it is situated beneath the mucous and serous membranes. It is also found between muscles, vessels, and nerves, forming investing sheaths for them, and connecting them with surrounding structures. In addition to this, it is found in the interior of organs, binding together the various lobes and lobules of the compound glands, the various coats of the hollow viscera, and the fibres of muscles, etc., and thus forms one of the most important connecting media of the various structures or organs of which the body is made up. In many parts the areolæ or interspaces of areolar tissue are occupied by fat-cells, constituting *adipose tissue*, which will presently be described.

Areolar tissue presents to the naked eye a flocculent appearance, somewhat like spun silk. When stretched out, it is seen to consist of delicate soft elastic threads interlacing with each other in every direction and forming a network of extreme delicacy. When examined under the microscope (Fig. 610) it is found to be composed of white fibres and elastic fibres intercrossing in all directions, and united together by a homogeneous cement or ground-substance, the *matrix*, showing cell-spaces wherein lie many cellular elements, the *connective-tissue corpuscles*; these contain the protoplasm out of which the whole is developed and regenerated.

The white fibres are arranged in waving bands or bundles of minute transparent homogeneous filaments or fibrillæ. The bundles have a tendency to split up longitudinally or send off slips to join neighboring bundles and receive others in return, but the individual fibres are unbranched and never join other fibres; the *yellow elastic fibres* have a well-defined outline and are considerably larger in size than the white fibrillæ. They vary much, being from the $\frac{1}{24000}$ to the $\frac{1}{4000}$ of an inch in diameter. The fibres form bold and wide curves, branch, and freely anastomose with each other. They are homogeneous in appearance, and tend to curl up, especially at their broken ends.

Connective-tissue Corpuscles.—The cells of areolar tissue are of three principal kinds: (1) Flattened lamellar cells, which may be either branched or unbranched. The branched lamellar cells are composed of clear cell-substance, in which is contained an oval nucleus. The processes of these cells unite so as to form an open network, as in the cornea. The unbranched cells are joined edge to edge like the cells of an epithelium. The "tendon-cells," presently to be described, are an example of this variety. (2) Granule-cells, which are ovoid or spheroidal in shape and formed of a soft protoplasm, containing granules which are albuminous in character and stain deeply with eosin. (3) Plasma-cells of Waldeyer, varying greatly in size and form, but always to be distinguished from the other two varieties by containing a largely vacuolated protoplasm. The vacuoles are filled with fluid, and the protoplasm between the spaces is clear, with occasionally a few scattered granules.

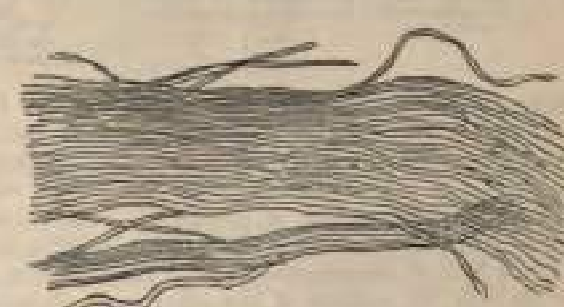


Fig. 611.—White fibrous tissue. High power.

In addition to these three typical forms of connective-tissue corpuscles, areolar tissue may be seen to possess *wandering cells*, *i. e.*, leucocytes which have emigrated from the neighboring vessels, and in some instances, as in the choroid coat of the eye, cells filled with granules of pigment (*pigment-cells*).

The connective-tissue corpuscles lie in spaces in the ground-substance between the bundles of fibres, and these spaces may be brought into view by treating the tissue with nitrate of silver and exposing it to the light. This will color the ground-substance and leave the cell-spaces unstained.

The **white fibrous tissue** (Fig. 611) is a true connecting structure, and serves three purposes in the animal economy. In the form of ligaments it serves to bind bones together; in the form of tendons, it serves to connect muscles to bones or other structures, and it forms an investing or protecting structure to various organs in the form of membranes. Examples of where it serves this latter office are to be found in the muscular fasciæ or sheaths, the periosteum, and perichondrium; the investments of the various glands (such as the tunica albuginea testis, the capsule of the kidney, etc.), the investing sheath of the nerves (epineurium), and of various organs, as the penis and the eye (sheath of the corpora cavernosa and corpus spongiosum, and of the sclerotic). In white fibrous tissue, as its name implies, the white fibres predominate, the matrix being apparent only as a cement-substance, the yellow elastic fibres comparatively few, while the tissue-cells are arranged in a special manner. It presents to the naked eye the appearance of silvery-white glistening fibres, covered over with a quantity of loose, flocculent tissue which binds the fibres together and carries the blood-vessels (Fig. 612). It is not possessed of any elasticity, and only the very slightest extensibility; it is exceedingly strong, so that upon the application of any external vio-

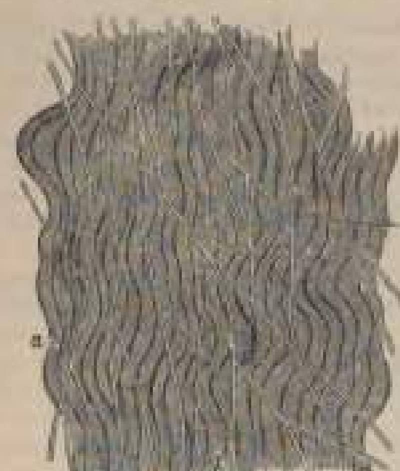


FIG. 612.—Connective tissue. (Klein and Noble Smith.) *a.* The white fibrous element—a layer of more or less sharply-outlined, parallel, wavy bundles of connective-tissue fibrils. On the surface of this layer is *b*, a network of fine elastic fibres.

FIG. 613.—Tendon of mouse's tail, stained with hæmatoxylin, showing chains of cells between the tendon-bundles. (From Quain's Anatomy. E. A. Schäfer.)

lence the bone with which it is connected will fracture before the fibrous tissue will give way. In ligaments and tendons the bundles run parallel with each other; in membranes they intersect one another in different places. The cells occurring in white fibrous tissue are often called "tendon cells." They are situated on the surface of groups of bundles and are quadrangular in shape, arranged in rows in single file, each cell being separated from its neighbors by a narrow line of cement-substance. The nucleus is generally situated at one end of the cell, the nucleus of the adjoining cell being in close proximity to it (Fig. 613). Upon the addition of acetic acid to white fibrous tissue it swells up into a glassy-looking, indistinguishable mass. When boiled in water it is converted almost completely into gelatin. The white fibres being composed of the albuminoid *collagen*, which is often regarded as the anhydride of gelatin.

Yellow Elastic Tissue.—In certain parts of the body a tissue is found which when viewed in mass is of a yellowish color, and is possessed of great elasticity, so that it is capable of considerable extension, and when the extending force is withdrawn returns at once to its original condition. This is *yellow elastic tissue*, which may be regarded as a connective tissue in which the yellow elastic fibres have developed to the practical exclusion of the other elements. It is found in the ligamenta subflava, in the vocal cords, in the longitudinal coat of the trachea and bronchi, in the inner coats of the blood-vessels, especially the larger arteries, and to a very considerable extent in the thyro-hyoid, crico-thyroid, and stylo-hyoid ligaments. It is also found in the ligamentum nuchæ of the lower animals (Fig. 614). In some parts, where the fibres are broad and large and the network close, the tissue presents the appearance of a membrane, with gaps or perforations corresponding to the intervening space. This is to be found in the inner coat of the arteries, and to it the name of *fenestrated membrane* has been given by Henle. The yellow elastic fibres remain unaltered by acetic acid. Chemically they are composed of the albuminoid body, *elastin*.

Vessels and Nerves of Connective Tissue.—The *blood-vessels* of connective tissue are very few—that is to say, there are few actually destined for the tissue itself,

FIG. 614.—Yellow elastic tissue. High power.

although many vessels may permeate one of its forms, the areolar tissue, carrying blood to other structures. In white fibrous tissue the blood-vessels usually run parallel to the longitudinal bundles and between them, sending transverse communicating branches across, and in some forms, as the periosteum and dura mater, they are fairly numerous. In the yellow elastic tissue the blood-vessels also run between the fibres, and do not penetrate them. *Lymphatic* vessels are very numerous in most forms of connective tissue, especially in the areolar tissue beneath the skin and the mucous and the serous surfaces. They are also found in abundance in the sheaths of tendons, as well as in the tendons themselves. *Nerves* are to be found in the white fibrous tissue, where they terminate in a special manner; but it is doubtful whether any nerves terminate in areolar tissue; at all events, they have not yet been demonstrated, and the tissue is possessed of very little sensibility.

Development of Connective Tissue.—Connective tissue is developed from embryonic connective-tissue cells derived from the mesoblast. These cells, at first rounded, become fusiform and branched, and ultimately become the connective-tissue corpuscles. A mucinous intercellular substance or **matrix**, partly formed from the cells themselves and partly from the lymph exuded by the neighboring blood-vessels, gradually separates the cells. In the matrix the

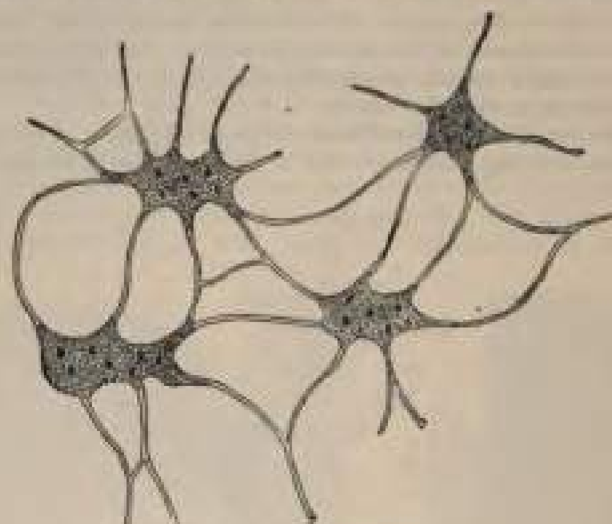


FIG. 615.—Mucous tissue.

fibres are deposited, probably under the influence of the cells, but not by any transformation of the cell protoplasm. In the case of yellow elastic fibres, rows of granules of elastin are first laid down, these eventually fusing to form the fully developed fibre.

1. **Mucous** tissue exists chiefly in the "jelly of Wharton," which forms the bulk of the umbilical cord, but is also found in other situations in the fœtus, chiefly as a stage in the development of the connective tissue. It consists of a matrix, largely made up of mucin, in which are nucleated cells with branching and anastomosing processes (Fig. 615). Few fibres are seen in typical mucous tissue, though, at birth, the umbilical cord shows considerable development of fibres. In the adult the vitreous humor of the eye is a persistent form of mucous tissue, in which there are no fibres, and from which the cells have disappeared, leaving only the mucinous ground-substance.

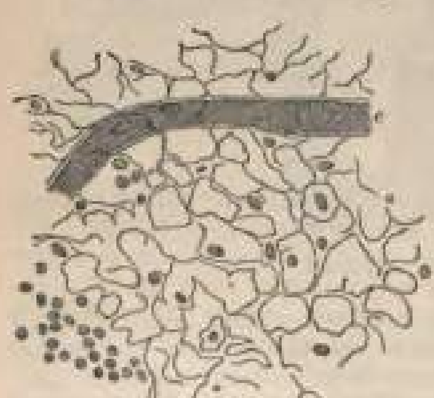


FIG. 616.—Retiform connective tissue, from a lymphatic gland; most of the lymph-corpuscles are removed. (From Klein's "Elements of Histology.") a, The reticulum. c, A capillary blood-vessel.

2. **Retiform** connective tissue is found extensively in many parts of the body, forming the framework of some organs and entering into the construction of many mucous membranes. It is a form of connective tissue, in which the intercellular or ground-substance has, in a great measure, disappeared, and has been replaced by fluid. It is apparently composed almost entirely of extremely fine bundles of white fibrous tissue, forming an intricate network, yet chemically it yields, besides gelatin, a fresh substance, *reticulin*. The fibres are covered and concealed by flattened branched connective-tissue cells, and these must be

removed or brushed away before the fibres become visible. In many situations the interstices of the network are filled with rounded lymph-corpuscles, and the tissue is then termed **lymphoid** or **adenoid tissue** (Fig. 616).

3. **Basement-membranes**, formerly described as homogeneous membranes, are really a form of connective tissue. They constitute the supporting membrane,

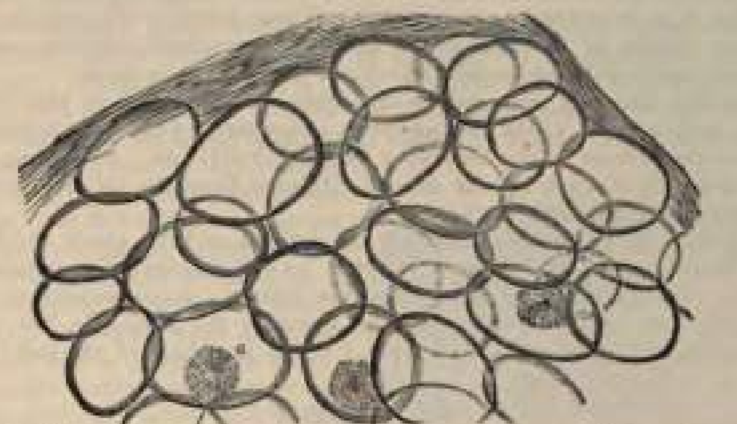


FIG. 617.—Adipose tissue. high power. *a*. Star-like appearance from crystallization of fatty acids.

or membrana propria, on which is placed the epithelium of mucous membranes or secreting glands, and in other situations. By means of staining with nitrate of silver they may be shown to consist of flattened cells in close opposition, and joined together by their edges, thus forming an example of an epithelioid arrangement of connective-tissue cells. In some situations the cells, instead of adhering by their edges, give off branching processes, which join with similar processes of other cells, and so form a network rather than a continuous membrane. In other instances basement-membranes are composed of elastic tissue, as in the cornea, or, again, in other cases of condensed ground-substance.

FIG. 618.—Development of fat. (Klein and Noble Smith.) *a*. Minute artery. *v*. Minute vein. *c*. Capillary blood-vessels in the course of formation; they are not yet completely hollowed out, there being still left in them protoplasmic septa. *d*. The ground-substance, containing numerous nucleated cells, some of which are more distinctly branched and flattened than others, and appear therefore more spindle-shaped.

Adipose Tissue.—In almost all parts of the body the ordinary areolar tissue contains a variable quantity of fat. The principal situations where it is not found are the subcutaneous tissue of the eyelids, the penis and scrotum, the nymphæ, within the cavity of the cranium, and in the lungs, except near their roots. Nevertheless, its distribution is not uniform: in some parts it is collected in great abundance, as in the subcutaneous tissue, especially of the abdomen; around the kidneys; on the surface of the heart between the furrows; and in some other situations. Lastly, fat enters largely into the formation of the marrow of bones. A distinction must be made between fat and adipose tissue; the latter being a distinct issue, the former an oily matter, which in addition to forming adipose tissue is also widely present in the body, as in the fat of the brain and liver, and in the blood and chyle, etc.

Adipose tissue consists of small vesicles, *fat-cells*, lodged in the meshes of areolar tissue. The fat-cells (Fig. 617) vary in size, but of about the average diameter of $\frac{1}{320}$ of an inch. They are formed of an exceedingly delicate protoplasmic membrane, filled with fatty matter, which is liquid during life, but becomes solidified after death. They are round or spherical where they have not been subjected to pressure; otherwise they assume a more or less angular outline. A nucleus is always present, and can be easily demonstrated by staining with hæmatoxylin; in the natural condition it is so compressed by the contained oily matter as to be scarcely recognizable. These fat-cells are contained in clusters in the areolæ of fine connective tissue, and are held together mainly by a network of capillary blood-vessels, which are distributed to them.

Chemically the oily material in the cells is composed of the fats, olein, palmitin, and stearin, which are glycerin compounds with fatty acids. Sometimes fat-crystals form in the cells after death (Fig. 617, *a*). By boiling the tissue in ether or strong alcohol, the fat may be extracted from the vesicle, which is then seen empty and shrunken.

Fat is said to be first detected in the human embryo about the fourteenth week. The fat-cells are formed by the transformation of connective-tissue corpuscles, in which small droplets of oil are formed; these coalesce to produce a larger drop, and this increases until it distends the corpuscle, the remaining protoplasm and the nucleus being crowded to the periphery of the cell (Fig. 618).

THE PIGMENT.

In various parts of the body *pigment* is found; most frequently in epithelial cells and in the cells of connective tissue. Pigmented epithelial cells are found in the external layer of the retina and on the posterior surface of the iris. Pigment is also found in the epithelial cells of the deeper layers of the cuticle in some parts of the body—such as the areola of the nipple and in colored patches of skin, and especially in the skin of the colored races, and also in hair. It is also found in the epithelial cells of the olfactory region and of the membranous labyrinth of the ear.

FIG. 619.—Pigment-cells from the choroid coat of the eyeball.

In the *connective-tissue cells* pigment is frequently met with in the lower vertebrates. In man it is found in the choroid coat of the eye (Fig. 619) and in the iris of all but the light-blue eyes and the albino. It is also occasionally met with in the cells of retiform tissue and in the pia mater of the upper part of the spinal cord. These cells are characterized by their larger size and branched processes, which, as well as the body of the cells, are filled with granules. The pigment consists of dark-brown or black granules of very small size, closely packed together within the cells, but not invading the nucleus. Occasionally the pigment is yellow, and when occurring in the cells of the cuticle constitutes "freckles."

THE CARTILAGE.

Cartilage is a non-vascular structure which is found in various parts of the body—in adult life chiefly in the joints, in the parietes of the thorax, and in various tubes, such as the air-passages, nostrils, and ears, which are to be kept permanently open. In the fœtus at an early period the greater part of the skeleton is cartilaginous. As this cartilage is afterward replaced by bone, it is called *temporary*, in contradistinction to that which remains unossified during the whole of life, and which is called *permanent*.

Cartilage is divided, according to its minute structure, into hyaline cartilage, fibro-cartilage, and yellow or elastic white fibro-cartilage. Besides these varieties met with in the adult human subject, there is a variety called *cellular cartilage*, which consists entirely, or almost entirely, of cells, united in some cases by a network of very fine fibres, in other cases apparently destitute of any intercellular substance. This is found in the external ear of rats, mice, and some other animals, and is present in the chorda dorsalis of the human embryo, but is not found in any other human structure. The various cartilages in the body are also classified, according to their function and position, into articular, interarticular, costal, and membraniform.

Hyaline cartilage, which may be taken as the type of this tissue, consists of a gristly mass of a firm consistence, but of considerable elasticity and of a pearly-bluish color. Except where it coats the articular ends of bones, it is covered externally by a fibrous membrane, the *perichondrium*, from the vessels of which it imbibes its nutritive fluids, being destitute of blood-vessels. It contains no nerves. Its intimate structure is very simple. If a thin slice is examined under the microscope, it will be found to consist of a rounded or bluntly angular form, lying in groups of two or more in a granular or almost homogeneous matrix (Fig. 620). The cells, when arranged in groups of two or more, have generally a straight outline where they are in contact with each other, and in the rest of their circumference are rounded. The cell-contents consist of clear translucent protoplasm, in which fine interlacing filaments and minute granules may sometimes be seen; imbedded in this are one or two round nuclei, having the usual intranuclear network. The cells are imbedded in cavities in the matrix, called *cartilage lacunæ*; around these the matrix is arranged in concentric lines, as if it had been formed in successive portions around the cartilage-cells. This constitutes the so-called *capsule* of the space. Each lacuna is generally occupied by a single cell, but during the division of the cells it may contain two, four, or eight cartilage-cells. By exposure to the action of an electric shock the cell assumes a jagged outline and shrinks away from the interior of the capsule.

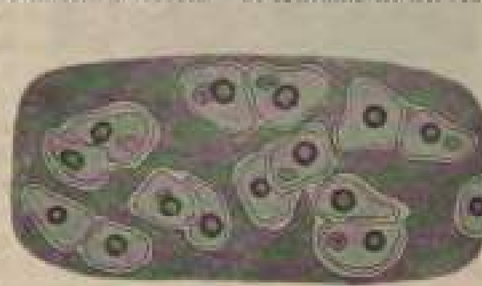


Fig. 620.—Human cartilage-cells from the cricoid cartilage. × 350.

The matrix is transparent and apparently without structure, or else presents a dimly granular appearance, like ground glass. Some observers have shown that the matrix of hyaline cartilage, and especially the articular variety, after prolonged maceration, can be broken up into fine fibrils. These fibrils are probably of the same nature, chemically, as the white fibres of connective tissue. It is believed by some histologists that the matrix is permeated by a number of fine channels, which connect the lacunæ with each other, and that these canals communicate with the lymphatics of the perichondrium, and thus the structure is permeated with a current of nutrient fluid. This, however, is somewhat doubtful.

Articular cartilage, costal cartilage, and temporary cartilage are all of the hyaline variety. They present minute differences in the size and shape of their cells and in the arrangement of their matrix. In **articular cartilage**, which shows no tendency to ossification, the matrix is finely granular under a high power; the cells and nuclei are small, and are disposed parallel to the surface in the superficial part, while nearer to the bone they become vertical. Articular cartilages have a tendency to split in a vertical direction; in disease this tendency becomes very manifest. Articular cartilage is not covered by perichondrium, on its free surface, where it is exposed to friction, though a layer of connective tissue can be traced in the adult over a small part of its circumference continuous with that of the synovial membrane, and here the cartilage-cells are more or less branched and pass insensibly into the branched connective-tissue corpuscles of the synovial membrane.

Articular cartilage forms a thin incrustation upon the joint-surfaces of the bones, and its elasticity enables it to break the force of any concussion, while its smoothness affords ease and freedom of movement. It varies in thickness according to the shape of the articular surface on which it lies; where this is convex the cartilage is thickest at the centre, where the greatest pressure is received; and the reverse is the case on the concave articular surfaces. Articular cartilage appears to derive its nutriment partly from the vessels of the neighboring synovial membrane, partly from those of the bone upon which it is implanted. Toynbee has shown that the minute vessels of the cancellous tissue as they approach the articular lamella dilate and form arches, and then return into the substance of the bone.

Fig. 621.—Costal cartilage from a man seventy-six years of age, showing the development of fibrous structure in the matrix. In several portions of the specimen two or three generations of cells are seen enclosed in a parent cell-wall. High power.

In **costal cartilage** the cells and nuclei are large, and the matrix has a tendency to fibrous striation, especially in old age (Fig. 621). In the thickest parts of the costal cartilages a few large vascular channels may be detected. This appears, at first sight, to be an exception to the statement that cartilage is a non-vascular tissue, but is not so really, for the vessels give no branches to the cartilage substance itself, and the channels may rather be looked upon as involutions of the perichondrium. The ensiform cartilage may be regarded as one of the costal cartilages, and the cartilages of the nose and of the larynx and trachea (except the epiglottis and cornicula laryngis, which are composed of elastic fibro-cartilage) resemble them in microscopical characters.

Temporary cartilage and the process of its ossification will be described with bone. The hyaline cartilages, especially in adult and advanced life, are prone to calcify—that is to say, to have their matrix permeated by the salts of lime without any appearance of true bone. The process of calcification occurs also and still more frequently, according to Rollett, in such cartilages as those of the trachea and in the costal cartilages, which are prone afterward to conversion into true bone.

White fibro-cartilage consists of a mixture of white fibrous tissue and cartilaginous tissue in various proportions; it is to the first of these two constituents that its flexibility and toughness are chiefly owing, and to the latter its elasticity. When examined under the microscope it is found to be made up of fibrous connective tissue arranged in bundles, with cartilage-cells between the bundles; these to a certain extent resemble tendon-cells, but may be distinguished from them by being surrounded by a concentrically striated area of cartilage matrix and by their being less flattened (Fig. 622). The fibro-cartilages admit of arrangement into four groups—interarticular, connecting, circumferential, and stratiform.

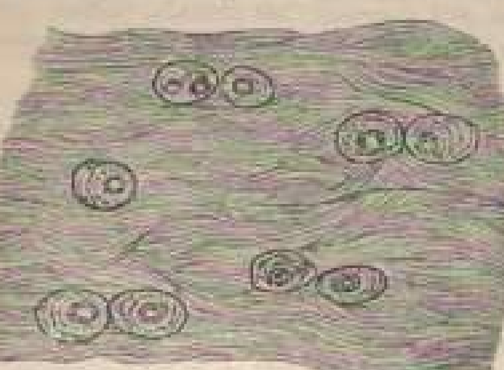


Fig. 622.—White fibro-cartilage from an intervertebral disc.

1. The **interarticular fibro-cartilages** (*menisci*) are flattened fibro-cartilaginous plates, of a round, oval, triangular, or sickle-like form, interposed between the articular cartilages of certain joints. They are free on both surfaces, thinner toward their centre than at their circumference, and held in position by the attachment of their

margins and extremities to the surrounding ligaments. The synovial membrane of the joint is prolonged over them a short distance from their attached margins. They are found in the temporo-mandibular, sterno-clavicular, acromio-clavicular, wrist- and knee-joints. These cartilages are usually found in those joints which are most exposed to violent concussion and subject to frequent movement. Their use is to maintain the apposition of the opposed surfaces in their various motions; to increase the depth of the articular surfaces and give ease to the gliding movement; to moderate the effects of great pressure and deaden the intensity of the shocks to which the parts may be subjected. Humphry has pointed out that these inter-articular fibro-cartilages serve an important purpose in increasing the variety of movements in a joint. Thus, in the knee-joint there are two kinds of motion, viz., angular movement and rotation, although it is a hinge joint, in which, as a rule, only one variety of motion is permitted; the former movement takes place between the condyles of the femur and the interarticular cartilage, the latter between the cartilage and the head of the tibia. So, also, in the temporo-mandibular joint, the upward and downward movement of opening and shutting the mouth takes place between the fibro-cartilage and the jaw-bone, the grinding movement between the glenoid cavity and the fibro-cartilage, the latter moving with the jaw-bone.

2. The **connecting fibro-cartilages** are interposed between the bony surfaces of those joints which admit of only slight mobility, as between the bodies of the vertebræ and between the pubic bones. They form disks, which adhere closely to both of the opposed surfaces, and are composed of concentric rings of fibrous tissue, with cartilaginous laminæ interposed, the former tissue predominating toward the circumference, the latter toward the centre.

3. The **circumferential fibro-cartilages** consist of a rim of fibro-cartilage, which surrounds the margin of some of the articular cavities, as the cotyloid cavity of the hip and the glenoid cavity of the shoulder; they serve to deepen the articular surface, and to protect its edges.

4. The **stratiform fibro-cartilages** are those which form a thin coating to osseous grooves through which the tendons of certain muscles glide. Small masses of fibro-cartilages are developed also in the tendons of some muscles, where they glide over bones, as in the tendons of the Peroneus longus and the Tibialis posticus.

Yellow or elastic fibro-cartilage is found in the human body in the auricle of the external ear, the Eustachian tubes, the cornicula laryngis, and the epiglottis. It consists of cartilage-cells and a matrix, the latter being pervaded in every direction, except immediately around each cell, where there is a variable amount of non-fibrillated hyaline, intercellular substance, by a network of yellow elastic fibres, branching and anastomosing in all directions (Fig. 623). The fibres resemble those of yellow elastic tissue, both in appearance and in being unaffected by acetic acid; and according to Rollett their continuity with the elastic fibres of the neighboring tissue admits of being demonstrated.

FIG. 623.—Yellow cartilage, ear of horse. High power.

The distinguishing feature of cartilage as to its chemical composition is that it yields on boiling a substance called *chondrin*, very similar to gelatin, but differing from it in several of its reactions. It is now believed that chondrin is not a simple body, but a mixture of gelatin with mucinoid substances, chief among which, perhaps, is a compound termed *chondro-mucoid*.

THE BONE.

Structure and Physical Properties of Bone.—Bone is one of the hardest structures of the animal body; it possesses also a certain degree of toughness and elasticity. Its color, in a fresh state, is of a pinkish white externally, and a deep red within. On examining a section of any bone, it is seen to be composed of two kinds of tissue, one of which is dense in texture, like ivory, and is termed *compact* tissue; the other consists of slender fibres and lamellæ, which join to form a reticular structure; this, from its resemblance to lattice-work, is called *cancellous tissue*. The compact tissue is always placed on the exterior of the bone; the cancellous is always internal. The relative quantity of these two kinds of tissue varies in different bones, and in different parts of the same bone, as strength or lightness is requisite. Close examination of the compact tissue shows it to be extremely porous, so that the difference in structure between it and the cancellous tissue depends merely upon the different amount of solid matter, and the size and number of spaces in each; the cavities being small in the compact tissue and the solid matter between them abundant, while in the cancellous tissue the spaces are large and the solid matter in smaller quantity.

Bone during life is permeated by vessels and is enclosed, except where it is coated with articular cartilage, in a fibrous membrane, the *periosteum*, by means of which many of these vessels reach the hard tissue. If the periosteum is stripped from the surface of the living bone, small bleeding points are seen, which mark the entrance of the periosteal vessels; and on section during life every part of the bone will be seen to exude blood from the minute vessels which ramify in it. The interior of the bones of the limbs presents a cylindrical cavity filled with marrow and lined by a highly vascular areolar structure, called the *medullary membrane* or *internal periosteum*, which, however, is rather the areolar envelope of the cells of the marrow than a definite membrane.

The **periosteum** adheres to the surface of the bones in nearly every part, excepting at their cartilaginous extremities. When strong tendons or ligaments are attached to the bone, the periosteum is incorporated with them. It consists of two layers closely united, the outer one formed chiefly of connective tissue, containing occasionally a few fat-cells; the inner one, of elastic fibres of the finer kind, forming dense membranous networks, which can again be separated into several layers. In young bones the periosteum is thick and very vascular, and is intimately connected at either end of the bone with the epiphyseal cartilage, but less closely with the shaft, from which it is separated by a layer of soft tissue, containing a number of granular corpuscles or "osteoblasts," in which ossification proceeds on the exterior of the young bone. Later in life the periosteum is thinner, less vascular, and the osteoblasts have become converted into an epithelioid layer, which is separated from the rest of the periosteum in many places by cleft-like spaces, which are supposed to serve for the transmission of lymph. The periosteum serves as a nidus for the ramification of the vessels previous to their distribution in the bone; hence the liability of bone to exfoliation or necrosis, when denuded of this membrane by injury or disease. Fine nerves and lymphatics, which generally accompany the arteries, may also be demonstrated in the periosteum.

The **marrow** not only fills up the cylindrical cavity in the shafts of the long bones, but also occupies the spaces of the cancellous tissue and extends into the larger bony canals (Haversian canals) which contain the blood-vessels. It differs in composition in different bones. In the shafts of adult long bones the marrow is of a *yellow* color, and contains, in 100 parts, 96 of fat, 1 of areolar tissue and vessels, and 3 of fluid, with extractive matter, and consists of a matrix of fibrous tissue, supporting numerous blood-vessels and cells, most of which are fat-cells, but some are "marrow-cells," such as occur in the red marrow, to be immediately described. In the flat and short bones, in the articular ends of the long bones, in the bodies of the vertebræ, in the cranial diploë, and in the sternum and ribs, it is of a *red* color, and contains, in 100 parts, 75 of water and 25 of solid matter, consisting of cell-globulin, nucleo-proteid, extractives, salts, and only a small proportion of fat. The red marrow consists of a small quantity of connective tissue, blood-vessels, and numerous cells (Fig. 624), some few of which are fat-cells, but the great majority roundish nucleated cells, the true "marrow-cells" of Kölliker. These marrow-cells proper resemble in appearance lymphoid corpuscles, and like them are amœboid. Among them may be seen smaller cells, which possess a slightly pinkish hue; these are the *erythroblasts*, from which, as we have seen, the red corpuscles of the adult are derived, and which may be regarded as descendants of the nucleated colored corpuscles of the embryo.

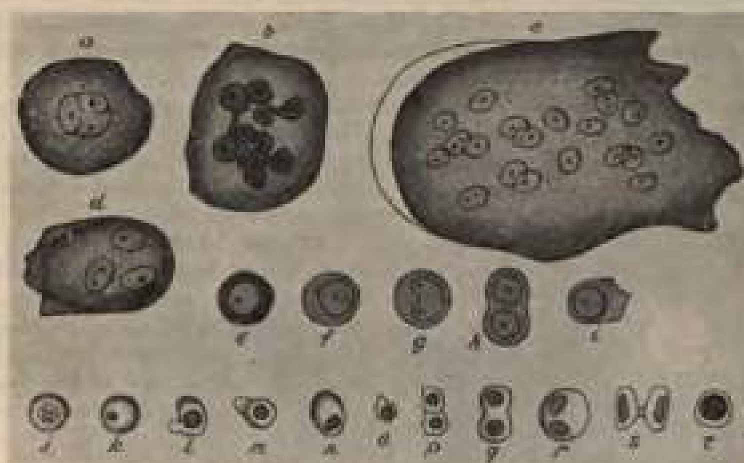


FIG. 624.—Cells of red marrow of the guinea-pig. (Schäfer.) *a*-*d*. Myeloplaques. *e*-*i*. Marrow-cells proper. *j*-*t*. Erythroblasts—some in process of division.

Giant-cells (*myelo-plaques, osteoclasts*), large, multinucleated, protoplasmic masses, are also to be found in both sorts of adult marrow, but more particularly in red marrow. They were believed by Kölliker to be concerned in the absorption of bone matrix, and hence the name which he gave to them—*osteoclasts*. They excavate small shallow pits or cavities, which are named *Howship's lacunæ*, in which they are found lying.

Vessels of Bone.—The blood-vessels of bone are very numerous. Those of the compact tissue are derived from a close and dense network of vessels ramifying in the periosteum. From this membrane vessels pass into the minute orifices in the compact tissue, running through the canals which traverse its substance. The cancellous tissue is supplied in a similar way, but by a less numerous set of larger vessels, which, perforating the outer compact tissue, are distributed to the cavities of the spongy portion of the bone. In the long bones numerous apertures may be seen at the ends near the articular surfaces, some of which give passage to the arteries of the larger set of vessels referred to; but the most numerous and largest apertures are for the veins of the cancellous tissue, which run separately from the arteries. The medullary canal in the shafts of the long bones is supplied by one large artery (or sometimes more), which enters the bone at the nutrient foramen (situated in most cases near the centre of the shaft), and perforates obliquely the compact structure. The *medullary* or *nutrient* artery, usually accompanied by one or two veins, sends branches upward and downward to supply the medullary membrane, which lines the central cavity and the adjoining canals. The ramifications of this vessel anastomose with the arteries both of the cancellous and compact tissues. In most of the flat, and in many of the short spongy bones, one or more large apertures are observed, which transmit, to the central parts of the bone, vessels corresponding to the medullary arteries and veins. The veins emerge from the long bones in three places (Kölliker): (1) by one or two large veins, which accompany the artery; (2) by numerous large and small veins at the articular extremities; (3) by many small veins which arise in the compact substance. In the flat cranial bones the veins are large, very numerous, and run in tortuous canals in the diploic tissue, the sides of the canals being formed by a thin lamella of bone, perforated here and there for the passage of branches from the adjacent cancelli. The same condition is also found in all cancellous tissue, the veins being enclosed and supported by osseous structure and having exceedingly thin coats. When the bony structure is divided, the vessels remain patulous, and do not contract in the canals in which they are contained. Hence the occurrence of purulent absorption after amputation in those cases where the stump becomes inflamed and the cancellous tissue is infiltrated and bathed in pus.

Lymphatic vessels, in addition to those found in the periosteum, have been traced by Cruikshank, into the substance of bone, and Klein describes them as running in the Haversian canals.

Nerves are distributed freely to the periosteum, and accompany the nutrient arteries into the interior of the bone. They are said by Kölliker to be most numerous in the articular extremities of the long bones, in the vertebræ and the larger flat bones.

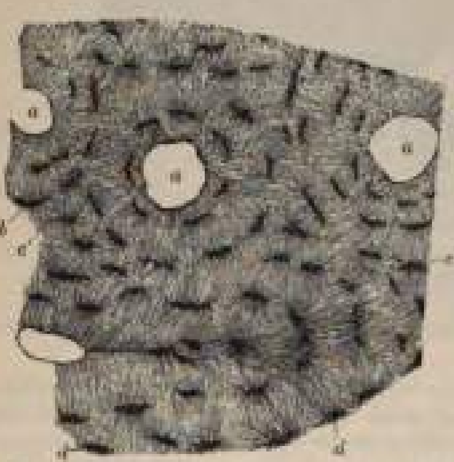


FIG. 625.—From a transverse section of the shaft of the humerus. Magnified 150 times. *a.* Haversian canals. *b.* Lacunæ, with their canaliculi in the lamellæ of these canals. *c.* Lacunæ of the interstitial lamellæ. *d.* Others at the surface of the Haversian systems, with canaliculi given off from one side.

Minute Anatomy.—The intimate structure of bone, which in all essential particulars is identical in the compact and cancellous tissue, is most easily studied in a transverse section from the compact wall of one of the long bones after maceration, such as is shown in Fig. 625.

If this is examined with a rather low power the bone will be seen to be mapped out into a number of circular districts, each one of which consists of a central hole, surrounded by a number of concentric rings. These districts are termed *Haversian systems*; the central hole is an *Haversian canal*, and the rings around are layers of bone-tissue arranged concentrically around the central canal, and termed *lamellæ*. Moreover, on closer examination, it will be found that between these lamellæ, and therefore also arranged concentrically around the central canal, are a number of little dark specks, the *lacunæ*, and that these lacunæ are connected with each other and with the central Haversian canal by a number of fine dark lines, which radiate like the spokes of a wheel and are called *canaliculi*. All these structures —the concentric lamellæ, the lacunæ, and the canaliculi—may be seen in any single Haversian system, forming a circular district round a central, Haversian, canal. Between these circular systems, filling in the irregular intervals which are left between them, are other lamellæ, with their lacunæ and canaliculi, running in various directions, but more or less curved (Fig. 626). These are termed *interstitial* lamellæ. Again, other lamellæ, for the most part found on the surface of the bone, are arranged concentrically to the circumference of bone, constituting, as it were, a single Haversian system of the whole bone, of which the medullary cavity would represent the Haversian canal. These latter lamellæ are termed *circumferential*, or by some authors *primary* or *fundamental* lamellæ, to distinguish them from those laid down around the axis of the Haversian canals, which are then termed *secondary* or *special* lamellæ.

The *Haversian canals*, seen as round holes in a transverse section of bone at or about the centre of each Haversian system, may be demonstrated to be true canals if a longitudinal section is made, as in Fig. 628. It will then be seen that these round holes are tubes cut across, which run parallel with the longitudinal axis of the bone for a short distance, and then branch and communicate. They vary considerably in size, some being as large as $\frac{1}{200}$ of an inch in diameter; the average size being, however, about $\frac{1}{500}$ of an inch. Near the medullary cavity the canals are larger than those near the surface of the bone. Each canal contains two blood-vessels, with a small quantity of delicate connective tissue and some nerve-filaments. In the larger ones there are also lymphatic spaces and branched cells, the processes of which communicate, through the canaliculi, with the branched processes of certain bone-cells in the substance of the bone. Those canals near the surface of the bone open upon it by minute orifices, and those near the medullary cavity open in the same way into this space, so that the whole of the bone is permeated by a system of blood-vessels running through the bony canals in the centre of the Haversian systems.

The *lamellæ* are thin plates of bone-tissue encircling the central canal, and may be compared, for the sake of illustration, to a number of sheets of paper pasted one over another around a central hollow cylinder. After macerating a piece of bone in dilute mineral acid these lamellæ may be stripped off in a lon-

FIG. 629.—Transverse section of compact tissue of bone. Magnified about 150 diameters. (Sharpey.)

gitudinal direction as thin films. If one of these is examined with a high power under the microscope, it will be found to be composed of a finely reticular structure, presenting the appearance of lattice-work made up of very slender, transparent fibres, decussating obliquely, and coalescing at the points of intersection so as to form an exceedingly delicate network. These fibres are composed of fine fibrils, identical with those of white connective tissue. The intercellular matrix between the fibres has been replaced by calcareous deposit, which the acid dissolves. In many places the various lamellæ may be seen to be held together by tapering fibres, which run obliquely through them, pinning or bolting them together. These fibres were first described by Sharpey, and were named by him *perforating fibres* (Fig. 630).

The *lacunæ* are situated between the lamellæ, and consist of a number of oblong spaces. In an ordinary microscopic section, viewed by transmitted light, they appear as dark, oblong, opaque spots, and were formerly believed to be solid cells. Subsequently, when it was seen that the Haversian canals were channels which lodge the vessels of the part, and the canaliculi, minute tubes by which the plasma of the blood circulates through the tissue, the theory was formulated that the lacunæ were hollow spaces filled during life with the same fluid, and only lined (if

lined at all) by a delicate membrane. But this view was s[...]
to be erroneous, for examination of the structure of bone,
Virchow to believe that the lacunæ are occupied during life [...]
termed a bone-cell or bone-corpuscle, the processes from wh[...]
canaliculi—a view which is now universally received (Fig. 627).
these cells that the fluids necessary for nutrition are brough[...]
the ultimate tissue of bone.

The *canaliculi* are exceedingly minute channels, which pass
and connect the lacunæ with the neighboring lacunæ and also
canal. From this central canal a number of the canaliculi a[...]
radiate from it, and open into the first set of lacunæ, arranged around the Haversian canal, between the first and second lamellæ. From these lacunæ a second set of canaliculi are given off, which pass outward to the next series of lacunæ, and so on until they reach the periphery of the Haversian system: here the canaliculi given off from the last series of lacunæ do not communicate with the lacunæ of neighboring Haversian systems, but after passing outward for a short distance form loops

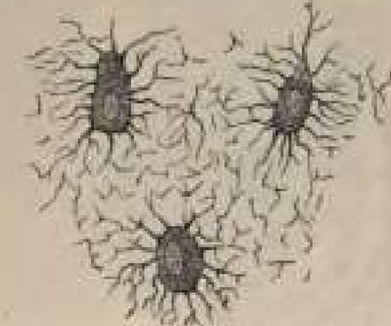


FIG. 627.—Nucleated bone-cells and their processes, contained in the bone-lacunæ and their canaliculi respectively. From a section through the vertebra of an adult mouse. (Klein and Noble Smith.)

FIG. 628.—Secti[...]
from the shaft of [...]
times. *a*. Haversi[...]
from the side. *c*. [...]
face in lamellæ wh[...]

and return to their own lacuna. Thus every part of the H[...]
supplied with nutrient fluids derived from the vessels in the H[...]
traversing the canaliculi and lacunæ.

The *bone-cells* are contained in the lacunæ, which, howeve[...]
pletely fill. They are flattened nucleated cells, which Virch[...]
homologous with those of connective tissue. The cells are
branches, especially in young bones, pass into the canaliculi fr[...]

If a longitudinal section is examined, as in Fig. 628, the str[...]
the same. The appearance of concentric rings is replaced by
rows of lacunæ, parallel to the course of the Haversian canal
appear like half-tubes instead of circular spaces. The tubes
and communicate, so that each separate Haversian canal runs o[...]
In other respects the structure has much the same appearan[...]
sections.

In sections of thin plates of bone (as in the walls of the c[...]
cancellous tissue) the Haversian canals are absent, and the cana[...]
spaces of the cancellous tissue (medullary spaces), which thus [...]
tion as the Haversian canals in the more compact bone.

Chemical Composition.—Bone consists of an animal and an earthy part intimately combined together.

The animal part may be obtained by immersing the bone for a considerable time in dilute mineral acid, after which process the bone comes out exactly the same shape as before, but perfectly flexible, so that a long bone (one of the ribs, for example) can easily be tied in a knot. If now a transverse section is made (Fig. 630), the same general arrangement of the Haversian canals, lamellæ, lacunæ, and canaliculi is seen, though not so plainly, as in the ordinary section.

The earthy part may be obtained separate by calcination, by which the animal matter is completely burned out. The bone will still retain its original form, but

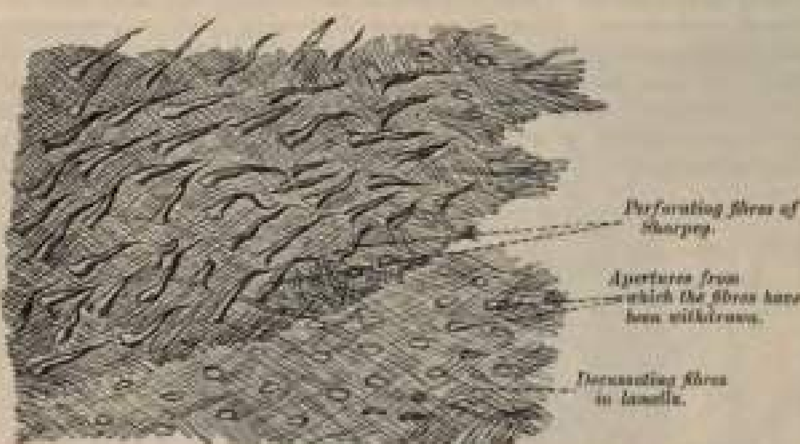


Fig. 629.—Lamellæ torn from a decalcified human parietal bone to show the perforating fibres of Sharpey. (Copied from a drawing by Allen Thomson.)

it will be white and brittle, will have lost about one-third of its original weight, and will crumble down with the slightest force. The earthy matter confers on bone its hardness and rigidity, and the animal matter its tenacity.

The animal basis is largely composed of *cassein*, which is identical with the collagen of white fibrous tissue, so that when boiled with water, especially under pressure, it is almost entirely resolved into gelatin.

The organic matter of bone forms about *one-third*, or 33.3 per cent.; the inorganic matter, *two-thirds*, or 66.7 per cent. Of the earthy matter, five-sixths is calcium phosphate, the remainder consisting of calcium carbonate, calcium fluoride, calcium chloride, and magnesium phosphate, with small amounts of sodium chloride and sulphate. Even after the removal of all the marrow a small percentage of fat is still found in bone.

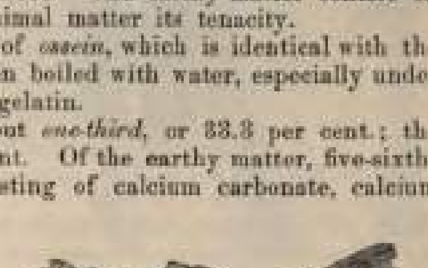


Fig. 630.—Section of bone after the removal of the earthy matter by the action of acids.

Some of the diseases to which bones are liable mainly depend on the disproportion between the two constituents of bone. Thus in the disease called rickets, so common in the children of the poor, the bones become bent and curved, either from the superincumbent weight of the body or under the action of certain muscles. This depends upon some defect of nutrition by which bone becomes deprived of its normal proportion of earthy matter, while the animal matter is of unhealthy quality. In the vertebræ of a rickety subject Bostock found in 100 parts 79.75 animal and 20.25 earthy matter.

Development of Bone.—In the fœtal skeleton some bones are preceded by membrane, such as those forming the roof and sides of the skull; others, such as the bones of the limbs, are preceded by rods of cartilage. Hence two kinds of ossification are described: the *intramembranous* and the *intracartilaginous*.

Intramembranous Ossification.—In the case of bones which are developed in membrane no cartilaginous mould precedes the appearance of the bone-tissue. The membrane, which occupies the place of the future bone, is of the nature of connective tissue, and ultimately forms the periosteum. At this stage it is seen to be composed of fibres and granular cells in a matrix. The outer portion is more fibrous, while internally, the cells or *osteoblasts* predominate; the whole tissue is richly supplied with blood-vessels. At the outset of the process of bone formation a little network of bony spiculæ is first noticed radiating from the point or centre of ossification. When these rays of growing bone are examined with a microscope, they are found to consist at their growing point of a network of fine clear fibres and granular corpuscles with an intervening ground substance (Fig. 631). The fibres are termed *osteogenetic* fibres, and are made up of fine fibrils differing little from those of white fibrous tissue. Like them, they are probably deposited in the matrix through the influence of the cells—in this case the osteo-

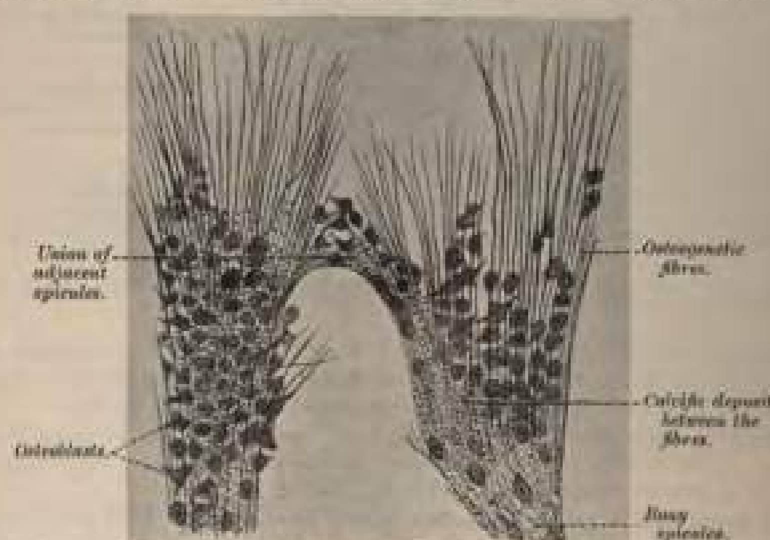


FIG. 631.—Part of the growing edge of the developing parietal bone of a fœtal cat. (After J. Lawrence.)

blasts. The osteogenetic fibres soon assume a dark and granular appearance from the deposition of calcareous granules in the fibres and in the intervening matrix, and as they calcify they are found to enclose some of the granular corpuscles or osteoblasts. By the fusion of the calcareous granules the bony tissue again assumes a more transparent appearance, but the fibres are no longer so distinctly seen. The involved osteoblasts form the corpuscles of the future bone, the spaces in which they are enclosed constituting the lacunæ. As the osteogenetic fibres grow out to the periphery they continue to calcify, and give rise to fresh bone spicules. Thus a network of bone is formed, the meshes of which contain the blood-vessels and a delicate connective tissue crowded with osteoblasts. The bony trabeculæ thicken by the addition of fresh layers of bone formed by the osteoblasts on their surface, and the meshes are correspondingly encroached upon. Subsequently successive layers of bony tissue are deposited under the periosteum and round the larger vascular channels, which become the Haversian canals, so that the bone increases much in thickness.

Intracartilaginous Ossification.—Just before ossification begins the bone is entirely cartilaginous, and in a long bone, which may be taken as an example, the process commences in the centre and proceeds toward the extremities, which for some time remain cartilaginous. Subsequently a similar process commences in one or more places in those extremities and gradually extends through them. The extremities do not, however, become joined to the shaft by bony tissue until growth has ceased, but are attached to it by a layer of cartilaginous tissue termed the *epiphyseal cartilage.*

The first step in the ossification of the cartilage is that the cartilage-cells, at the point where ossification is commencing and which is termed a *centre of ossification*, enlarge and arrange themselves in rows (Fig. 632). The matrix in which they are imbedded increases in quantity, so that the cells become further separated from each other. A deposit of calcareous material now takes place in this matrix,

FIG. 632.—Section of fœtal bone of cat. *ir.* Irruption of the subperiosteal tissue. *p.* Fibrous layer of the periosteum. *o.* Layer of osteoblasts. *im.* Subperiosteal bony deposit. (From Quain's *Anatomy*, E. A. Schäfer.)

FIG. 633.—Part of a longitudinal section of the developing femur of a rabbit. *a.* Flattened cartilage-cells. *b.* Enlarged cartilage-cells. *c, d.* Newly-formed bone. *e.* Osteoblasts. *f.* Giant-cells or osteoclasts. *g, h.* Shrunken cartilage-cells. (From *Atlas of Histology*, Klein and Noble Smith.)

between the rows of cells, so that they become separated from each other by longitudinal columns of calcified matrix, presenting a granular and opaque appearance. Here and there the matrix between two cells of the same row also becomes calcified, and transverse bars of calcified substance stretch across from one calcareous column to another. Thus there are longitudinal groups of the cartilage-cells enclosed in oblong cavities, the walls of which are formed of calcified matrix, which cuts off all nutrition from the cells, and they, in consequence, waste, leaving spaces called the *primary areolæ* (Sharpey).

At the same time that this process is going on in the centre of the solid bar of cartilage of which the fœtal bone consists, certain changes are taking place on its surface. This is covered by a very vascular membrane, the *perichondrium*, entirely similar to the embryonic connective tissue already described as constituting the basis of membrane-bone, on the inner surface of which, that is to say, on the surface in contact with the cartilage, are gathered the formative cells, the *osteoblasts*. By the agency of these cells a thin layer of bony tissue is being formed between the perichondrium and the cartilage, by the *intramembranous* mode of ossification just described. There are then, in this first stage of ossification, two processes going on simultaneously: in the centre of the cartilage the formation of a number of oblong spaces, formed of calcified matrix and containing the withered cartilage-cells, and on the surface of the cartilage the formation of a layer of true membrane-bone. The second stage consists in the prolongation into the cartilage of processes of the deeper or osteogenetic layer of the perichondrium, which has now become periosteum (Fig. 632, *ir*). The processes consist of blood-vessels and cells—*osteoblasts* or bone-formers, and *osteoclasts*, or bone-destroyers.

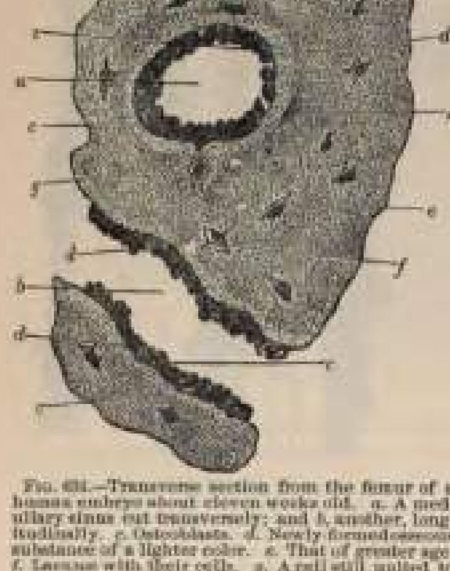


FIG. 633.—Transverse section from the femur of a human embryo about eleven weeks old. *a*. A medullary sinus cut transversely; and *b*, another, longitudinally. *c*. Osteoblasts. *d*. Newly formed osseous substance of a lighter color. *e*. That of greater age. *f*. Lacunæ with their cells. *g*. A cell still united to an osteoblast.

FIG. 634.—Vertical section from the edge of the ossifying portion of the diaphysis of a metatarsal bone from a fœtal calf. (After Müller.) *a*. Ground-mass of the cartilage. *b*. Of the bone. *c*. Newly-formed bone-cells in profile, more or less imbedded in intercellular substance. *d*. Medullary canal in process of formation, with vessels and medullary cells. *e*, *f*. Bone-cells on their broad aspect. *g*. Cartilage-capsules arranged in rows, and partly with shrunken cell-bodies.

The latter are similar to the giant-cells (myelo-plaques) found in marrow, and they excavate passages through the new-formed bony layer by absorption, and pass through it into the calcified matrix (Fig. 632). Wherever these processes come in contact with the calcified walls of the primary areolæ they absorb it, and thus cause a fusion of the original cavities and the formation of larger spaces, which are termed the *secondary areolæ* (Sharpey) or *medullary spaces* (Müller). In these secondary spaces the original cartilage-cells having disappeared, become filled with embryonic marrow, consisting of osteoblasts and vessels, and derived in the manner described above, from the osteogenetic layer of the periosteum (Fig. 633).

Thus far there has been traced the formation of enlarged spaces (secondary areolæ), the perforated walls of which are still formed by calcified cartilage-matrix, containing an embryonic marrow, derived from the processes sent in from the osteogenetic layer of the periosteum, and consisting of blood-vessels and round cells, osteoblasts (Fig. 633). The walls of these secondary areolæ are at this time of only inconsiderable thickness, but they become thickened by the deposition of layers of new bone on their interior. This process takes place in the following manner: Some of the osteoblasts of the embryonic marrow, after undergoing rapid division, arrange themselves as an epithelioid layer on the surface of the wall of the space (Fig. 634). This layer of osteoblasts form a bony stratum, and thus the wall of the space becomes gradually covered with a layer of true osseous substance. On this a second layer of osteoblasts arrange themselves, and in their turn form an osseous layer. By the repetition of this process the original cavity becomes very much reduced in size, and at last only remains as a small circular hole in the centre, containing the remains of the embryonic marrow — that is, a blood-vessel and a few osteoblasts. This small cavity constitutes the Haversian canal of the perfectly ossified bone. The successive layers of osseous matter which have been laid down and which encircle this central canal constitute the lamellæ of which, as we have seen, each Haversian system is made up. As the successive layers of osteoblasts form osseous tissue, certain of the osteoblastic cells remain included between the various bony layers. These persist as the corpuscles of the future bone, the spaces enclosing them forming the lacunæ (Figs. 634 and 636). The **canaliculi**, at first extremely short, are supposed to be extended by absorption, so as to meet those of neighboring lacunæ.

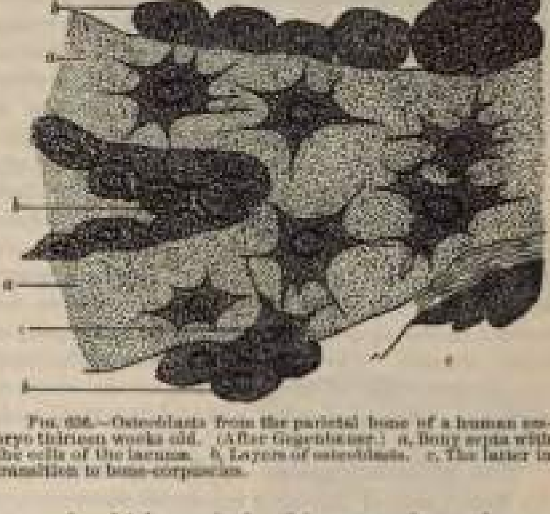


FIG. 634.—Osteoblasts from the parietal bone of a human embryo thirteen weeks old. (After Gegenbaur.) *a*, Bony septa with the cells of the lacunæ. *b*, Layers of osteoblasts. *c*, The latter in transition to bone-corpuscles.

Such are the changes which may be observed at one particular point, the centre of ossification. While they have been going on here a similar process has been set up in the surrounding parts and has been gradually proceeding toward the end of the shaft, so that in the ossifying bone all the changes described above may be seen in different parts, from the true bone in the centre of the shaft to the hyaline cartilage at the extremities. The bone thus formed differs from the bone of the adult in being more spongy and less regularly lamellated.

Thus far, then, we have followed the steps of a process by which a solid bony mass is produced, having vessels running into it from the periosteum, Haversian canals in which those vessels run, medullary spaces filled with fœtal marrow, lacunæ with their contained bone-cells, and canaliculi growing out of these lacunæ.

This process of ossification, however, is not the origin of the whole of the skeleton, for even in those bones in which the ossification proceeds in a great measure from a single centre, situated in the cartilaginous shaft of a long bone, a considerable part of the original bone is formed by intramembranous ossification beneath the perichondrium or periosteum; so that the girth of the bone is increased by bony deposit from the deeper layer of this membrane. The shaft of the bone is at first solid, but a tube is hollowed out in it by absorption around the vessels passing into it, which becomes the medullary canal. This absorption is supposed to be brought about by large "giant-cells," the so-called osteoclasts of Kölliker (Fig. 633). They vary in shape and size, and are known by containing a large number of clear nuclei, sometimes as many as twenty. The occurrence of similar cells in some tumors of bones has led to such tumors being denominated "myeloid."

As more and more bone is removed by this process of absorption from the interior of the bone to form the medullary canal, so more and more bone is deposited on the exterior from the periosteum, until at length the bone has attained the shape and size which it is destined to retain during adult life. As the ossification of the cartilaginous shaft extends toward the articular ends it carries with it, as it were, a layer of cartilage, or the cartilage grows as it ossifies, and thus the bone is increased in length. During this period of growth the articular end, or epiphysis, remains for some time entirely cartilagineus; then a bony centre appears in it, and it commences the same process of intracartilaginous ossification; but this process never extends to any great distance. The epiphyses remain separated from the shaft by a narrow cartilaginous layer for a definite time. This layer ultimately ossifies, the distinction between shaft and epiphysis is obliterated, and the bone assumes its completed form and shape. The same remarks also apply to the processes of bone which are separately ossified, such as the trochanters of the femur. The bones, having been formed, continue to grow until the body has acquired its full stature. They increase in length by ossification continuing to extend in the epiphysial cartilage, which goes on growing in advance of the ossifying process. They increase in circumference by deposition of new bone, from the deeper layer of the periosteum, on their external surface, and at the same time an absorption takes place from within, by which the medullary cavity is increased.

The medullary spaces which characterize the cancellous tissue are produced by the absorption of the original fœtal bone in the same way as the original medullary canal is formed. The distinction between the cancellous and compact tissue appears to depend essentially upon the extent to which this process of absorption has been carried; and we may perhaps remind the reader that in morbid states of the bone inflammatory absorption produces exactly the same change, and converts portions of bone naturally compact into cancellous tissue.

The number of ossific centres is different in different bones. In most of the short bones ossification commences by a single point in the centre, and proceeds toward the circumference. In the long bones there is a central point of ossification for the shaft or diaphysis; and one or more for each extremity, the epiphysis. That for the shaft is the first to appear. The union of the epiphyses with the shaft takes place in the reverse order to that in which their ossification began, with the exception of the fibula, and appears to be regulated by direction of the nutrient artery of the bone. Thus the nutrient arteries of the bones of the arm and forearm are directed toward the elbow, and the epiphyses of the bones forming this joint become united to the shaft before those at the opposite extremity. In the lower limb, on the other hand, the nutrient arteries pass in a direction from the knee: that is, upward in the femur, downward in the tibia and fibula; and in them it is observed that the upper epiphysis of the femur, and the lower epiphysis of the tibia and fibula, become first united to the shaft.

Where there is only one epiphysis, the medullary artery is directed toward that end of the bone where there is no additional centre, as toward the acromial end of the clavicle, toward the distal end of the metacarpal bone of the thumb and great toe, and toward the proximal end of the other metacarpal and metatarsal bones.

Besides these epiphyses for the articular ends, there are others for projecting parts or processes, which are formed separately from the bulk of the bone. For an account of these the reader must be referred to the description of the individual bones in the sequel.

A knowledge of the exact periods when the epiphyses become joined to the shaft is often of great importance in medico-legal inquiries. It also aids the surgeon in the diagnosis of many of the injuries to which the joints are liable; for it not infrequently happens that, on the application of severe force to a joint, the epiphysis becomes separated from the shaft, and such injuries may be mistaken for fracture or dislocation.

THE MUSCULAR TISSUE.

The **muscles** are formed of bundles of reddish fibres, endowed with the property of contractility. The two principal kinds of muscular tissue found in the body are voluntary and involuntary. The former of these, from the characteristic appearances which their fibres exhibit under the microscope, are known as the "striped" muscles, and from the fact that it is capable of being put into action and controlled by the will, as "voluntary" muscle. The fibres of the latter do not present any cross-striped appearance, and for the most part are not under the control of the will; hence they are known as the "unstriped" or "involuntary" muscles. The muscular fibres of the heart differ in certain particulars from both these groups, and they are therefore separately described as "cardiac" muscular fibres.

Thus it will be seen that there are three varieties of muscular fibres: (1) Transversely striated muscular fibres, which are for the most part voluntary and under the control of the will, but some of which are not so, such as the muscles of the pharynx and upper part of the œsophagus. This variety of muscle is sometimes called *skeletal*. (2) Transversely striated muscular fibres, which are not under the control of the will—*i. e.*, the cardiac muscle. (3) Plain or unstriped muscular fibres, which are involuntary and controlled by a different part of the nervous system from that which controls the activity of the voluntary muscles. Such are the muscular walls of the stomach and intestine, of the uterus and bladder, of the blood-vessels, etc.

FIG. 637.—Transverse section from the sterno-mastoid in man. Magnified 30 times. *a.* External perimysium. *b.* Fasciculus. *c.* Internal perimysium. *d.* Fibre.

The **striped** or **voluntary muscles** are composed of bundles of fibres enclosed in a delicate web called the "perimysium," in contradistinction to the sheath of areolar tissue which invests the entire muscle, the "epimysium" (Fig. 637). The bundles are termed "fasciculi"; they are prismatic in shape, of different sizes in different muscles, and for the most part placed parallel to one another, though they have a tendency to converge toward their tendinous attachments. Each fasciculus is made up of a bundle of *fibres*, which also run parallel with each other, and which are separated from one another by a delicate connective tissue derived from the perimysium, and termed *endomysium*. This does not form the sheath of the fibres, but serves to support the blood-vessels and nerves ramifying between them. The fibres are enclosed in a separate and distinct sheath of their own, but it is not areolar tissue, and is therefore not derived from the perimysium.

A *muscular fibre* may be said to consist of a soft contractile substance enclosed in a tubular sheath, named by Bowman the *sarcolemma*. The fibres are cylindrical or prismatic in shape, and are of no great length, not exceeding, it is said, an inch and a half. They end either by blending with the tendon or aponeurosis, or else by rounded or tapering extremities which are connected to the neighboring fibres by means of the sarcolemma. Their breadth varies in man from $\frac{1}{400}$ to $\frac{1}{200}$ of an inch. As a rule, the fibres do not divide or anastomose; but occasionally, especially in the tongue and facial muscles, the fibres may be seen to divide into several branches. The precise mode in which the muscular fibre joins the tendon has been variously described by different observers. It may, perhaps, be sufficient to say that the sarcolemma, or membranous investment of the muscular fibre, appears to become blended with a small bundle of fibres, into which the tendon becomes subdivided, while the muscular substance terminates abruptly and can readily be made to retract from the point of junction. The areolar tissue between the fibres appears to be prolonged more or less into the tendon, so as to form a kind of sheath around the tendon bundles for a longer or shorter distance. When muscular fibres are attached to the skin or mucous membranes, their fibres are described by Hyde Salter as becoming continuous with those of the areolar tissue.

The *sarcolemma*, or tubular sheath of the fibre, is a transparent, elastic, and apparently homogeneous membrane of considerable toughness, so that it will sometimes remain entire when the included substance is ruptured (see Fig. 638). On

Fig. 638.—Two human muscular fibres. Magnified 350 times. In the one, the bundle of fibrillæ (*b*) is torn, and the sarcolemma (*a*) is seen as an empty tube.

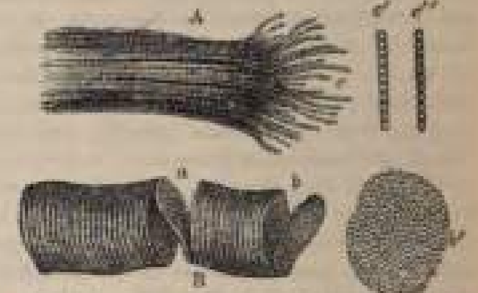


Fig. 639.—Fragments of striped muscular fibres, showing a cleavage in opposite directions. Magnified 300 diameters. A. Longitudinal cleavage. The longitudinal and transverse lines are both seen. Some longitudinal lines are darker and wider than the rest, and are not continuous from end to end. This results from partial separation of the fibrillæ. *c.* Fibrillæ separated from one another by violence at the broken end of the fibre, and marked by transverse lines equal in width to those on the fibre. *c'*, *c''* represent two appearances commonly presented by the separated single fibrillæ (more highly magnified). At *c'* the borders and transverse lines are all perfectly rectilinear, and the included spaces perfectly rectangular. At *c''* the borders are scalloped and the spaces bead-like. When most distinct and definite the fibrilla presents the former of these appearances. B. Transverse cleavage. The longitudinal lines are scarcely visible. *a.* Incomplete fracture following the opposite surfaces of a disk, which stretches across the interval, and retains the two fragments in connection. The edge and surfaces of this disk are seen to be minutely granular, the granules corresponding in size to the thickness of the disk and to the distance between the faint longitudinal lines. *b.* Another disk nearly detached. *b'.* Detached disk, more highly magnified, showing the sarcous elements.

the internal surface of the sarcolemma in mammalia, and also in the substance of the fibre in the lower animals, elongated nuclei are seen, and in connection with these a row of granules, apparently fatty, is sometimes observed.

Upon examination of a voluntary muscular fibre by transmitted light, it is found to be apparently marked by alternate light and dark bands or striæ, which pass transversely, or somewhat obliquely, round the fibre (Fig. 638). The dark and light bands are of nearly equal breadth, and alternate with great regularity. They vary in breadth from about $\frac{1}{1100}$ to $\frac{1}{1700}$ of an inch. If the surface is carefully focussed, rows of granules will be detected at the point of junction of the dark and light bands, and very fine longitudinal lines may be seen running through the dark bands and joining these granules together. By treating the specimen with certain reagents (*e. g.*, chloride of gold) fine lines may be seen running transversely between the granules, uniting them together. This appearance is believed to be due to a reticulum or network of interstitial substance lying between the contractile portions of the muscle. The longitudinal striation gives the fibre the appearance of being made up of a bundle of fibrillæ, which have been termed *sarcostyles* or *muscle-columns;* and if the fibre is hardened in alcohol, it can be broken up longitudinally and the sarcostyles separated from each other (Fig. 639, A). The reticulum, with its longitudinal and transverse meshes, is *sarcoplasm.*

If now a transverse section of a muscular fibre is made, it is seen to be divided into a number of areas, called the *areas of Cohnheim,* more or less polyhedral in shape, and consisting of the transversely divided sarcostyles, surrounded by transparent series of sarcoplasm (Fig. 639, B, *b*).

Upon closer examination, and by somewhat altering the focus, the appearances become more complicated, and are susceptible of various interpretations. The transverse striation, which in Figs. 638 and 639 appears as a mere alternation of dark and light bands, is resolved into the appearance seen in Fig. 640, which shows a series of broad dark bands, separated by light bands, which are divided into two by a dark dotted line. This line is termed *Krause's membrane* (Fig. 642, K), because it was believed by Krause to be an actual membrane continuous with

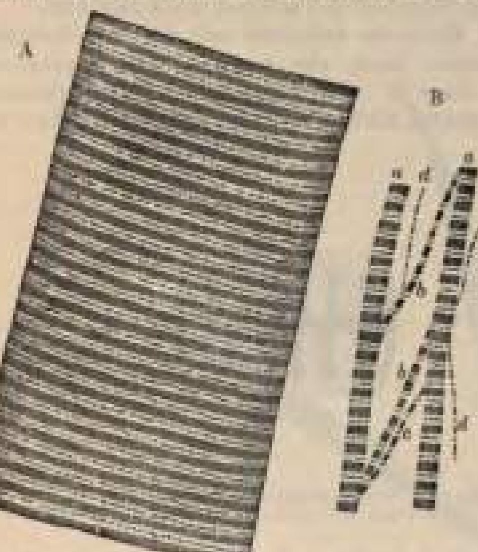


FIG. 640.—Portion of a medium-sized human muscular fibre. Magnified nearly 800 diameters. B. Separated bundles of fibrils, equally magnified. *a, a.* Larger, and *b, b.* smaller collections. *c.* Still smaller. *d, d.* The smallest which could be detached.

FIG. 641.—Part of a striped muscular fibre of the water-beetle, prepared with absolute alcohol. Magnified 300 diameters. (Klein and Noble Smith.) *a.* Sarcolemma. *b.* Membrane of Krause; owing to contraction during hardening, the sarcolemma shows regular bulgings. At the side of Krause's membrane is the transparent lateral disk. Several nuclei of muscle-corpuscles are shown, and in them a minute network.

the sarcolemma, and dividing the light band into two compartments. It is now more usually regarded as being due to an optical phenomenon, from the light being reflected between disks of different refrangibility. In addition to the membrane of Krause, fine clear lines may be made out, with a sufficiently high power, crossing the centre of the dark band; these are known as the *lines of Hensen* (Fig. 642, H).

Formerly it was supposed by Bowman that a muscular fibre was made up of a number of quadrangular particles, which he named sarcous elements, joined together like so many bricks forming a column, and he came to this conclusion because he found that under the influence of certain reagents the fibre could be broken up transversely into disks, as well as longitudinally into fibrillæ (Fig. 639, B). But it is now believed that this cross-cleavage is purely artificial, and that a muscular fibre is built up of fibrillæ and not of small quadrangular particles.

Assuming that this is so, we have now to consider a little more in detail the minute structure of these longitudinal fibrillæ, or sarcostyles, as they are termed. Perhaps there are few subjects in histology which have received more attention and in which the appearances seen under the microscrope have been more differently interpreted, than the minute anatomy of muscular fibre. Schäfer has recently worked out this subject, particularly in the wing-muscles of insects, which are peculiarly adapted for this purpose on account of the large amount of interstitial sarcoplasm which separates the sarcostyles. In the following description we shall closely follow that given by Professor Schäfer (Fig. 642).

Each sarcostyle may be said to be made up of successive portions, each of which Schäfer terms a *sarcomere*. This is the portion, situated between two membranes of Krause, which transversely divides the light band. Each sarcomere consists of a central dark part, which forms a portion of the dark band of the whole fibre, and is named by Schäfer a *sarcous element*.[1] This sarcous element really consists of two parts, superimposed one on the top of the other, and when the fibre is stretched, these two parts become separated from each other at the line of Hensen (Fig. 642, A). On either side of this central dark portion is a clear layer, most visible when the fibre is extended; this is situated between the dark centre and the membrane of Krause, and when the sarcomeres are joined together to form the sarcostyle, constitutes the light band of the striated muscular fibre.

When the sarcostyle is extended, the clear intervals are well marked and plainly to be seen; when, on the other hand, the sarcostyle is contracted, that is to say, the muscle is in a state of contraction, these clear portions are very small or they may have disappeared altogether (Fig. 642, B). When the

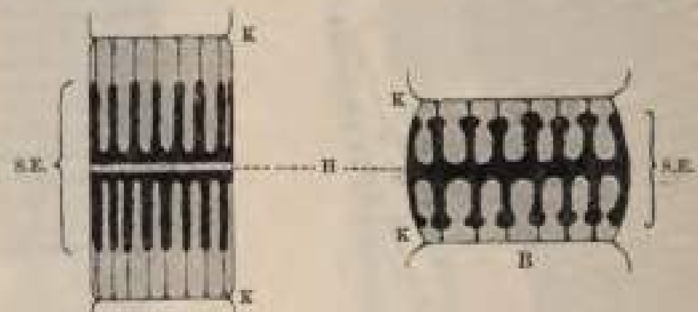


FIG. 642.—Diagram of a sarcomere. (After Schäfer.) A. In moderately extended condition. B. In a contracted condition. K.K. Membranes of Krause; H. Line or plane of Hensen; S.E. Poriferous sarcous element.

sarcostyle is stretched to its full extent, not only is the clear portion very well marked, but the dark portion—the sarcous element—will be seen to be separated into its two constituents along the line of Hensen.

The sarcous element does not lie free in the sarcomere, for when the sarcostyle is stretched, so as to render the clear portion visible, very fine lines, which are probably septa, may be seen running through it from the sarcous element to the membrane of Krause.

Schäfer explains these phenomena in the following way. He considers that each sarcous element is made up of a number of longitudinal channels, which open into the clear part toward the membrane of Krause, but are closed at the line of Hensen. When the muscular fibre is contracted the *clear* part of the muscular substance finds its way into these channels or tubes, and is therefore hidden from sight, but at the same time it swells up the sarcous element and widens and shortens the sarcomere. When, on the other hand, the fibre is extended, this clear substance finds its way out of the tubes and collects between the sarcous element and the membrane of Krause, and gives the appearance of the light part between these two structures; by this means it elongates and narrows the sarcomere.

If this view is true, it is a matter of great interest, and, as Schäfer has shown, harmonizes the contraction of muscle with the amœboid action of proto-

[1] This must not be confused with the "sarcous element of Bowman." (See above.)

plasm. In an amœboid cell there is a framework of spongioplasm, which stains with hæmatoxylin and similar reagents, enclosing in its meshes a clear substance, hyaloplasm, which will not stain with these reagents. Under stimulation the hyaloplasm passes into the pores of the spongioplasm; without stimulation it tends to pass out as in the formation of pseudopodia. In muscle there is the same thing: viz., a framework of spongioplasm staining with hæmatoxylin—the substance of the sarcous element—and this encloses a clear hyaloplasm, the clear substance of the sarcomere, which resists staining with this reagent. During contraction of the muscle—*i. e.*, stimulation—this clear substance passes into the pores of the spongioplasm; while during extension of the muscle—*i. e.*, when there is no stimulation—it tends to pass out of the spongioplasm.

In this way the contraction is brought about: under stimulation the protoplasmic material (the clear substance of the sarcomere) recedes into the sarcous element, causing the sarcomere to widen out and shorten. The contraction of the muscle is merely the sum total of this widening out and shortening of these bodies.

The *capillaries* of striped muscle are very abundant, and form a sort of rectangular network, the branches of which run longitudinally in the endomysium

FIG. 643.—Non-striated muscular fibre. (From Kirke's *Physiology*.)

between the muscular fibres, and are joined at short intervals by transverse anastomosing branches. The larger vascular channels, arteries and veins, are found only in the perimysium, between the muscular fasciculi.

Nerves are profusely distributed to striped muscle. The mode of their termination will be described on a subsequent page.

The existence of *lymphatic* vessels in striped muscle has not been ascertained, though they have been found in tendons and in the sheath of the muscle.

The **unstriped plain, or involuntary muscle**, is found in the walls of the hollow viscera—viz., the lower half of the œsophagus and the whole of the remainder of the gastro-intestinal tube; in the trachea and bronchi, and the alveoli and infundibula of the lungs; in the gall-bladder and ductus communis choledochus; in the large ducts of the salivary and pancreatic glands; in the pelvis and calices of the kidney, the ureter, bladder, and urethra; in the female sexual organs—viz., the ovary, the Fallopian tubes, the uterus (enormously developed in pregnancy), the vagina, the broad ligaments, and the erectile tissue of the clitoris; in the male sexual organs—viz., the dartos of the scrotum, the vas deferens and epididymis, the vesiculæ seminales, the prostate gland, and the corpora cavernosa and corpus spongiosum; in the ducts of certain glands, as in Wharton's duct; in the capsule and trabeculæ of the spleen; in the mucous membranes, forming the muscularis mucosæ; in the skin, forming the arrectores pilorum, and also in the sweat-glands; in the arteries, veins, and lymphatics; in the iris and the ciliary muscle.

Plain or unstriped muscle is made up of spindle-shaped cells, called *contractile fibre-cells*, collected into bundles and held together by a cement-substance (Fig. 643). These bundles are further aggregated into larger bundles or flattened bands, and bound together by ordinary connective tissue.

The *contractile fibre-cells* are elongated, spindle-shaped, nucleated cells of various lengths, averaging from $\frac{1}{500}$ to $\frac{1}{200}$ of an inch in length, and $\frac{1}{3000}$ to $\frac{1}{5000}$ of an inch in breadth. On transverse section they are more or less polyhedral in shape, from mutual pressure. They present a faintly longitudinal striated appearance, and consist of an elastic cell-wall containing a central bundle of fibrillæ, representing the contractile substance, and an oval or rod-like nucleus, which includes, within a membrane, a fine network communicating at the poles of the nucleus with the contractile fibres (Klein). The adhesive interstitial cement-substance, which connects the fibre-cells together, represents the endomysium, or delicate connective tissue which binds the fibres of striped muscular tissue into fasciculi; while the tissue connecting the individual bundles together represents the perimysium. The unstriped muscle, as a rule, is not under the control of the will, nor is the contraction rapid and involving the whole muscle, as is the case with the voluntary muscles. The membranes which are composed of the unstriped muscle slowly contract in a part of their extent, generally under the influence of a mechanical stimulus, as that of distention or of cold; and then the contracted part slowly relaxes while another portion of the membrane takes up the contraction. This peculiarity of action is most strongly marked in the intestines, constituting their *vermicular motion*.

Cardiac Muscular Tissue.—The fibres of the heart differ very remarkably from those of other striped muscles. They are smaller by one-third, and their transverse striæ are by no means so distinct. The fibres are made up of distinct quadrangular cells joined end to end (Fig. 644). Each cell contains a clear oval nucleus, situated near the centre of the cell. The extremities of the cells have a tendency to branch or divide, the subdivisions uniting with offsets from other cells, and thus producing an anastomosis of the fibres. The connective tissue between the bundles of fibres is much less than in ordinary striped muscle, and no sarcolemma has been proved to exist.

FIG. 644.—Anastomosing muscular fibres of the heart, seen in a longitudinal section. On the right the limits of the separate cells with their nuclei are exhibited somewhat diagrammatically.

Development of Muscle-Fibres.—Voluntary muscular fibres are developed from the mesoblast, the embryonic cells of which elongate, show multiplication of nuclei, and eventually become striated; the striation is first obvious at the side of the fibre, spreads around the circumference, and ultimately extends to the centre. The nuclei, at first situated centrally, gradually pass out to assume their final position immediately beneath the sarcolemma. In the case of plain muscle the mesoblastic cells assume a pointed shape at the extremities and become flattened, the nucleus also lengthening out to its permanent rod-like form.

Chemical Composition of Muscle.—In chemical composition the muscular fibres may be said, in round numbers, to consist of 75 per cent. of water, about 20 per cent. of proteids, 2 per cent. of fat, 1 per cent. of nitrogenous extractives and carbohydrates, and 2 per cent. of salts, which are mainly potassium phosphate and carbonate.

THE NERVOUS TISSUE.

The **nervous tissues** of the body are comprised in two great systems—the *cerebro-spinal* and the *sympathetic;* and each of these systems consist of a *central organ*, or series of central organs, and of *nerves*.

The *cerebro-spinal* system comprises the brain (including the medulla oblongata), the spinal cord, the cranial nerves, the spinal nerves, and the ganglia connected with both these classes of nerves. The *sympathetic* system consists of a double chain of ganglia, with the nerves which go to and come from them. It is not directly connected with the brain or spinal cord, though it is so indirectly by means of its numerous communications with the cranial and spinal nerves.

All these nervous tissues are composed chiefly of two different structures—the *gray* or *cineritious* and the *white* or *fibrous*. It is in the former, as is generally supposed, that nervous impressions and impulses originate, and by the latter that they are conducted. Hence the gray matter forms the essential constituent of all the ganglionic centres, both those in the isolated ganglia and those aggregated in the cerebro-spinal axis; while the white matter is found in all the commissural portions of the nerve-centres and in all the cerebro-spinal nerves. The nerves of the sympathetic system are chiefly composed of a material of a somewhat different structure, which is named *gray* or *gelatinous* nerve-fibre. This form of nerve-fibre is also found in some of the cerebro-spinal nerves.

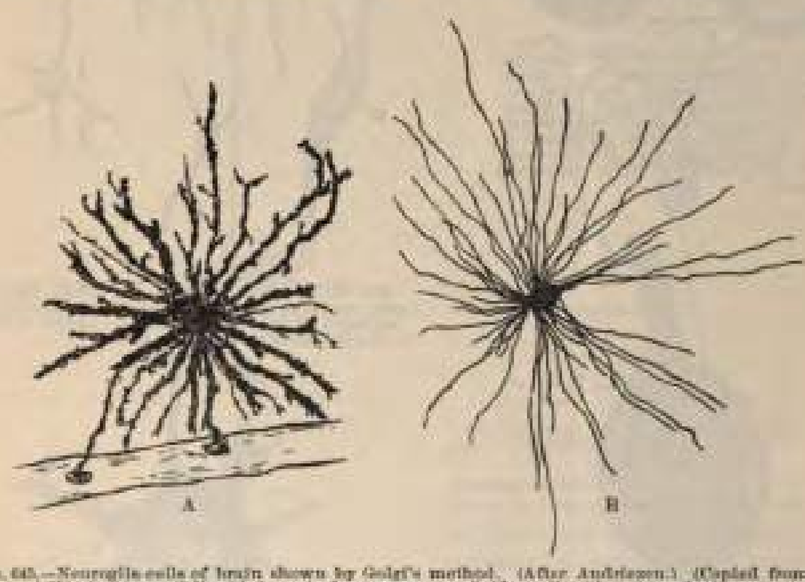


FIG. 645.—Neuroglia-cells of brain shown by Golgi's method. (After Andriezen.) (Copied from Schäfer's *Essentials of Histology*.) A. Cell with branched processes. B. Spider-cell with unbranched processes.

The **gray nervous substance** is distinguished by its dark reddish-gray color and soft consistence. It is found in the brain, spinal cord, and various ganglia intermingled with the fibrous nervous substance, and also in some of the nerves of special sense, and in gangliform enlargements which are found here and there in the course of certain cerebro-spinal nerves. It is composed of cells, commonly called *nerve-cells* or *ganglion-corpuscles*, containing nuclei and nucleoli. The cells together with the blood-vessels in the gray nerve-substance, and the nerve-fibres and vessels in the white nerve-substance, are imbedded in a peculiar ground substance, named by Virchow *neuroglia*. It consists of fibres and cells. Some of the cells are stellate in shape, and their fine processes become neuroglia-fibres, which extend radially and unbranched (Fig. 645, B) among the nerve-cells and fibres which they aid in supporting. Other cells give off fibres which branch repeatedly (Fig. 645, A). In addition to these fibres there are others which do not appear to be connected with the neuroglia-cells. They start from the epithelial cells lining the ventricles of the brain and central canal of the spinal cord, and pass through the nervous tissue, branching repeatedly to terminate in slight enlargements on the pia mater. Thus, neuroglia is evidently a connective tissue in function, but is not so in development; it is epiblastic in origin, whereas all connective tissues are mesoblastic.

Each nerve-cell consists of a finely fibrillated protoplasmic material, of a reddish or yellowish-brown color, which occasionally presents patches of a deeper

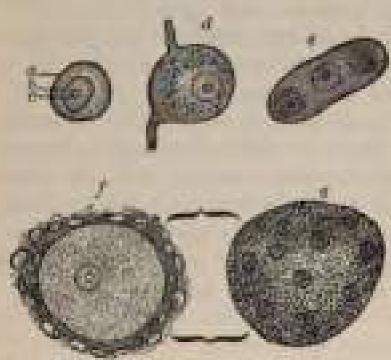


FIG. 646.—Nerve-cells from the Gasserian ganglion of the human subject. *a*. A globular one with defined border. *b*. Its nucleus. *c*. Its nucleolus. *d*. Caudate cell. *e*. Elongated cell with two groups of pigment-particles. *f*. Cell surrounded by its sheath or capsule of nucleated particles. *g*. The same, the sheath only being in focus. Magnified 200 diameters.

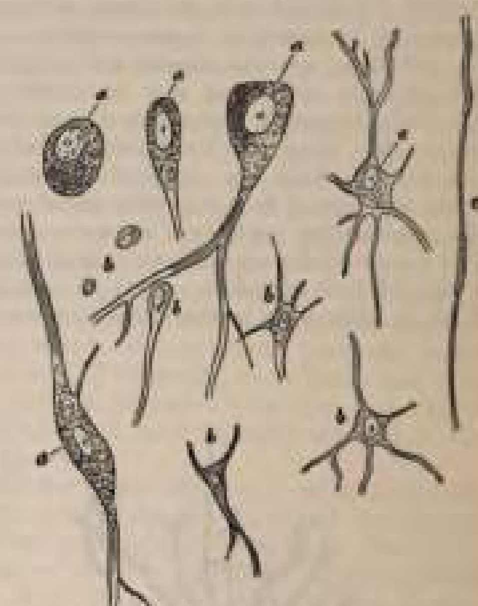


FIG. 647.—Nerve-cells from the inner part of the gray matter of the convolutions of the human brain. Magnified 200 times. Nerve-cells: *a*. Larger. *b*. Smaller. *c*. Nerve-fibre with axis-cylinder.

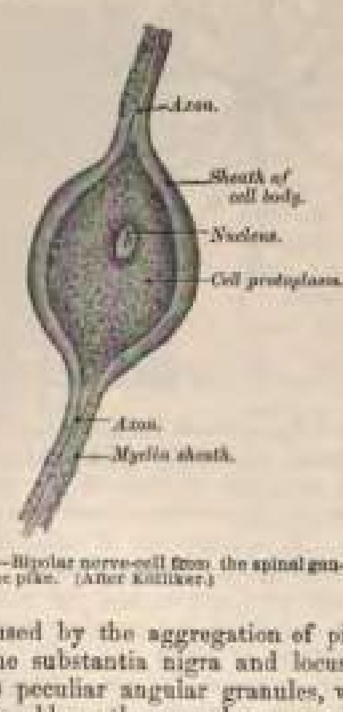


FIG. 648.—Bipolar nerve-cell from the spinal ganglion of the pike. (After Kölliker.)

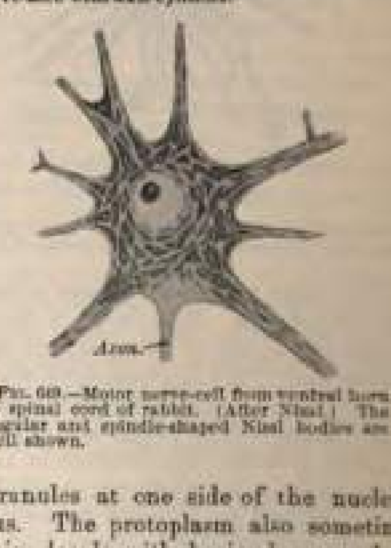


FIG. 649.—Motor nerve-cell from ventral horn of spinal cord of rabbit. (After Nissl.) The angular and spindle-shaped Nissl bodies are well shown.

tint, caused by the aggregation of pigment-granules at one side of the nucleus, as in the substantia nigra and locus cæruleus. The protoplasm also sometimes contains peculiar angular granules, which stain deeply with basic dyes, such as methylene-blue; these are known as *Nissl's granules* (Fig. 649). The nucleus is, as a rule, a large, well-defined, round, vesicular body, often presenting an intranuclear network, and containing a nucleolus which is peculiarly clear and brilliant. The nerve-cells vary in shape and size, and have one or more processes. They may be divided for purposes of description into three groups, according to the number of processes which they possess: (1) Unipolar cells, which are found in the spinal ganglia; their single process, after a short course, divides in a T-shaped manner. (2) Bipolar cells, also found in the spinal ganglia (Fig. 648), when the cells are in an embryonic condition. They are best demonstrated in the sympathetic ganglion-cells of a frog. Sometimes the processes come off from opposite poles of the cell, and the cell then assumes a spindle-shape; at others they both emerge at the same point. In some cases where two fibres are apparently connected with a cell, one of the fibres is really derived from an adjoining nerve-cell and is passing to end in a ramification around the ganglion-cell, or, again, it may be coiled spirally round the nerve process which is issuing from the cell. (3) Multipolar cells, which are caudate or stellate in shape, and characterized by their large size and by the tail-like processes which issue from them. The processes are of two kinds: one of them is termed the *axis-cylinder process* or *axon*, because it becomes the axis-cylinder of a nerve-fibre (Figs. 649, 650, 651). The others are termed the *protoplasmic processes* or *dendrons;* they begin to divide and subdivide as soon as they emerge from the cell, and finally end in minute twigs and become lost among the other elements of the nervous tissue.

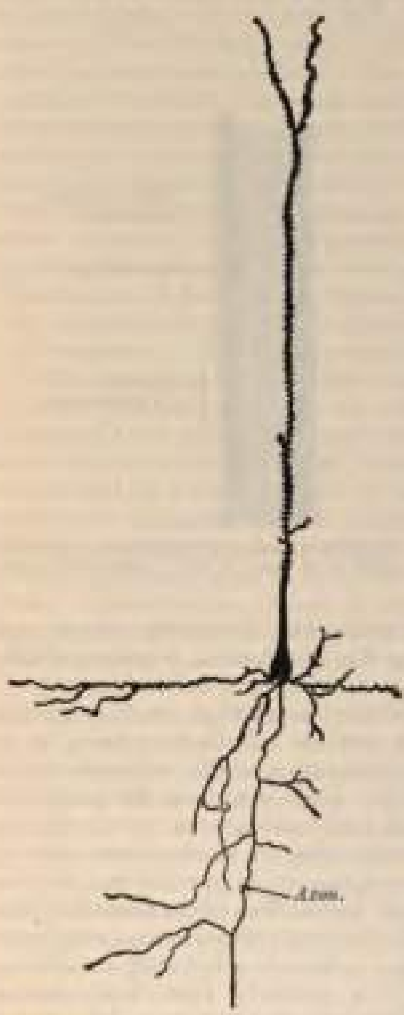


FIG. 650.—Pyramidal cell from the cerebral cortex of a mouse. (After Ramón y Cajal.)

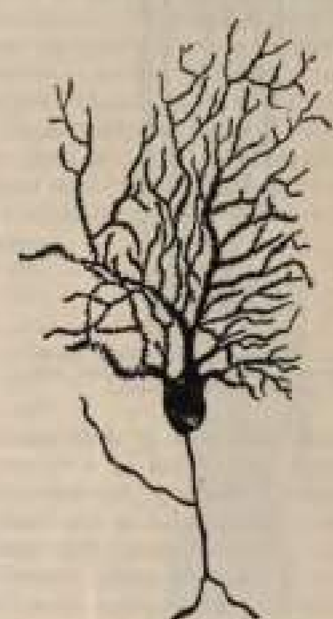


FIG. 651.—Cell of Purkinje from the cerebellum of a cat. (After Ramón y Cajal.)

The **white** or **fibrous** nerve-substance or *nerve-fibre* is found universally in the nervous cords, and also constitutes a great part of the brain and spinal cord. The fibres of which it consists are of two kinds, the *medullated* or *white* fibres, and the *non-medullated* or *gray* fibres.

The **medullated** fibres form the white part of the brain and spinal cord, and also the greater part of the cerebro-spinal nerves, and gives to these structures their opaque, white aspect. When perfectly fresh they appear to be homogeneous; but soon after removal from the body they present, when examined by transmitted light, a double outline or contour, as if consisting of two parts (Fig. 652). The central portion is named the *axis-cylinder of Purkinje;* around this is a sort of sheath of fatty material, staining black with osmic acid, named

Fig. 652.—White or medullated nerve-fibres showing the sinuous outline and double contours. (After Schäfer.)

Fig. 653.—Longitudinal section through a nerve-fibre from the sciatic nerve of a frog. × 850. (After Böhm and Davidoff.)

the *white substance of Schwann,* which gives to the fibre its double contour, and the whole is enclosed in a delicate membrane, the *neurilemma, primitive sheath,* or *nucleated sheath of Schwann* (Fig. 652).

The *axis-cylinder* is the essential part of the nerve-fibre, and is always present; the other parts, the medullary sheath and the neurilemma, being occasionally absent, especially at the origin and termination of the nerve-fibre. It undergoes no interruption from its origin in the nerve-centre to its peripheral termination, and must be regarded as a direct prolongation of a nerve-cell. It constitutes about one-half or one-third of the nerve-tube, the whole substance being greater in proportion in the nerves than in the central organs. It is perfectly transparent, and is therefore indistinguishable in a perfectly fresh and natural state of the nerve. It is made up of exceedingly fine fibrils, which stain darkly with gold chloride (Fig. 653). At its termination the axis-cylinder of a nerve-fibre may be seen to break up into fibrillæ, confirming the view of its structure. These fibrillæ have been termed the *primitive fibrillæ* of Schultze. The axis-cylinder is said by some to be enveloped in a special, reticular sheath, which separates it from the white matter of Schwann, and is composed of a substance called *neurokeratin.* The more common opinion is that this network or reticulum is contained in the white matter of Schwann, and by some it is believed to be produced by the action of the reagents employed to show it. The *medullary sheath* or *white matter of Schwann* (Fig. 653) is regarded as being a fatty matter in a fluid state, which insulates and protects the essential part of the nerve—the axis-cylinder. The white matter varies in thickness to a very

Fig. 654.—A node of Ranvier of a medullated nerve-fibre, viewed from above, magnified about 750 diameters. The medullary sheath is discontinuous at the node, whereas the axis-cylinder passes from one segment into the other. At the node the sheath of Schwann appears thickened. (Klein and Noble Smith.)

considerable extent, in some forming a layer of extreme thinness, so as to be scarcely distinguishable; in others forming about one-half the nerve-tube. The size of the nerve-fibres, which varies from $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch, depends mainly upon the amount of the white substance, though the axis-cylinder also varies in size within certain limits. The white matter of Schwann does not always form a continuous sheath to the axis-cylinder, but undergoes interruptions in its continuity at regular intervals, giving to the fibre the appearance of constriction at these points. These were first described by Ranvier, and are known as the *nodes of Ranvier* (Fig. 654). The portion of nerve-fibre between two nodes is called an *internodal segment*. The neurilemma or primitive sheath is not interrupted at the nodes, but passes over them as a continuous membrane. In addition to these interruptions oblique clefts may be seen in the medullary sheath, subdividing it into irregular portions, which are termed *medullary segments*, or *segments of Lantermann* (Fig. 653). There is reason to believe that these clefts are artificially produced in the preparation of the specimens. Medullated nerve-fibres, when examined, frequently present a beaded or varicose appearance: this is due to manipulation and pressure causing the oily matter to collect into drops, and in consequence of the extreme delicacy of the primitive sheath, even slight pressure will cause the transudation of the fatty matter, which collects as drops of oil outside the membrane. This is, of course, promoted by the action of certain reagents.

The *neurilemma* or *primitive sheath* (sometimes called the *tubular membrane* or *sheath of Schwann*) presents the appearance of a delicate, structureless membrane. Here and there beneath it, and situated in depressions in the white matter of Schwann, are nuclei surrounded by a small amount of protoplasm. The nuclei are oval and somewhat flattened, and bear a definite relation to the nodes of Ranvier; one nucleus generally lying in the centre of each internode. The primitive sheath is not present in all medullated nerve-fibres, being absent in those fibres which are found in the brain and spinal cord.

FIG. 655.—A small nervous branch from the sympathetic of a mammal. a. Two medullated nerve-fibres among a number of gray nerve-fibres, b.

Non-medullated Fibres.—Most of the nerves of the sympathetic system, and some of the cerebrospinal, consist of another variety of nervous fibres, which are called the *gray* or *gelatinous* nerve-fibres —*fibres of Remak* (Fig. 655). These consist of a central core or axis-cylinder enclosed in a nucleated sheath, which tends to split into fibrillæ, and is probably of the nature of neurokeratin. In external appearance the gelatinous nerves are semi-transparent and gray or yellowish-gray. The individual fibres vary in size, generally averaging about half the size of the medullated fibres.

Development of Nerve-cells and Fibres.—The nerve-cells are developed from certain of the cells which line the neural canal or form the neural crest of the embryo (see section on Development). Some of these cells assume a rounded form and are termed *neuroblasts*, and from each neuroblast there grows out a process, the axis-cylinder process or axon, and subsequently the branching processes or dendrons. The axis-cylinders, at first naked, acquire their medullary sheath, possibly by some metamorphosis of their outer layer. The neurilemma is thought to be derived from mesoblastic cells which become flattened and wrapped round the fibre, the cement-substance at their apposed ends forming the material which stains with silver nitrate at the nodes of Ranvier. Nerve-cells in the sympathetic and peripheral ganglia take their origin from small collections of neuroblasts, which are split off from the rudimentary spinal ganglia. Cells which are, originally, similar to neuroblasts seem to give rise to neuroglia-cells, numerous processes sprouting from the cell to form the neuroglial fibres.

Chemical Composition.—The amount of water in nervous tissue varies with the situation. Thus in the gray matter of the cerebrum it constitutes about 83 per cent., in the white matter from the same region about 70 per cent., while in the peripheral nerves, such as the sciatic, it may fall to 60 per cent. The solids consist of proteids (in the gray matter they form half the total solids), neurokeratin, nuclein, protagon, lecithin, cerebrosides, cholesterin, nitrogenous extractives, and salts, with some gelatin and fat from the adherent connective tissue.

The nervous structures are divided, as before mentioned, into two great systems, viz., the *cerebro-spinal*, comprising the brain and spinal cord, the nerves connected with these structures, and the ganglia situated on them; and the *sympathetic*, consisting of a double chain of ganglia and the nerves connected with them. All these structures require separate consideration; they are composed of the two kinds of nervous tissue above described, intermingled in various proportions, and having, in some parts, a very intricate arrangement.

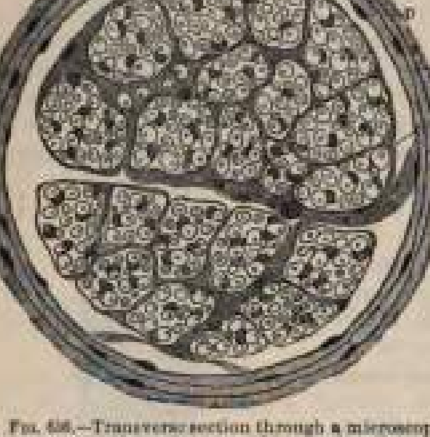


FIG. 656.—Transverse section through a microscopic nerve, representing a compound nerve-bundle, surrounded by perineurium. Magnified 130 diameters. The medullated fibres are seen as circles with a central dot—viz. medullary sheath and axis-cylinder—in transverse section. They are embedded in endoneurium, containing numerous nuclei, which belong to the connective-tissue cells of the latter. (Klein and Noble Smith.) p. Perineurium, consisting of laminæ of fibrous connective-tissues, alternating with flattened nucleated connective-tissue cells. l. Lymph-space between epineurium and surface of nerve-bundle.

The **brain** or **encephalon** is that part of the cerebro-spinal system which is contained in the cavity of the skull. It is divided into several parts, which will be described in the sequel. In these parts the gray or vesicular nervous matter is found partly on the surface of the brain, forming the convolutions of the cerebrum and the laminæ of the cerebellum. Again, gray matter is found in the interior of the brain, collected into large and distinct masses or ganglionic bodies, such as the corpus striatum, optic thalamus, and corpora quadrigemina. Finally, gray matter is found intermingled intimately with the white, but without definite arrangement, as in the gray matter in the pons Varolii and the floor of the fourth ventricle.

The white matter of the brain is divisible into three distinct classes of fibres: (1) Diverging or peduncular fibres, which connect the hemispheres with the medulla oblongata and the spinal cord. (2) Commissural fibres, which connect together the two hemispheres. (3) Association fibres, which connect different parts of the same hemisphere.

The manner in which these fibres are intermingled with each other and with the gray matter in the brain and spinal cord is very intricate, and can be fully understood only by a careful study of the details of its descriptive anatomy in the sequel. The further consideration of this subject will therefore be deferred until after the description of the various divisions of which the cerebro-spinal system is made up.

The **nerves** are round or flattened cords, formed of the nerve-fibres already described. They are connected at one end with the cerebro-spinal centre or with the ganglia, and are distributed at the other end to the various textures of the body; they are subdivided into two great classes—the *cerebro-spinal*, which proceed from the cerebro-spinal axis, and the *sympathetic* or *ganglionic* nerves, which proceed from the ganglia of the sympathetic. The **cerebro-spinal nerves** consist of numerous nerve-fibres collected together and enclosed in a membranous sheath (Fig. 656). A small bundle of primitive fibres, enclosed in a tubular sheath, is called a *funiculus*; if the nerve is of small size, it may consist only of a single funiculus; but if large, the funiculi are collected together into larger bundles or fasciculi, which are bound together in a common membranous investment, and constitute the nerve.

In structure the common membranous investment, or sheath of the whole nerve, which is called the *epineurium*, as well as the septa given off from it, and which separate the fasciculi, consists of connective tissue, composed of white and yellow elastic fibres, the latter existing in great abundance. The tubular sheath of the funiculi, called the *perineurium*, consists of a fine, smooth, transparent membrane, which may be easily separated, in the form of a tube, from the fibres it encloses; in structure it consists of connective tissue, which has a distinctly lamellar arrangement, consisting of several lamellæ, separated from each other by spaces containing lymph. The nerve-fibres are held together and supported within the funiculus by delicate connective tissue called the *endoneurium*. It is continuous with septa which pass inward from the innermost layer of the perineurium, and consists of a ground-substance in which are embedded fine bundles of fibrous connective tissue which run for the most part longitudinally. It serves to support the capillary vessels, which are arranged so as to form a network with elongated meshes. The cerebro-spinal nerves consist almost exclusively of the medullated nerve-fibres, the non-medullated existing in very small proportions.

The blood-vessels supplying a nerve terminate in a minute capillary plexus, the vessels composing which pierce the perineurium and run, for the most part, parallel with the fibres; they are connected together by short, transverse vessels, forming narrow, oblong meshes, similar to the capillary system of muscle. Fine non-medullated nerve-fibres accompany these capillary vessels, *vaso-motor fibres*, and break up into elementary fibrils, which form a network around the vessel. Horsley has also demonstrated certain medullated fibres as running in the epineurium and terminating in small spheroidal tactile corpuscles or end-bulbs of Krause. These nerve-fibres, which Marshall believes to be sensory, and which he has termed *nervi nervorum*, are considered by him to have an important bearing upon certain neuralgic pains.

The nerve-fibres, as far as is at present known, do not coalesce, but pursue an uninterrupted course from the centre to the periphery. In separating a nerve, however, into its component funiculi, it may be seen that they do not pursue a perfectly insulated course, but occasionally join at a very acute angle with other funiculi proceeding in the same direction; from this, branches are given off, to join again in like manner with other funiculi. It must be distinctly understood, however, that in these communications the nerve-fibres do not coalesce, but merely pass into the sheath of the adjacent nerve, become intermixed with its nerve-fibres, and again pass on, to become blended with the nerve-fibres in some adjoining funiculus.

Nerves, in their course, subdivide into branches, and these frequently communicate with branches of a neighboring nerve.

The communications which take place between two or more nerves form what is called a *plexus*. Sometimes a plexus is formed by the primary branches of the trunks of the nerves—as the cervical, brachial, lumbar, and sacral plexuses—and occasionally by the terminal funiculi, as in the plexuses formed at the periphery of the body. In the formation of a plexus the component nerves divide, then join, and again subdivide in such a complex manner that the individual funiculi become interlaced most intricately; so that each branch leaving a plexus may contain filaments from each of the primary nervous trunks which form it. In the formation also of smaller plexuses at the periphery of the body there is a free interchange of the funiculi and primitive fibres. In each case, however, the individual filaments remain separate and distinct, and do not inosculate with one another.

It is probable that through this interchange of fibres the different branches passing off from a plexus have a more extensive connection with the spinal cord than if they each had proceeded to be distributed without such connection with other nerves. Consequently the parts supplied by these nerves have more extended relations with the nervous centres; by this means, also, groups of muscles may be associated for combined action.

The **sympathetic** nerves are constructed in the same manner as the cerebro-spinal nerves, but consist mainly of non-medullated fibres, collected into funiculi, and enclosed in a sheath of connective tissue. There is, however, in these nerves a certain admixture of medullated fibres, and the amount varies in different nerves, and may be known by their color. Those branches of the sympathetic which present a well-marked gray color are composed more especially of gelatinous nerve-fibres, intermixed with a few medullated fibres; while those of a white color contain more of the latter fibres and a few of the former. Occasionally, the gray and white cords run together in a single nerve, without any intermixture, as in the branches of communication between the sympathetic ganglia and the spinal nerves, or in the communicating cords between the ganglia.

The nerve-fibres, both of the cerebro-spinal and sympathetic system, convey impressions of a twofold kind. The sensory nerves, called also *centripetal* or *afferent* nerves, transmit to the nervous centres impressions made upon the peripheral extremities of the nerves, and in this way the mind, through the medium of the brain, becomes conscious of external objects. The *motor* nerves, called also *centrifugal* or *efferent* nerves, transmit impressions from the nervous centres to the parts to which the nerves are distributed, these impressions either exciting muscular contraction, or influencing the processes of nutrition, growth, and secretion.

Origin and Termination of Nerves.—By the expression "the termination of nerve-fibres" is signified their connection with the nerve-centres, and with the parts they supply. The former are sometimes called their *origin*, or *central* termination; the latter their *peripheral* termination. The origin in some cases is single—that is to say, the whole nerve emerges from the nervous centre by a single root; in other instances the nerve arises by two or more roots, which come off from different parts of the nerve-centre, sometimes widely apart from each other, and it often happens, when a nerve arises in this way by two roots, that the functions of these two roots are different; as, for example, in the spinal nerves, each of which arises by two roots, the anterior of which is motor and the posterior sensory. The point where the nerve root or roots emerge from the nervous centre is named the *superficial* or *apparent* origin, but the fibres of which the nerve consists can be traced for a certain distance into the nervous centre to some portion of the gray substance, which constitutes the *deep* or *real* origin of the nerve.

The manner in which these fibres arise at their deep origin varies with their functions. The centrifugal or efferent nerve-fibres originate in the nerve-cells of the gray substance, the axis-cylinder processes of these cells being prolonged to form the fibres. In the case of the centripetal or afferent nerves the fibres grow inward either from nerve-cells in the organs of special sense (*e. g.*, the retina) or from nerve-cells in the ganglia. Having entered the nerve-centre, they branch and send their ultimate twigs among the cells, without, however, uniting with them.

Peripheral Terminations of Nerves.—Nerve-fibres terminate peripherally in various ways, and these may be conveniently studied in the sensory and motor nerves, respectively. **Sensory** nerves would appear to terminate either in *minute primitive fibrillæ* or networks of these; or else in special terminal organs, which have been termed *peripheral end-organs*, and of which there are several principal varieties, viz., the end-bulbs of Krause, the tactile corpuscles of Wagner, the Pacinian corpuscles, and the neuro-tendinous and neuro-muscular spindles.

Termination in Fibrillæ.—When a medullated nerve-fibre approaches its termination, the white matter of Schwann suddenly disappears, leaving only the axis-cylinder, surrounded by the neurilemma, and forming a non-medullated fibre. This, after a time, loses its neurilemma, and consists only of an axis-cylinder, which can be seen, in preparations stained with chloride of gold, to be made up of fine varicose fibrils. Finally, the axis-cylinder breaks up into its constituent primitive nerve-fibrillæ, which often present regular varicosities and anastomose with one another, thus forming a network. This network passes between the elements of the tissue to which the nerves are distributed, which is always epithelial, the nerve-fibrils lying in the interstitial substance between the epithelial cells, and there terminating, though some observers maintain that the actual terminations are within the cells. In this way nerve-fibres have been found to terminate in the epithelium of the skin and mucous membranes, and in the anterior epithelium of the cornea.

The **end-bulbs of Krause** (Fig. 657) are minute cylindrical or oval bodies, consisting of a capsule formed by the expansion of the connective-tissue sheath of a medullated fibre, and containing a soft semifluid core in which the termination of the axis-cylinder is situated, ending either as a bulbous extremity, or in a coiled-up plexiform mass. End-bulbs are found in the conjunctiva of the eye, where they are spheroidal in shape in man, but cylindrical in most other animals, in the mucous membrane of the lips and tongue, and in the epineurium of nerve-trunks. They are also found in the genital organs of both sexes, the penis in the male, and the clitoris in the female. In this situation they have a mulberry-like appearance, from being constricted by connective-tissue septa into from two to six knob-like masses, and have received the name of *genital corpuscles.* Very similar corpuscles are found in the epineurium of nerve-trunks. In the synovial membrane of certain joints (*e. g.*, those of the fingers), rounded or oval end-bulbs have been found: these are designated *articular end-bulbs.*

Tactile corpuscles have been described by Grandry as occurring in the papillæ of the beak and tongue of birds, and by Merkel as occurring in the papillæ and epithelium of the skin of man and animals, especially in those parts of the skin devoid of hair. They consist of a capsule composed of a very delicate, nucleated membrane, and contain two or more granular, somewhat flattened cells, between which the medullated nerve-fibre, which enters the capsule by piercing its investing membrane, is supposed to terminate.

Fig. 657.—End-bulb of Krause. *a.* Medullated nerve-fibre. *b.* Capsule of corpuscle. (From Klein's *Elements of Histology.*)

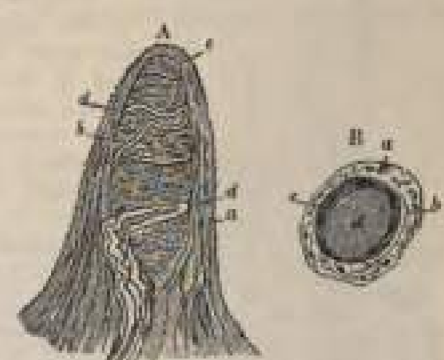


Fig. 658.—Tactile papilla of the hand treated with acetic acid. Magnified 350 times. A. Side view of a papilla of the hand. *a.* Cortical layer. *b.* Tactile corpuscle, with transverse nuclei. *c.* Small nerve of the papilla, with neurilemma. *d.* Its two nervous fibres running with spiral coils around the tactile corpuscle. *e.* Apparent termination of one of these fibres. B. A tactile papilla seen from above, so as to show its transverse section. *a.* Cortical layer. *b.* Nerve-fibre. *c.* Outer layer of the tactile body, with nuclei. *d.* Clear interior substance.

The **tactile corpuscles** (Fig. 658), described by Wagner and Meissner, are oval-shaped bodies, made up of connective tissue, and consisting of a capsule, and imperfect membranous septa, derived from it, which penetrate its interior. The axis-cylinder of the medullated fibres passes through the capsule, and having entered the corpuscle terminates in a small globular or pyriform enlargement, near the inner surface of the capsule. These tactile corpuscles have been described as occurring in the papillæ of the corium of the hand and foot, the front of the forearm, skin of the lips, and the mucous membrane of the tip of the tongue, the palpebral conjunctiva, and the skin of the nipple. They are not found in all the papillæ; but from their existence in those parts in which the skin is highly sensi-

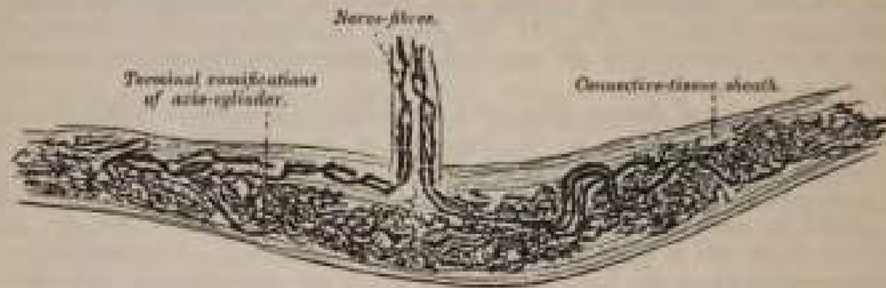


FIG. 659.—Nerve-ending of Ruffini. (After A. Ruffini, *Arch. ital. de Biol.*, Turin, t. xxi. 1894.)

tive, it is probable that they are specially concerned in the sense of touch, though their absence from the papillæ of other tactile parts shows that they are not essential to this sense.

Ruffini has described a special variety of nerve-ending in the subcutaneous tissue of the human finger (Fig. 659). These are usually known as *Ruffini's endings*. They are principally situated at the junction of the corium with the subcutaneous tissue; they are oval in shape, and consist of a strong connective-tissue sheath, inside which the nerve-fibre divides into numerous branches, which show varicosities and end in small free knobs. They resemble the corpuscles of Golgi.

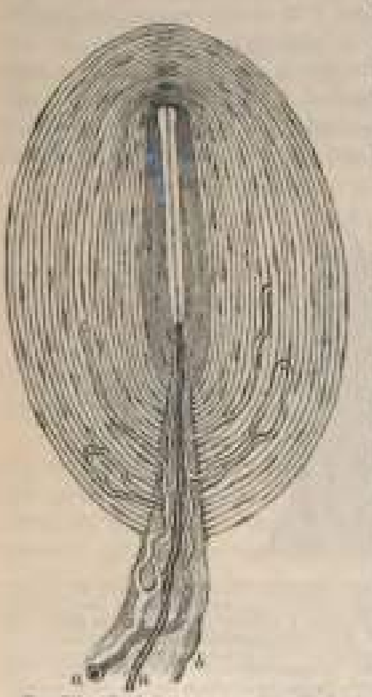


FIG. 660.—Pacinian corpuscle, with its system of capsules and central cavity. *a.* Arterial twig, ending in capillaries, which form loops in some of the inter-capsular spaces, and one penetrates to the central capsule. *b.* The fibrous tissue of the stalk prolonged from the perineurium. *n.* Nerve-tube advancing to the central capsule, there losing its white matter, and stretching along the axis to the opposite end, where it is fixed by a tubercular enlargement.

The **Pacinian corpuscles**[1] (Fig. 660) are found in the human subject chiefly on the nerves of the palm of the hand and sole of the foot and in the genital organs of both sexes, lying in the subcutaneous tissue; but they have also been described as connected with the nerves of the joints, and in some other situations, as the mesentery of the cat and along the tibia of the rabbit. Each of these corpuscles is attached to and encloses the termination of a single nerve-fibre. The corpuscle, which is perfectly visible to the naked eye (and which can be most easily demonstrated in the mesentery of a cat), consists of a number of lamellæ or capsules, arranged more or less concentrically around a central clear space, in which the nerve-fibre is contained. Each lamella is composed of bundles of fine connective-tissue fibres, and is lined on its inner surface by a single layer of cells. The central clear space, which is elongated or cylindrical in shape, is filled with a transparent material, in the middle of which is the single medullated fibre, which traverses the space to near its distal extremity. Here it terminates in a rounded knob or end, sometimes bifurcating previously, in which case each branch has a similar arrangement. Todd and Bowman have described minute arteries as entering by the sides of the nerves and forming capillary loops in the intercapsular spaces, and even penetrating into the central space.

[1] Often called in German anatomical works "corpuscles of Vater."

Other authors describe the artery as entering the corpuscle at the pole opposite to the nerve-fibre.

Herbst has described a somewhat similar "nerve-ending" to the Pacinian corpuscle, as being found in the mucous membrane of the tongue of the duck and in some other situations. It differs, however, from the Pacinian corpuscles, in being smaller, its capsules thinner and more closely approximated, and especially in the fact that the axis-cylinder in the central clear space is coated with a continuous row of nuclei. These bodies are known as the *corpuscles of Herbst.*

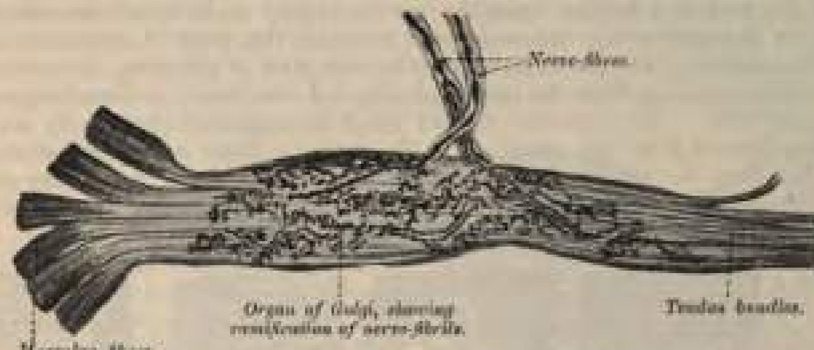


FIG. 661.—Organ of Golgi (neuro-tendinous spindle) from the human tendon Achillis. (After Ciaccio.)

Neuro-tendinous spindles.—The nerves supplying tendons have a special modification of the terminal fibres, especially numerous at the point where the tendon is becoming muscular. The tendon bundles become enlarged, and the nerve-fibres—one, two, or more in number—penetrate between the fasciculi of the tendon and spread out between the fibres to end in irregular discs or varicosities. A spindle-shaped body is thus formed, composed of tendon bundles and nerve-fibres, which is known as the *organ of Golgi* (Fig. 661).

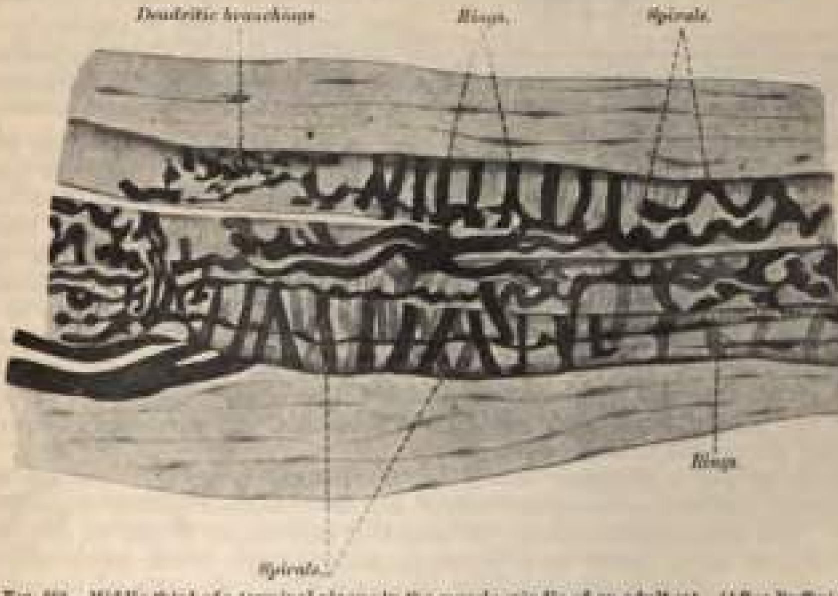


FIG. 662.—Middle third of a terminal plaque in the muscle spindle of an adult cat. (After Ruffini.)

Neuro-muscular spindles.—In the majority of voluntary muscles there have been found special end-organs consisting of a small bundle of peculiar muscular fibres (intrafusal fibres), embryonic in type, invested by a capsule within which nerve-fibres, experimentally shown to be sensory in origin, terminate. These neuro-muscular spindles vary in length from $\frac{1}{30}$ to $\frac{1}{5}$ of an inch and have a distinctly fusiform appearance. The large medullated nerve-fibres passing to the end-organ are from one to three or four in number; entering the fibrous capsule they divide several times, and, losing their medulla, ultimately end in naked axis-cylinders encircling the intrafusal fibres by flattened expansions, or irregular ovoid or rounded discs (Fig. 662). Neuro-muscular spindles have not yet been demonstrated in the tongue or eye muscles.

In the organs of **special sense** the nerves appear to terminate in cells which belong to the epithelial class, and have received the name of *sensory* or *nerve-epithelium* cells. This is not, however, the real state of the case; the nerve-fibre is in reality a process from the epithelial cell, and terminates by branching around a ganglion-cell. The stimulus carried by it is continued onward by an axis-cylinder, derived from the ganglion, to the brain. These nerve-epithelium cells must therefore be regarded as modified forms of nerve-cells. They will be more particularly described in the sequel, in connection with the description of the organs of special sense.

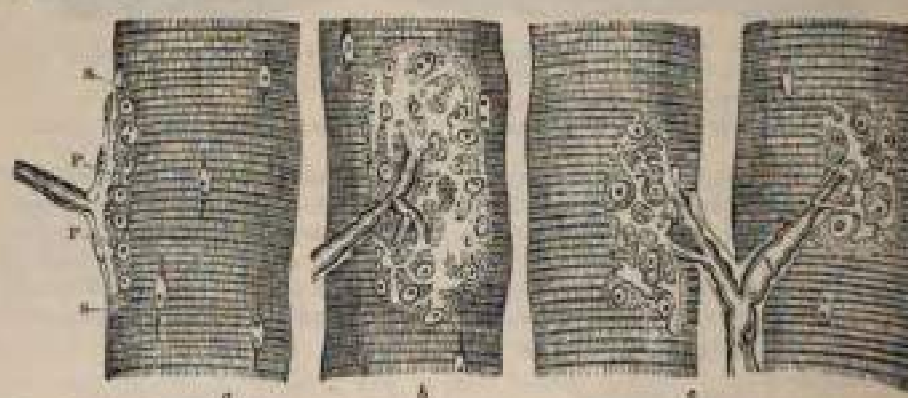


FIG. 663.—Muscular fibres of *Lacerta viridis* with the terminations of nerves. *a.* Seen in profile. P.P. The nerve end-plates. S.S. The base of the plate, consisting of a granular mass with nuclei. *b.* The same as seen in looking at a perfectly fresh fibre, the nervous ends being probably still excitable. (The forms of the variously divided plate can hardly be represented in a woodcut by sufficiently delicate and pale contours to reproduce correctly what is seen in nature.) *c.* The same as seen two hours after death from poisoning by curare.

Motor nerves are to be traced either into unstriped or striped muscular fibres. In the **unstriped** or **involuntary** muscles the nerves are derived from the sympathetic, and are composed mainly of the non-medullated fibres. Near their termination they divide into a number of branches, which communicate and form an intimate plexus. At the junction of the branches small triangular nuclear bodies (ganglion-cells) are situated. From these plexuses minute branches are given off, which divide and break up into the ultimate fibrillæ of which the nerve is composed. These fibrillæ course between the involuntary muscle-cells, and, according to Elischer, terminate on the surface of the cell, opposite the nucleus, in a minute swelling. Arnold and Frankenhäuser believed that these ultimate fibrillæ penetrated the muscular cell and ended in the nucleus. More recent observation, however, has tended to disprove this.

In the **striped** or **voluntary** muscle, the nerves supplying the muscular fibres are derived from the cerebro-spinal nerves, and are composed mainly of medullated fibres. The nerve, after entering the sheath of the muscle, breaks up into fibres, or bundles of fibres, which form plexuses, and gradually divide until, as a rule, a single nerve-fibre enters a single muscular fibre. Sometimes, however, if the muscular fibre is long, more than one nerve-fibre enters it. Within the muscular fibre the nerve terminates in a special expansion, called by Kühne, who first accurately described them, *motorial end-plates* (Fig. 663).[1] The nerve-fibre,

[1] They had, however, previously been noticed, though not accurately described, by Doyère, who named them "nerve-hillocks."

on approaching the muscular fibre, suddenly loses its white matter of Schwann, which abruptly terminates; the neurilemma becomes continuous with the sarcolemma of the muscle, and only the axis-cylinder enters the muscular fibre, where it immediately spreads out, ramifying like the roots of a tree, immediately beneath the sarcolemma, and is imbedded in a layer of granular matter, containing a number of clear, oblong nuclei, the whole constituting an end-plate from which the contractile wave of the muscular fibre is said to start.

The **Ganglia** may be regarded as separate small aggregations of nerve-cells, connected with each other, with the cerebro-spinal axis, and with the nerves in various situations. They are found on the posterior root of each of the spinal nerves; on the posterior or sensory root of the fifth cranial nerve; on the facial and auditory nerves; and on the glosso-pharyngeal and pneumogastric nerves. They are also found in a connected series along each side of the vertebral column, forming the trunk of the sympathetic; and on the branches of that nerve, generally in the plexuses or at the point of junction of two or more nerves with each other or with branches of the cerebro-spinal system. On section they are seen to consist of a reddish-gray substance, traversed by numerous white nerve-fibres; they vary considerably in form and size; the largest are found in the cavity of the abdomen; the smallest, not visible to the naked eye, exist in considerable numbers upon the nerves distributed to the different viscera. The ganglia are invested by a smooth and firm, closely adhering membranous envelope, consisting of dense areolar tissue; this sheath is continuous with the perineurium of the nerves, and sends numerous processes into the interior of the ganglion, which support the blood-vessels supplying its substance.

Fig. 664.—Section through a microscopic ganglion. Magnified 300 diameters. (Klein and Noble Smith.) c. Capsule of the ganglion. n. Nerve-fibres passing out of the ganglion. The nerve-fibres which entered the ganglion are not represented. The nerve-fibres are ordinary medullated fibres, but the details of their structure are not shown, owing to the low magnifying power. The ganglion-cells are invested by special capsules, lined by a few nuclei, which are here represented as if contained in the capsule.

In structure all ganglia are essentially similar (Fig. 664), consisting of the same structural elements as the other nervous centres, viz., a collection of nerve-cells and nerve-fibres. Each nerve-cell has a nucleated sheath, which is continuous with the sheath of the nerve-fibre with which the cell is connected. The nerve-cells in the ganglia of the spinal nerves are pyriform in shape, and have only one process, the axis-cylinder or axon. A short distance from the cell, and while still within the ganglion, this process divides in a T-shaped manner, one limb of the cross-bar passing centrally and forming the central portion of a sensory nerve-fibre; the other limb passing peripherally to form the axis-cylinder process of the peripheral nerve-fibre. In the sympathetic ganglia the nerve-cells are multipolar and have one axis-cylinder process or axon and several protoplasmic processes or dendrons. The former of these emerges from the ganglion as a non-medullated nerve-fibre. Similar cells are found in the ganglia connected with the fifth cranial nerve, and these ganglia are therefore regarded by some as the cranial portions of the sympathetic system. The nerve-cells are disposed in the ganglia in groups of varying size, and these groups are separated from each other by bundles of nerve-fibres, some of which traverse the ganglia without being connected with the cells.

THE VASCULAR SYSTEM.

The **Vascular System,** exclusive of its central organ, the heart, is divided into four classes of vessels: the arteries, capillaries, veins, and lymphatics; the minute structure of these vessels will be briefly described here, the reader being referred to the body of the work for the details of their ordinary anatomy.

Structure of Arteries (Fig. 665).—The arteries are composed of three coats: internal or endothelial coat (*tunica intima* of Kölliker); middle muscular coat (*tunica media*); and external connective-tissue coat (*tunica adventitia*).

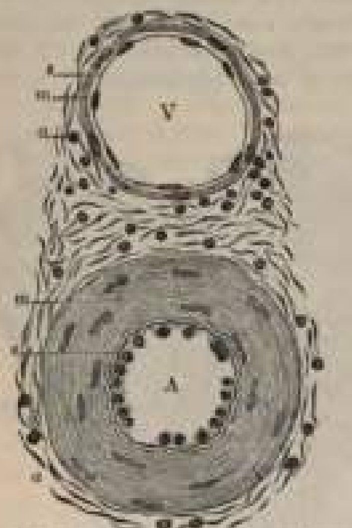


Fig. 665.—Transverse section through a small artery and vein of the mucous membrane of the epiglottis of a child. Magnified about 350 diameters. (Klein and Noble Smith.) A. Artery, showing the nucleated endothelium, *e*, which lines it: the vessel being contracted, the endothelial cells appear very thick. Underneath the endothelium is the wavy elastic intima. The chief part of the wall of the vessel is occupied by the circular muscle-coat *m*; the staff-shaped nuclei of the muscle-cells are well seen. Outside this is *a*, part of the adventitia. This is composed of bundles of connective-tissue fibres, shown in section, with the nuclei of the connective-tissue corpuscles. The adventitia gradually merges into the surrounding connective tissue. V. Vein showing a thin endothelial membrane, *e*, raised accidentally from the intima, which on account of its delicacy is seen as a mere line on the media *m*. This latter is composed of a few circular unstriped muscle-cells. *a*. The adventitia, similar in structure to that of an artery.

The two inner coats together are very easily separated from the external, as by the ordinary operation of tying a ligature on an artery. If a fine string be tied forcibly upon an artery and then taken off, the external coat will be found undivided, but the internal coats are divided in the track of the ligature and can easily be further dissected from the outer coat. The *inner coat* can be separated from the middle by a little maceration, or it may be stripped off in small pieces; but, on account of its friability, it cannot be separated as a complete membrane. It is a fine, transparent, colorless structure which is highly elastic, and is commonly corrugated into longitudinal wrinkles. The inner coat consists of—1. A layer of pavement-endothelium, the cells of which are polygonal, oval, or fusiform, and have very distinct round or oval nuclei. This endothelium is brought into view most distinctly by staining with nitrate of silver. 2. A subendothelial layer, consisting of delicate connective tissue with branched cells lying in the interspaces of the tissue. In arteries of less than a line in diameter the subendothelial layer consists of a single stratum of stellate cells, and the connective tissue is only largely developed in vessels of a considerable size. 3. An elastic or fenestrated layer, which consists of a membrane containing a network of elastic fibres, having principally a longitudinal direction and in which, under the microscope, small, elongated apertures or perforations may be seen, giving it a fenestrated appearance. It was therefore called by Henle the *fenestrated membrane.* This membrane forms the chief thickness of the inner coat, and can be separated into several layers, some of which present the appearance of a network of longitudinal elastic fibres, and others present a more membranous character, marked by pale lines having a longitudinal direction. The fenestrated membrane in microscopic arteries is a very thin layer, but in the larger arteries, and especially in the aorta, it has a very considerable thickness.

The *middle coat* (*tunica media*) is distinguished from the inner by its color and by the transverse arrangement of its fibres, in contradistinction to the longitudinal direction of those of the inner coat. In the smaller arteries it consists principally of muscular tissue, being made up of plain muscle-fibres in fine bundles, arranged in lamellæ and disposed circularly around the vessel. These lamellæ vary in number according to the size of the vessel; the very small arteries having only a single layer, and those not larger than one-tenth of a line in diameter three or four layers. It is to this coat that the great thickness of the walls of the artery is

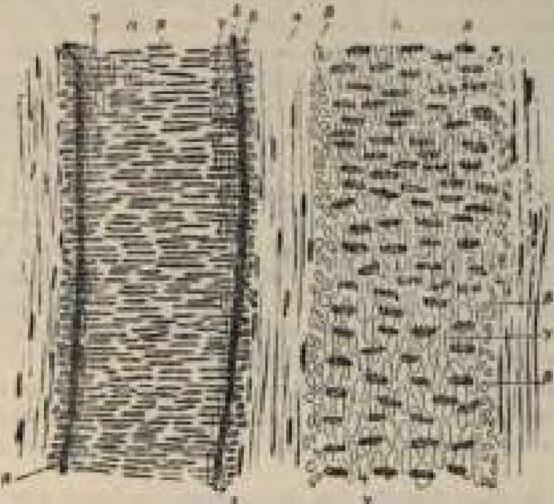


FIG. 666.—Longitudinal section of artery and vein. *a*, an artery from the mesentery of a child, .062''', and *b*, vein .067''' in diameter, treated with acetic acid and magnified 350 times. α. Tunica adventitia, with elongated nuclei. β. Nuclei of the contractile fibre-cells of the tunica media, seen partly from the surface, partly apparent in transverse section. γ. Nuclei of the endothelial cells. δ. Elastic longitudinal fibrous coat.

mainly due (Fig. 665, A, *m*). In the larger vessels, as the iliac, femoral, and carotid, elastic fibres unite to form lamellæ, which alternate with the layers of

FIG. 667.—Section of a medium-sized artery. (After Grünstein.)

muscular fibre and are united by elastic fibres which pass between the muscular bundles, and are connected with the fenestrated membrane of the inner coat (Fig. 667). In the largest arteries, as the aorta and innominate, the amount of elastic tissue is very considerable. In these vessels also bundles of white connective tissue have been found in small quantities in the middle coat. The muscle-fibre cells of which the middle coat is made up are about $\frac{1}{500}$ of an inch in length, and contain well-marked, rod-shaped nuclei, which are often slightly curved.

The *external* coat (*tunica adventitia*) consists mainly of fine and closely felted bundles of white connective tissue, but also contains elastic fibres in all but the smallest arteries. The elastic tissue is much more abundant next the tunica media, and is sometimes described as forming here, between the adventitia and media, a special layer, the *tunica elastica externa* of Henle. This layer is most marked in arteries of medium size. In the largest vessels the external coat is relatively thin; but in small arteries it is of greater proportionate thickness. In the smaller arteries it consists of a single layer of white connective tissue and elastic fibres; while in the smallest arteries, just above the capillaries, the elastic fibres are wanting, and the connective tissue, of which the coat is composed, becomes more homogeneous the nearer it approaches the capillaries, and is gradually reduced to a thin membranous envelope which finally disappears.

Some arteries have extremely thin coats in proportion to their size; this is especially the case in those situated in the cavity of the cranium and spinal canal, the difference depending on the greater thinness of the external and middle coats.

The arteries, in their distribution throughout the body, are included in a thin fibro-areolar investment, which forms what is called their *sheath*. In the limbs this is usually formed by a prolongation of the deep fascia; in the upper part of the thigh it consists of a continuation downward of the transversalis and iliac fasciæ of the abdomen; in the neck, of a prolongation of the deep cervical fascia. The included vessel is loosely connected with its sheath by a delicate areolar tissue; and the sheath usually encloses the accompanying veins, and sometimes a nerve. Some arteries, as those in the cranium, are not included in sheaths.

All the larger arteries are supplied with blood-vessels like the other organs of the body; they are called the *vasa vasorum*. These nutrient vessels arise from a branch of the artery or from a neighboring vessel, at some considerable distance from the point at which they are distributed; they ramify in the loose areolar tissue connecting the artery with its sheath, and are distributed to the external coat, but do not, in man, penetrate the other coats; though in some of the larger mammals some few vessels have been traced into the middle coat. Minute veins serve to return the blood from these vessels; they empty themselves into the vein or veins accompanying the artery. Lymphatic vessels and lymphatic spaces are also present in the outer coat.

Arteries are also supplied with nerves, which are derived chiefly from the sympathetic, but partly from the cerebro-spinal system. They form intricate plexuses upon the surfaces of the larger trunks, and run along the smaller arteries as single filaments or bundles of filaments, which twist around the vessel and unite with each other in a plexiform manner. The branches derived from these plexuses penetrate the external coat, and are principally distributed to the muscular tissue of the middle coat, and thus regulate, by causing the contraction and relaxation of this tissue, the amount of blood sent to any part.

The Capillaries.—The smaller arterial branches (excepting those of the cavernous structure of the sexual organs, of the spleen, and in the uterine placenta) terminate in a network of vessels which pervade nearly every tissue of the body. These vessels, from their minute size, are termed capillaries (*capillus*, a hair). They are interposed between the smallest branches of the arteries and the commencing veins, constituting a network, the branches of which maintain the same diameter throughout; the meshes of the network being more uniform in shape and size than those formed by the anastomoses of the small arteries and veins.

The *diameter* of the capillaries varies in the different tissues of the body, their usual size being about $\frac{1}{3000}$ of an inch. The smallest are those of the brain and the mucous membranes of the intestines; and the largest those of the skin and the marrow of bone, where they are stated to be as large as $\frac{1}{1200}$ of an inch.

The *form* of the capillary net varies in the different tissues, the meshes being generally rounded or elongated. The *rounded form of mesh* is most common, and prevails where there is a dense network, as in the lungs, in most glands and mucous membranes, and in the cutis; here the meshes are more or less angular, sometimes nearly quadrangular or polygonal; or more often irregular and not of an absolutely circular outline.

Elongated meshes are observed in the muscles and nerves, the meshes being usually of a parallelogram form, the long axis of the mesh running parallel with the long axis of the nerve and fibre. Sometimes the capillaries have a *looped* arrangement; a single vessel projecting from the common network and returning after forming one or more loops, as in the papillæ of the tongue and skin. The number of the capillaries, and the size of the meshes, determine the degree of vascularity of a part. The closest network and the smallest interspaces are found in the lungs and in the choroid coat of the eye. In these situations the inter-

FIG. 668.—Capillaries from the mesentery of a guinea-pig after treatment with solution of nitrate of silver. *a.* Cells. *b.* Their nuclei.

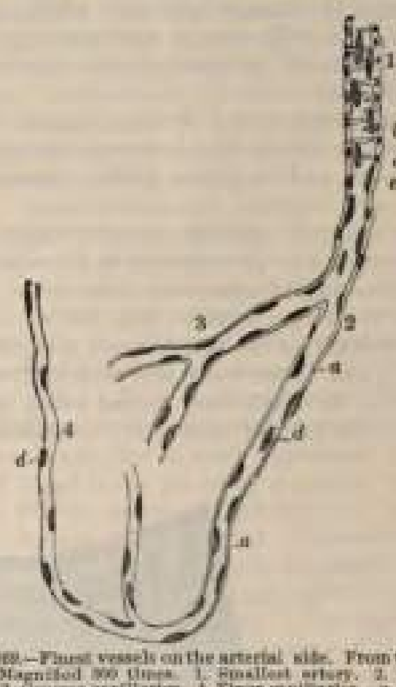


FIG. 669.—Finest vessels on the arterial side. From the human brain. Magnified 300 times. 1. Smallest artery. 2. Transition vessel. 3. Coarser capillaries. 4. Finer capillaries. *a.* Structureless membrane still with some nuclei, representative of the tunica adventitia. *b.* Nuclei of the muscular fibre-cells. *c.* nuclei within the small artery, perhaps appertaining to an endothelium. *d.* Nuclei in the transition vessels.

spaces are smaller than the capillary vessels themselves. In the kidney, in the conjunctiva, and in the cutis the interspaces are from three to four times as large as the capillaries which form them; and in the brain from eight to ten times as large as the capillaries in their long diameter, and from four to six times as large in their transverse diameter. In the adventitia of arteries the width of the meshes is ten times that of the capillary vessels. As a general rule, the more active the function of the organ, the closer is its capillary net and the larger its supply of blood; the meshes of the network being very narrow in all growing parts, in the glands, and in the mucous membranes; wider in bones and ligaments, which are comparatively inactive; and nearly altogether absent in tendons, in which very little organic change occurs after their formation.

Structure.—The walls of the capillaries consist of a fine, transparent, endothelial layer, composed of cells joined edge to edge by an interstitial cement-substance, and continuous with the endothelial cells which line the arteries and veins. When stained with nitrate of silver the edges which bound the epithelial cells are brought into view (Fig. 668). These cells are of large size and of an irregular polygonal or lanceolate shape, each containing an oval nucleus which may be brought into view by carmine or hæmatoxylin. Between their edges, at various points of their meeting, roundish dark spots are sometimes seen, which have been described as stomata, though they are closed by intercellular substance. They have been believed to be the situation through which the white corpuscles of the blood, when migrating from the blood-vessels, emerge; but this view, though probable, is not universally accepted.

Kolossow, a Russian observer, describes these cells as having a rather more complex structure. He states that they consist of two parts: of hyaline ground-plates, and of a protoplasmic granular part, in which is imbedded the nucleus, on the outside of the ground-plates. The hyaline internal coat of the capillaries does not form a complete membrane, but consists of "plates" which are inelastic, and, though in contact with each other, are not continuous; when, therefore, the capillaries are subjected to intra-vascular pressure, the plates become separated from each other; the protoplasmic portions of the cells, on the other hand, are united together.

In many situations a delicate sheath or envelope of branched nucleated connective-tissue cells is found around the simple capillary tube, particularly in the larger ones; and in other places, especially in the glands, the capillaries are invested with retiform connective tissue.

In the largest capillaries (which ought, perhaps, to be described rather as the smallest arteries or pre-capillaries) there is, outside the epithelial layer, a muscular layer, consisting of contractile fibre-cells, arranged transversely, as in the tunica media of the larger arteries (Fig. 669).

The **veins**, like the arteries, are composed of three coats—internal, middle, and external; and these coats are, with the necessary modifications, analogous to the coats of the arteries; the internal being the endothelial, the middle the muscular, and the external the connective or areolar (Fig. 670). The main difference be-

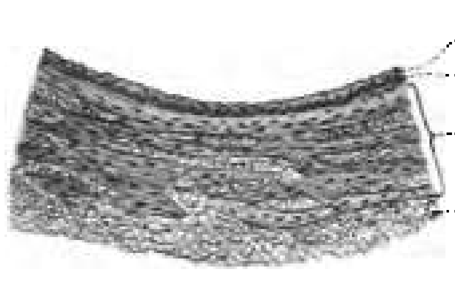


FIG. 670.—Transverse section of part of the wall of one of the posterior tibial veins. (After Schäfer.)

tween the veins and the arteries is the comparative weakness of the middle coat of the former, and to this is due the fact that the veins do not stand open when divided, as the arteries do, and that they are passive rather than active organs of the circulation.

In the veins immediately above the capillaries the three coats are hardly to be distinguished. The endothelium is supported on an outer membrane separable into two layers, the outer of which is the thicker, and consists of a delicate, nucleated membrane (adventitia), while the inner is composed of a network of longitudinal elastic fibres (media). In the veins next above these in size (one-fifth of a line, according to Kölliker) a muscular layer and a layer of circular fibres can be traced, forming the middle coat, while the elastic and connective elements of the outer coat become more distinctly perceptible. In the middle-sized veins the typical structure of these vessels becomes clear. The endothelium is of the same character as in the arteries, but its cells are more oval, less fusiform. It is supported by a connective-tissue layer, consisting of a delicate network of branched cells, and external to this is a layer of longitudinal elastic fibres, but seldom any appearance of a fenestrated membrane. This constitutes the *internal* coat. The *middle* coat is composed of a thick layer of connective tissue with elastic fibres, intermixed, in some veins, with a transverse layer of muscular fibres. The white fibrous element is in considerable excess, and the elastic fibres are in much smaller proportion in the veins than in the arteries. The *outer* coat consists of areolar tissue, as in the arteries, with longitudinal elastic fibres. In the largest veins the outer coat is from two to five times thicker than the middle coat, and contains a large number of longitudinal muscular fibres. This is most distinct in the inferior vena cava, and at the termination of this vein in the heart, in the trunks of the hepatic veins, in all the large trunks of the vena portæ, in the splenic, superior mesenteric, external iliac, renal, and azygos veins. In the renal and portal veins it extends through the whole thickness of the outer coat, but in the other veins mentioned a layer of connective and elastic tissue is found external to the muscular fibres. All the large veins which open into the heart are covered for a short distance with a layer of striped muscular tissue continued on to them from the heart. Muscular tissue is wanting in the veins—(1) of the maternal part of the placenta; (2) in the venous sinuses of the dura mater and the veins of the pia mater of the brain and spinal cord; (3) in the veins of the retina; (4) in the veins of the cancellous tissue of bones; (5) in the venous spaces of the corpora cavernosa. The veins of the above-mentioned parts consist of an internal endothelial lining supported on one or more layers of areolar tissue.

Most veins are provided with valves, which serve to prevent the reflux of the blood. They are formed by a reduplication of the inner coat, strengthened by connective tissue and elastic fibres, and are covered on both surfaces with endothelium, the arrangement of which differs on the two surfaces. On the surface of the valve next the wall of the vein the cells are arranged transversely; whilst on the other surface, over which the current of blood flows, the cells are arranged vertically in the direction of the current. The valves are semilunar. They are attached by their convex edge to the wall of the vein; the concave margin is free, directed in the course of the venous current, and lies in close apposition with the wall of the vein as long as the current of blood takes its natural course; if, however, any regurgitation takes place, the valves become distended, their opposed edges are brought into contact, and the current is interrupted. Most commonly two such valves are found placed opposite one another, more especially in the smaller veins or in the larger trunks at the point where they are joined by smaller branches; occasionally there are three and sometimes only one. The wall of the vein on the cardiac side of the point of attachment of each segment of the valve is expanded into a pouch or sinus, which gives to the vessel, when injected or distended with blood, a knotted appearance. The valves are very numerous in the veins of the extremities, especially of the lower extremities, these vessels having to conduct the blood against the force of gravity. They are absent in the very small veins—*i. e.* those less than $\frac{1}{12}$ of an inch in diameter; also in the venæ cavæ, the hepatic veins, portal vein and most of its branches, the renal, uterine, and ovarian veins. A few valves are found in the spermatic veins, and one also at their point of junction with the renal vein and inferior vena cava, respectively. The cerebral and spinal veins, the veins of the cancellated tissue of bone, the pulmonary veins, and the umbilical vein, and its branches, are also destitute of valves. They are occasionally found, few in number, in the venæ azygos and intercostal veins.

The veins are supplied with nutrient vessels, *vasa vasorum*, like the arteries. Nerves also are distributed to them in the same manner as to the arteries, but in much less abundance.

The **lymphatic** vessels, including in this term the lacteal vessels, which are identical in structure with them, are composed of three coats. The *internal* is an endothelial and elastic coat. It is thin, transparent, slightly elastic, and ruptures sooner than the other coats. It is composed of a layer of elongated endothelial cells with serrated margins, by which the adjacent cells are dovetailed into one another. These are supported on a single layer of longitudinal elastic fibres. The *middle* coat is composed of smooth muscular and fine elastic fibres, disposed in a transverse direction. The *external*, or fibro-areolar, coat consists of filaments of connective tissue, intermixed with smooth muscular fibres, longitudinally or obliquely disposed. It forms a protective covering to the other coats, and serves to connect the vessel with the neighboring structures. The above description applies only to the larger lymphatics; in the smaller vessels there is no muscular or elastic coat, and their structure consists only of a connective-tissue coat, lined by endothelium. The thoracic duct (Fig. 671) is a somewhat more complex structure than the other lymphatics; it presents a distinct subendothelial layer of branched corpuscles, similar to that found in the arteries,

Fig. 671.—Transverse section through the coats of the thoracic duct of man. Magnified 30 times. *a.* Endothelium, striated lamellæ, and inner elastic coat. *b.* Longitudinal connective tissue of the middle coat. *c.* Transverse muscles of the same. *d.* Tunica adventitia, with *e*, the longitudinal muscular fibres.

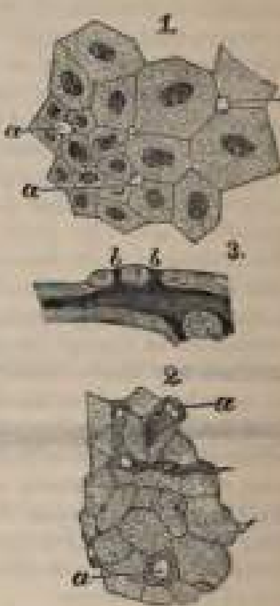


Fig. 672.—Stroma of serous membranes. 1. Endothelium from the under surface of the centrum tendineum of the rabbit. *a.* Stomata. 2. Endothelium of the mediastinum of the dog. *a.* Stomata. 3. Section through the pleura of the same animal. *b.* Free orifices of short lateral passages of the lymph-canals. (Copied from Ludwig, Schweigger-Seydel, and Dybkowsky.)

and in the middle coat is a layer of connective tissue with its fibres arranged longitudinally. The lymphatics are supplied by nutrient vessels, which are distributed to their outer and middle coats; and here also have been traced many non-medullated nerve-fibres in the form of a fine plexus of fibrils.

The lymphatics are very generally provided with valves, which assist materially in effecting the circulation of the fluid they contain. These valves are formed of a thin layer of fibrous tissue, lined on both surfaces by endothelium, which presents the same arrangement upon the two surfaces as was described in connection with the valves of veins. Their form is semilunar; they are attached by their convex edge to the sides of the vessel, the concave edge being free and directed along the course of the contained current. Usually two such valves, of equal size, are found opposite one another; but occasionally exceptions occur, especially at or near the anastomoses of lymphatic vessels. Thus, one valve may be of very rudimentary size and the other increased in proportion.

The valves in the lymphatic vessels are placed at much shorter intervals than in the veins. They are most numerous near the lymphatic glands, and they are found more frequently in the lymphatics of the neck and upper extremity than in the lower. The wall of the lymphatics immediately above the point of attachment of each segment of a valve is expanded into a pouch or sinus, which gives to these vessels, when distended, the knotted or beaded appearance which they present. Valves are wanting in the vessels composing the plexiform network in which the lymphatics usually originate on the surface of the body.

Origin of Lymphatics.—The finest visible lymphatic vessels (lymphatic capillaries) form a plexiform network in the tissues and organs, and they consist of a single layer of endothelial plates, with more or less sinuous margins. These vessels commence in an intercommunicating system of clefts or spaces which have no complete endothelial lining in the connective tissue of the different organs. They have been named the *rootlets* of the lymphatics, and are identical with the spaces in which the connective-tissue corpuscles are contained. This then is properly regarded as one method of their commencement, when the lymphatic vessels are apparently continuous with spaces in the connective tissue, and Klein has described and figured a direct communication between these spaces and the lymphatic vessel.[1] But the lymphatics have also other modes of origin, for the intestinal lacteals commence by closed extremities, though some observers believe that the closed extremity is continuous with a minute network contained in the substance of the villus, through which the lacteal is connected with the endothelial cells covering it. Again, it seems now to be conclusively proved that the serous membranes present stomata or openings between the endothelial cells (Fig. 672) by which there is an open communication with the lymphatic system, and through which the lymph is thought to be pumped by the alternate dilatation and contraction of the serous surface, due to the movements of respiration and circulation,[2] so that the serous and synovial sacs may be regarded, in a certain sense, as large lymph-cavities or sinuses. Von Recklinghausen was the first to observe the passage of milk and other colored fluids through these stomata on the peritoneal surface of the central tendon of the diaphragm. Again, in most glandular structures the lymphatic capillaries have a lacunar origin. Here they begin in irregular clefts or spaces in the tissue of the part; occupying the penetrating connective tissue and surrounding the lacunæ or tubules of the gland, and in many places separating the capillary network from the alveolus or tubule, so that the interchange between the blood and the secreting cells of the part must be carried on through this lymph-space or lacuna. Closely allied to this is the mode of origin of lymphatics in perivascular and perineural spaces. Sometimes a minute artery may be seen to be ensheathed for a certain distance by a lymphatic capillary vessel, which is often many times wider than a blood-capillary. These are known as perivascular lymphatics.

Terminations of Lymphatics.—The lymphatics, including the lacteals, discharge their contents into the veins at two points; namely, at the angles of junction of the subclavian and internal jugular veins: on the left side by means of the thoracic duct, and on the right side by the right lymphatic duct. (See description of lymphatics on page 623.)

Lymphatic glands (*conglobate glands*) are small oval or bean-shaped bodies, situated in the course of lymphatic and lacteal vessels, so that the lymph and chyle pass through them on their way to the blood. They generally present on one side a slight depression—the *hilum*—through which the blood-vessels enter and leave the interior. The efferent lymphatic vessel also emerges from the gland at this spot, while the afferent vessels enter the organ at different parts of the periphery. On section (Fig. 673), a lymphatic gland displays two different structures: an external, of lighter color—the *cortical;* and an internal, darker—the *medullary*. The cortical structure does not form a complete investment, but is deficient at the hilum, where the medullary portion reaches the surface of the gland; so that the efferent vessel is derived directly from the medullary structure, while the afferent vessels empty themselves into the cortical substance.

Lymphatic glands consist of (1) a fibrous envelope, or *capsule*, from which a framework of processes (*trabeculæ*) proceed inward, dividing the gland into open spaces (*alveoli*) freely communicating with each other; (2) a quantity of lymphoid tissue occupying these spaces without completely filling them; (3) a free supply of blood-vessels, which are supported on the trabeculæ; and (4) the *afferent* and *efferent* vessels. Little is known of the nerves, though Kölliker describes some fine nervous filaments passing into the hilum.

[1] *Atlas of Histology*, pl. viii. fig. xiv.

[2] The resemblance between lymph and serum led Hewson long ago to regard the serous cavities as sacs into which the lymphatics open. Recent microscopic discoveries confirm this opinion in a very interesting manner.

The *capsule* is composed of a layer of connective tissue, and from its internal surface are given off a number of membranous septa or lamellæ, consisting, in man, of connective tissue, with a small admixture of plain muscle-fibres; but in many of the lower animals composed almost entirely of involuntary muscle. They pass inward, radiating toward the centre of the gland, for a certain distance; that is to say, for about one-third or one-fourth of the space between the circumference and the centre of the gland. They thus divide the outer part of its interior into a number of oval compartments or *alveoli* (Fig. 673). This is the cortical portion of the gland. After having penetrated into the gland for some distance, these septa break up into a number of smaller trabeculæ, which form flattened bands or cords, interlacing with each other in all directions, forming in the central part of the organ a number of intercommunicating spaces, also called *alveoli*. This is the medullary portion of the gland, and the spaces or alveoli in it not only freely communicate with each other, but also with the alveoli of the cortical portion. In these alveoli or spaces (Fig. 674) is contained the proper gland-substance or lymphoid tissue.

FIG. 673.—Diagrammatic section of lymphatic gland, showing the course of the lymph.

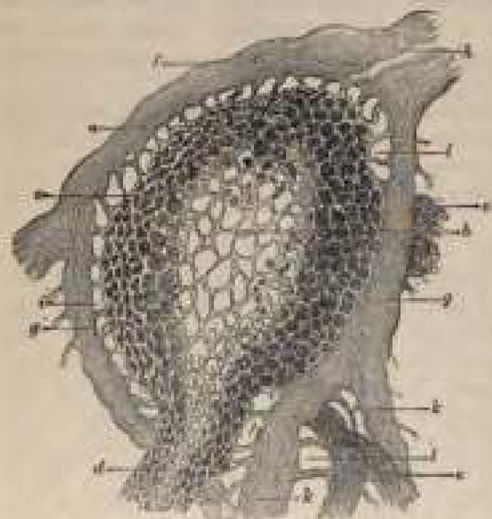


FIG. 674.—Follicle from a lymphatic gland of the dog, in vertical section. *a.* Reticular intervascular substance of the more external portion, *b*, of the more internal, and *c*, of the most external and most finely webbed part on the surface of the follicle. *d.* Origin of a large lymph-tube. *e.* Of a smaller one. *f.* Capsule. *g.* Septa. *h.* Vas afferens. *i.* Investing space of the follicle, with its retinacula. *k.* One of the divisions of the septa. *l, l.* Attachment of the lymph-tubes to the septa.

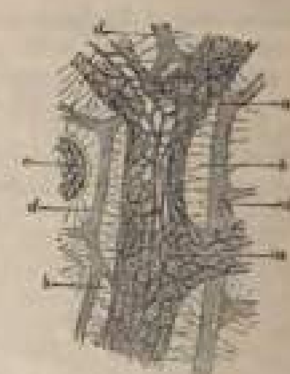


FIG. 675.—From the medullary substance of an inguinal gland of the ox. (After His.) *a.* Lymph-tube, with its complicated system of vessels. *b.* Retinacula stretched between the tube and the septa. *c.* Portion of another lymph-tube. *d.* Septa.

The gland-pulp does not, however, completely fill the alveolar spaces, but leaves, between its outer margin and the trabeculæ forming the alveoli a channel or space of uniform width throughout. This is termed the *lymph-path* or *lymph-sinus* (Fig. 676). Running across it are a number of trabeculæ of retiform connective tissue, the fibres of which are, for the most part, covered by ramified cells. This tissue appears to serve the purpose of maintaining the gland-pulp in the centre of the space in its proper position.

On account of the peculiar arrangement of the framework of the organ, the gland-pulp in the cortical portion is disposed in the form of nodules, and in the medullary part in the form of rounded cords. It consists of ordinary lymphoid tissue, being made up of a delicate reticulum of retiform tissue, which is continuous with that in the lymph-paths, but marked off from it by a closer reticulation; in its meshes are closely packed lymph-corpuscles, traversed by a dense plexus of capillary blood-vessels.

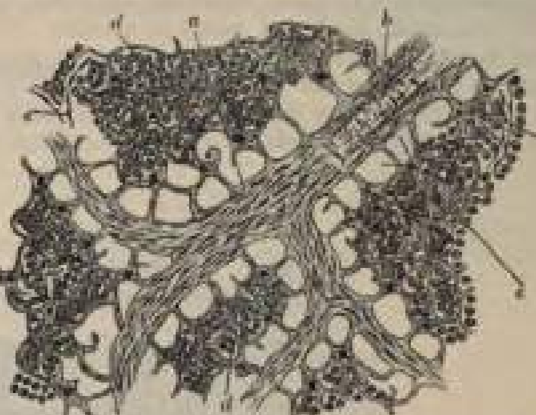


FIG. 676.—Section of lymphatic gland tissue. *a.* Trabecula. *b.* Small artery in substance of same. *c.* Lymph-paths. *d.* Lymph-corpuscles. *e.* Capillary plexus.

The *afferent vessels*, as above stated, enter at all parts of the periphery of the gland, and after branching and forming a dense plexus in the substance of the capsule, open into the lymph-sinuses of the cortical part. In doing this they lose all their coats except their endothelial lining, which is continuous with a layer of similar cells lining the lymph-paths. In like manner the *efferent* vessel commences from the lymph-sinuses of the medullary portion. The stream of lymph carried to the gland by the afferent vessel thus passes through the plexus in the capsule to the lymph-paths of the cortical portion, where it is exposed to the action of the gland-pulp; flowing through these, it enters the paths or sinuses of the medullary portion, and finally emerges from the hilum by means of the efferent vessel. The stream of lymph in its passage through the lymph-sinuses is much retarded by the presence of the reticulum. Hence morphological elements, either normal or morbid, are easily arrested and deposited in the sinuses. This is a matter of considerable importance in connection with the subject of poisoned wounds and the absorption of the poison by the lymphatic system, since by this means septic organisms carried along the lymphatic vessels may be arrested in the lymph-sinuses of the gland tissue, and thus be prevented from entering the general circulation. Many lymph-corpuscles pass with the efferent lymph-stream to join the general blood-stream. The arteries of the gland enter at the hilum, and either pass at once to the gland-pulp, to break up into a capillary plexus, or else run along the trabeculæ, partly to supply them and partly running across the lymph-paths to assist in forming the capillary plexus of the gland-pulp. This plexus traverses the lymphoid tissue, but does not pass into the lymph-sinuses. From it the veins commence, and emerge from the organ at the same place as that at which the artery enters.

THE SKIN AND ITS APPENDAGES.

The **skin** (Fig. 677) is the principal seat of the sense of touch, and may be regarded as a covering for the protection of the deeper tissues; it plays an important part in the regulation of the body temperature, and is also an excretory and absorbing organ. It consists principally of a layer of vascular tissue, named the *derma*, *corium*, or *cutis vera*, and an external covering of epithelium, termed the *epidermis* or *cuticle*. On the surface of the former layer are the sensitive *papillæ*; and within, or imbedded beneath it, are certain organs with special functions, namely, the *sweat-glands*, *hair-follicles*, and *sebaceous glands*.

The **epidermis** or **cuticle** (*scarf-skin*) is non-vascular, and consists of stratified epithelium (Fig. 678). It is accurately moulded on the papillary layer of the derma. It forms a defensive covering to the surface of the true skin, and limits the evaporation of watery vapor from its free surface. It varies in thickness in different parts. In some situations, as in the palms of the hands and soles of the feet, it is thick, hard, and horny in texture. This may be partly due to the fact that these parts are exposed to intermittent pressure, but that this is not the only cause is proved by the fact that the condition exists to a very considerable extent at birth. The more superficial layer of cells, called the *horny* layer (*stratum corneum*), may be separated by maceration from the deeper layers, which are called

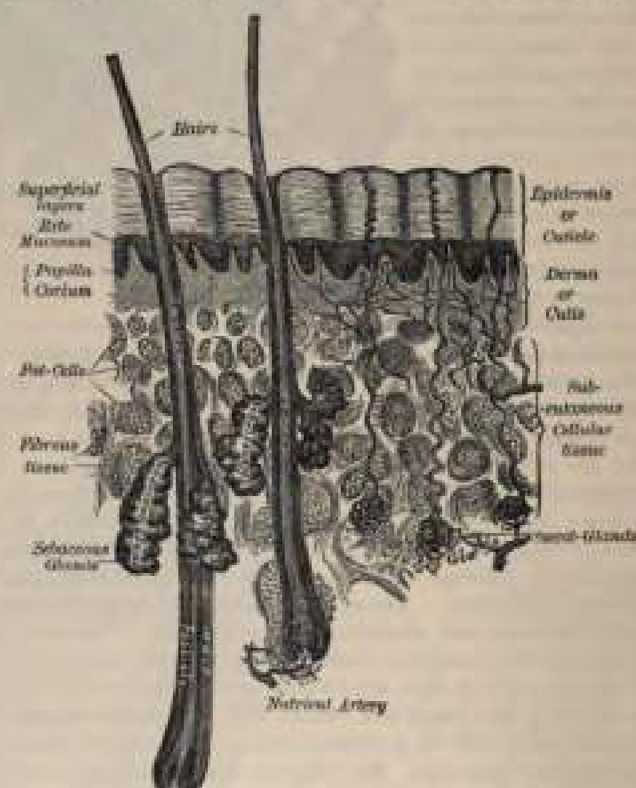


Fig. 677.—A sectional view of the skin (magnified).

the *rete mucosum* or *stratum Malpighii*, and which consist of several layers of differently shaped cells. The free surface of the epidermis is marked by a network of linear furrows of variable size, marking out the surface into a number of spaces of polygonal or lozenge-shaped form. Some of these furrows are large, as opposite the flexures of the joints, and correspond to the folds in the dermis produced by their movements. In other situations, as upon the back of the hand, they are exceedingly fine, and intersect one another at various angles; upon the palmar surface of the hand and fingers and upon the sole of the foot these lines are very distinct and are disposed in curves. They depend upon the large size and peculiar arrangement of the papillæ upon which the epidermis is placed. The deep surface of the epidermis is accurately moulded upon the papillary layer of the dermis, each papilla being invested by its epidermic sheath; so that when this layer is removed by maceration, it presents on its under surface a number of pits or depressions corresponding to the elevations in the papillæ, as well as the ridges left in the intervals between them. Fine tubular prolongations are continued from this layer into the ducts of the sudoriferous and sebaceous glands.

In structure the epidermis consists of several layers of epithelial cells agglutinated together and having a laminated arrangement. These several layers may be described as composed of four different strata from within outward: (1) The *stratum Malpighii*, composed of several layers of epithelial cells, of which the deepest layer is columnar in shape and placed perpendicularly on the surface of the corium,

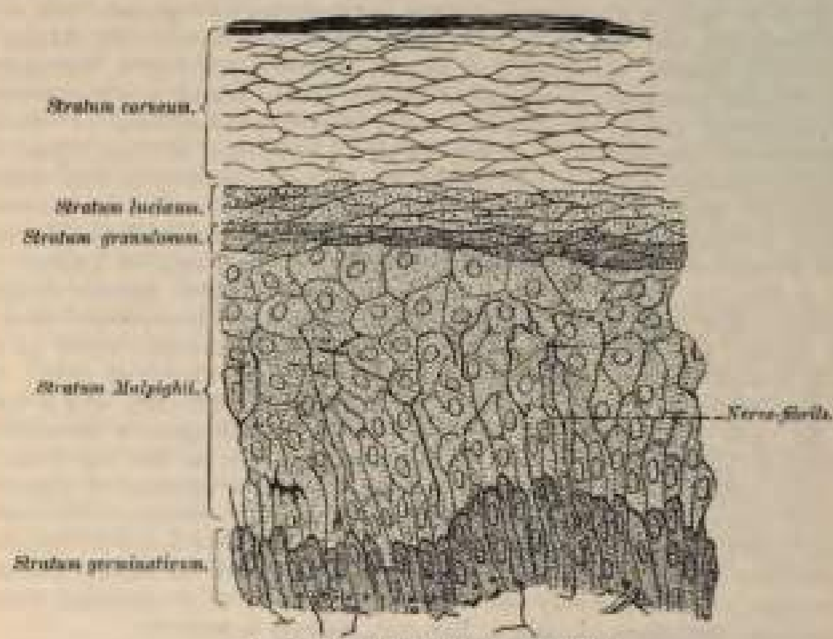


FIG. 878.—Section of epidermis. (Ranvier.)

their lower ends being denticulate, to fit into corresponding denticulations of the true skin; this deepest layer is sometimes termed the basilar layer or *stratum germinativum*; the succeeding laminæ consist of cells of a more rounded or polyhedral form, the contents of which are soft, opaque, granular, and soluble in acetic acid.

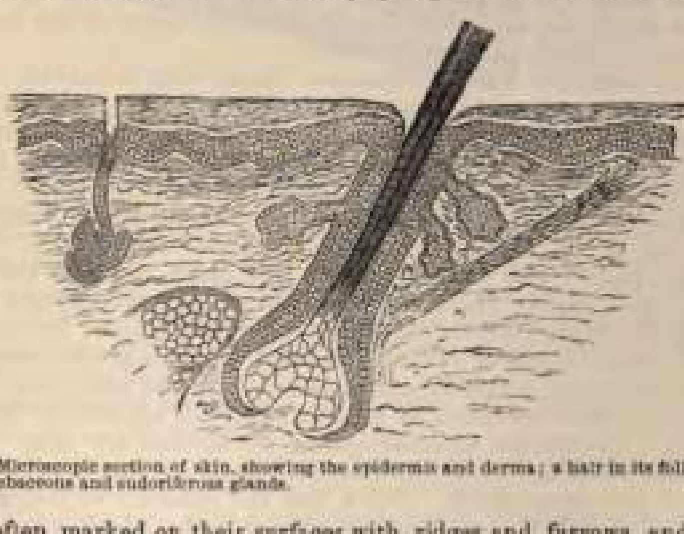


FIG. 879.—Microscopic section of skin, showing the epidermis and derma; a hair in its follicle; the erector pili muscle; sebaceous and sudoriferous glands.

They are often marked on their surfaces with ridges and furrows, and are covered with numerous fibrils, which connect the surfaces of the cells: these are known as *prickle* cells. (See page 1075.) They contain numerous epidermic fibrils, which are stained violet with hæmatoxylin and red by carmine, and form threads of union connecting adjacent cells. Between the cells are fine intercellular clefts, which serve for the passage of lymph and in which lymph-corpuscles or pigment granules may be found. (2) Immediately superficial to these are two or three layers of flattened, spindle-shaped cells, the *stratum granulosum*, which contain granules that become deeply stained in hæmatoxylin; the granules consist of a material named *eleidin*, an intermediate substance in the formation of horn. They are supposed to be cells in a transitional stage between the protoplasmic cells of the stratum Malpighii and the horny cells of the superficial layers. (3) Above this layer the cells become indistinct, and appear, in sections, to form a homogeneous or dimly striated membrane, composed of closely packed scales, in which traces of a flattened nucleus may be found. It is called the *stratum lucidum*. (4) As these cells successively approach the surface by the development of fresh layers from beneath, they assume a flattened form from the evaporation of their fluid contents, and consist of many layers of horny epithelial scales in which no nucleus is discernible, forming the *stratum corneum*. These cells are unaffected by acetic acid, the protoplasm having become changed into horny material or *keratin*. According to Ranvier, they contain granules of a material which has the characters of beeswax. The deepest layer of the stratum Malpighii is separated from the papillæ by an apparently homogeneous basement membrane, which is most distinctly brought into view in specimens prepared with chloride of gold. This, according to Klein, is merely the deepest portion of the epithelium, and is "made up of the basis of the individual cells, which have undergone a chemical and morphological alteration." The black color of the skin in the negro and the tawny color among some of the white races is due to the presence of pigment in the cells of the cuticle. This pigment is more especially distinct in the cells of the deeper layer, or stratum Malpighii, and is similar to that found in the cells of the pigmentary layer of the retina. As the cells approach the surface and desiccate, the color becomes partially lost; the disappearance of the pigment from the superficial layers of the epidermis is, however, difficult to explain.

The derma, corium, or cutis vera, is tough, flexible, and highly elastic, in order to defend the parts beneath from violence.

It varies in thickness, from a quarter of a line to a line and a half, in different parts of the body. Thus it is very thick in the palms of the hands and soles of the feet; thicker on the posterior aspect of the body than the front, and on the outer than the inner side of the limbs. In the eyelids, scrotum, and penis it is exceedingly thin and delicate. The skin is generally thicker in the male than in the female, and in the adult than in the child.

The corium consists of felted connective tissue, with a varying amount of elastic fibres and numerous blood-vessels, lymphatics, and nerves. The fibro-areolar tissue forms the framework of the cutis, and is differently arranged in different parts, so that it is usual to describe it as consisting of two layers: the deeper or *reticular* layer, and the superficial or *papillary* layer. Unstriped muscular fibres are found in the superficial layers of the corium, wherever hairs are found; and in the subcutaneous areolar tissue of the scrotum, penis, labia majora of the female, and the nipples. In the latter situation the fibres are arranged in bands, closely reticulated and disposed in superimposed laminæ.

The *reticular* layer consists of strong interlacing fibrous bands, composed chiefly of the white variety of fibrous tissue, but containing, also, some fibres of the yellow elastic tissue, which vary in amount in different parts, and connective-tissue corpuscles, which are often to be found flattened against the white fibrous tissue-bundles. Toward the attached surface the fasciculi are large and coarse, and the areolæ which are left by their interlacement are large, and occupied by adipose tissue and sweat-glands. Below this the elements of the skin become gradually blended with the subcutaneous areolar tissue, which, except in a few situations, contains fat. Toward the free surface the fasciculi are much finer, and their mode of interlacing close and intricate.

The *papillary layer* is situated upon the free surface of the *reticular layer*; it consists of numerous small, highly sensitive, or vascular eminences, the *papillæ*, which rise perpendicularly from its surface. The papillæ are conical-shaped eminences, having a round or blunted extremity, occasionally divided into two or more parts and are received into corresponding pits on the under surface of the cuticle. Their average length is about $\frac{1}{100}$ of an inch, and they measure at their base $\frac{1}{250}$ of an inch in diameter. On the general surface of the body, more especially in those parts which are endowed with slight sensibility, they are few in number, short, exceedingly minute, and irregularly scattered over the surface; but in some situations, as upon the palmar surface of the hands and fingers, upon the plantar surface of the feet and toes, and around the nipple, they are long, of large size, closely aggregated together, and arranged in parallel curved lines, forming the elevated ridges seen on the free surface of the epidermis. Each ridge contains two rows of papillæ, and between the two rows the ducts of the sweat-glands pass outward to open on the summit of the ridges. In structure the papillæ consist of very small and closely interlacing bundles of finely fibrillated tissue, with a few elastic fibres; within this tissue is a capillary loop, and in some, especially in the palms of the hands and fingers, there are tactile corpuscles.

The *arteries* supplying the skin form a network in the subcutaneous tissue, from which branches are given off to supply the sweat-glands, the hair-follicles, and the fat. Other branches are given off which form a plexus immediately beneath the corium; from this fine capillary vessels pass into the papillæ, forming, in the smaller papillæ, a single capillary loop, but in the larger a more or less convoluted vessel. There are numerous *lymphatics* supplied to the skin which form two networks, superficial and deep, communicating with each other and with those of the subcutaneous tissue by oblique branches. They originate in the cell-spaces of the tissue.

The *nerves* of the skin terminate partly in the epidermis and partly in the cutis vera. The former are prolonged into the epidermis from a dense plexus in the

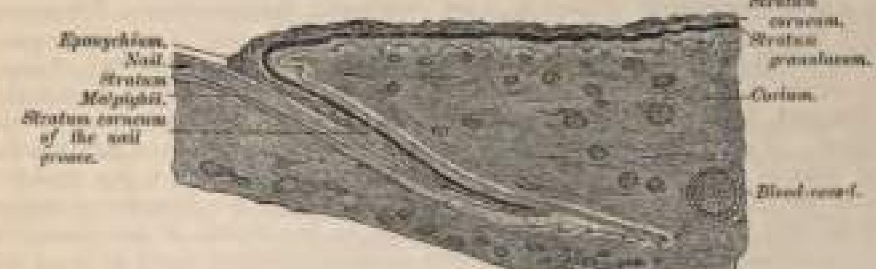


FIG. 680.—Longitudinal section through human nail and its nail groove (sulcus). (From Böhm and Davidoff's *Histology*).

superficial layer of the corium and terminate between the cells in bulbous extremities; or, according to some observers, in the deep epithelial cells themselves. The latter terminate in end-bulbs, touch-corpuscles, or Pacinian bodies, in the manner already described; and, in addition to these, a considerable number of fibrils are distributed to the hair-follicles, which are said to entwine the follicle in a circular manner. Other nerve-fibres are supplied to the plain muscular fibres of the hair-follicles (arrectores pili) and to the muscular coat of the blood-vessels. These are probably non-medullated fibres.

The **appendages of the skin** are the nails, the hairs, the sudoriferous and sebaceous glands, and their ducts.

The nails and hairs are peculiar modifications of the epidermis, consisting essentially of the same cellular structure as that tissue.

The **nails** (Figs. 680, 681) are flattened, elastic structures of a horny texture, placed upon the dorsal surface of the terminal phalanges of the fingers and toes. Each nail is convex on its outer surface, concave within, and is implanted by a portion, called the *root*, into a groove in the skin; the exposed portion is called the *body*, and the anterior extremity the *free edge*. The nail has a very firm adhesion to the cutis, being accurately moulded upon its surface, as the epidermis is in other parts. The part of the cutis beneath the body and root of the nail is called the *matrix*, because it is the part from which the nail is produced. Corresponding to the body of the nail, the matrix is thick, and raised into a series of longitudinal

FIG. 681.—Transverse section through human nail and its sulcus. (From Böhm and Davidoff's *Histology*.)

ridges, which are very vascular, and the color is seen through the transparent tissue. Behind this, near the root of the nail, the papillæ are small, less vascular, and have no regular arrangement, and here the tissue of the nail is somewhat more opaque; hence this portion is of a whiter color, and is called the *lunula* on account of its shape.

The cuticle, as it passes forward on the dorsal surface of the finger or toe, is attached to the surface of the nail, a little in advance of its root; at the extremity of the finger it is connected with the under surface of the nail a little behind its free edge. The cuticle and horny substance of the nail (both epidermic structures) are thus directly continuous with each other. The nails consist of a greatly thickened stratum lucidum, the stratum corneum forming merely the thin cuticular fold (*eponychium*) which overlaps the lunula. The cells have a laminated arrangement, and are essentially similar to those composing the epidermis. The deepest layer of cells, which lie in contact with the papillæ of the matrix, are columnar in form and arranged perpendicularly to the surface; those which succeed them are of a rounded or polygonal form, the more superficial ones becoming broad, thin, and flattened, and so closely compacted as to make the limits of each cell very indistinct. It is by the successive growth of new cells at the root and under surface of the body of the nail that it advances forward and maintains a due thickness, while, at the same time, the growth of the nail in the proper direction is secured. As these cells in their turn become displaced by the growth of new ones, they assume a flattened form, and finally become closely compacted together into a firm, dense, horny texture. In *chemical composition* the nails resemble the upper layers of the epidermis. According to Mulder, they contain a somewhat larger proportion of carbon and sulphur.

The **hairs** are peculiar modifications of the epidermis, and consist essentially of the same structure as that membrane. They are found on nearly every part of the surface of the body, excepting the palms of the hands, soles of the feet, and the glans penis. They vary much in length, thickness, and color in different parts of the body and in different races of mankind. In some parts, as in the skin of the eyelids, they are so short as not to project beyond the follicles containing them; in others, as upon the scalp, they are of considerable length: again, in other parts, as the eyelashes, the hairs of the pubic region, and the whiskers and beard, they are remarkable for their thickness. Straight hairs are stronger than curly hairs, and present on transverse section a cylindrical or oval outline; curly hairs, on the other hand, are flattened.

A hair consists of a *root*, the part implanted in the skin; the *shaft* or *stem*, the portion projecting from its surface; and the *point*.

The *root of the hair* presents at its extremity a bulbous enlargement, which is whiter in color and softer in texture than the shaft, and is lodged in a follicular involution of the epidermis called the *hair-follicle* (Fig. 679). When the hair is of considerable length the follicle extends into the subcutaneous cellular tissue. The hair-follicle commences on the surface of the skin with a funnel-shaped opening, and passes inward in an oblique or curved direction—the latter in curly hair—to become dilated at its deep extremity, where it corresponds with the bulbous condition of the hair which it contains. It has opening into it, near its free extremity, the orifices of the ducts of one or more sebaceous glands. At the bottom of each hair-follicle is a small conical, vascular eminence or papilla, similar in every respect to those found upon the surface of the skin; it is continuous with the dermic layer of the follicle, is highly vascular, and probably supplied with nervous fibrils. In structure the hair-follicle consists of two coats—an outer or *dermic*, and an inner or *epidermic*.

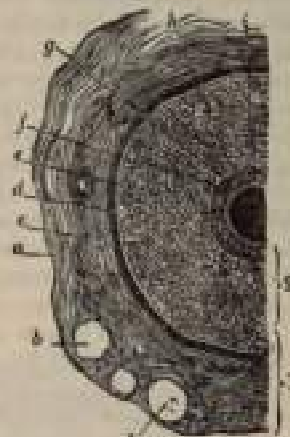


FIG. 682.—Transverse section of hair-follicle. 1. Dermic coat of follicle. 2. Epidermic coat or root-sheath. *a.* Outer layer of dermic coat, with blood-vessels. *b, b.* Vessels cut across. *c.* Middle layer. *d.* Inner or hyaline layer. *e.* Outer root-sheath. *f, g.* Inner root-sheath. *h.* Cuticle of root-sheath. *i.* Hair. (From Quain's Anatomy, Biesiadecki.)

The *outer* or *dermic* coat is formed mainly of fibrous tissue; it is continuous with the corium, is highly vascular, and supplied by numerous minute nervous filaments. It consists of three layers (Fig. 682). The most internal, next the cuticular lining of the follicle, consists of a hyaline basement-membrane, having a glassy, transparent appearance, which is well marked in the larger hair-follicles, but is not very distinct in the follicles of minute hairs. It is continuous with the basement-membrane of the surface of the corium. External to this is a compact layer of fibres and spindle-shaped cells arranged circularly around the follicle. This layer extends from the bottom of the follicle as high as the entrance of the ducts of the sebaceous glands. Externally is a thick layer of connective tissue, arranged in longitudinal bundles, forming a more open texture and corresponding to the reticular part of the corium. In this are contained the blood-vessels and nerves.

The *inner* or *epidermic* layer is closely adherent to the root of the hair, so that when the hair is plucked from its follicle this layer most commonly adheres to it and forms what is called the *root-sheath*. It consists of two strata, named respectively the *outer* and *inner root-sheath;* the former of these corresponds with the Malpighian layer of the epidermis, and resembles it in the rounded form and soft character of its cells; at the bottom of the hair-follicle these cells become continuous with those of the root of the hair. The *inner* root-sheath consists of a delicate cuticle next the hair, composed of a thin layer of imbricated scales having a downward direction, so that they fit accurately over the upwardly directed imbricated scales of the hair itself; then of one or two layers of horny, flattened, nucleated cells, known as *Huxley's layer;* and finally of a single layer of horny oblong cells without visible nuclei, called *Henle's layer.*

The hair-follicle contains the root of the hair, which terminates in a bulbous extremity, and is excavated so as to exactly fit the papilla from which it grows. The bulb is composed of polyhedral epithelial cells, which as they pass upward into the root of the hair become elongated and spindle-shaped, except some in the centre which remain polyhedral. Some of these latter cells contain pigment-granules, which give rise to the color of the hair. It occasionally happens that these pigment-granules completely fill the cells in the centre of the bulb, which gives rise to the dark tract of pigment often found, of greater or less length, in the axis of the hair.

The *shaft of the hair* consists of a central pith or medulla, the fibrous part of the hair, and the cortex externally. The medulla occupies the centre of the shaft and ceases toward the point of the hair. It is usually wanting in the fine hairs covering the surface of the body, and commonly in those of the head. It is more opaque and deeper colored when viewed by transmitted light than the fibrous part; but when viewed by reflected light it is white. It is composed of rows of polyhedral cells, which contain granules of eleidin and frequently air-bubbles. The fibrous portion of the hair constitutes the chief part of the shaft; its cells are elongated and unite to form flattened fusiform fibres. Between the fibres are found minute spaces which contain either pigment-granules in dark hair or minute air-bubbles in white hair. In addition to this there is also a diffused pigment contained in the fibres. The cells which form the cortex of the hair consist of a single layer which surrounds those of the fibrous part; they are converted into thin, flat scales, having an imbricated arrangement.

Connected with the hair-follicles are minute bundles of involuntary muscular fibres, termed *arrectores pili*. They arise from the superficial layer of the corium, and are inserted into the outer surface of the hair-follicle, below the entrance of the duct of the sebaceous gland. They are placed on the side toward which the hair slopes, and by their action elevate the hair (Fig. 679).[1]

The sebaceous glands are small, sacculated, glandular organs, lodged in the substance of the corium. They are found in most parts of the skin, but are especially abundant in the scalp and face: they are also very numerous around the apertures of the anus, nose, mouth, and external ear; but are wanting in the palms of the hands and soles of the feet. Each gland consists of a single duct, more or less capacious, which terminates in a cluster of small secreting pouches or saccules. The sacculi connected with each duct vary, as a rule, in number from two to five, but in some instances may be as many as twenty. They are composed of a transparent, colorless membrane, enclosing a number of epithelial cells. Those of the outer or marginal layer are small and polyhedral, and are continuous with the lining cells of the duct. The remainder of the sac is filled with larger cells, containing fat, except in the centre, where the cells have become broken up, leaving a cavity containing their débris and a mass of fatty matter, which constitutes the sebaceous secretion. The orifices of the ducts open most frequently into the hair-follicles, but occasionally upon the general surface, as in the labia minora and the free margin of the lips. On the nose and face the glands are of large size, distinctly lobulated, and often become much enlarged from the accumulation of pent-up secretion. The largest sebaceous glands are those found in the eyelids—the Meibomian glands.

The sudoriferous or **sweat-glands** are the organs by which a large portion of the aqueous and gaseous materials is excreted by the skin. They are found in almost every part of this structure, and are situated in small pits on the under surface of the corium, or, more frequently, in the subcutaneous areolar tissue, surrounded by a quantity of adipose tissue. They are small, lobular, reddish bodies, consisting of a single convoluted tube, from which the efferent duct proceeds upward through the corium and cuticle, becomes somewhat dilated at its extremity, and opens on the surface of the cuticle by an oblique valve-like aperture. The efferent duct, as it passes through the epidermis, presents a spiral arrangement, being twisted like a corkscrew, in those parts where the epidermis is thick; where, however, it is thin, the spiral arrangement does not exist. In the superficial layer of the corium the duct is straight, but in the deeper layers it is convoluted or even twisted. The spiral course of these ducts is especially distinct in the thick cuticle of the palm of the hand and sole of the foot. The size of the glands varies. They are especially large in those regions where the amount of perspiration is great, as in the axillæ, where they form a thin, mammillated layer of a reddish color, which corresponds exactly to the situation of the hair in this region; they are large also in the groin. Their number varies. They are most numerous on the palm of the hand, presenting, according to Krause, 2800 orifices on a square

[1] Arthur Thomson suggests that the contraction of these muscles on follicles which contain weak thin hairs will tend to produce a permanent curve in the follicle, and this curve will be impressed on the hair which is moulded within it, so that the hair, on emerging through the skin, will be curled. Curved hair-follicles are characteristic of the scalp of the Bushman.

inch of the integument, and are rather less numerous on the sole of the foot. In both of these situations the orifices of the ducts are exceedingly regular, and open on the curved ridges. In other situations they are more irregularly scattered, but the number in a given extent of surface presents a fairly uniform average. In the neck and back they are least numerous, their number amounting to 417 on the square inch (Krause). Their total number is estimated by the same writer at 2,381,248, and, supposing the aperture of each gland to represent a surface of $\frac{1}{56}$ of a line in diameter, he calculates that the whole of these glands would present an evaporating surface of about eight square inches. Each gland consists of a single tube intricately convoluted, terminating at one end by a blind extremity, and opening at the other end upon the surface of the skin. In the larger glands this single duct usually divides and subdivides dichotomously; the smaller ducts ultimately terminating in short cæcal pouches, rarely anastomosing. The wall of the duct is thick, the width of the canal rarely exceeding one-third of its diameter. The tube, both in the gland and where it forms the excretory duct, consists of two layers—an outer, formed by fine areolar tissue, and an inner layer of epithelium (Fig. 683). The external or fibro-cellular coat is thin, continuous with the superficial layer of the corium, and extends only as high as the surface of the true skin. The epithelial lining in the distal part of the coiled tube of the gland proper consists of a single layer of cubical epithelium, supported on a basement-membrane, and beneath it, between the epithelium and the fibro-cellular coat, is a layer of longitudinally or obliquely arranged fibres, which are usually regarded as muscular, though the evidence that this is so is not conclusive. In the duct and the proximal part of the coiled tube of the gland proper there are two or more layers of polyhedral cells, lined on their internal surface—*i. e.*, next the lumen of the tube—by a delicate membrane or cuticle, and on their outer surface by a limiting membrana propria, but there are no muscular fibres. The epithelium is continuous with the epidermis and with the delicate internal cuticle of the epidermic portion of the tube. When the cuticle is carefully removed from the surface of the cutis, these convoluted tubes of epithelium may be drawn out and form short, thread-like processes on its under surface.

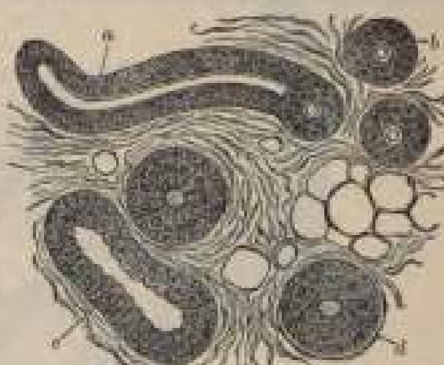


FIG. 683.—Coiled tube of a sweat-gland cut in various directions. *a.* Longitudinal section of the proximal part of the coiled tube. *b.* Transverse section of the same. *c.* Longitudinal section of the distal part of the coiled tube. *d.* Transverse section of the same. (From Klein and Noble Smith's *Atlas of Histology.*)

The contents of the smaller sweat-glands are quite fluid; but in the larger glands the contents are semifluid and opaque, and contain a number of colored granules and cells which appear analogous to endothelial cells.

SEROUS MEMBRANES.

The **serous membranes** form shut sacs, and may be regarded as lymph-sacs, from which lymphatic vessels arise by stomata or openings between the endothelial cells. (See page 1133.) The sac consists of one portion which is applied to the walls of the cavity which it lines—the *parietal* portion; and another reflected over the surface of the organ or organs contained in the cavity—the *visceral* portion. Sometimes the sac is arranged quite simply, as the tunica vaginalis testis; at others with numerous involutions or recesses, as the peritoneum, in which, nevertheless, the membrane can always be traced continuously around the whole circumference. The sac is completely closed, so that no communication exists between the serous cavity and the parts in its neighborhood. An apparent exception exists in the peritoneum of the female; for the Fallopian tube opens freely into the peritoneal cavity in the dead subject, so that a bristle can be passed from the one into the other.

But this communication is closed during life, except at the moment of the passage of the ovum out of the ovary into the tube, as is proved by the fact that no interchange of fluids ever takes place between the two cavities in dropsy of the peritoneum or in accumulation of fluid in the Fallopian tubes.[1] The serous membrane is often supported by a firm, fibrous layer, as is the case with the pericardium, and such membranes are sometimes spoken of as "fibro-serous."

The various serous membranes are the peritoneum, lining the cavity of the abdomen; the two pleuræ and the pericardium, covering the lungs and heart respectively; and the tunicæ vaginales, surrounding each testicle in the scrotum.[2] Serous membranes are thin, transparent, glistening structures, lined on their inner surface by a single layer of polygonal or pavement endothelial cells, supported on a matrix of fibrous connective tissue, with networks of fine elastic fibres, in which are contained numerous capillaries and lymphatics. On the surface of the endothelium between the cells numerous apertures or interruptions are to be seen. Some of these are stomata, surrounded by a ring of cubical endothelium (see Fig. 684),

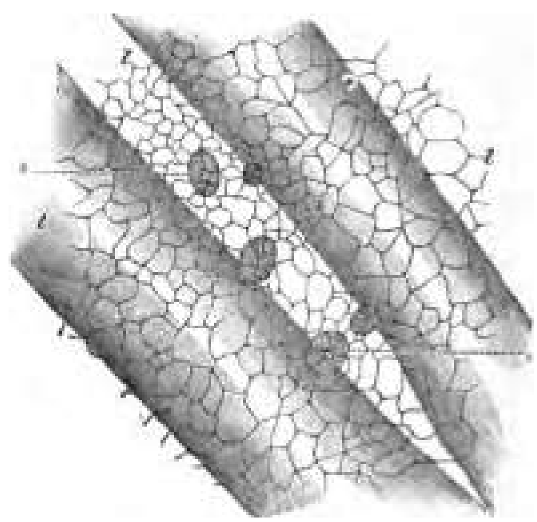


FIG. 684.—Part of peritoneal surface of the central tendon of diaphragm of rabbit, prepared with nitrate of silver. *s.* Stomata. *l.* Lymph channels. *t.* Tendon bundles. The stomata are surrounded by germinating epithelial cells. (From *Handbook for the Physiological Laboratory*, Klein.)

and communicating with a lymphatic capillary; others (*pseudostomata*) are mere interruptions in the endothelial layer, and are occupied by processes of the branched connective-tissue corpuscle of the subjacent tissue or by accumulations of the intercellular cement-substance.

The amount of fluid contained in these closed sacs is, in most cases, only sufficient to moisten the surface, but not to furnish any appreciable quantity of fluid. When a small quantity can be collected, it is found to resemble lymph, and like that fluid coagulates spontaneously; but when secreted in large quantities, as in dropsy, it is a more watery fluid, but still contains a considerable amount of proteid which is coagulated on boiling.

[1] The communication between the uterine cavity and the peritoneal sac is not only apparent in the dead subject, but is an anatomical fact, which is established by the continuity of its epithelium with that covering the uterus, Fallopian tubes, and fimbriæ.

[2] The arachnoid membrane, lining the brain and spinal cord, was formerly regarded as a serous membrane, but is now no longer classed with them, as it differs from them in structure, and does not form a shut sac as do the other serous membranes.

SYNOVIAL MEMBRANES.

Synovial membranes, like serous membranes, are connective-tissue membranes placed between two movable tissues, so as to diminish friction, as in movable joints; or between a tendon and a bone, where the former glides over the latter; and between the skin and various subcutaneous bony prominences.

The synovial membranes are composed essentially of connective tissue, with the cells and fibres of that structure, containing numerous vessels and nerves. It was formerly supposed that these membranes were analogous in structure to the serous membranes, and consisted of a layer of flattened cells on a basement-membrane. No such continuous layer, however, exists, although here and there are patches of cells probably epithelial in nature. They are surrounded and held together by an albuminous ground-substance. Long villus-like processes (Fig. 685) are often found projecting from the surface of synovial membranes; they are covered by small rounded cells, and are supposed to extend the surface for the secretion of the fluid which moistens the membranes, and which is named *synovia.* It is a rich lymph, plus a mucin-like substance, and to the latter constituent it owes its viscidity. A further description of the synovial membranes will be found in the descriptive anatomy of the joints.

Fig. 685.—Villus of synovial membrane. (After Hammar).

MUCOUS MEMBRANE.

Mucous membranes line all those passages by which the internal parts communicate with the exterior, and are continuous with the skin at the various orifices of the surface of the body. They are soft and velvety, and very vascular, and their surface is coated over by their secretion, *mucus,* which is of a tenacious consistence, and serves to protect them from the foreign substances introduced into the body with which they are brought in contact.

They are described as lining the two tracts—the gastro-pulmonary and the genito-urinary; and all, or almost all, mucous membranes may be classed as belonging to and continuous with the one or the other of these tracts.

The deep surfaces of these membranes are attached to the parts which they line by means of connective tissue, which is sometimes very abundant, forming a loose and lax bed, so as to allow considerable movement of the opposed surfaces on each other. It is then termed the *submucous tissue.* At other times it is exceedingly scanty, and the membrane is closely connected to the tissue beneath; sometimes, for example, to muscle, as in the tongue; sometimes to cartilage, as in the larynx; and sometimes to bone, as in the nasal fossæ and sinuses of the skull.

In structure a mucous membrane is composed of *corium* and *epithelium.* The epithelium is of various forms, including the squamous, columnar, and ciliated, and is often arranged in several layers. This epithelial layer is supported by the corium, which is analogous to the dermis of the skin, and consists of connective tissue, either simply areolar or containing a greater or less quantity of lymphoid tissue. This tissue is usually covered on its external surface by a transparent basement-membrane generally composed of clear flattened cells, placed edge to edge; on this the epithelium rests. It is only in some situations that the basement-membrane can be demonstrated. The corium is an exceedingly vascular membrane, containing a dense network of capillaries, which lie immediately beneath the epithelium, and are derived from small arteries in the submucous tissue.

The fibro-vascular layer of the corium contains, besides the areolar tissue and vessels, unstriped muscle-cells, which form in many situations a definite layer, called the *muscularis mucosæ*. These are situated in the deepest part of the membrane, and are plentifully supplied with nerves. Other nerves pass to the epithelium and terminate between the cells. Lymphatic vessels are found in great abundance, commencing either by cæcal extremities or in networks, and communicating with plexuses in the submucous tissue.

Imbedded in the mucous membrane are found numerous glands, and projecting from it are processes (villi and papillæ) analogous to the papillæ of the skin. These glands and processes, however, exist only at certain parts, and they have been described for the sake of convenience, and with the parts as they occurred.

SECRETING GLANDS.

The **secreting glands** are organs whose cells produce, by the metabolism of their protoplasm, certain substances, called "secretions," of a more or less definite composition; the material for the secretion being primarily selected from the blood. The essential parts, therefore, of a secreting gland are *cells*, which have the power of extracting from the blood certain matters, and in some cases converting them into new chemical compounds; and *blood-vessels*, by which the blood is brought into close relationship with these cells. The general arrangement in all secreting structures—that is to say, not only in secreting glands, but also in secreting membranes—is that the cells are arranged on one surface of an extravascular basement-membrane, which supports them, and a minute plexus of capillary vessels ramifies on the other surface of the membrane. The cells then extract from the blood certain constituents which pass through the membrane into the cells, where they are prepared and elaborated. The basement-membrane does not, however, always exist, and any free surface would appear to answer the same purpose in some cases.

By the various modifications of this secreting surface the different glands are formed. This is generally effected by an invagination of the membrane in different ways, the object being to increase the extent of secreting surface within a given bulk.

In the simplest form a single invagination takes place, constituting a *simple* gland; this may be either in the form of an open tube (Fig. 686, A), or the wall of the tube may be dilated so as to form a saccule (Fig. 686, B). These are named the *simple tubular* or *saccular* glands. Or, instead of a short tube, the invagination may be lengthened to a considerable extent, and then coiled up to occupy less space. This constitutes the *simple convoluted tubular* gland, an example of which may be seen in the sweat-glands of the skin (Fig. 686, C).

If, instead of a single invagination, secondary invaginations take place from the primary one, as in Fig. 686, D and E, the gland is then termed a compound one. These secondary invaginations may assume either a saccular or tubular form, and so constitute the two subdivisions—the *compound saccular* or *racemose* gland, and the *compound tubular*. The racemose gland in its simplest form consists of a primary invagination which forms a sort of duct, upon the extremity of which are found a number of secondary invaginations called saccules or alveoli, as in Brunner's glands (Fig. 686, D). But, again, in other instances, the duct, instead of being simple, may divide into branches, and these again into other branches, and so on, each ultimate ramification terminating in a dilated cluster of saccules, and thus we may have the secreting surface almost indefinitely extended, as in the salivary glands (Fig. 686, E). In the *compound tubular* glands the division of the primary duct takes place in the same way as in the racemose glands, but the branches retain their tubular form, and do not terminate in saccular recesses, but become greatly lengthened out (Fig. 686, F). The best example of this form of gland is to

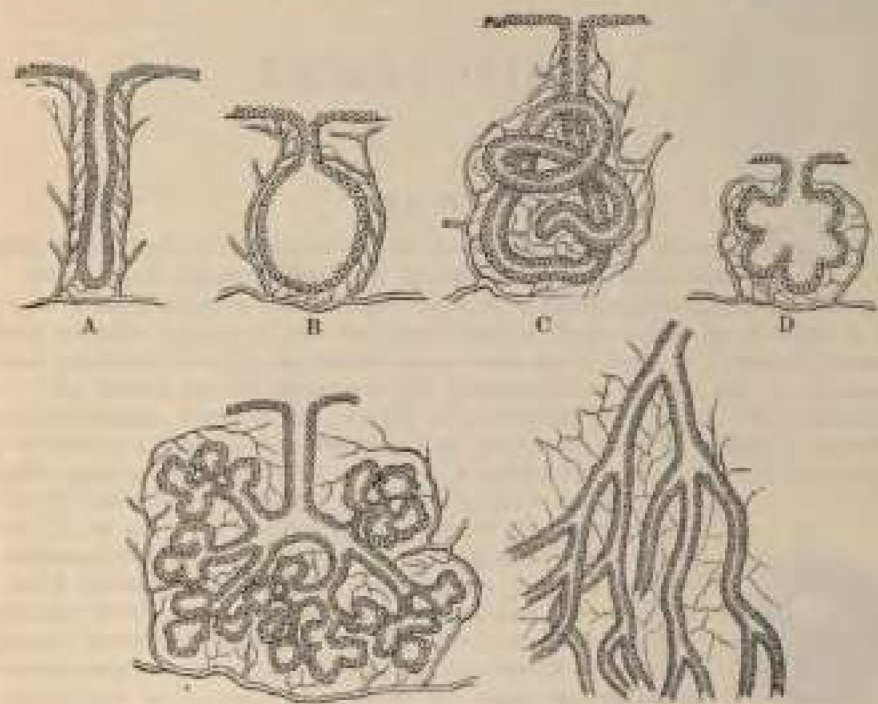


FIG. 686.—Diagrammatic plan of varieties of secreting glands. A. Simple gland. B. Sacculated simple gland. C. Simple convoluted tubular gland. D, E. Racemose gland. F. Compound tubular gland.

be found in the kidney. All these varieties of glands are produced by a more or less complicated invagination of a secreting membrane, and they are all identical in structure; that is to say, the saccules or tubes, as the case may be, are lined with cells, generally spheroidal or columnar in figure, and on their outer surface is an intimate plexus of capillary vessels. The secretion, whatever it may be, is eliminated by the cells from the blood, and is poured into the saccule or tube, and so finds it way out through the primary invagination on to the free surface of the secreting membrane. In addition, however, to these glands, which are formed by an *invagination* of the secreting membrane, there are some few others which are formed by a *protrusion* of the same structure, as in the vascular fringes of synovial membranes. This form of secreting structure is not nearly so frequently met with.

EMBRYOLOGY.

THE OVUM.

THE whole body is developed out of the **ovum** or female element (Figs. 687 and 688) after it has been fertilized by the spermatozoön or male element. The ovum is a simple nucleated cell, and all the complicated changes by which the various intricate organs of the body are formed from it may be reduced to two general processes, viz., the *segmentation* or *cleavage* of cells, and their *differentiation*. The former process consists in the division of the nucleus and the surrounding cell-substance, whereby the original cell is represented by two. The differentiation of cells is a term used to describe that unknown power or tendency impressed on cells, apparently identical in structure, whereby they grow into different forms; so that (to take one of the first phenomena which occurs in the growth of the embryo) the indifferent cells of the vascular area are differentiated, some of them into blood-globules, others into the solid tissue which forms the blood-vessels. The extreme complexity of the process of development renders it at all times difficult to describe intelligibly, and still more so in a work like this, where adequate space and illustration can hardly be afforded, having respect to the main purpose of the work, and therefore an outline of the principal facts only will be given. Many of the statements which are accepted in human embryology are made on the strength of what has been observed to occur in the lower animals, and their existence in the human subject is merely a matter of inference. Within recent years, however, much has been added to our knowledge of the development of the human embryo, and this more especially by the important researches of Professor His and others.

Fig. 687.—Human ovum from a middle-sized follicle. Magnified 350 times. *a.* Zona pellucida or zona radiata. *b.* External border of the yolk and internal border of the vitelline membrane. *c.* Germinal vesicle and germinal spot.

The **ovum** is a small spheroidal body situated in the immature Graafian follicle near its centre, but in the mature one in contact with the membrana granulosa,[1] at that part of the follicle which projects from the surface of the ovary. The cells of the membrana granulosa are accumulated round the ovum in greater number than at any other part of the follicle, forming a kind of granular zone, the *discus proligerus*.

The **human ovum** (Fig. 687) is extremely minute, measuring from $\frac{1}{120}$ to $\frac{1}{125}$ of an inch in diameter. It is a cell consisting externally of a transparent striated envelope, the *zona pellucida*, *zona radiata*, or *vitelline membrane*. The extranuclear protoplasm contained within the zona pellucida is known as *the cytoplasm*; it is a sponge-like material, containing in its meshes numerous large fatty and albuminous granules, which constitute the *yolk* or *vitellus*; in the neighborhood of the nucleus, however, these granules are comparatively few in number. The nucleus is a large spherical body, which is known by the name of the *germinal vesicle*, and resembles in structure the nucleus of an ordinary cell. Within it there is generally one nucleolus, which is large and well marked, and is known as the *germinal spot*. The zona pellucida is believed to be pierced by numerous pores which are probably channels of nutrition and which give it

[1] See the description of the ovary at a future page.

the appearance of being radially striated, while in some animals (*e.g.*, insects) it presents a small perforation or hole, which is known by the name of the *micropyle*, and is believed to be the means by which the spermatozoa enter the ovum.

The phenomena attending the discharge of the ova from the Graafian follicles, since they belong as much or more to the ordinary function of the ovary than to the general subject of the development of the body, are described with the anatomy of the ovaries on a subsequent page.

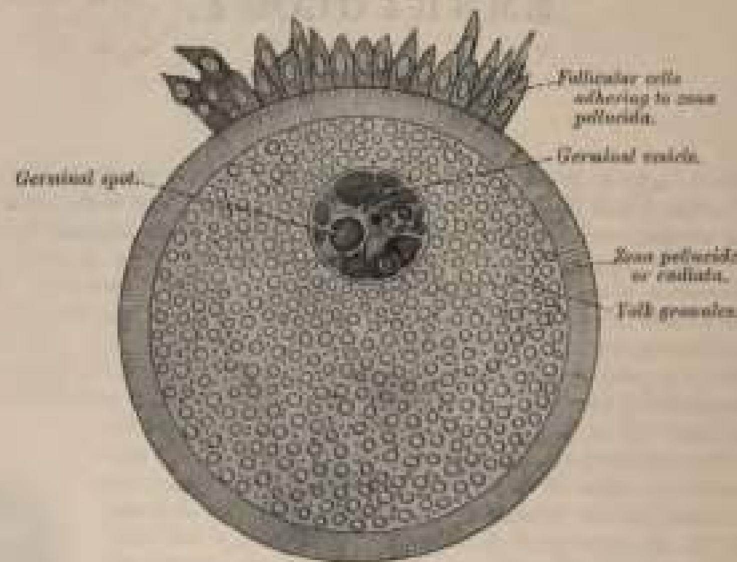


FIG. 688.—Ovum of rabbit. Highly magnified. (After Waldeyer.)

Maturation of the Ovum previous to Fertilization.—Either before or immediately after its escape from the Graafian follicle, important changes take place in the nucleus of the ovum, which result in its partial disappearance and in the formation and extrusion from the yolk of two peculiar bodies, the *polar bodies* or *polar globules* of Robin. These changes constitute what is termed the *maturation of the ovum*, and are preparatory to its being fertilized by the male element or spermatozoon. The nucleus approaches the periphery of the ovum and undergoes the changes associated with karyokinesis; it then divides into two, and the upper daughter nucleus, with a thin investment of protoplasm, becomes extruded as the first polar body into a space between the yolk and the vitelline membrane, which has been formed in consequence of a contraction or shrinking of the yolk. The lower daughter nucleus undergoes the same process of division, and forms a second polar body, which is in like manner extruded (Fig. 689). The greater part (three-fourths) of the original nucleus is therefore expelled from the yolk in the form of the two polar bodies, and the remaining fourth, which is now called the *female pronucleus*, recedes toward the centre of the ovum. The shrinking of the vitellus still continues, and a fluid—the *perivitelline* fluid—collects in the space between it and the zona pellucida; in it, spermatozoa, which have passed through the zona pellucida, may sometimes be seen.

Although the process of maturation has been closely followed in many of the lower animals, it has not yet been successfully demonstrated in mammals.

It is interesting to note that a similar nuclear reduction occurs in connection with the development of spermatozoa. In the germinal ridge, which is to become the future testicle, certain cells, identical with primitive ova, are found. These are termed *spermatoblasts*, and they become enlarged to form what are called *spermatocytes*, while each spermatocyte ultimately divides into four *spermatids*. The spermatids become changed, without further subdivision, into spermatozoa, and hence the fully developed spermatozoon contains only one-fourth of the nucleus of the original spermatocyte. The matured ovum and the spermatozoon may therefore be looked upon as of the same morphological value.

FIG. 689.—Formation of polar bodies in Asterias glacialis. (Hertwig.) In I. the polar spindle (sp) has advanced to the surface of the egg. In II. a small elevation (rk) is formed which receives a half of the spindle. In III. the elevation is constricted off, forming a polar body (rk'). Out of the remaining half of the previous spindle a second complete spindle (sp) has arisen. In IV. is seen a second elevation, which in V. has become constricted off as the second polar body. Out of the remainder of the spindle (IV.) is developed the female pronucleus.

FERTILIZATION AND SEGMENTATION OF THE OVUM.

The first changes in the ovum which take place at the time of conception are as follows:

1. **Impregnation.**—One, or perhaps more, spermatozoa penetrate the zona pellucida and are contained in the perivitelline fluid. A single spermatozoon,

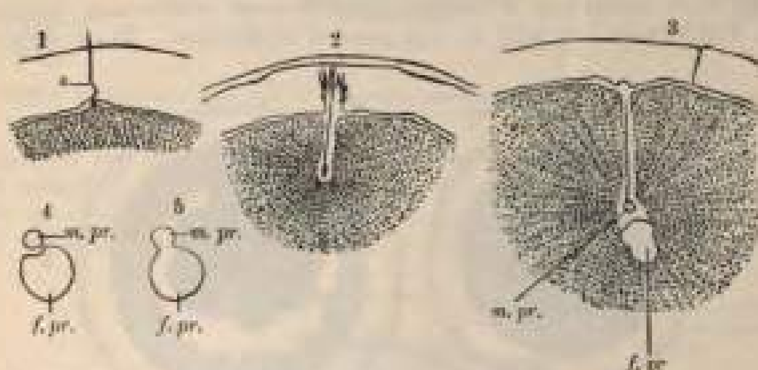


FIG. 690.—Fertilization of the ovum of an echinoderm. s. Spermatozoon. m. pr. Male pronucleus. f. pr. Female pronucleus. 1. Accession of a spermatozoon to the periphery of the vitellus. 2. Its penetration. 3. Transformation of the head of the spermatozoon into the male pronucleus. 4, 5. Blending of the male and female pronuclei. (From Quain's *Anatomy*, Selenka.)

more advanced than the rest, becomes buried in the yolk, the tail disappears, and the head constitutes the *male pronucleus*. This gradually approaches the female pronucleus, and ultimately the two pronuclei come into contact and fuse to form a new nucleus, containing both male and female elements, and named the *segmentation* or *cleavage* nucleus, and the whole cell thus modified is called the blastosphere (Fig. 690). It seems as if this normally occurs in the Fallopian tube,[1] but it is possible that it sometimes takes place before the ovum has entered

[1] Many physiologists, as Bischoff and Dr. M. Barry, taught that the ovum is fecundated in the ovary, but the reasoning of Dr. Allen Thomson appears very cogent in proving that the usual spot at which the spermatozoa meet the ovum is in the tube, down which it slowly travels to the uterus, in its course becoming surrounded by an albuminous envelope derived from the walls of the tube.

cell-walls); the inner layer assumes the form of a prismatic epithelium, and is named the *cytoblast* (Fig. 695). These two layers form the *ectoplacenta* or *chorion*, and entirely replace the lining epithelium of the uterus where the blastodermic vesicle comes into contact with it. According to Van Beneden, the cells of the inner mass partly undergo atrophy (Fig. 694), giving rise to a cavity, limited above by the cytoblast and below by a layer of cells, which constitutes the primitive upper layer of the embryo, the *epiblast* or *ectoderm*, and which is continuous peripherally with the cytoblast. The cavity thus formed is the *primitive amniotic cavity*, and becomes the permanent amniotic cavity in man and monkeys, and in some of the bats (Fig. 695). It will thus be seen that from the inner mass of cells two layers are formed—an outer of prismatic cells, the epiblast or ectoderm, and an inner of flattened cells, the hypoblast or entoderm—and this double layer constitutes the *blastodermic membrane*, which at this stage is *bilaminar*.[1]

FIG. 696.—Embryo of a rabbit of eight days. (After Kölliker.) ag. Embryonic area. pr. Primitive streak.

3. **Formation of the Mesoblast.**—At first the area of the blastodermic membrane assumes the form of a small disk, the *germinal disk* or *germinal area*. This disk becomes oval in shape, with its more pointed end situated posteriorly. In it the first traces of the embryo are seen as a faint streak, the *primitive streak* (Fig. 696), which makes its appearance at the posterior or narrow end of the oval disk and from there gradually extends forward. The epiblast covering the primitive streak becomes indented by a groove, the *primitive groove*, the anterior end of which communicates through a canal with the yolk-sac, forming what is termed the *blastopore*. The primitive streak results from a multiplication of the cells of the epiblast, so that it becomes thickened and grows downward toward the hypoblast, which also undergoes proliferation. Together they form a thick cellular column, in which it is no longer possible to distinguish the epiblastic from the hypoblastic cells. From the sides of this column a layer of cells grows out between the epiblast and hypoblast, having been derived partly from both; this layer constitutes the *mesoblast* or *mesoderm*.

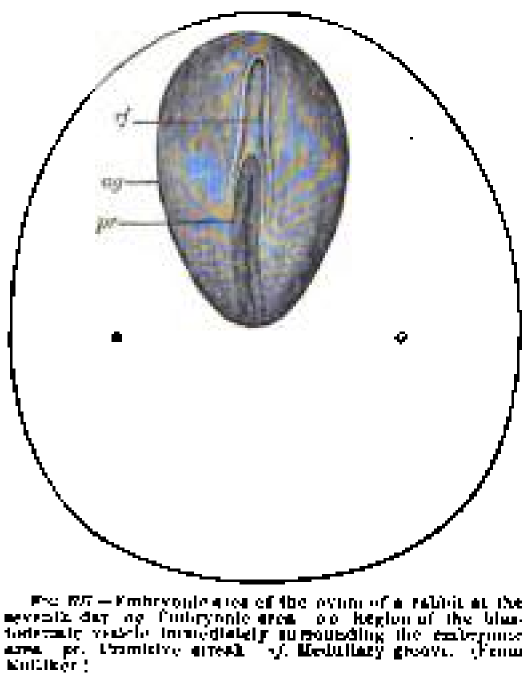


FIG. 697.—Embryonic area of the ovum of a rabbit at the seventh day. ag. Embryonic area. o o. Region of the blastodermic vesicle immediately surrounding the embryonic area. pr. Primitive streak. mf. Medullary groove. (From Kölliker.)

In this way the blastodermic membrane comes to consist of three layers, and is now known as the *trilaminar blastoderm*. Each layer has distinctive characters, the outer and inner presenting the appearance of epithelial cells, while the middle consists of a mass of branched cells without any definite arrangement. The external is termed the *epiblast*, or [illegible] internal the *hypoblast*, or *entoderm*; and the middle, the [illegible] (Fig. 698).

[1] [illegible] articles by Van Beneden and Kollmann, *Anatomischer Anzeiger.*

enclose the lower cells, so that by the ninth or tenth division there is an external layer of pale cells enclosing a mass of slightly smaller, more opaque cells, which, in consequence of their diminished rate of cleavage, are fewer in number (Fig.

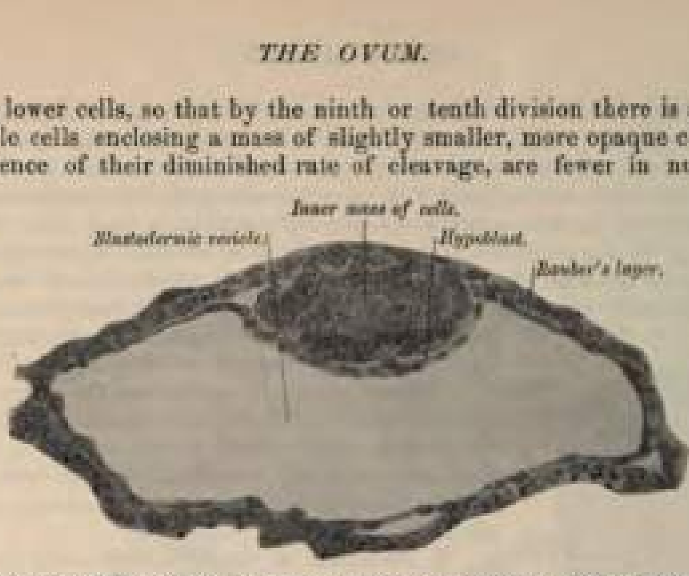


FIG. 693.—Blastodermic vesicle of Vespertilio murinus. (After Van Beneden.) (Reduced from a drawing in the *Anatomischer Anzeiger*, xvi. Band, Sept. 8, 1899.)

692). Fluid collects between the two sets of cells, except at one part, termed the *embryonal pole*, so that a vesicle, the *blastodermic vesicle*, is formed. This vesicle consists of an outer layer of cells, termed Rauber's layer, derived from the

FIG. 694.—Section through embryonic area of Vespertilio murinus. (After Van Beneden.) (Reduced from a drawing in the *Anatomischer Anzeiger*, xvi. Band, Sept. 8, 1899.)

subdivision of the primary upper cell, enclosing at the embryonal area an inner mass of cells (Fig. 693) resulting from the cleavage of the primary lower cell. Rauber's layer takes no share in the formation of the embryo proper, which is entirely developed from the inner mass of cells. The deepest cells of this mass

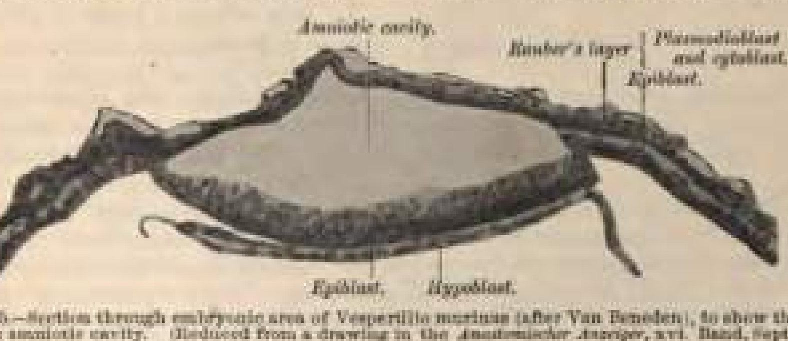


FIG. 695.—Section through embryonic area of Vespertilio murinus (after Van Beneden), to show the formation of the amniotic cavity. (Reduced from a drawing in the *Anatomischer Anzeiger*, xvi. Band, Sept. 8, 1899.)

become differentiated as a layer of flattened cells, termed the *hypoblast*, which spreads outward beneath Rauber's layer. The latter, by subdivision of the cells of its upper hemisphere, is differentiated into two strata, the outer of which becomes rapidly thickened and forms a *plasmodioblast* (*i. e.*, a mass of protoplasm containing numerous nuclei, but not subdivided into individual cells by means of cell-walls); the inner layer assumes the form of a prismatic epithelium, and is named the *cytoblast* (Fig. 695). These two layers form the *ectoplacenta* or *chorion*, and entirely replace the lining epithelium of the uterus where the blastodermic vesicle comes into contact with it. According to Van Beneden, the cells of the inner mass partly undergo atrophy (Fig. 694), giving rise to a cavity, limited above by the cytoblast and below by a layer of cells, which constitutes the primitive upper layer of the embryo, the *epiblast* or *ectoderm*, and which is continuous peripherally with the cytoblast. The cavity thus formed is the *primitive amniotic cavity*, and becomes the permanent amniotic cavity in man and monkeys, and in some of the bats (Fig. 695). It will thus be seen that from the inner mass of cells two layers are formed—an outer of prismatic cells, the epiblast or ectoderm, and an inner of flattened cells, the hypoblast or entoderm—and this double layer constitutes the *blastodermic membrane*, which at this stage is *bilaminar*.[1]

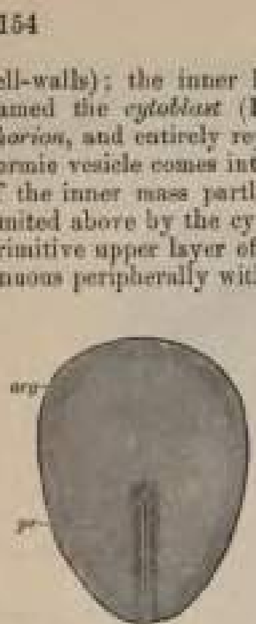


FIG. 696.—Embryo of a rabbit of eight days. (After Kölliker.) *arg.* Embryonic area. *pr.* Primitive streak.

3. **Formation of the Mesoblast.**—At first the area of the blastodermic membrane assumes the form of a small disk, the *germinal disk* or *germinal area*. This disk becomes oval in shape, with its more pointed end situated posteriorly. In it the first traces of the embryo are seen as a faint streak, the *primitive streak* (Fig. 696), which makes its appearance at the posterior or narrow end of the oval disk and from there gradually extends forward. The epiblast covering the primitive streak becomes indented by a groove, the *primitive groove*, the anterior end of which communicates through a canal with the yolk-sac, forming what is termed the *blastopore*. The primitive streak results from a multiplication of the cells of the epiblast, so that it becomes thickened and grows downward toward the hypoblast, which also undergoes proliferation. Together they form a thick cellular column, in which it is no longer possible to distinguish the epiblastic from the hypoblastic cells. From the sides of this column a layer of cells grows out between the epiblast and hypoblast, having been derived partly from both; this layer constitutes the *mesoblast* or *mesoderm*.

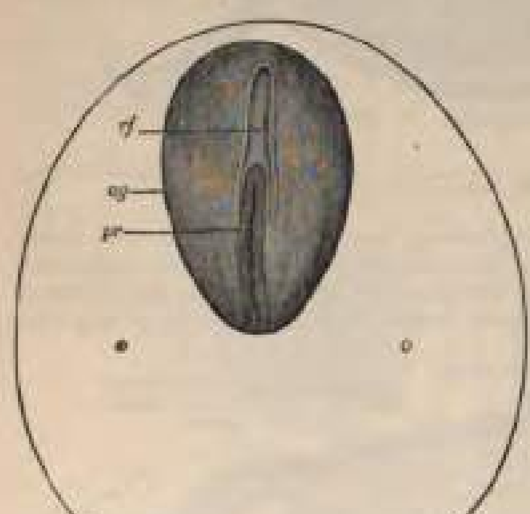


FIG. 697.—Embryonic area of the ovum of a rabbit at the seventh day. *ag.* Embryonic area. *o o.* Region of the blastodermic vesicle immediately surrounding the embryonic area. *pr.* Primitive streak. *rf.* Medullary groove. (From Kölliker.)

In this way the blastodermic membrane comes to consist of three layers, and is now known as the *trilaminar blastoderm*. Each layer has distinctive characters, the outer and inner presenting the appearance of epithelial cells, while the middle consists of a mass of branched cells without any definite arrangement. The external is termed the *epiblast*, or *ectoderm*; the internal the *hypoblast*, or *entoderm*; and the middle, the *mesoblast*, or *mesoderm* (Fig. 698).

[1] Consult, in this connection, articles by Van Beneden and Kollmann, *Anatomischer Anzeiger*, 1899 and 1900.

The *epiblast* consists of a layer of columnar epithelial cells, which, however, are somewhat flattened toward the circumference of the germinal disk. It forms the whole of the nervous system (central and peripheral), the epidermis of the skin, the hairs and nails, the lining cells of the sebaceous, sweat, and mammary glands, the enamel of the teeth, and the epithelial lining of the nasal passage and of portions of the mouth and pharynx.

The *hypoblast* consists, at first, of flattened epithelial cells, which subsequently become columnar and even larger than those of the epiblast. It forms the epithelial lining of the whole of the alimentary canal except the anus and part of the mouth (which are developed from involutions of the epiblast), the epithelial lining of all the glands opening into the alimentary canal, the epithelium of the Eustachian tube and tympanic cavity, and of the trachea, bronchial tubes, and air-sacs of the lungs, the epithelium of the bladder and urethra, and also that which lines the follicles of the thyroid and thymus glands. The endothelial lining of the heart,

FIG. 698.—Section across the anterior part of the medullary groove of an early embryo of the guinea-pig. (By Schäfer. From Quain's *Anatomy*, 1890.) Folds of epiblast rising up on either side of the middle line, and thus bounding the medullary groove. *m.g.* Middle of medullary groove. *hy.* Hypoblast, which is in contact with the medullary epiblast at the middle of the groove, but is elsewhere separated from it by mesoblast, *m*, which has burrowed forward between the two primary layers. A cleft is seen in the mesoblast on either side; this is the commencement of the anterior part of the body-cavity.

blood-vessels, and serous cavities is also of hypoblastic origin, while recent observations tend to show that the primitive red blood-cells are derived from the same source.

The *mesoblast* consists of loosely arranged branched cells, which are surrounded by a considerable amount of intercellular fluid, and which therefore may be considered as resembling embryonic connective tissue. All the other tissues of the embryo are developed from it, including the extra-endothelial portion of the walls of the blood-vessels, the skeleton and voluntary muscles, the connective tissues, the spleen, the generative and urinary organs (except the epithelium of the bladder and urethra), and the involuntary muscles.

FIRST RUDIMENTS OF THE EMBRYO.

The *primitive streak* alluded to above is a very transitory structure, which merely marks the direction of the embryonic axis, the embryo proper being developed immediately in front of it in the following manner (Figs. 697 and 701):

First, two longitudinal ridges, caused by a looping or folding up of the epiblast, appear, one on either side of the middle line. These commence in the anterior part of the area germinativa, where they are united, and extend backward, one on either side of the primitive streak, gradually enclosing it, and thus converting the blastopore into the *neurenteric canal.* This folding up of the epiblast gives rise to a longitudinal groove, the *medullary* or *neural groove* (Figs. 697 and 698), in consequence of the manner in which the cells of the epiblast are heaped up into two longitudinal ridges, with a furrow between them so that the sides and floor of the groove are formed of epiblastic cells (Fig. 698). The mesoblast fills up the space between the epiblast and hypoblast, so that the sides of the groove are occupied by a longitudinal thickening of mesoblast; the two longitudinal thicken-

ings of mesoblast being at first separated at the bottom of the
tion of the epiblast and hypoblast (Fig. 698). The gro
in consequence of the further growing up of the cells to

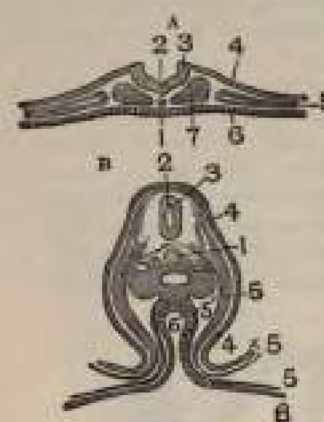


FIG. 699.—Transverse sections through the embryo chick, before and some time after the closure of the medullary canal, to show the upward and downward inflections of the blastoderm. (After Remak.) A. At the end of the first day. 1. Notochord. 2. Primitive groove in the medullary canal. 3. Edge of the dorsal laminæ. 4. Corneous layer or epiblast. 5. Mesoblast divided in its inner part. 6. Hypoblast or epithelial layer. 7. Section of protovertebral plate. B. On the third day in the lumbar region. 1. Notochord in its sheath. 2. Medullary canal now closed in. 3. Section of the medullary substance of the spinal cord. 4. Corneous layer. 5. Somatopleure of the mesoblast. 5'. Splanchnopleure (one figure is placed in the pleuro-peritoneal cavity). 6. Layers of hypoblast in the intestines spreading also over the yolk. 4 × 5. Part of the fold of the amnion formed by epiblast and somatopleure.

either side. In this way the ri
come two plates, the *laminæ do*
plates, which finally coalesce an
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groove becomes closed off from
enteron and forms a rod of cell
the hypoblast and the neural
cells is known as the *notochord*
and when fully developed is co
thelium-like cells enclosed in a
(Fig. 700). It is essentially an embryonic structure, though trac
centre of the intervertebral disks throughout life. The collection
which forms a thick longitudinal column on either side of the ne
the *paraxial* mesoblast, as distinguished from the outer or *later*

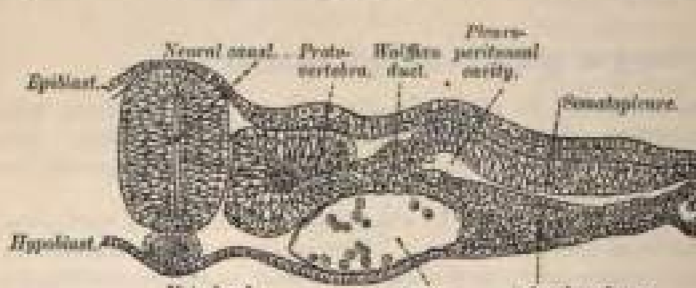

FIG. 700.—Section across the dorsal part of a chick embryo of forty-five hours' in

blastic layer. The paraxial mesoblast undergoes a series of
tions and becomes converted into a row of well-defined, dark,
masses, the *protovertebræ* or *mesoblastic somites*, separated
intervals (Figs. 700 and 701). They first make their appear
which afterward becomes the neck, and from there extend

entire length of the trunk. These bodies, as will be explained hereafter, are not the representatives of the permanent vertebræ, but are differentiated, partly into the vertebræ and partly into the muscles and true skin. On either side of the protovertebræ the lateral mesoblast splits into two layers; the upper becomes applied to the epiblast, forming with it the *somatopleure* or body wall, while the lower becomes attached to the hypoblast and with it forms the *splanchnopleure* or wall of the alimentary tube (Fig. 699). The space between them is the *cœlum* or

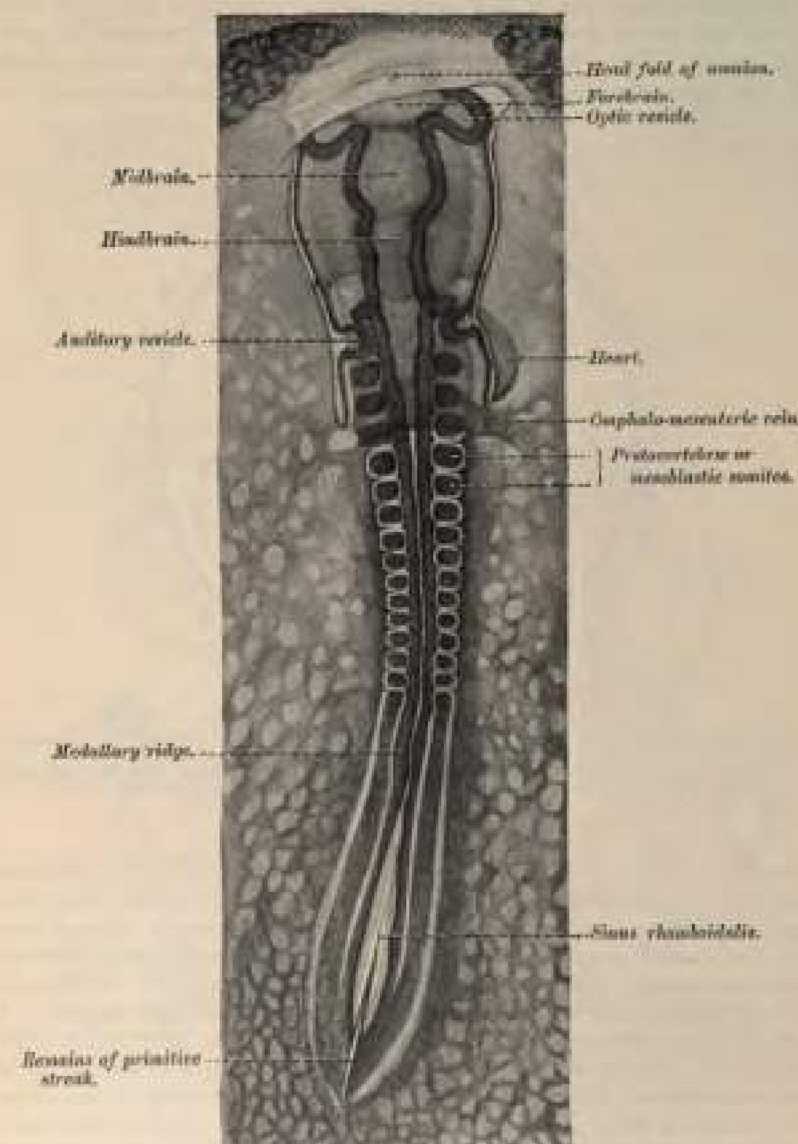

FIG. 701.—Chick embryo of thirty-three hours' incubation, viewed from the dorsal aspect; × 20. (From Duval's *Atlas d'Embryologie*.)

pleuro-peritoneal cavity (Fig. 700). While the parietes of the body are still unclosed, this cavity is continuous with the space between the amnion and chorion, as seen in Fig. 705. The embryo, which at first seems to be a mere streak, extends longitudinally and laterally. As its grows forward the cephalic end becomes remarkably curved on itself (cephalic flexure), and a smaller but similar folding-over takes place at its hinder end (caudal flexure). At the same time the sides of the embryo, formed by the somatopleure, grow and curve ventrally toward each other, so that the embryo at this stage is aptly compared to a canoe turned over, and becomes marked off from the general blastoderm by a *limiting sulcus*. In consequence of this incurving of the embryo, both in an antero-posterior and a lateral direction, the blastodermic vesicle becomes nipped by the somatopleure and resembles an hour-glass with two unequal parts. The smaller portion is enclosed within the body of the embryo, and constitutes the *enteron* or primitive alimentary canal, while the larger portion, left outside the embryo, is termed the *yolk-sac* or *umbilical vesicle*. These two parts of the original blastodermic vesicle communicate through the constricted portion, which is the site of the future umbilicus, and,

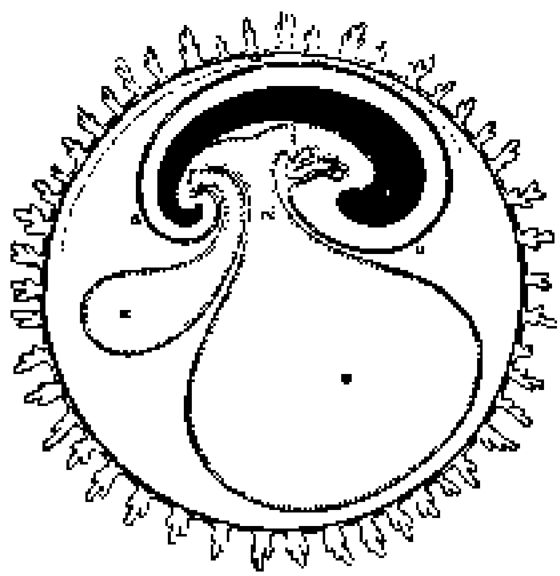

FIG. 703.—Diagrammatic section through the ovum of a mammal in the long axis of the embryo. c. The cranio-vertebral axis. f, i. The cephalic and caudal portions of the primitive alimentary canal. a. The amnion. a'. The point of reflection into the false amnion. v. Yolk-sac, communicating with the middle part of the intestine by v i, the vitello-intestinal duct. u. The allantois. The ovum is surrounded externally by the villous chorion.

when the body cavity is ultimately closed at the umbilicus, the constriction is narrowed to form a small duct, the *omphalo-mesenteric* or *vitelline duct* (Figs. 702, 703, and 705). The cephalic part of the primitive alimentary canal is named the *fore-gut*, the caudal portion the *hind-gut*, while the intermediate portion which communicates directly with the yolk-sac, is termed the *mid-gut*. The yolk-sac is of small importance and very temporary duration in the human subject. It is for the purpose of supplying nutrition to the embryo during the very earliest period of its existence. In the oviparous animals, however, where no supply of nourishment can be obtained from the mother, since the egg is entirely separated from her, the yolk-sac is large and of great importance, as it supplies nutrition to the chick during the whole of fœtation. Vessels developed in the mesoblast soon cover the yolk-sac, forming the *vascular area*; these are named the *omphalo-mesenteric* vessels, and are two in number (Fig. 704). They appear to absorb the fluid of the yolk-sac which, when the fluid has disappeared, dries up and has no further function. The activity of the yolk-sac ceases about the fifth or sixth week, at the same time that the allantois, which is the great bond of vascular connection between the embryo and the uterine tissues, is formed. The yolk-sac remains visible, however, up to the fourth or fifth month, with its pedicle and the omphalo-

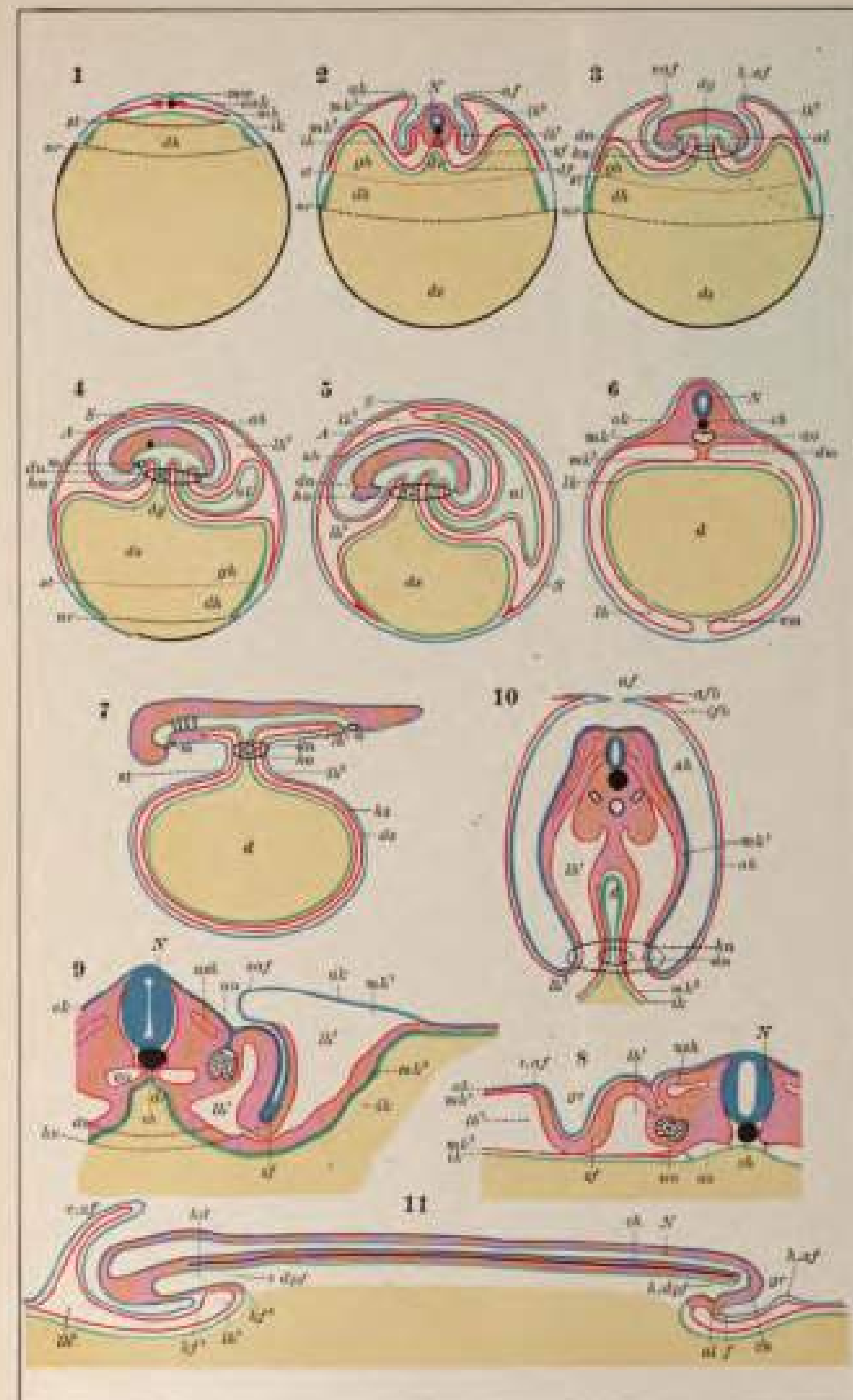

Fig. 702.—Diagrams to illustrate the development of the embryo with its yolk-sac, amnion, and allantois. (From Hertwig's 'Embryology.')

a. External germinal layer. *mw*. Medullary groove. *N*. Neutral canal. *af*. Amnion fold. *vaf*. Anterior. *haf*. Posterior. *saf*. Lateral amniotic folds. *A*. Amnion. *ah*. Amniotic cavity. *S*. Serous covering. *hn*. Umbilicus. *sf*. Lateral folds. *kf*[1], *kf*[2]. Head fold. *afh*. External. *ifh*. Internal layers of amnion. *ur*. Border of embryonic area. *dr*. Intestinal groove. *dg*. Vitelline duct. *al*. Allantois. *ds*. Vitellus. *dn*. Intestinal portion of umbilicus. *mk*. Middle germinal layer. *mk*[1]. Parietal leaf of mesoderm. *mk*[2]. Visceral leaf of mesoderm. *st*. Sinus terminalis. *dm*. Dorsal. *vm*. Ventral mesenterium. *lh*. Somatic cavity. *lh*[1]. Embryonal portion. *lh*[2]. Extra-embryonal portion of somatic cavity. Figs. 1, 2, 6, 8, 9, and 10 transections. Figs. 3, 4, 5, 7, and 11 long-sections of embryo. Figs. 1, 2, 3, 4, and 5 chick embryo. Fig. 6 fish embryo. Figs. 7 and 11 selachian embryo.

mesenteric vessels. The latter vessels become atrophied as the functional activity of the body with which they are connected ceases.

So far we have traced: (1) the segmentation or cleavage of the ovum and the formation of a blastodermic vesicle, consisting of (*a*) an external envelope, and (*b*) an internal mass of cells applied to it at the embryonal pole, but separated elsewhere by an albuminous fluid. (2) The separation of the hypoblast from the inner surface of this internal mass and its extension as a lining to the external envelope. (3) The development of the epiblast, also from the internal mass of cells, absorption taking place between it and the external layer to form a cavity, the primitive amniotic cavity. (4) The formation of an oval-shaped disk, the germinal disk, and the appearance of the primitive streak at its posterior end.

Fig. 704.—Magnified view of the human embryo of four weeks, with the membranes opened. (From Leishman, after Coste.) *y.* The umbilical vesicle with the omphalo-mesenteric vessels, *v*, and its long tubular attachment to the intestine. *c.* The villi of the chorion. *m.* The amnion opened. *a.* Cul-de-sac of the allantois, and on each side of this the umbilical vessels passing out to the chorion. In the embryo: *o.* The eye. *e.* The ear-vesicle. *h.* The heart. *l.* The liver. *u.* The upper; *p*, the lower limb. *w.* Wolffian body, in front of which are the mesentery and fold of intestine. The Wolffian duct and tubes are not represented.

(5) The development of the mesoblast from the primitive streak and its extension between the epiblast and mesoblast. (6) The formation of the "neural groove" in front of this primitive streak, caused by the growing-up of the epiblast on either side of it, so as to form two longitudinal ridges, called the "laminæ dorsales." (7) The increase and incurvation of these laminæ dorsales, until they meet dorsally and enclose the "neural canal," from the epiblastic lining of which the nervous centres are developed. (8) The formation, from the hypoblast immediately under the canal, of a continuous rod of cells, the "cauda dorsalis" or "notochord." (9) The formation, from the paraxial mesoblast, on either side of the notochord, of a number of square segments, the "protovertebræ" or "mesoblastic somites." (10) The splitting of the lateral mesoblast into two layers

to form the "somatopleure" and "splanchnopleure," the space between the two constituting the "cœlom" or "pleuro-peritoneal cavity." (11) The curving of the embryo on itself, both longitudinally and laterally, so as to be comparable to a canoe, part of the blastodermic vesicle being enclosed within the embryo to form the "primitive alimentary tube," part being left outside as the "yolk-sac," the two communicating by a duct, the "omphalo-mesenteric" duct. The yolk-sac provides nutrition to the embryo through the omphalo-mesenteric vessels until such time as the placenta is formed.

FORMATION OF MEMBRANES.

In order to have a clear understanding of the manner in which the embryo is developed, it is necessary at this stage to describe the development of the fœtal membranes.

The **membranes** investing the fœtus are the amnion, the chorion, and the decidua. The first two are developed from fœtal structures, and are proper to the fœtus; the last is formed in the uterus, and is derived from the **maternal** structures.

The Amnion.—The amnion is the innermost of the membranes which surround the embryo. It is at first of small size, but increases considerably toward the middle of pregnancy, as the fœtus acquires the power of independent movement. It exists only in reptiles, birds, and mammals, which are hence called "Amniota," but is absent in amphibia and fishes. In man, monkeys, and some of the bats, the primitive amniotic cavity, already described on page 1154, persists. In reptiles, birds, and certain mammals the amnion is formed in the following manner. At or

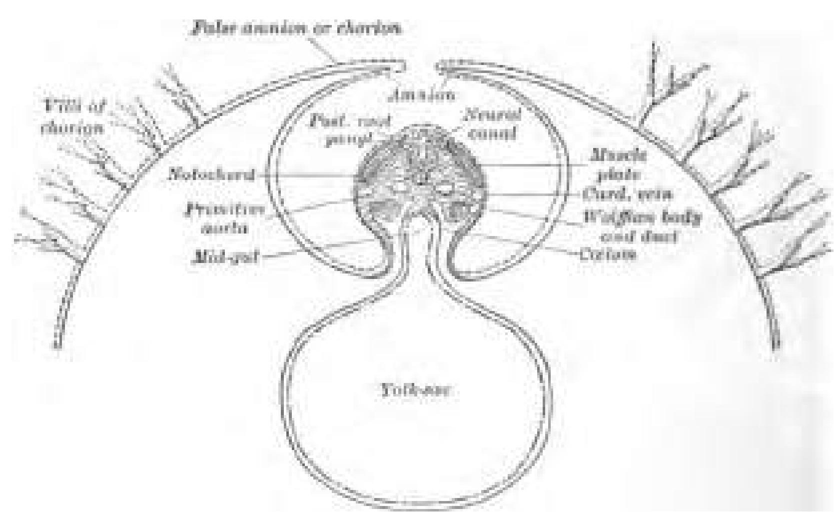

FIG. 705.—Diagram of a transverse section of a mammalian embryo, showing the mode of formation of the amnion. The amniotic folds have nearly united in the middle line. (From Quain's Anatomy, vol. i, pt. i, 1890.) Epiblast, - - - -; mesoblast, — · — · —; hypoblast and notochord, continuous line.

near the extremities of the incurved fœtus—that is to say, at the point of constriction of the blastodermic vesicle where the primitive alimentary canal of the embryo joins the yolk-sac—a reflection or folding backward of the somatopleure, which has become separated from the splanchnopleure by the formation of the pleuro-peritoneal cavity, takes place (Fig. 702, 2, 3). This fold commences first at the cephalic extremity, and subsequently at the caudal end and sides, and deepens more and more, in consequence of the sinking of the embryo into the blastodermic vesicle, until, gradually approaching, the different parts meet on the dorsal aspect of the embryo (Figs. 702, 10, and 705). After they come in contact they fuse together, and the septum between them disappears; so that the inner layer of the cephalic fold becomes continuous with the inner layer of the caudal and lateral folds, and the outer with the outer. Thus we have two membranes, one formed by the inner layer of the fold—*the true amnion*—which encloses a space over the back of the embryo—the *amniotic cavity* (Fig. 702, 4, 5)—containing a clear fluid, the *liquor amnii.* The other, the outer layer of the fold—the *false amnion*—lines the internal surface of the original zona pellucida. Between the two is an interval, which of course communicates with the pleuroperitoneal cavity until the body-walls of the embryo have coalesced at the umbilicus. Then the amniotic fold is carried downward, and encloses the umbilical cord, by which the fœtus is attached to the placenta. The true amnion—or, as it is usually called, the amnion—is formed of two layers, inner and outer, derived respectively from the epiblast and from the parietal layer of the mesoblast.

The amnion is at first in close contact with the surface of the body of the embryo, but about the fourth or fifth week fluid begins to accumulate, and thus separates the two. The quantity of fluid steadily increases up to about the sixth month of pregnancy, after which it diminishes somewhat. The use of the liquor amnii is believed to be chiefly to allow of the movements of the fœtus in the later stages of pregnancy, though it no doubt serves other purposes. It contains about 1 per cent. of solid matter, chiefly albumen, with traces of urea, the latter probably derived from the urinary secretion of the fœtus.

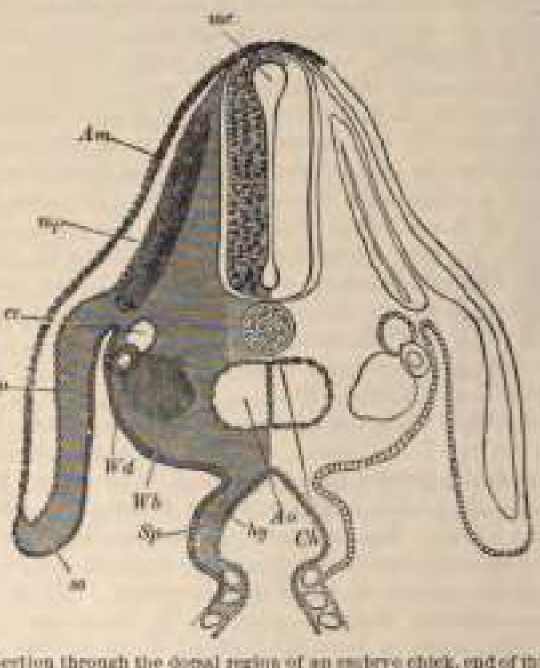

Fig. 706.—Transverse section through the dorsal region of an embryo chick, end of third day. (From Foster and Balfour.) *Am.* Amnion. *mp.* Muscle-plate. *cv.* Cardinal vein. *Ao.* Dorsal aorta, at the point where its two roots begin to join. *Ch.* Notochord. *Wd.* Wolffian duct. *Wb.* Commencement of formation of Wolffian body. *ep.* Epiblast. *So.* Somatopleure. *Hy.* Hypoblast. The section passes through the place where the alimentary canal (*hy*) communicates with the yolk-sac. *Sp.* Splanchnopleure.

The Chorion.—The chorion takes its origin, as has already been seen (page 1154), from the external covering of the blastodermic, vesicle the cells of the decidua or uterine mucous membrane contributing no elements to it. From its outer surface numerous finger-like processes, termed the *villi of the chorion*, project. These increase rapidly in size and at the same time undergo great ramification; hence they were likened by Dalton to tufts of seaweed (Figs. 705 and 708). They invade the decidua of the uterus and probably absorb from it nutritive materials for the growth of the embryo: they can be forcibly withdrawn from the decidua until the third month of pregnancy. Until about the end of the second month the villi cover the whole surface of the chorion and are of an almost uniform size, but after this they develop unequally. On that part which invades the decidua serotina they increase greatly in size and complexity, and constitute the *chorion frondosum*, which becomes the fœtal part of the placenta (Fig. 706). Over the remainder of the chorion they undergo atrophy, so that by the fourth month hardly any trace of them is left, and hence this part becomes smooth, and is therefore named the *chorion læve*. The chorionic villi are at first non-vascular, but subsequently they become vascularized by the growth into them of the allantoic mesoblast, which carries to them the branches of the allantoic arteries.

The Allantois.—The allantois grows outward as a hollow bud from the hind gut, and is therefore lined by hypoblast and covered by mesoblast (Figs. 702, 4, 5 and 704). It is projected into the space between the amnion and the chorion, and in its mesoblast are carried a pair of arteries, the *allantoic* or *umbilical arteries*, which are continued from the two primary aortæ. The allantoic mesoblast gradually spreads out on the inner surface of the chorion, and, invading the chorionic villi, supplies them with blood-vessels. In this way the allantois becomes the chief agent of the fœtal circulation, since it carries the vessels which convey the blood of the embryo to the chorion, where it is exposed to the influence of the maternal blood circulating in the decidua; from the maternal blood it imbibes the materials of nutrition and to it it gives up effete materials, the removal of which is necessary for the purification of the fœtal blood. In some animals the allantois is a hollow projection, and is usually styled the *allantoic vesicle*; but in most mammals, and especially in man, the external or mesoblastic element undergoes great development, while the internal or hypoblastic element undergoes little increase beyond the body of the embryo, so that it is very doubtful whether any cavity exists in the allantois beyond the limits of the umbilicus, or whether it does not rather consist of a solid mass of material derived from the mesoblastic tissue.[1] The proximal part of the allantoic vesicle within the body-cavity is eventually destined to form the bladder, while the remainder forms an impervious cord, the *urachus*, stretching from the summit of the bladder to the umbilicus. The part of the allantois external to the fœtus forms the umbilical cord, by which the fœtus is connected with the placenta.

The Decidua.—The growth of the chorion and placenta can be understood only by tracing the formation of the decidua.

The decidua is formed from the uterine mucous membrane before the fertilized ovum reaches the cavity of the uterus. The mucous membrane becomes vascular and tumid, its glands are greatly elongated, and their deeper portions are dilated and tortuous, while the interglandular tissue becomes crowded with epithelial-like cells (*decidual cells*). The mucous membrane, thus altered, is named the *decidua vera*; it lines the cavity of the uterus as far as the os internum, without, however, occluding the orifices of the Fallopian tubes. When the fertilized ovum reaches the uterus, which is thus prepared for its reception, it becomes attached to the decidua, in most cases in the neighborhood of the fundus uteri. The decidua then grows up around the ovum and ultimately covers it in. The part of the decidua which grows up to envelop the ovum is named the *decidua reflexa*; that portion to which the ovum originally became attached is termed the *decidua serotina*, and from it the maternal part of the placenta is derived. After conception the cervix uteri is closed by a plug of mucus (Fig. 708).

By the fourth month the decidua vera has acquired a thickness of about half

[1] Indeed, it would appear, from the researches of His, that in the human embryo the allantois is formed unusually early, being present from a very early period as a stalk of mesoblast connecting the posterior extremity of the embryo with the chorion. This stalk is termed the *abdominal stalk* (Bauchstiel).

an inch, and consists of the following strata: (1) *Stratum compactum*, next the free surface, in which the uterine glands are little altered and where they preserve a comparatively narrow lumen lined by columnar epithelium; between the glands are large numbers of decidual cells. (2) *Stratum spongiosum*, in which the gland tubes are very tortuous and greatly dilated, while their lining cells are flattened or cubical. (3) *Basal layer*, next the uterine muscular wall, in which the glands are not dilated and where they retain their columnar epithelium. It is through this basal layer that the placenta is separated after the birth of the child (Fig. 707).

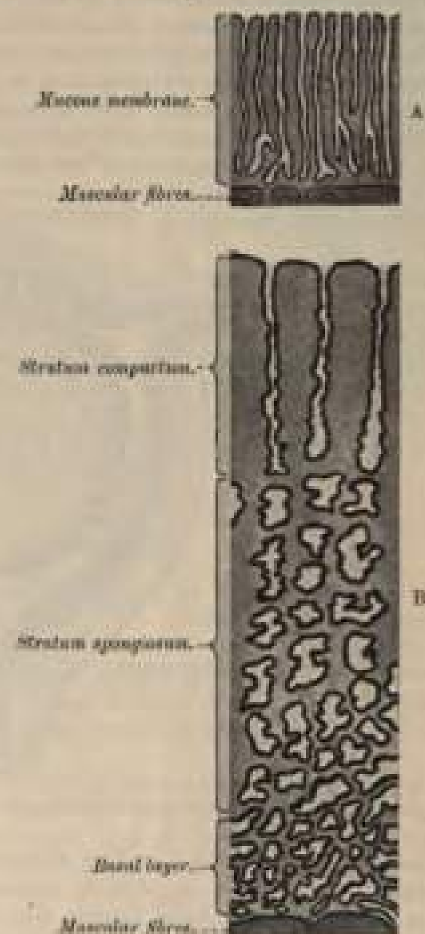

FIG. 707.—Diagrammatic sections of the uterine mucous membrane: (A) of the non-pregnant uterus; (B) of the pregnant uterus, showing the thickened mucous membrane and the altered condition of the uterine glands.

The decidua reflexa is gradually expanded by the growing ovum, and ultimately comes into contact and blends with the decidua vera so as completely to obliterate the uterine cavity. This obliteration is followed by the degeneration of the deciduæ; the glands of the decidua reflexa become atrophied, and the entire decidua practically disappears, while the decidua vera is much thinned and its glands also disappear, except their deepest portions, which persist in the basal layer.

In this manner the embryo becomes surrounded by three membranes: (1) the *amnion*, derived, in the case of reptiles, birds, and some mammals, from the outer layer of the mesoblast and the epiblast; (2) the *chorion*, formed by the allantois (which is derived from the hypoblast and inner layer of the mesoblast) and the false amnion; and (3) the *decidua*, derived from the mucous membrane of the uterus.

Much additional interest has been given to the physiology of the decidua by the fact, which seems to be now established by the researches of Sir John Williams, that every discharge of an ovum, whether impregnated or not, is, as a rule, accompanied by the formation of a decidua, and that the essence of menstruation consists in the separation of a decidual layer of the mucous membrane from the uterus; while in the case of pregnancy there is no exfoliation of the membrane, but, on the contrary, it undergoes further development in the manner described above.

Formation of the Placenta.—The placenta is developed partly from maternal and partly from fœtal tissues—the maternal portion being derived from the decidua serotina, the fœtal from the villi of the chorion frondosum. These villi penetrate the decidua serotina, which then undergoes a series of complicated and, as yet, imperfectly understood changes. Decidual cells accumulate between the uterine glands, while the glands with their epithelial lining undergo degeneration—a degeneration which does not, however, extend as deep as the basal layer, where the glands persist, and retain their epithelial lining throughout the entire period of gestation. Ultimately the superficial portion of the decidual tissue disappears, and the uterine vessels become expanded to form a labyrinth of freely communicating blood-channels or sinuses, which are filled with maternal blood, and in which are suspended the now greatly ramified tufts of the chorionic villi. These uterine sinuses anastomose freely with one another, and form, at the edge of the placenta, a venous channel with an irregular calibre, which runs round the whole circumference of the placenta, and is termed the *marginal sinus*. Some of the chorionic villi are attached by fibrous bands to the basal layer of the decidua and to the imperfect septa between the sinuses, but the majority of them hang free.

Circulation through the Placenta.—The maternal blood is brought to the

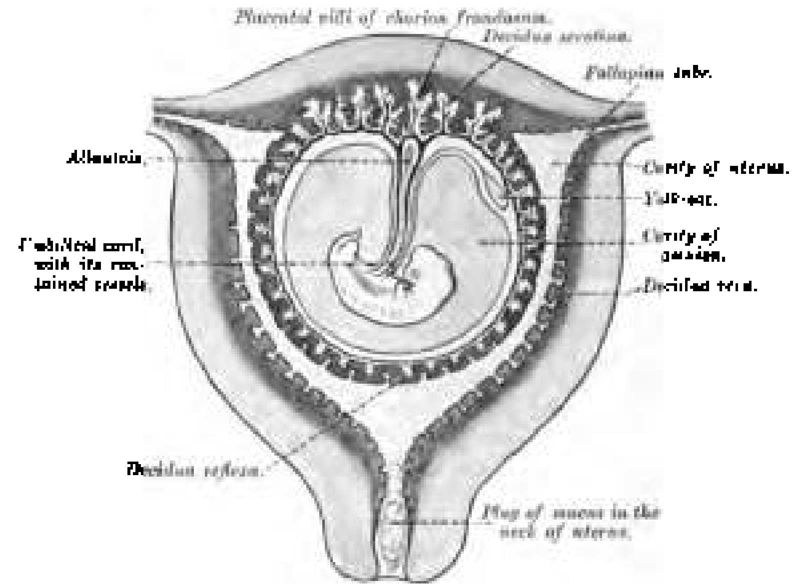

Fig. 70[illegible].—Sectional plan of the gravid uterus in the third and fourth months. (Modified from Wagner.)

uterine sinuses by the "curling arteries" of the uterus and drained away by the uterine veins, while, as already stated, within the chorionic villi are found the ramifications of the fœtal vessels derived from the allantoic or umbilical arteries. Since the villi are suspended in the sinuses, they are necessarily bathed in the maternal blood, and hence it follows that the maternal and fœtal blood-currents are brought into close relationship. There is, however, no intermingling of the two currents, or, in other words, no direct communication between the vascular system of the mother and that of the fœtus, the interchange of materials necessary for the growth of the fœtus and for the purification of the fœtal blood taking place through the walls of the villi. The purified blood is carried back to the fœtus by the umbilical vein. From what has been said, it will be understood that the placenta is the organ by which the connection between the fœtus and the mother is established, and which subserves the purposes of nutrition, respiration, and excretion.

Placenta.—At the end of the gestation period the placenta presents the form of a disk which weighs about a pound and has a diameter of from six to eight inches. Its average thickness is about an inch and a quarter, but diminishes rapidly near the circumference of the disk. Its outer or *decidual* surface blends with the uterine wall, but if examined after the separation of the placenta, it presents a comparatively smooth surface, which on inspection is seen to be incompletely divided into a number of masses named *cotyledons*. Its inner or *chorionic surface* is smooth, being closely invested by the amnion. The umbilical cord is attached near the centre of this surface, and from this attachment the larger branches of the umbilical vessels are seen radiating under the amnion. On section the placenta presents a soft, spongy appearance, caused by its freely communicating blood-sinuses with their contained villi. Owing to the rapid thinning of the placenta at the periphery of the disk, the decidual and chorionic surfaces come into contact.

Separation of the Placenta.—After the birth of the child the placenta and the membranes (*i. e.*, the amnion and chorion) are expelled as the *after-birth*, the separation of the placenta from the uterine wall taking place through the basal layer of the decidua and necessarily causing rupture of the uterine vessels. The orifices of the torn vessels are, however, closed by the firm contraction of the uterine muscular fibres, and this, together with the formation of a blood clot over the placental site, prevents *post-partum hemorrhage*. The epithelial lining of the uterus is regenerated from the epithelium which lines the persistent portions of the uterine glands in the basal layer of the decidua.

The **umbilical cord** appears about the end of the fifth week after conception. It consists of the coils of two arteries and a single vein, the *umbilical arteries and vein*, united together by a gelatinous tissue (*jelly of Wharton*). There are originally two umbilical veins, but one of these vessels becomes obliterated, as do also the two omphalo-mesenteric arteries and veins and the duct of the umbilical vesicle, all of which are originally contained in the rudimentary cord. The umbilical cord also contains the remains of the allantois, and is covered externally by a layer of the amnion, reflected over it from the umbilicus.

DEVELOPMENT OF THE EMBRYO.

The further development of the embryo will, perhaps, be better understood if we follow briefly the principal facts relating to the development of the chief parts of which the body consists, viz., the spine, the cranium, the pharyngeal cavity, mouth, etc., the nervous centres, the organs of the senses, the circulatory system, the alimentary canal and its appendages, the organs of respiration, and the genito-urinary organs. The reader is also referred to the chronological table of the development of the fœtus at the end of this section.

Development of the Spine.—The first steps in the formation of the spine have already been traced, viz.: (1) The looping up of two longitudinal folds from the cells of the epiblast in front of the primitive streak, to form the *neural groove*, and the gradual growing together of the *laminæ dorsales* so as to convert the groove into the *neural canal*. (2) The formation on the ventral aspect of this groove of a continuous cellular cord, the *notochord* or *chorda dorsalis* (Fig. 700), which extends from the cephalic to the caudal extremity of the embryo, and lies in the situation which is afterward occupied by the bodies of the vertebræ. (3) The segmentation of the paraxial mesoblast on either side of the neural canal into a number of quadrilateral masses, the *protovertebræ* or *mesoblastic somites* (Fig. 701). The process of segmentation commences in the cervical region and proceeds successively through the other regions of the spine until a number of segments are formed, which correspond very closely to the number of the permanent vertebræ. Subsequently the protovertebral somites divide into two parts—a ventral and a dorsal. From the ventral division the vertebræ are formed; the dorsal is termed the *muscle-plate*, and from it the muscles of the back are developed. From the ventral division of the protovertebral somites masses of cells are budded off, which grow inward toward the middle line, those from opposite sides meeting and enclosing the notochord and extending dorsally around the neural canal, which they also envelop. Fusion of the ventral divisions also occurs in the antero-posterior direction, so that all trace of their originally segmented condition is lost and the notochord and spinal cord are surrounded by a continuous investment of mesoblast, the *membranous vertebral column*. This investment also extends forward and envelops the primitive brain, forming the *membranous* or *primordial cranium*. From this investment the base of the skull, the vertebræ and their ligaments, and the membranes of the cerebro-spinal nervous system are developed. The future vertebræ make their first appearance about the beginning of the second month in the form of two small masses of cartilage which

are seen in the membranous vertebral column, one on each side
These small masses lie opposite to the intervals between the m
alternate with these structures. They are soon joined across
the ventral aspect of the no
chordal cartilaginous bar, w
appears, except in the case
tebra, where it forms the an
bone. The vertebral bodie
diately to the dorsal aspe
chordal bars, alternating wi
which represent the ori
somites. The notochord con
of this chondrifying mass
to grow, but becomes in t
relatively smaller, so as,
mere slender thread, excep
tervals between the bodies
vertebræ. Here it presen

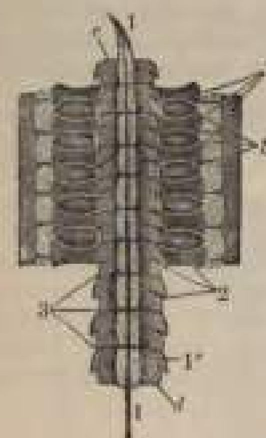

FIG. 709.—Cervical part of the primitive vertebral column and adjacent parts of an embryo of the sixth day, showing the division of the primitive vertebral segments. (From Kölliker, after Remak.) 1, 1. Chorda dorsalis in its sheath, pointed at its upper end. 2 points by three lines to the original intervals of the primitive vertebræ. 3, in a similar manner, indicates the places of new division into permanent bodies of vertebræ. c indicates the body of the first cervical vertebra; in this and the next the primitive division has disappeared, as also in the two lowest represented, viz. d and the one above; in those intermediate the line of division is shown. 4 points in three places to the vertebral arches; and 5, similarly, to three commencing ganglia of the spinal nerves; the dotted segments outside these parts are the muscular plates.

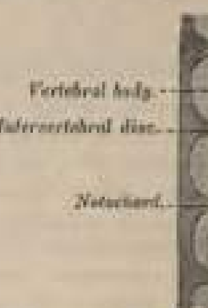

FIG. 710.—Longitudinal section o
eight weeks' human fœtus. (Kölliker

forms an irregular network, the remains of which are to be
of life in the central pulp of the intervertebral disks (Figs. 709
Development of the Ribs and Sternum.—The ribs are form
plates of the protovertebral somites, from which also the muscl
the true skin of the body-wall are formed. The ribs consist o
mesoblastic material, which speedily undergo chondrification, a
laginous bars, which become separated from the vertebræ at thei
ties. At their anterior ends the nine upper costal bars tur
together so as to form a cartilaginous strip bounding a central r
strips on either side then join in the middle line from before ba
rise to a longitudinal piece of cartilage, which represents the m
olus of the sternum. In the process of development the stern
eighth rib disappears, while that of the ninth subdivides, on
attached to the inferior extremity of the cartilaginous ster
developed into the ensiform cartilage, the other portion recedi
and becoming attached to the cartilage of the eighth rib.
The further development of the vertebræ, ribs, and sternu
tion of their cartilaginous framework, are described in the bod
Development of the Cranium and Face.—It has been seen th
the embryo consists in the formation of a longitudinal fold of t
side of the neural groove, and that these folds or ridges grow
in the median line, thus forming the neural canal. This ca
extremity of the embryo, is dilated and forms a bulbous enla
bous enlargement soon expands into three vesicular dilatations

cerebral vesicles, from which all the different parts of the encephalon are developed. The primary cerebral vesicles at this time freely communicate with each other at the points of constriction.

The three cavities are lined by epiblast and covered by the same structure. Between these two layers of epiblast a layer of mesoblast spreads over the whole surface of the cerebral vesicles and forms the membranous cranium. From these structures the cranium and its contents are developed. The external layer of the epiblast forms the epidermis and hairs of the scalp. The mesoblastic layer forms the true skin, the blood-vessels (all but their endothelial lining), muscles, connective tissue, bones of the skull, and membranes of the brain. The layer of epiblast lining the vesicles forms the nervous substance of the encephalon, while the vesicles themselves constitute the ventricles.

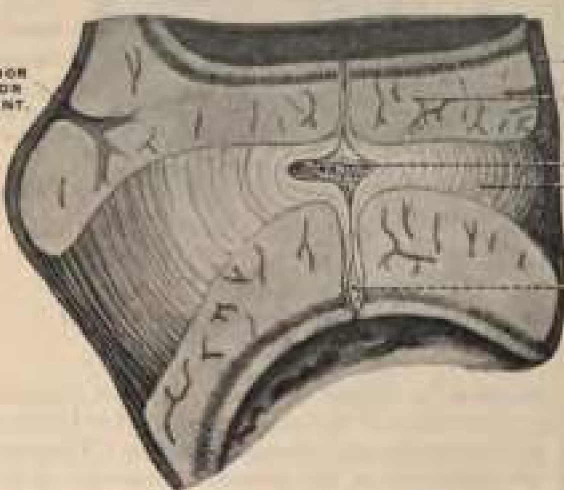

FIG. 711.—Sagittal section through the intervertebral disk and adjacent parts of two vertebræ of an advanced sheep's embryo. (Kölliker.)

The cephalic end of the notochord terminates in a pointed extremity which extends as far forward as the situation of the future basi-sphenoid, and is imbedded in a mass of mesoblast, the "investing mass of Rathke." The posterior part of this mass, which corresponds to the future basi-occipital, shows a subdivision into four segments, the three roots of the hypoglossal nerve indicating their lines of separation. Two cartilaginous bars, the *parachordal cartilages*, then become developed in this investing mass, and these surround the notochord, meeting first on its ventral and next on its dorsal aspect to form the *basilar plate*, the anterior margin of which forms the future dorsum sellæ. From this plate are developed the basi-occipital and basi-sphenoid, and by lateral expansions from it the ex-occipitals and the greater wings of the sphenoid. On either side of the parachordal cartilage a cartilaginous capsule, the *labyrinthine* or *periotic cartilage*, surrounds the otic vesicle, and from it the petrous and mastoid portions of the temporal bone are developed. In front of the investing mass of Rathke two lateral bars are directed forward, enclosing between them a space, which forms the pituitary fossa, in which the pituitary body is eventually developed. These bars are named the *prechordal cartilages* or *trabeculæ cranii*, and extend as far forward as the anterior extremity of the head, where they coalesce with each other to form the *ethmoid plate* (Fig. 712). This encloses the olfactory pits forming the cartilaginous nasal capsule, from which the ethmoid and turbinated bones are developed. A portion of the ethmoid plate remains unossified and constitutes the cartilaginous part of the nasal septum and the cartilages of the outer nose. From the trabeculæ cranii the presphenoid is developed, and from this two lateral expansions extend to form its lesser wings; each of these arises by two roots, one above and one below the optic nerve, and, uniting outside the nerve, enclose the optic foramen. The base of the primitive cranium therefore consists of two parts, *prechordal* and *parachordal*; the former receives the organ of smell and is indented by the eyeball; the latter surrounds the auditory vesicle. Thus it will be seen that the bones which form the

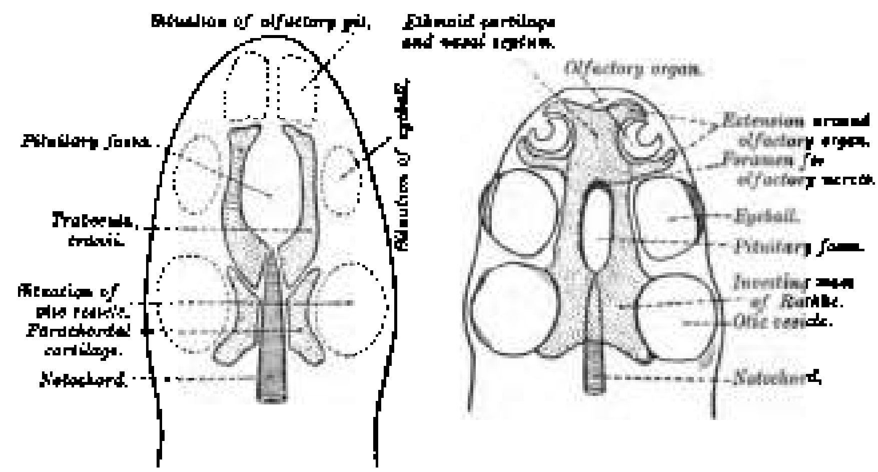

FIG. 712.—Diagrams of the cartilaginous cranium. (Wiedersheim.)

base of the skull are preceded by masses of cartilage, which together form the *chondrocranium*. Those of the vault of the skull, on the other hand, are of membranous formation, and are termed *dermal* or *covering bones*. They are developed in the mesoblast which lies superficial to the primordial cranium, or in that which lies subjacent to the epithelial lining of the foregut. They comprise the upper portion of the tabular part of the occipital (interparietal), the squamous-temporals and tympanic rings, the two parietals, the frontal, the vomer, the internal pterygoid plates, and the bones of the face. Some of them remain distinct throughout life (*e. g.*, parietal and frontal), while others join with the bones of the chondrocranium (*e. g.*, interparietal, squamous-temporal, and internal pterygoid plates).

The head at first consists simply of a cranial cavity, the face and neck being subsequently developed in the manner now to be described.

In all vertebrate animals there is at one period of their development a series of grooves in the upper neck region of the embryo. These are named the *branchial* or *visceral clefts*, and in man are four in number from before backward. They take origin as paired grooves or pouches from the side of the pharynx, and over each groove a corresponding indentation of the epiblast occurs, so that the latter comes into contact with the hypoblast lining the pharynx, and these two layers unite to form thin septa, along the bottom of the grooves, between the pharyngeal cavity and the exterior. In gill-bearing animals these septa disappear and the grooves become complete clefts, the gill clefts, opening from the pharynx on to the exterior; perforation does not, however, occur in birds and mammals. In front and behind each cleft the mesoblast becomes thickened in the form of arches, the *branchial arches* (Figs. 713, 750). In the human embryo there are five pairs of these arches, one in front of the first cleft, one behind the last, and the three remaining ones between the first and second, the second and third, and the third and fourth clefts, respectively. The first arch is named the *mandibular*; the second the *hyoid*; the third the *thyro-hyoid*, while the fourth and fifth have no distinctive names. In each arch there is developed a cartilaginous bar which gives it firmness and stability, and in each there is also found one of the primitive aortic arches. Continuous with the dorsal end of the first arch and growing forward from it is a triangular process, the *maxillary process* (Figs. 714, 716, 738). Ventrally it is separated from the mandibular arch by a V-shaped notch; the first branchial arch may therefore be said to divide into two, viz., the mandibular arch

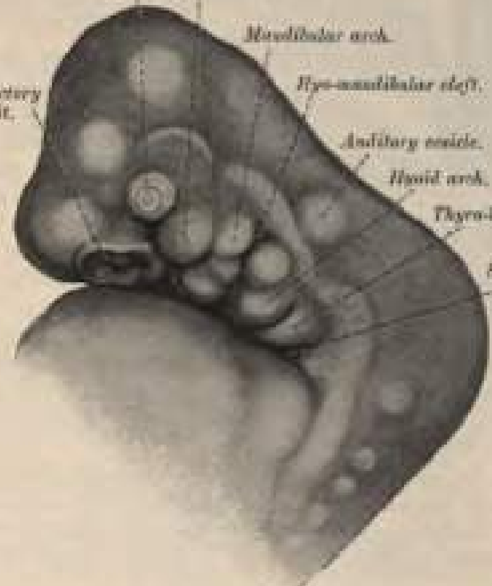

Fig. 713.—Profile view of the head of a human embryo, estimated as twenty-seven days old. (After His.)

and the maxillary process. In front of the mandibular arch is a pentagonal depression, termed the *oral sinus* or *stomodæum*, since it forms the future mouth. It is bounded anteriorly by a median process, the *fronto-nasal* process, and laterally by the maxillary processes (Fig. 714), and will be referred to again.

These parts must now be considered with a little more detail.

The *fronto-nasal process* covers the forebrain and contains the coalesced portion of the trabeculæ cranii; it consists of a central or *mid-frontal* process and two lateral parts. By the invagination of the *olfactory pits*, which communicate below with the cavity of the mouth, each lateral portion is subdivided into an *outer* and an *inner nasal process*—the latter having been termed by His the *processus globularis*. The lateral nasal process is separated from the maxillary process by a groove which extends from the eye to the olfactory pit; this is the rudiment of the lachrymal duct (Figs. 714, 715, and 716). The globular processes are prolonged backward as plates, termed the *nasal laminæ;* these laminæ are at first some distance apart, but, gradually approaching, they ultimately fuse and form the nasal septum, while the globular processes themselves meet in the middle line and form the præmaxillæ and central part of the upper lip (Fig. 717). The depressed part of

Fig. 714.—Under surface of the head of a human embryo, about twenty-nine days old. (After His.)

the midfrontal process between the globular processes forms th
nasal septum, w
seen a prominen
comes the futur
higher, a flat are
of the nose (Fig
alæ of the nose i
the lateral nasal
The *maxill*
scend for a short
the outer wall of
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then incline in
the lateral nasa
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from the rest c
tinuing their co
inward, they joi

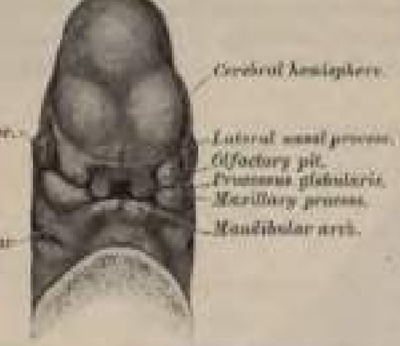

FIG. 715.—Under surface of the head of a human embryo, about thirty days old. (After His.)

esses, and with them complete the alveolar arch and upper l
of palatal processes are formed by inward extensions of the m
these coalesce with each other in the median line, thus separatin
mouth from the nasal fossæ, and completing the palate (Fig. 7
palatal processes join with the premaxillæ, except in the middle
remains which constitutes the naso-palatine canal.

The *mandibular* arch, by its junction with the corresponding
side, forms the lower jaw or mandible. The cartilaginous rod w
long been known as the "cartilage of Meckel." The proximal
is in contact with the periotic capsule, and from it are developed

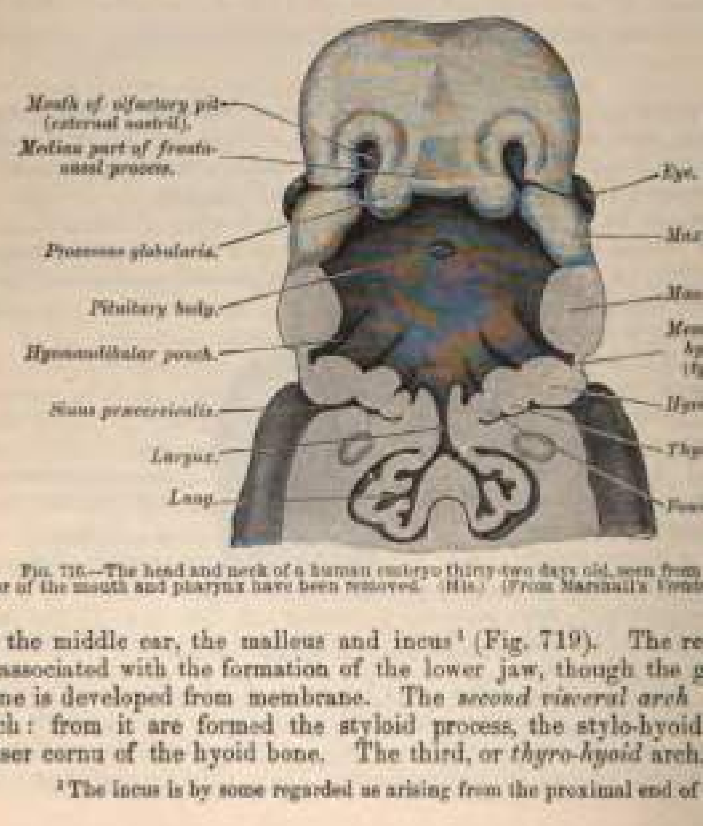

FIG. 716.—The head and neck of a human embryo thirty-two days old, seen from
floor of the mouth and pharynx have been removed. (His.) (From Marshall's Verte

of the middle ear, the malleus and incus[1] (Fig. 719). The re
is associated with the formation of the lower jaw, though the g
bone is developed from membrane. The *second visceral arch*
arch: from it are formed the styloid process, the stylo-hyoid
lesser cornu of the hyoid bone. The third, or *thyro-hyoid* arch,

[1] The incus is by some regarded as arising from the proximal end of

great cornu of the hyoid bone, while the body of this bone is formed between the second and third arches. The *fourth* and *fifth* arches are rudimentary.

Between the maxillary processes and the mandibular arch the buccal cavity or mouth is formed. As has already been stated (page 1157) the cephalic end of the

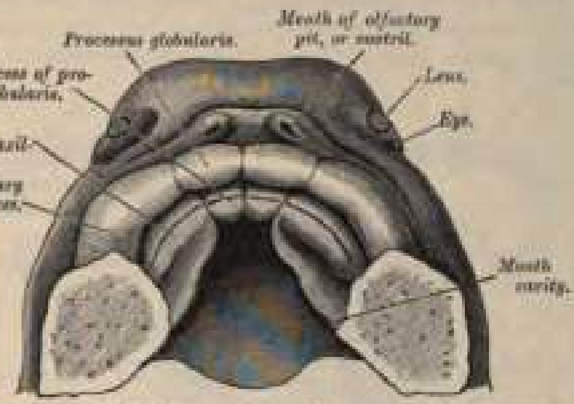

FIG. 717.—The roof of the mouth of a human embryo of about two and a half months old, showing the mode of formation of the palate. (His.) (From Marshall's *Vertebrate Embryology*.)

embryo becomes remarkably curved on itself, the fore-brain and mid-brain bending downward over the anterior portion of the original blastodermic vesicle, which is thus enclosed within the body of the embryo and constitutes the fore-gut; the fore-gut terminates in a blind extremity beneath the head (Figs. 720 and 759). Another prominence, the rudimentary heart, appears on the ventral surface of the fore-gut. Between these two prominences, caused by the projection of the fore-brain and the heart, an involution of the epiblast takes place, gradually deepening until it comes in contact with the blind end of the fore-gut. This is the *oral pit* or *stomodæum*, already referred to; it presents the form of a pentangular opening, bounded in front by the fronto-nasal process, behind by the mandibular arch, and laterally by the maxillary processes. From the beginning the mesoblast is absent in the region of the oral pit, and hence its epiblastic lining meets the hypoblastic covering of the blind anterior end of the fore-gut and forms a thin septum, the *pharyngeal septum* (Fig. 759); this soon breaks down, and a communication is established between the mouth and the future pharynx. The oral pit or stomodæum is not equivalent in extent to the adult mouth, since the latter includes the tongue, which is developed from the floor of the pharynx; in fact, as His has pointed out, the anterior pillars of the fauces are developed from the second branchial or hyoid arch.

FIG. 718.—Head of a human embryo of about eight weeks, in which the nose and mouth are formed. (His.)

From the upper part of the stomodæum a pocket-like involution of the epiblast, the *pouch of Rathke*, extends upward between the trabeculæ cranii toward the thalamencephalon. This involution ultimately loses its connection with the stomodæum, and, becoming applied to the infundibulum, forms the anterior lobe of the pituitary body (Fig. 720).

The anterior visceral arches grow more rapidly than the posterior, with the result that the latter become telescoped within the former, and a deep depression, the *sinus præcervicalis*, is produced. This sinus is bounded in front by the hyoid arch, and ultimately becomes obliterated by the fusion of its anterior and posterior walls.

Before leaving the subject of the visceral arches and clefts it is necessary to mention that the clefts disappear early in embryonic life, with the exception of portions of the first, which remain permanent—the inner portion, or the Eustachian tube and tympanum; the outer, as the external auditory meatus, while the septum

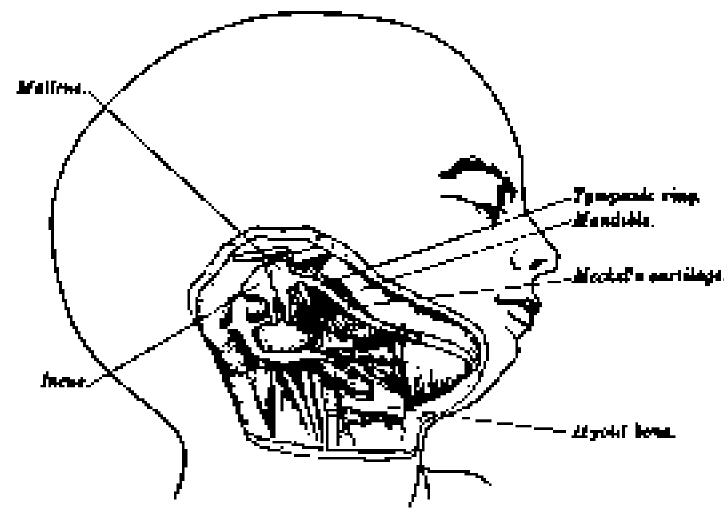

Fig. 719.—Head and neck of a human embryo eighteen weeks old, with Meckel's cartilage and hyoid bar exposed. (After Kölliker.)

between the two portions becomes invaded by mesoblast and forms the membrana tympani.

Development of the Nervous Centres and the Nerves.—The medullary or neural groove already described (page 1155) is the rudiment of the cerebro-spinal axis. As has been seen, this groove is converted into a canal (the neural canal): its cephalic end becomes dilated into a sac, from which the brain is developed; the remainder forms the spinal cord. The cavity of the canal becomes the central canal of the spinal cord, and that of the upper dilated portion the ventricles of the brain. The wall of the canal, formed of epiblastic cells, undergoes great changes, and from it the nervous matter and neuroglia are developed. It consists at first of a layer of columnar epithelium, covered on its exterior by a basement-membrane. The wall becomes thickened, partly by the elongation of the columnar cells and partly by the formation of new cells. The elongation of the columnar cells, now called *spongioblasts*, is followed by the breaking up of their outer ends into a reticulum, which is termed the *myelo-spongium*, and eventually forms the neuroglia. The new cells which are formed appear between the inner ends of the columnar cells as rounded masses, which speedily divide, and are termed *neuroblasts;* they become pear-shaped, and projecting from each of them is a tapering process which perforates the basement-membrane. These neuroblasts are the primitive nerve-cells, and their tapering processes the rudimentary axis-cylinders of the cells (Figs. 721 and 722).

It will be convenient, in the first place, to trace the changes which take place in the cavity of the cerebro-spinal axis, ignoring for a time those which go on in the enclosing wall. But before doing so, it is necessary to mention that in consequence of the curve which the cephalic portion of the embryo undergoes, a marked bend forward of the canal takes place, so that the plane of the ventricles is almost at right angles with the long axis of the central canal of the cord.

The early stage thus consists of a hollow sac, which is the rudimentary brain, and a hollow canal, which is the rudimentary cord; the sac and the canal freely communicate with each other. The sac first of all becomes elongated; then two constrictions appear in it, which partially divide it into three; these are named *anterior, middle,* and *posterior cerebral vesicles,* or the *fore-brain, mid-brain,* and *hind-brain* (Fig. 701). Subsequently the anterior and posterior vesicles each become constricted into two, while the middle one remains undivided. It will thus be seen that at the anterior extremity of the medullary canal there are five dilatations, separated from each other by constrictions, through which, however, they freely communicate with each other. These five vesicles are the five fundamental divisions of the adult brain, and are named from before backward: prosencephalon, thalamencephalon, mesencephalon, epencephalon, and metencephalon (Figs. 723

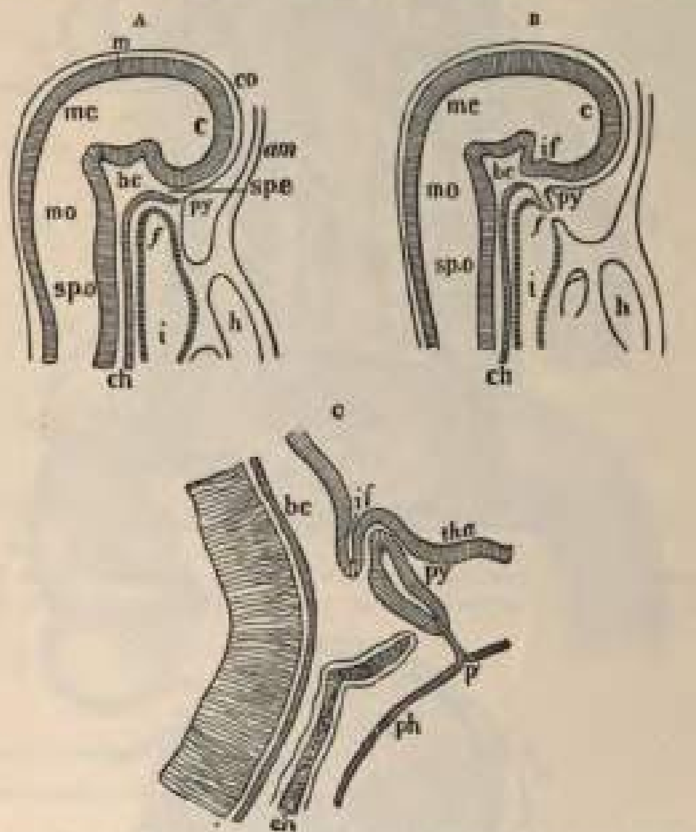

FIG. 724.—Vertical section of the head in early embryos of the rabbit. Magnified. (From Mihalkovics.) A. From an embryo five millimetres long. B. From an embryo six millimetres long. C. Vertical section of the anterior end of the notochord and pituitary body, etc., from an embryo sixteen millimetres long. In A, the faucial opening is still closed. In B, it is formed. *c.* Anterior cerebral vesicle. *mc.* Mesocerebrum. *mo.* Medulla oblongata. *co.* Corneous layer. *m.* Medullary layer. *if.* Infundibulum. *am.* Amnion. *spe.* Spheno-ethmoidal. *bc.* Central (dorsum sellæ), and *spo.* spheno-occipital parts of the basis-cranii. *h.* Heart. *f.* Anterior extremity of primitive alimentary canal and opening (later) of the fauces. *i.* Cephalic portion of primitive intestine. *tha.* Thalamus. *p'.* Closed opening or the involuted part of the pituitary body (*py*). *ch.* Notochord. *ph.* Pharynx.

and 725). They are at first fairly uniform in size and shape, but soon begin to grow at different rates and assume different forms. The changes are most marked in the first vesicle.

The first secondary vessel (*prosencephalon*) sends out two hollow protrusions, one on either side, from the forepart of its lateral surface; these grow rapidly and spread out and extend forward, laterally, and backward over the sides of the first and second vesicles, forming large cavities, which become the lateral ventricles (Fig. 725, C). From each, three prolongations take place: one, forward and outward; a second, backward and inward; and a third, at first backward, outward, and downward, and then forward and inward; these form the horns of the lateral ventricles. These prolongations far exceed in size the original vesicle from which they sprung, which does not increase to any great extent. It remains as the anterior part of the third ventricle (Fig. 725, A), and the communication between it and the future lateral ventricle persists as the *foramen of Monro* (Fig. 725, M).

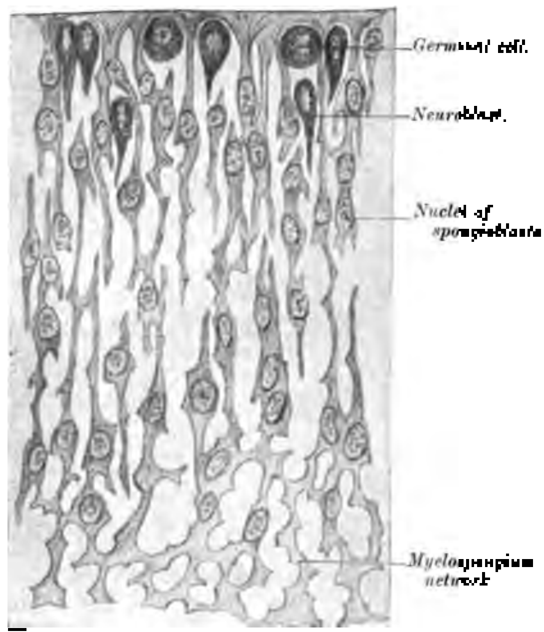

FIG. 721.—Transverse section of the spinal cord of a human embryo at the beginning of the fourth week. (After His.) The top of the figure corresponds to the lining of the central canal.

The second vesicle (*thalamencephalon*) becomes elongated from before backward and compressed laterally so as to form the greater part of the third

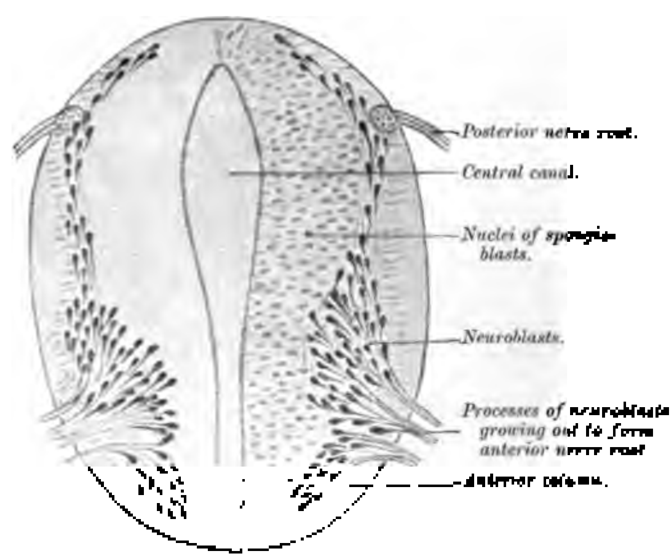

FIG. 722.—Section of spinal cord of a four weeks' embryo. (His.)

ventricle (Fig. 725, D). From each side of that part of the forebrain which ultimately becomes the second vesicle is budded off a hollow projection, the primary optic vesicle, which is developed eventually into optic nerve and retina: it will be considered later on. The constriction between the first and second vesicle disappears, so as to throw the whole of the cavity (the future third

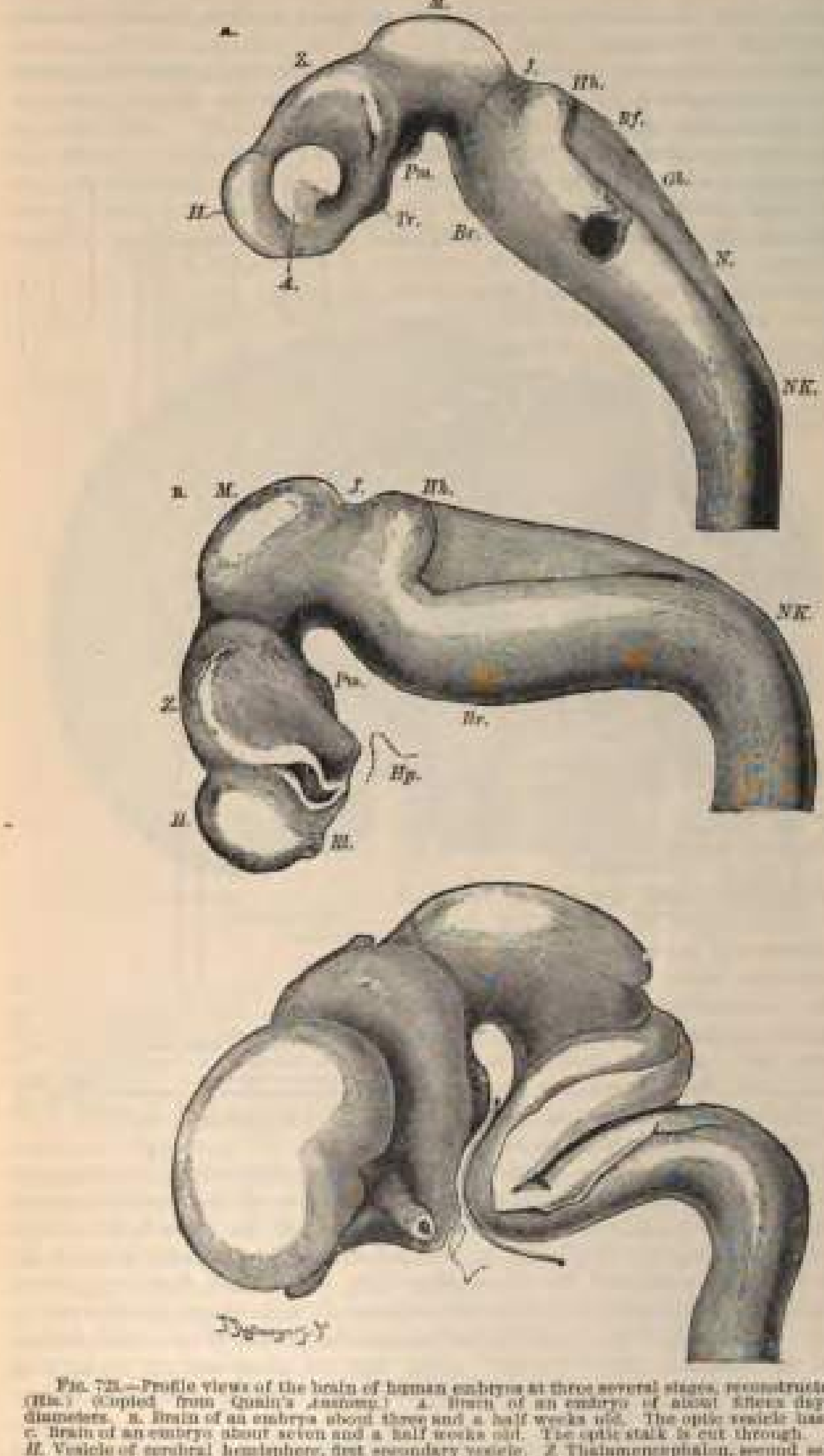

FIG. 723.—Profile views of the brain of human embryos at three several stages, reconstructed from sections. (His.) (Copied from Quain's *Anatomy.*) A. Brain of an embryo of about fifteen days, magnified 25 diameters. B. Brain of an embryo about three and a half weeks old. The optic vesicle has been cut away. C. Brain of an embryo about seven and a half weeks old. The optic stalk is cut through. *A.* Optic vesicle. *H.* Vesicle of cerebral hemisphere, first secondary vesicle. *Z.* Thalamencephalon, second secondary vesicle. *M.* Mid-brain. *J.* Isthmus between mid- and hind-brain. *Hh.* Fourth secondary vesicle. *N.* Fifth secondary vesicle. *Gh.* Otic vesicle. *Rf.* Fourth ventricle. *NK.* Neck curvature. *Br.* Pons curvature. *Pm.* Mammillary process. *Tr.* Infundibulum. *Hp.* (in B). Outline of hypophysis-fold of buccal epiblast. *Ri.* Olfactory bud. In C the basilar artery is represented along its whole course.

ventricle), formed by the remains of the first vesicle and the whole of the second vesicle, into one.

The third vesicle (*mesencephalon*) is converted into a narrow channel, the *iter a tertio ad quartum ventriculum* (Fig. 725, C).

The fourth vesicle (*epencephalon*) becomes widened out, and assumes a triangular form, with its apex directed forward, and situated at the original point of constriction where the third vesicle joins the fourth. It is at the same time flattened from above downward, and constitutes the anterior half of the fourth ventricle (Fig. 725, D).

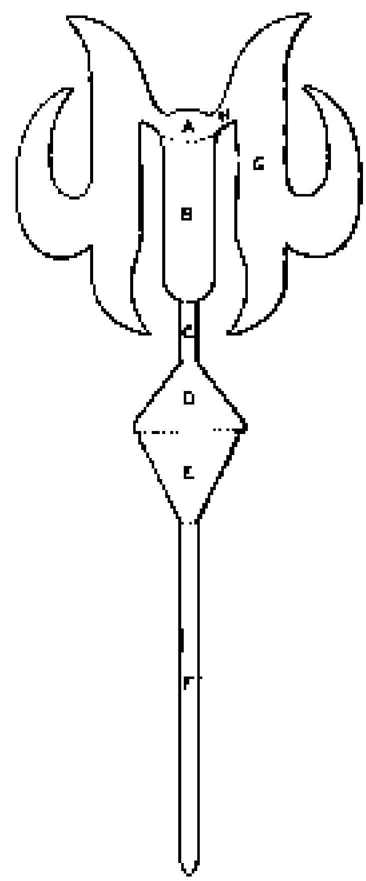

Fig. 725.—Plan showing the mode of formation of the ventricles of the brain and the central canal of the spinal cord (After Gerlach). A. Prosencephalon. B. Thalamencephalon. C. Mesencephalon. D. Epencephalon. E. Metencephalon. F. Central canal of cord. G. Lateral ventricle. H. Foramen of Monro.

The fifth vesicle (*metencephalon*) undergoes the same change in form as the fourth, becoming triangular in shape and flattened from above downward, but with this difference, that the apex of the triangle is directed backward, and is continuous with the portion of the medullary

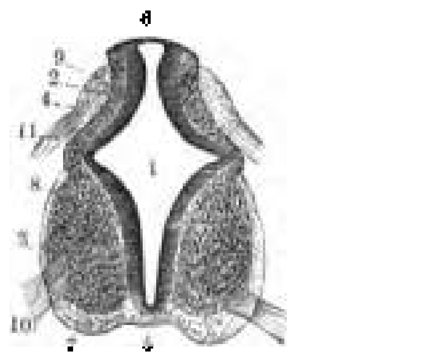

Fig. 724.—Section of the medulla in the cervical region, at six weeks. Magnified 50 diameters. 1. Central canal. 2. Neuroepithelium. 3. Anterior gray matter. 4. Posterior gray matter. 5. Anterior commissure. 6. Posterior portion of the canal, closed by the epithelium only. 7. Anterior column. 8. Lateral column. 9. Posterior column. 10. Anterior roots. 11. Posterior roots.

canal which goes to form the central canal of the spinal cord (Fig. 725, E). The base is directed forward and is continuous with the base of the triangular space formed by the fourth vesicle; the constriction between the two vesicles having disappeared, the two spaces freely communicate, and together form a rhomboidal cavity which is the fourth ventricle.

These vesicles do not remain in the same plane, but certain definite flexures take place, which result in an alteration of the position of the vesicles to one another. The first of these flexures (*cephalic*) is opposite the base of the middle vesicle, which becomes sharply bent on itself over the end of the notochord. This has the effect of causing the mid-brain to become the most prominent part of the encephalon on the convexity of the curve (Fig. 723). A second flexure (*pontal*) with its curve in the opposite direction, takes place in the epencephalon, and is very abrupt. A third but less marked flexure (*nuchal*) takes place in the metencephalon at its junction with the cord. The first of these curves or flexures remains permanent, but the second and third almost entirely disappear in the further development of the brain.

The manner in which the different parts of the encephalon and cord are formed from the walls of this greatly altered medullary canal must now be considered, and it will be convenient first of all to study the development of the spinal cord.

The lateral walls of the medullary canal become thickened and marked off into two laminæ: a dorsal, or *alar lamina*, and a ventral, or *basal lamina*, the portion of the canal in the mid-line both on its dorsal and ventral surfaces remaining thin, and form the *roof* and *floor plates* respectively (Fig. 724). In the thickened lateral portion the neuroblasts begin to collect into groups; one especially being noticeable in the basal lamina at the situation of the future anterior horn. The processes of this group of cells pass out of the cord and form the anterior nerve-roots: outside this group of cells is the reticulated tissue of the myelospongium, which represents the white matter at this stage, and through which these processes pass obliquely before they leave the cord (Fig. 722). The anterior and posterior columns make their appearance soon after, and as the cornua

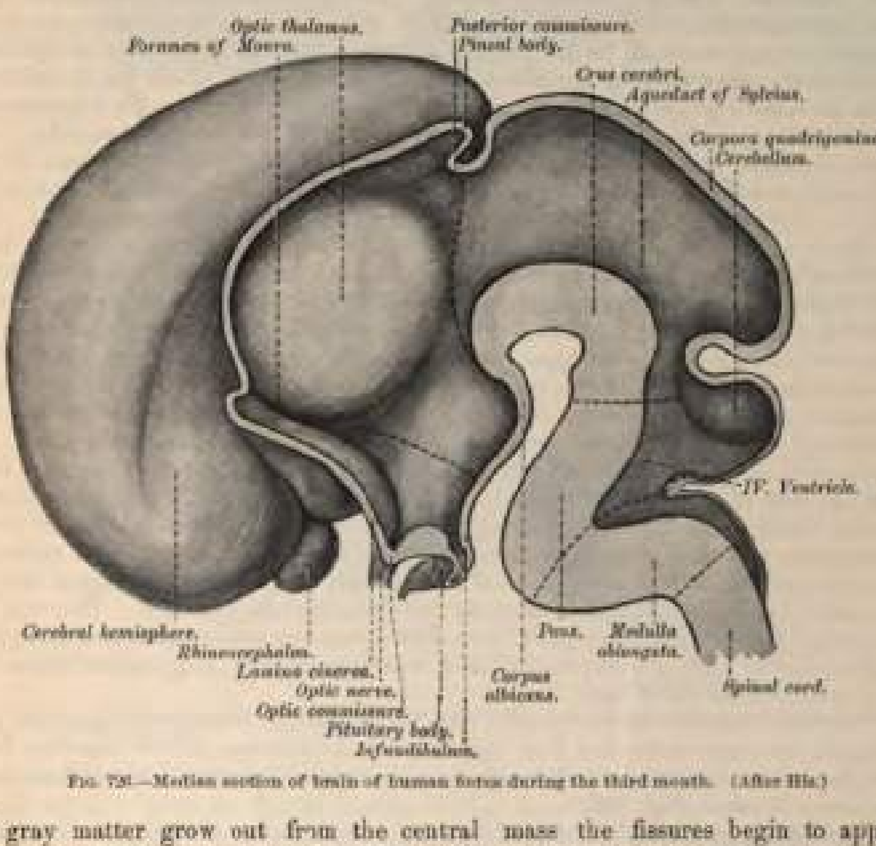

FIG. 725.—Median section of brain of human fœtus during the third month. (After His.)

of gray matter grow out from the central mass the fissures begin to appear. The anterior fissure is a cleft left between the lateral halves of the cord. The mode of formation of the posterior fissure is uncertain; many believe that it is a portion of the neural canal, which, dividing into two, forms an anterior part, the *permanent* canal, and a posterior portion, which becomes filled with a septum of connective tissue from the pia mater, and forms the posterior fissure of the cord. Others are of opinion that it is developed independently of the central canal, as a cleft formed by the enlargement of the lateral halves of the cord, into which an ingrowth of connective tissue from the pia mater takes place.

At first the fœtal spinal cord occupies the whole length of the spinal canal, but after the fourth month the spinal column begins to grow in length more rapidly than the cord, so that the latter no longer occupies the lower part of the canal.

The ventricles of the encephalon are developed in the manner above described from the five secondary vesicles into which the primary expansion of the anterior extremity of the medullary tube is differentiated.

The first vesicle or prosencephalon sends out two hollow spread rapidly, and in the walls of these nervous matter is de stitutes the cerebral hemispheres (Fig. 723, H), the cavitie lateral ventricles. As these hemispheres extend they grow the anterior extremity of the primitive brain, and lie side by si longitudinal fissure; they also grow upward, and again lyin separated by another portion of the same fissure, containin mesoblast, which forms the falx cerebri; behind and laterally t and sides of the other cerebral vesicles, so that by the seventh behind them. In the floor of each of these hemispheres t thickening, which forms the *corpus striatum*, which is continu optic thalamus, presently to be described. The surface of t first smooth, but about the fifth month a sulcus or groov hemisphere just external to the corpus striatum; this is the subsequently other fissures appear on the surface, three of wh depth to cause a projection into the lateral ventricle. These fissure, corresponding to the hippocampus major of the late parieto-occipital fissure, corresponding with the bend of the p ventricle; and the calcarine fissure, corresponding with the proj avis.

The remainder of the first vesicle and the second, as the third ventricle; in its normal walls a thickening takes pla *optic thalamus.* From the floor of this ventricle a hollow prot ward, and is intimately connected with a diverticulum from form the *pituitary body or hypophysis cerebri* (Figs. 720, 7 greater part of the roof of the third ventricle is very thin, and forms the *velum interpositum;* from its posterior part an outgr the *pineal body* or *epiphysis cerebri.* Where the cerebral h separated in the middle line by the falx, in front and for some over the roof of the third ventricle their mesial surfaces come certain extent fuse together, leaving however a small porti takes place, and thus a slit-like cavity is left; this is termed though it will be at once seen that its development is quite dif the other ventricles. Its lateral walls form the *septum luci* this cavity becomes thickened, and nerve-fibres pass across from to the other to form the *corpus callosum,* while in its floor lon developed to form the *fornix.*

The third vesicle, the cavity of which forms the iter a terti triculum, develops in its roof four well-marked thickenings, w the *corpora quadrigemina,* while its lateral regions become the *crura cerebri* (Fig. 726).

The dorsal surface of the fourth vesicle, or epencephalon, of the fourth ventricle, and in it a thickening occurs, which is *cerebellum;* its ventral and lateral regions form the *pons* (Fig.

In the fifth vesicle or metencephalon the lateral parts incre ward on each side toward the middle line, forming the *medull* surface assists in forming the roof of the fourth ventricle.

On making a transverse section of the lower part of the f alar and basal laminæ, already referred to as being present in t recognized, while the thin roof-plate is seen to be greatly The dorsal part of the alar lamina becomes folded outward an ing what is termed the *rhomboid lip* (Fig. 727). This is at f groove from the lateral aspect of the alar lamina, but ultimatel the central canal of the cord opens out to form the fourth ven basal laminæ come to occupy the floor of the ventricle—the nearest the mesial plane.

The Nerves.—The nerves are developed, like the rest of t from epiblast. The spinal nerves are developed as follows: close to the point of involution of the epiblast in the median line, that is to say, in the angle of junction of the neural and general epiblast, a cellular swelling, the *neural crest,*

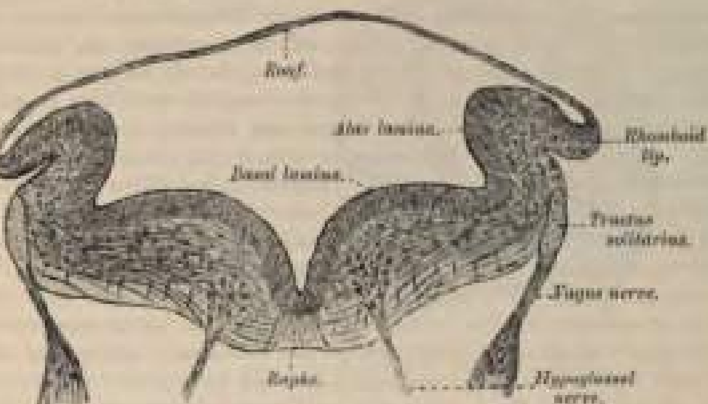

FIG. 727.—Transverse section of medulla oblongata of human embryo. (After His.)

appears and forms a continuous ridge of epiblast on the dorsal aspect of the neural canal (Fig. 728). On this crest enlargements occur corresponding with the middle of each protovertebral segment. These enlargements grow downward between

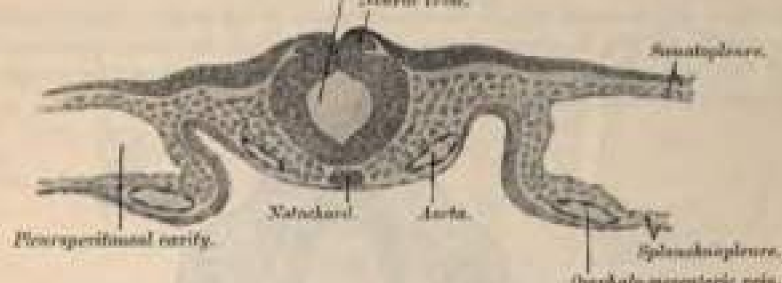

FIG. 728.—Transverse section of a portion of a chick embryo of twenty-nine hours' incubation. (From Duval's *Atlas d'Embryologie.*)

the neural canal and the protovertebræ, and occupy a position on the lateral wall of the canal. They are the rudiments of the ganglia of the posterior roots, and at first are attached to the neural crest from which they spring, but subsequently this attachment becomes lost, and they then form isolated masses on either side of the neural canal. They consist of oval cells, from either end of which a process eventually springs; one, growing centrally, passes into the embryonic cord and constitutes the posterior root of the nerve; the other, growing peripherally, joins the fibres of the anterior root to form the spinal nerve.

The anterior root is, according to the researches of His, a direct outgrowth of the neuroblasts which are found in the rudimentary cord (Fig. 722). These cells, at first rounded or oval, become pear-shaped, with their tapering prolongations directed outward toward the surface of the cord. These prolongations are the future axis-cylinders of the anterior nerve-roots; they pass out of the cord in bundles and penetrate the mesoblast to join with the fibres of the posterior root, and from the point of union the nerve grows toward its peripheral termination.

Cranial Nerves.—With the exception of the olfactory and optic nerves, which will be specially referred to, the cranial nerves may be developmentally considered as consisting of two sets: (1) those which arise as outgrowths from neuroblasts situated in the brain, similar to the mode of origin of the anterior spinal nerve-roots; (2) those which arise from ganglionic rudiments situated outside the brain and derived from the neural crest; from the neuroblasts of these ganglionic rudiments one process grows into the brain and the other outward toward the periphery, similar to the arrangement which exists regarding the posterior spinal nerve-roots. To the first group belong the third, fourth, sixth, seventh, eleventh, and twelfth nerves, together with the motor roots of the fifth, ninth, and tenth. To the second group belong the eighth and the sensory roots of the fifth, ninth, and tenth. While, however, the anterior spinal nerve-roots arise in one series from the ventral part of the cord, the cranial motor fibres arise by two sets of roots, *ventral* and *lateral*; the former include the roots of the sixth and twelfth and probably those of the third and fourth, the latter embrace the spinal accessory and the motor roots of the fifth, seventh, ninth, and tenth.

The olfactory lobe, or rhinencephalon, arises toward the end of the fourth week as a protrusion of the antero-ventral part of each cerebral hemisphere (Fig. 726), and extends forward toward the thickened epiblast of the olfactory area (see page 1169). It is subsequently divided by a transverse constriction into two parts: an anterior, which gives rise to the olfactory bulb and tract together with the trigonum olfactorium, and a posterior, which becomes the peduncle of the corpus callosum and the greater part of the anterior perforated space. Neuroblastic cells, formed within the olfactory area, pass out and form a ganglion between the area and the olfactory bulb. From this ganglion cell-processes grow centripetally to form the nerve-roots, and centrifugally to form the olfactory nerves which ramify in the olfactory mucous membrane, while the ganglion itself fuses with the olfactory bulb.

The optic nerve arises as a hollow outgrowth of the brain, which subsequently becomes solid. It will be considered in connection with the development of the eye.

The sympathetic nerves are developed as outgrowths from the ganglia on the roots of the spinal and cranial nerves.

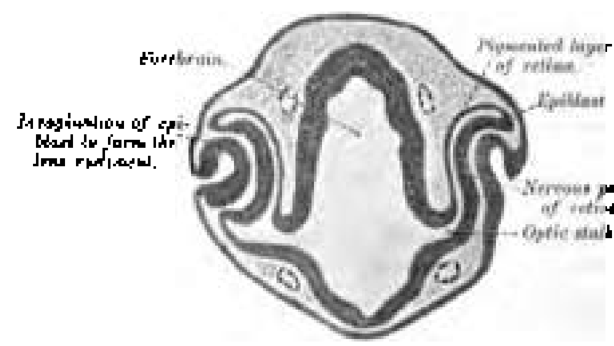

Fig. 729.—Transverse section of head of chick embryo of forty-eight hours' incubation; × 36. (From Duval's Atlas d'Embryologie.)

Development of the Eye.—The optic nerve and retina are developed as an outgrowth from the rudimentary brain, which extends toward the side of the head, and is there met by an ingrowth from the epiblast, out of which the lens and the epithelium of the conjunctiva and cornea are developed.

The first appearance of the eye consists in a hollow protrusion of the forebrain; this is called the *primitive optic vesicle*. It is at first an open cavity communicating by a hollow stalk with that of the cerebral vesicle. As it is prolonged forward, the epiblast lying immediately over it becomes thickened, and then forms a depression which gradually encroaches on the most prominent part of the primitive ocular vesicle; this in its turn appears to recede before it, so as to become at first depressed and then inverted in the manner indicated in Figs. 729 and 730, so that the cavity of the vesicle is almost obliterated by the folding back of its anterior half, and the original vesicle converted into a cup, the *optic cup*, in which the involuted epiblastic layer, the rudiment of the lens, is received (Fig. 730); at the same time the proximal part of the vesicle becomes elongated and narrowed into a hollow stalk, the *optic stalk.* This cup-shaped cavity consists therefore of two layers: one, the outer, originally the posterior half of the primitive ocular vesicle, is thin, and eventually forms the pigmented layer of the retina;[1] the other layer, the inner, originally the anterior or more prominent half, which has become folded back, is much thicker, and is converted into the nervous layers of the retina (Figs. 730 and 732). Between the two is the remnant of the cavity of the original primary optic vesicle, which finally becomes obliterated by the union of its two layers. When the retina is established, the optic nerve-fibres originate from its cells and grow backward toward the brain, along the optic stalk, and thus convert it into a solid optic nerve. The nerve-fibres become ultimately connected with the mesencephalon, a relationship

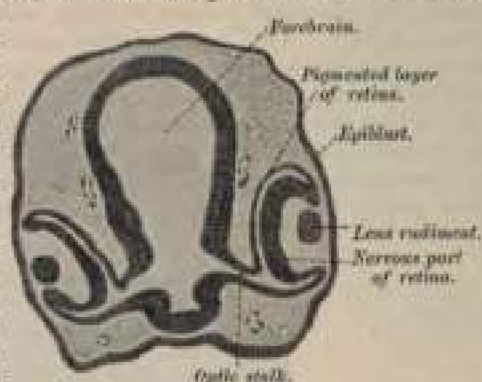

FIG. 730.—Transverse section of head of chick embryo of fifty-two hours' incubation. (From Duval's *Atlas d'Embryologie.*)

FIG. 731.—Diagram of development of the lens. A, B, C. Different stages of development. 1. Epidermic layer. 2. Thickening of this layer. 3. Crystalline depression. 4. Primitive ocular vesicle, its anterior part pushed back by the crystalline depression. 5. Posterior part of the primitive ocular vesicle, forming the external layer of the secondary ocular vesicle. 6. Point of separation between the lens and the epidermic layer. 7. Cavity of the secondary ocular vesicle, occupied by the vitreous.

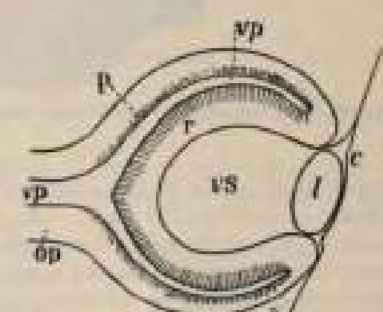

FIG. 732.—Diagrammatic sketch of a vertical longitudinal section through the eyeball of a human fœtus of four weeks. (After Kölliker.) Magnified 100 diameters. The section is a little to the side, so as to avoid passing through the ocular cleft. *c.* The cuticle, where it becomes later the epithelium of the cornea. *l.* The lens. *op.* Optic nerve formed by the pedicle of the primary optic vesicle. *vp.* Primary medullary cavity of the optic vesicle. *p.* The pigment layer of the retina. *r.* The inner wall forming the nervous layers of the retina. *vs.* Secondary optic vesicle containing rudiment of the vitreous humor.

which is permanently maintained. The mouth of the optic cup overlaps the equator of the lens as far as the future aperture of the pupil. In this region the inner or retinal layer of the cup does not become differentiated into nervous elements, but remains as a single layer of columnar cells, which becomes applied to the cells of the pigmented layer, and the conjoined strata form the *pars ciliaris pars iridica retinæ* of the adult (Fig. 734). As development proceeds the optic cup increases in size, and thus a space is formed between it and the rudimentary lens; this is the *secondary optic vesicle*, and in it the vitreous humor is developed (Figs. 731, C, and 732). The folding in of the primary optic vesicle to produce

[1] This layer was formerly described as belonging to the choroid, but developmentally it is seen to be a part of the retina.

the optic cup not only takes place in front, at its most promi
the lens, but also along its postero-inferior aspect, where a
formed, the *choroidal fissure*, through which the mesoblast
vitreous humor. This gap or cleft is continued for some distan
the optic vesicle, and thus allows a process of the mesoblast t
stalk to form the arteria centralis retinæ and its accompanyi
After a time the gap or fissure becomes closed, by a coalescenc
the line of union remains apparent for a considerable period.

The lens is at first a thickening of the epiblast, then a depr
takes place, thus forming an open follicle, the margins o

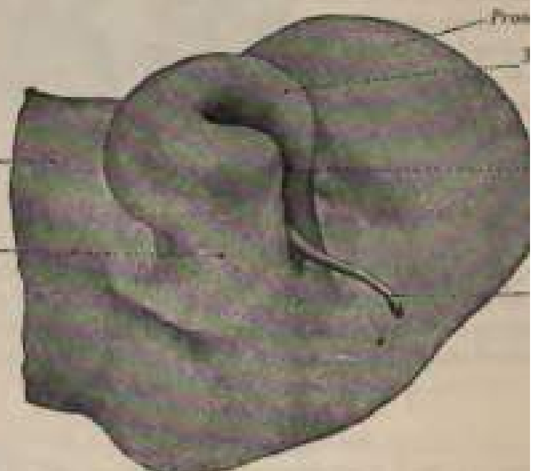

FIG. 733.—Optic cup and choroidal fissure seen from below, from a human embry
(Kollmann.)

approach each other and coalesce, forming a cavity, the *lens*
epiblastic cells (Fig. 731, B C). At the point of involution th
epiblast separates from the lens and passes freely over the surf
becomes disconnected from the general epiblast, and recedes i
while the cuticular layer covering it is developed into the corn
cells forming the posterior or inner wall of the lens vesicle
size, becoming elongated and developed into the lens-fibres
cavity, convert it into a solid body. The cells on the anteri
cellular character, and form the anterior lens epithelium
secondary optic vesicle, or space between the lens and the holl
(Figs. 731, 7, and 734), contains a quantity of mesoblastic tis
the general mesoblast through the choroidal fissure. This
verted into the vitreous humor, and surrounds the lens with a
the *vascular capsule of the lens*. From the central artery
branches are prolonged forward through the vitreous body to
lens, but by the sixth month these have all undergone atroph
persists till the ninth month as the *arteria hyaloidea*. It
before birth, and its position is indicated in the adult by the c
Stilling. The front part of the vascular capsule of the crysta
membrana pupillaris, and also attaches the iris to the capsule
appears about the seventh month. The sclera, cornea, and ch
from the mesoblast surrounding the optic vesicle.

The eyelids are formed at the end of the third month, as s
(Fig. 734), which come together and unite in front of the globe
union is broken up and the eyelids separate before the end of
The lachrymal sac and nasal duct appear to result from

epiblast in the groove between the lateral nasal and maxillary processes. This thickening becomes hollowed out into a channel, and the lips of the groove meet

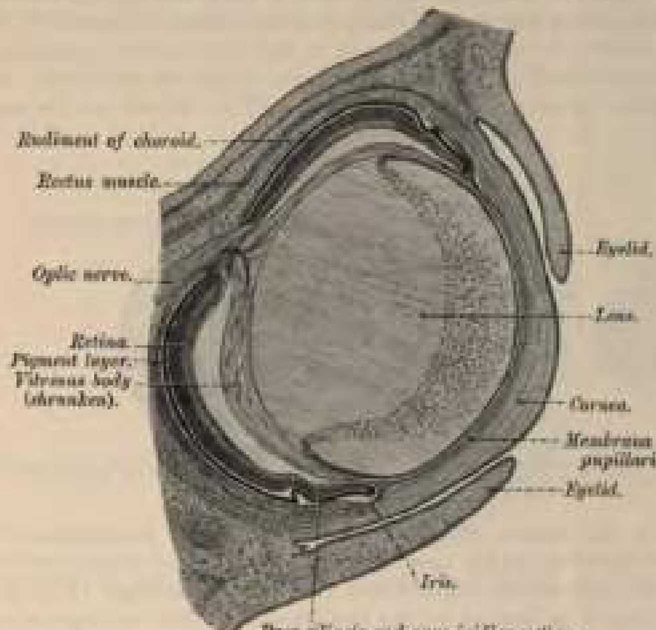

FIG. 734.—Horizontal section through the eye of an eighteen days' embryo rabbit; × 30. (Kölliker.)

over it, enclose it, and convert it into a duct, which eventually opens into the nasal fossa.

Development of the Ear.—The first rudiment of the ear appears shortly after that of the eye, in the form of a thickening of the epiblast, on the outside of that part of the third primary cerebral vesicle which eventually forms the medulla oblongata. The thickening is then followed by an involution of the epiblast (Fig. 735), which becomes deeper and deeper, and sinking toward the base of the skull, forms a flask-shaped cavity; by the narrowing of the external aperture the neck of the flask constitutes the *recessus labyrinthi*. The mouth of the flask then becomes closed, and thus a shut sac is formed, the *primitive auditory* or *otic vesicle* (Fig. 736), which by its sinking inward comes to be placed between the ali-sphenoid and basi-occipital matrices. From it the epithelial lining of the labyrinth is formed.

FIG. 735.—Section through the head of a human embryo, about twelve days old, in the region of the hind-brain. (Kollmann.)

The primary otic vesicle becomes imbedded in a mass of mesoblastic tissue, which rapidly undergoes chondrification and ossification. The vesicle is at first flask- or pear-shaped; the neck of the flask, or *recessus labyrinthi*, prolonged backward, forms the aquæductus vestibuli. From it are given off certain prolongations or diverticula, from which the various parts of the labyrinth are formed. One from the anterior end gradually elongates, and, forming a tube, bends on itself and becomes the cochlea. Three others, which appear on the surface of the vesicle, form the semicircular canals, of which the external canal is the last to be developed (Figs. 738 and 739). Subsequently a constriction takes place in the original vesicle, which nearly divides it into two, and from these are formed the utricle and saccule (Fig. 739). Finally, the auditory nerve, which has been developed from the "neural crest" in the manner above described (page 1180), pierces the auditory capsule in two main divisions—one for the vestibule, the other for the cochlea. The middle ear and Eustachian tube are the remains of the inner part of the first branchial cleft (hyomandibular), and are closed externally by the membrana tympani, which originally consists of a layer of epiblast externally, and a layer of hypoblast internally; between these two layers the mesoblast extends to form the substantia propria of the membrane. With regard to the exact mode

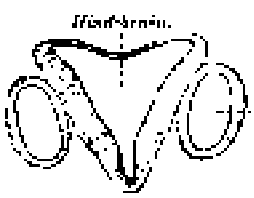

FIG. 736.—Section through hind-brain and otic vesicle of an embryo more advanced than that of Fig. 735. (After His.)

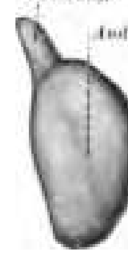

FIG. 737.—Left auditory vesicle of a human embryo of four weeks, seen from the outer surface. (W. His, Jr.)

of development of the ossicles of the middle ear there is considerable difference of opinion. The most probable view is that the *incus* and *malleus* are developed from the proximal end of the mandibular (Meckel's) cartilage (Fig. 719); that the base of the *stapes* is formed by the ossification of the cartilage which fills in the foramen ovale and its arch from the ossified proximal end of the hyoidean arch.

The external auditory meatus is formed from the outer part of the hyo-

FIG. 738.—Left auditory vesicle of a human embryo of five weeks, seen from the outer surface. (W. His, Jr.)

mandibular cleft, while the pinna is developed by the gradual differentiation of a series of processes which appear around the outer margin of the cleft (Fig. 741).

Development of the Nose.—The olfactory fossæ, like the primary auditory vesicles, are formed in the first instance by a thickening and involution of the epiblast, which takes place about the fourth week, at a point below and in front of the ocular vesicle (Fig. 725). The borders of the involuted portion very soon become prominent, in consequence of the development of the mesial and lateral nasal processes already referred to (page 1169), and which are formed on either side of the rudimentary fossa (Figs. 714, 715). As these processes increase, the fossa deepens and becomes converted into a channel, which eventually forms the olfactory region of the nose; this comprises the portion to which the olfactory nerves are distributed. At this time the nasal cavity is continuous with the buccal cavity; but as the palatal septum is formed, the buccal cavity is divided into two parts, the upper of which

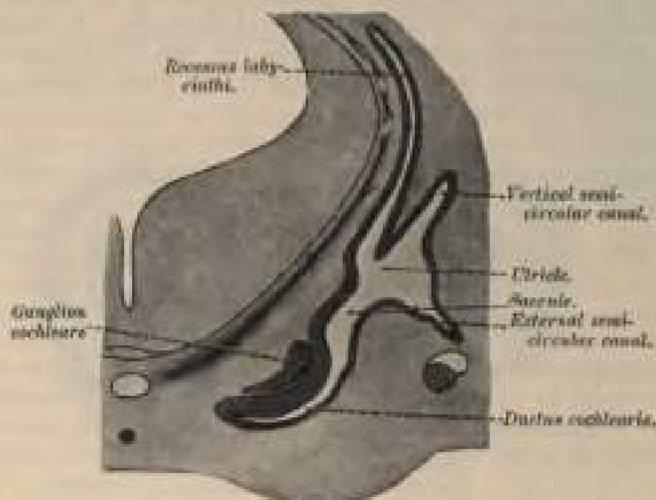

FIG. 759.—Transverse section through head of fœtal sheep, in the region of the labyrinth. × 30. (After Boettcher.)

forms the lower part of the nasal fossæ, while the remainder forms the permanent mouth. On the mesial wall of the nasal fossa a small blind pit of epiblast becomes invaginated and extends backward into the nasal septum. This forms the rudiment of *Jacobson's organ*, which ultimately becomes partly enclosed in a curved cartilaginous plate derived from a cartilage of the nasal septum.

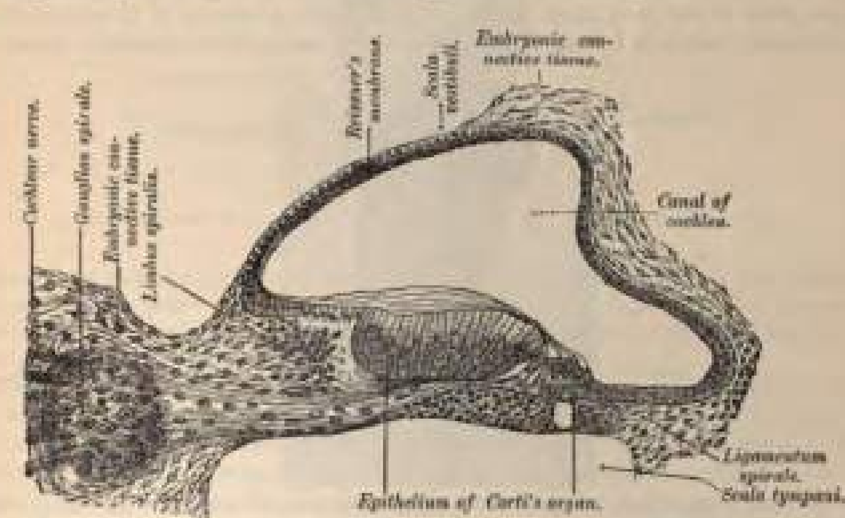

FIG. 760.—Transverse section of the canal of the cochlea of a fœtal cat. (After Boettcher and Ayres.) (From Kollmann's *Entwickelungsgeschichte*.)

The development of the external nose has already been described. It is perceptible about the end of the second month. The nostrils are at first closed by epithelium, but this disappears about the fifth month.

The olfactory lobe (rhinencephalon) is formed, as already explained, by an evagination of the anterior cerebral vesicle.

75

Development of the Skin, Glands, and Soft Parts.—The epidermis and its appendages, consisting of the hairs, nails, sebaceous and sweat glands, are developed from the epiblast, while the corium or true skin is of mesoblastic origin. About the fifth week the epidermis consists of two layers of cells, the deeper one corresponding to the rete mucosum. The subcutaneous fat forms about the fourth month, and the papillæ of the true skin about the sixth. A considerable desquamation of epidermis takes place during fetal life, and this desquamated epidermis, mixed with a sebaceous secretion, constitutes the *vernix caseosa*, with which the

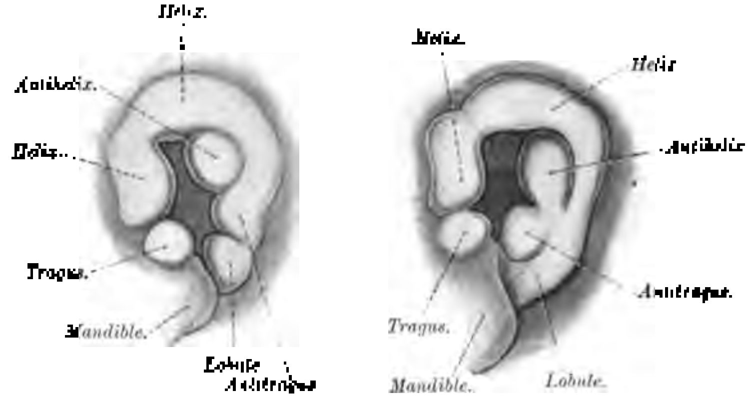

FIG. 7[illegible].—Left ears of human embryos, estimated at thirty-five and thirty-eight days respectively. (After His.)

skin is smeared during the last three months of fetal life. The nails are formed at the third month, and begin to project from the epidermis about the sixth. The hairs appear between the third and fourth months in the form of solid downgrowths of the deeper layer of the epidermis, which then become inverted by papillary projections from the corium. About the fifth month, the fetal hairs (*lanugo*) appear, first on the head and then on the other parts; they drop off after birth and give place to the permanent hairs. The cellular structure of the sudoriferous and sebaceous glands is formed from the epiblast, while the connective tissue and

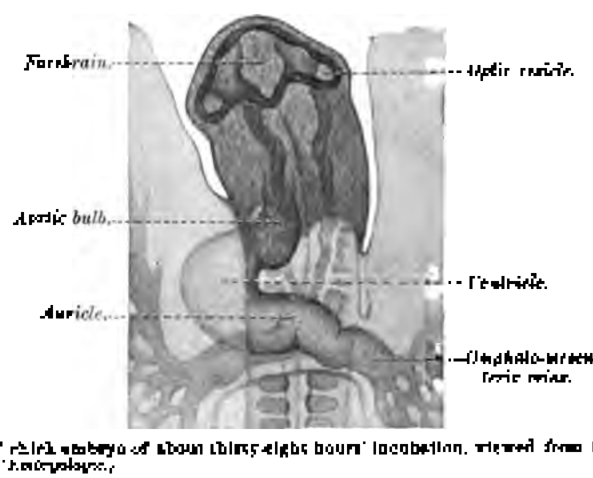

FIG. 7[illegible].—Head of chick embryo of about thirty-eight hours' incubation, viewed from the ventral surface. (From Duval's Atlas d'Embryologie.)

blood-vessels are derived from the mesoblast. The mammary gland is also formed partly from mesoblast and partly from epiblast—its blood-vessels and connective tissue being derived from the former, its cellular elements from the latter. Its first rudiment is seen about the third month, in the form of a small projection inward of epithelial elements, which invade the mesoblast; from this, similar tracts of cellular elements radiate; these subsequently give rise to the glandular follicles and ducts. The development of the former, however, remains imperfect, except in the adult female.

Development of the Limbs.—The upper and lower limbs begin to project, as buds, from the anterior and posterior part of the embryo about the fourth week. These buds are formed by a projection of the somatopleure from the point where the mesoblast splits into its parietal and visceral layers, just external to the vertebral somites, of which they may be regarded as lateral extensions. The division of the terminal portion of the bud into fingers and toes is early indicated, and soon a notch or constriction marks the future separation of the hand or foot from the forearm or leg. Next, a similar groove appears at the site of the elbow or knee. The indifferent tissue, of which the whole projection is at first composed, is differentiated into muscle and cartilage, before the appearance of any internal clefts for the joints between the chief bones.

The **muscles** become visible about the seventh or eighth week. The voluntary muscles are developed from the muscle-plates of the protovertebral somites, which are at first segmentally arranged on either side of the rudimentary spine. Each muscle-plate becomes differentiated into two parts, superficial and deep. The former is termed the *cutis plate*, and from it the corium or true skin is developed, while the latter becomes developed into longitudinal groups of muscle-fibres, extending forward into the neck and head region of the embryo and laterally to enclose the cavities of the thorax and abdomen. The muscles of the limbs are also

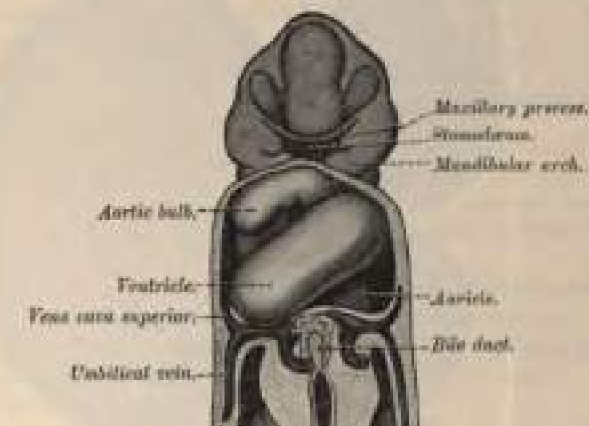

FIG. 742.—Heart of human embryo of about fifteen days. (Reconstruction by His.)

formed from the same source, being produced by outgrowths from the protovertebral somites in those situations where the limb buds appear. The involuntary muscles are derived from the splanchnopleure mesoblast, and are therefore not connected in any way with the protovertebral somites.

Development of the Blood-vascular System.—There are three distinct stages in the development of the circulatory system, each in accordance with the manner in which nourishment is provided for at different periods of the existence of the individual. In the first stage there is the *vitelline circulation*, during which nutriment is extracted from the *vitellus* or contents of the yolk-sac. In the second stage there is the *placental circulation*, during which nutrition is obtained by means of the placenta from the blood of the mother. In the third stage there is the *complete circulation of the adult*, commencing at birth, during which nutrition is provided for by the organs of the individual itself.

1. The **vitelline circulation** is carried on partly within the body of the embryo, and partly external to it in the vascular area of the yolk-sac. It consists of a median tubular heart, from which two vessels (arteries) project anteriorly. These carry the blood to a plexus of capillaries spread over the vascular area, from which

the blood is returned by two vessels (veins) which enter the he
thus a complete circulation is formed (Fig. 744).

In these vessels and the heart a fluid (*blood*) is contain
mentary corpuscles are found. The mode of formation of the
must first be considered.

In mammalia the heart is formed by a longitudinal fold of
with its underlying hypoblast on either side of the median l
anterior extremity of the rudimentary pharynx, at about the le
primary cerebral vesicle. The folds become tubes, their walls
two distinct strata of cells: the inner and thinner layer, deriv
blast, forms the endocardium; the outer and thicker, derived
mesoblast, forms the muscular wall of the heart. In its prim
heart consists therefore of a pair of tubes, one on either side of
however, soon coalesce in the median line, and, fusing toge
central tube.[1] Each of the two primary tubes receives poste
(the omphalo-mesenteric vein), and is prolonged anteriorly i
primitive aorta). So that after fusion of the heart-tubes has t
in the primitive vitelline circulation, as above mentioned, a si

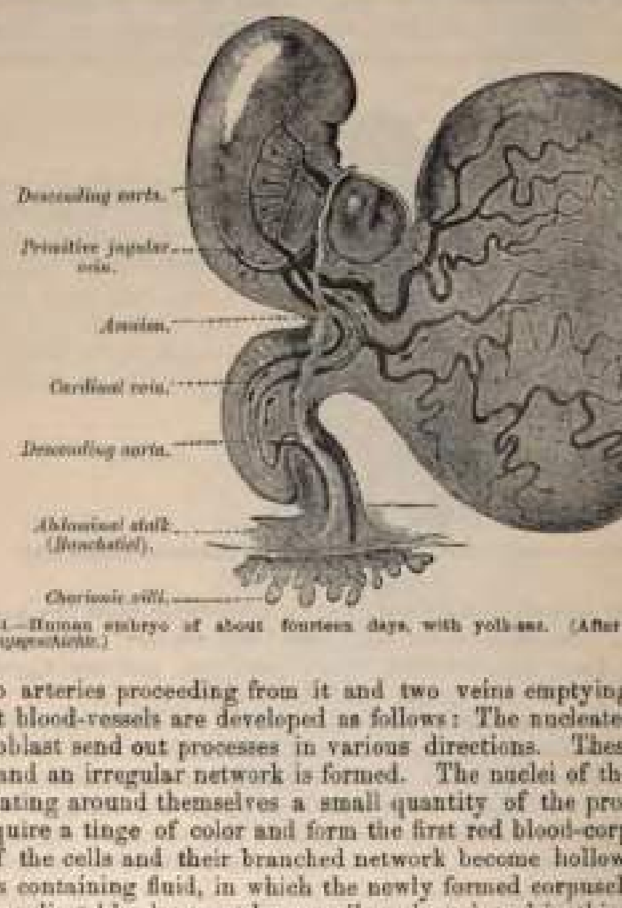

FIG. 744.—Human embryo of about fourteen days, with yolk-sac. (After
Entwickelungsgeschichte.)

with two arteries proceeding from it and two veins emptying
The first blood-vessels are developed as follows: The nucleated
the mesoblast send out processes in various directions. These
gether, and an irregular network is formed. The nuclei of the
accumulating around themselves a small quantity of the prot
they acquire a tinge of color and form the first red blood-corp
plasm of the cells and their branched network become hollowe
of canals containing fluid, in which the newly formed corpuscle

The earliest blood-corpuscles are all nucleated, and in this
that is, in their possession of amœboid movements and in their

[1] In most fishes and in amphibia the heart originates as a single median

[2] Recent observers incline to the view that the blood-corpuscles are of h
developed from the endothelium of the vessels, the sequence of the devel
structures being: first the heart, then the blood-vessels, and lastly the bloo
Dr. Ernest Mehnert's *Biomechanik*, Jena, 1898.)

going multiplication by division—resemble the white corpuscles. Soon, however, true white corpuscles make their appearance, and it seems that they are derived from the rudiments of the thymus gland.[1] The nucleated condition of the red globules ceases before birth. The vitelline circulation commences about the fifteenth day and lasts till the fifth week. When fully established, it is carried on as follows: Proceeding from the anterior end of the tubular heart are two arteries, the primitive aortæ; these run down in front of the primitive vertebræ and behind the walls of the intestinal cavity into the two *omphalo-mesenteric* arteries, which ramify in the *vascular area* of the yolk-sac. Here they terminate peripherally in a circular vessel—the *terminal sinus*, which surrounds the vascular area. The blood is collected from the capillaries of the vascular area into the two *omphalo-mesenteric* veins, which open into the posterior extremity of the heart.

FIG. 745.—Various forms of mother-cells undergoing development into blood-vessels, from the middle layer of the chick's blastoderm. (Klein.) *a*. Large mother-cell vacuolated, forming the rudimentary vessel. *b*. The wall of this cell formed of protoplasm, with nuclei embedded, and in some cases more or less detached and projecting. *c*. Processes connected with neighboring cells, formed of the common cellular substance of the germinal area. *d*. Blood-corpuscles. *f*. Small mother-cells—vacuolation commencing. *g*. Mother-cell in which only obscure granular matter is found.

2. The Placental Circulation.—As the umbilical vesicle diminishes, the allantois and the placenta are developed in the manner above described (page 1162). When the umbilical vesicle atrophies the placenta becomes the only source of nutrition for the embryo. The allantois carries with it two arteries (*umbilical* or *allantoic*), derived from the primitive aortæ, and two veins; these vessels become much enlarged as the placental circulation is established, but subsequently one of the veins disappears, and in the later stages of uterine life the circulation is carried on between the fœtus and the placenta by two umbilical arteries and one umbilical vein.

During the occurrence of these changes great alterations take place in the primitive heart and blood-vessels, and now require description.

Further Development of the Heart.—The following is an outline of the changes which take place during the further development of the heart.

The simple tubular heart, already described, becomes elongated and bent on itself, so as to form an S-shaped loop, the anterior part bending to the right and the posterior part to the left. The intermediate portion arches transversely from right to left, and then turns sharply forward into the anterior part of the loop. Slight constrictions make their appearance in the tube and divide it into four parts, viz.: (1) the *sinus venosus* (*sinus reuniens* of His); (2) the common auricle; (3) the common ventricle; (4) the aortic bulb. The common auricle and ventricle communicate by a short canal, the *auricular canal* (Figs. 742, 743, and 746).

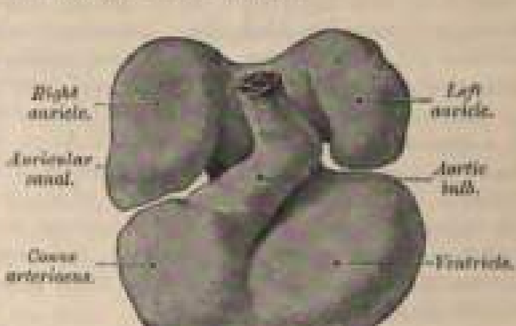

FIG. 746.—Heart of a human embryo of 5 mm. in length, seen from the front; × 30. (His.)

The sinus venosus is situated in the septum transversum (a layer of mesoblast from which the ventral part of the Diaphragm is developed) behind the common

[1] Consult an article by J. Beard. *Anatomischer Anzeiger*, December, 1900.

auricle, and is formed by the union of three pairs of veins, viz., (1) the veins or ducts of Cuvier from the body of the embryo; (2) the omphalo-mesenteric veins from the yolk-sac; (3) the umbilical veins from the placenta (Fig. 747). The sinus is at first placed transversely, and opens by a median aperture into the common auricle. Soon, however, it assumes an oblique position, and its right half or horn becomes larger than the left, while the opening into the auricle is found to be in the right portion of the auricular cavity. The right horn ultimately becomes incorporated with and forms a part of the right auricle, the line of union between it and the auricle proper being indicated in the interior of the adult auricle by a vertical crest, the *crista terminalis* of His. The left horn, which ultimately receives only the left duct of Cuvier, persists as the coronary sinus (Fig. 753). The omphalo-mesenteric and umbilical veins are soon replaced by a single vessel, the inferior vena cava, and the three veins (inferior vena cava and right and left Cuvierian ducts) open into the dorsal aspect of the auricle by a common slit-like aperture. The upper part of this aperture represents the opening

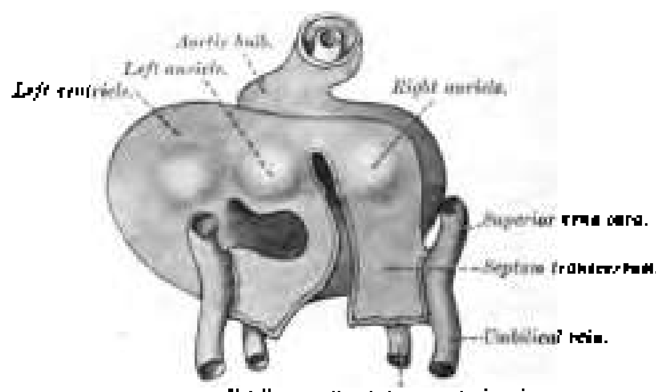

FIG. 747.—Heart of a human embryo 4.3 mm. in length, seen from behind. (His.)

of the permanent superior vena cava, the lower part that of the inferior vena cava, and the intermediate part the orifice of the coronary sinus. The slit-like aperture lies obliquely, and is bordered on its mesial and lateral aspects by a fold of endocardium. The mesial part of the fold disappears, while from the lateral part the Eustachian and Thebesian valves are developed. At the lower extremity of the slit is a triangular thickening, the *spina vestibuli* of His, which partly closes the aperture between the two auricles, and which, according to His, takes a part in the formation of both the interauricular and interventricular septum.

The common auricle becomes gradually subdivided into right and left auricles by a septum, the *septum superius*, which grows from its dorsal and upper wall so that the two auricles communicate with each other only below the margin of the septum. This communication (*ostium primum* of Born) does not, however, represent the future foramen ovale, for the septum grows downward and blends with the partition which comes to subdivide the auricular canal. The foramen ovale (*ostium secundum* of Born) results from a perforation of the upper part of the septum superius.

The auricular canal is at first a short straight tube connecting the auricular with the ventricular portion of the heart, but it becomes overlapped by the growing auricles and ventricles so that its position on the surface of the heart is indicated only by an annular constriction (Fig. 746). Its lumen is reduced to a transverse slit, and a thickening appears on its dorsal and ventral walls. These thickenings, or *endocardial cushions* as they are termed, project into the canal, and, meeting in the middle line, divide the canal into two channels, the future right and left auriculo-ventricular orifices.

The common ventricle becomes divided by a septum, the *septum inferius*, which grows upward from the lower part of the ventricle, its position being indicated on the surface of the heart by a furrow. It extends upward almost as far as the auricular canal, but for some time an interventricular foramen exists between it and the septum of the auricular canal (Fig. 748).

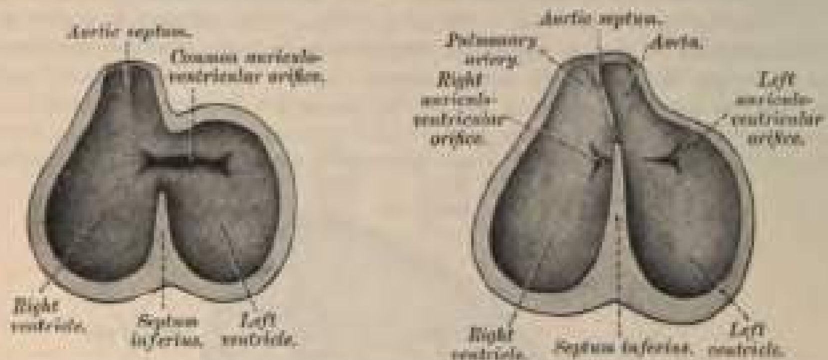

FIG. 748.—Showing the development of the septum of the aortic bulb and of the ventricles. (Born.)

The aortic bulb is divided by the *aortic septum*. This makes its appearance at the distal end of the bulb as two ridge-like thickenings of its endothelial lining; these increase in size, and, projecting into the lumen, ultimately fuse to form the septum, and thus the aortic bulb is divided into the pulmonary artery and the aorta. The aortic septum takes a spiral course toward the proximal end of the bulb, so that the two vessels lie side by side above; but near the heart the pulmonary artery is in front of the aorta (Fig. 749). The septum grows down into the ventricle as an oblique partition, which ultimately blends with the septum

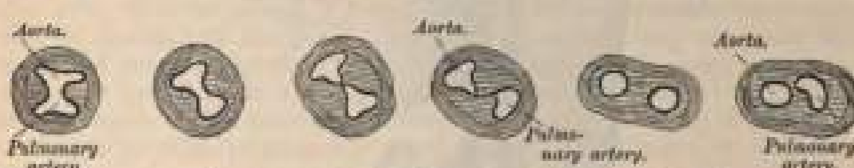

FIG. 749.—Transverse sections through the aortic bulb to show the growth of the aortic septum. The lowest section is on the left, the highest on the right, of the figure. (After His.)

inferius of the ventricles in such a way as to bring the left ventricle into communication with the aorta and the right with the pulmonary artery.

Peculiarities of the Fœtal Heart.—In early fœtal life the heart is placed directly under the head and is relatively of large size. Later it assumes its position in the thorax but lies at first in the middle line; toward the end of pregnancy it gradually becomes oblique. Its auricular portion is at first larger than the ventricular part, and the two auricles communicate freely through the foramen ovale. In consequence of the communication, through the ductus arteriosus, between the pulmonary artery and the aorta, the contents of the right ventricle are mainly carried into the latter vessel instead of to the lungs, and hence the wall of the right ventricle is as thick as that of the left. At the end of fœtal life, however, the left ventricle is thicker than the right, a difference which becomes more and more emphasized after birth.

Further Development of the Arteries.—In the vitelline circulation, two arteries were described as coming off from the primitive heart, and running down in front of the developing vertebræ. The first change consists in the fusion of these arteries into one vessel at some distance from the heart; this vessel is the descending thoracic and abdominal aorta. In consequence of the lengthening of the neck the heart falls backward to its lower part and then into the thorax, and the two original arteries, proceeding from the heart to their point of fusion in the common

descending aorta, become elongated and assume an arched form,
on each side, from the front of the body toward the vertebral co
These are the *first or primitive aortic arches*. As the heart rece
and these arches, which correspond in position to the mandib
elongated, four additional pairs of arches are formed behind
pharynx, one in each branchial arch (Fig. 750). The arche
remain permanent in fishes, giving off from their convex bor
arteries to supply the gills. In many animals the five pairs do
for the first two have disappeared before the others are formed;
in man, where all five arches are present and pervious during
embryonic existence (Fig. 750). Only some of the arches in m

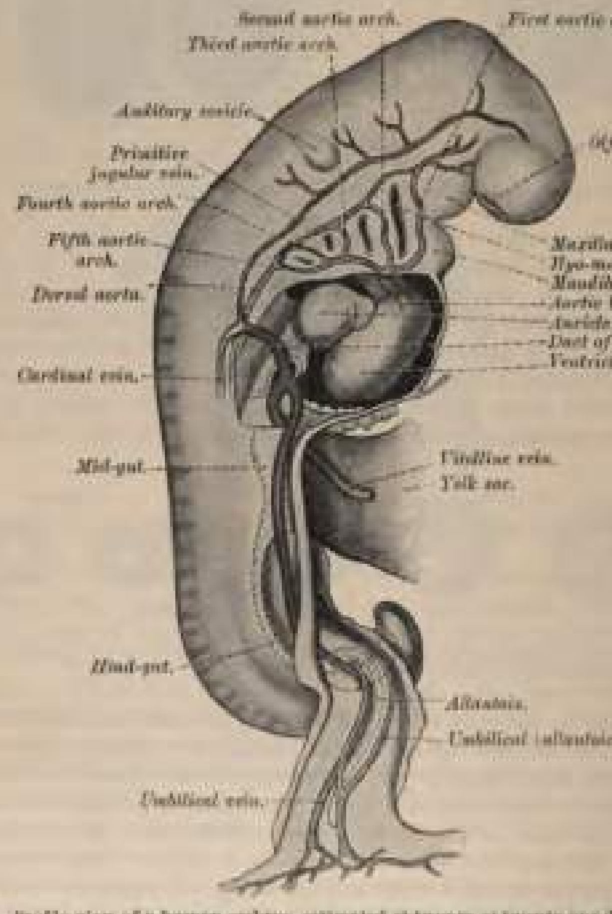

FIG. 750.—Profile view of a human embryo, estimated at twenty or twenty-one da

permanent structures; the others, or portions of them, become
appear. The first two arches entirely disappear. The third re
the internal carotid artery, the remainder being formed by the
posterior aortic root—*i. e.*, the descending part of the original
ceeded from the rudimentary tubular heart. The common an
arteries are formed from the anterior aortic root—that is, the as
the same primitive vessel. The fourth arch on the left side becor
the permanent arch of the aorta in mammals; but in birds it is
the right side which forms the aortic arch; in reptiles the fourth
persists, so that these animals possess a permanent double aortic
arch on the right side forms the subclavian artery, and by the j

mencement with the anterior aortic root, from which the common carotid is developed, it forms the innominate artery.[1] The fifth arch on the left side forms the pulmonary artery and the ductus arteriosus; that on the right side becomes atrophied and disappears. The first part of the fifth left arch remains connected with that part of the aortic bulb which is separated as the pulmonary stem, and with it forms the common pulmonary artery. From about the middle of this arch two branches are given off, which form the right and left pulmonary arteries,

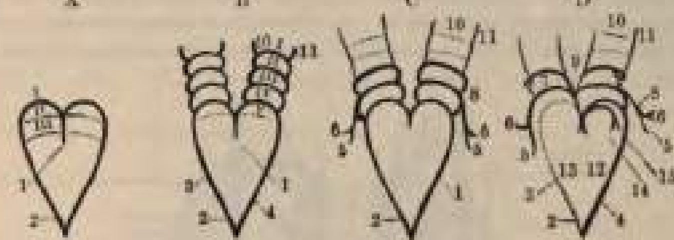

FIG. 751.—Showing the formation of the aortic arches and the large arteries. I. II. III. IV. V. First, second, third, fourth, and fifth aortic arches. A. Common trunk from which the first pair spring; the place where the succeeding pairs are formed is indicated by dotted lines. B. Common trunk, with four arches and a trace of the fifth. C. Common trunk, with the three last pairs, the first two having been obliterated. D. The persistent arteries, those which have disappeared being indicated by dotted lines. 1. Common arterial trunk. 2. Thoracic aorta. 3. Right branch of the common trunk which is only temporary. 4. Left branch, permanent. 5. Axillary artery. 6. Vertebral. 7, 8. Subclavian. 9. Common carotid. 10. External, and 11. Internal carotid. 12. Aorta. 13. Pulmonary artery. 14, 15. Right and left pulmonary arteries.

respectively, and the remaining portion—that is, the part beyond the origin of the branches—communicates with the left fourth arch, and constitutes the ductus arteriosus. This duct remains pervious during the whole of fœtal life, but after birth becomes obliterated (Fig. 752). A series of intersegmental or intervertebral arteries arise from the primitive dorsal aortæ, those in the neck alternating with the cervical segments of the spine. The intersegmental artery which lies between the sixth and seventh segments forms the lower part of the vertebral artery; its upper part is formed by an antero-posterior anastomosis between the higher intersegmental vessels. The subclavian artery is originally a branch of the vertebral, but, owing to the subsequent growth of the upper limb, it comes to exceed in size the parent trunk.

The development of the arteries in the lower part of the body is going on during the same time. It has been seen that originally there were two primitive aortæ coming off from the simple tubular heart. These two vessels course downward, one on either side of the notochord, and supply the omphalo-mesenteric arteries to the yolk-sac. At the hinder end of the embryo the primitive aortæ give off the two umbilical or allantoic arteries which run in the walls of the allantois to the umbilicus, beyond which they are carried in the umbilical cord to the placenta. The two primitive aortæ soon fuse to form a single vessel, the future descending aorta; the fusion begins in the thoracic region, and from there proceeds backward and forward, and the umbilical arteries now appear as if resulting from the bifurcation of the single vessel; the part of the fused vessels, beyond their origin, is indicated, however, by the middle sacral artery. The common and internal iliac arteries represent the proximal end of the umbilical artery; the remainder of the vessel, with the exception of the part which gives off the superior vesical artery, becomes obliterated after birth; and the obliterated portions of the two umbilical arteries, together with the urachus, carry off the peritoneum from the bladder as its superior false ligament. The external iliac and femoral arteries are developed from a minute branch given off from the umbilical artery near its origin, and are at first of comparatively small size.

[1] This is interesting in connection with the position of the recurrent laryngeal nerve, which is thus seen to hook round the same primitive fœtal structure, which becomes on the right side the subclavian artery, on the left the arch of the aorta.

Development of the Veins.—The formation of the great veins of the embryo may be best considered under two groups, visceral and parietal.

The *visceral veins* are the two vitelline or omphalo-mesenteric veins bringing the blood from the yolk-sac, and the two umbilical or allantoic veins returning the blood from the placenta; these four veins open close together into the sinus venosus (Fig. 747).

The vitelline veins run upward at first in front, and subsequently on either side of the intestinal canal. They unite on the ventral aspect of the canal before they reach the liver, and then encircle the intestinal tube by forming around it two venous rings, the first on its dorsal, the second on its ventral aspect. The portions of the veins above the upper ring become invaded by the developing

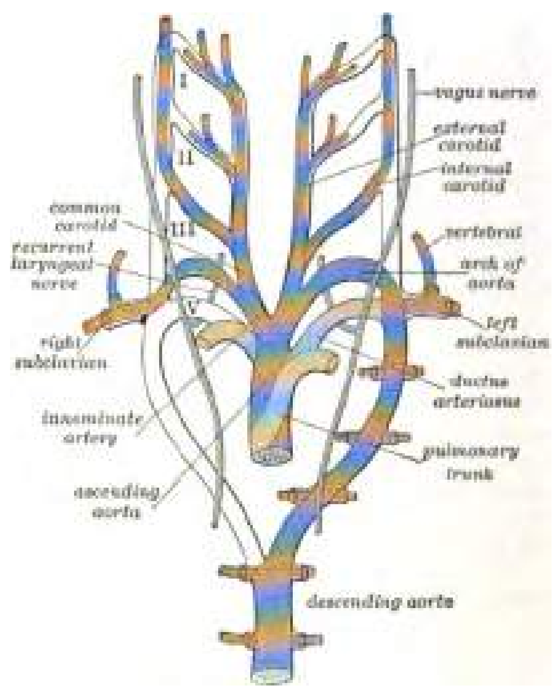

FIG. 752.—Showing the destination of the arterial arches in man and mammals. (Modified from Rathke.) (From Quain's Anatomy, 1890, vol. i., pt. i.) The truncus arteriosus and the five arterial arches springing from it are represented in outline only; the permanent vessels in shade: those belonging to the aortic system in heavy shaded line, to the pulmonary system in light shaded line.

liver and broken up by it into a network of smaller vessels, the central part of the network consisting of a capillary plexus. The branches which convey the blood to this plexus are named the *venæ advehentes*, and become the branches of the portal vein; while the vessels which drain the plexus into the sinus venosus are termed the *venæ revehentes*, and form the future hepatic veins (Figs. 753 and 754).

The lower part of the *portal vein* is formed from the fused vitelline veins which receive the veins from the alimentary canal; its upper part is derived from the venous rings by the persistence of the left half of the lower and the right half of the upper ring, so that the vessel forms a spiral turn round the duodenum (Fig. 754).

The two umbilical veins fuse early to form a single trunk in the allantois, but remain double for some time in the embryo and pass forward to the sinus venosus in the side walls of the body. Like the vitelline veins, their direct connection with the sinus venosus becomes interrupted by the invasion of the liver, and thus at this stage the whole of the blood from the yolk-sac and placenta passes through the substance of the liver before it reaches the heart. The right umbilical vein shrivels up and almost entirely disappears; the left, on the other hand, becomes much enlarged after the establishment of the placental circulation, and opens into the upper venous ring. Finally a direct branch is established between this ring and the right hepatic vein; this branch is the *ductus venosus* or *vena ascendens*, and, enlarging rapidly, it forms a wide channel through which most of the blood, returned from the placenta, is carried direct to the heart (Fig. 754).

The Parietal Veins.—The first indication of a parietal system consists in the appearance of two short transverse veins (the *ducts of Cuvier*), which open, one on either side, into the auricular portion of the heart. Each of these ducts is formed by an ascending and a descending vein. The ascending veins return the blood from the parietes of the trunk and from the Wolffian bodies, and are called *cardinal* veins. The descending veins return the blood from the head,

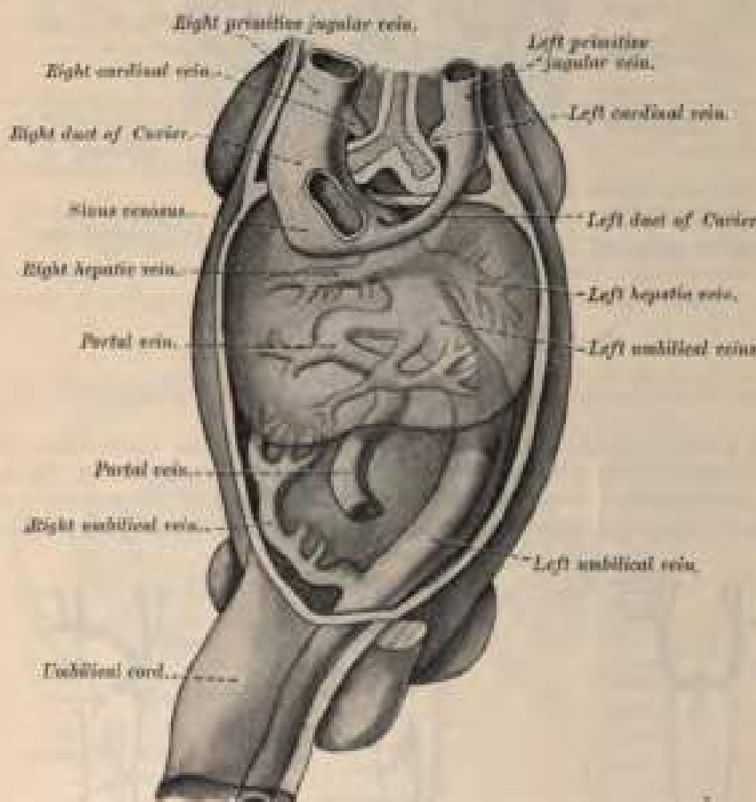

FIG. 753.—Human embryo with heart and anterior body wall removed to show the sinus venosus and its tributaries. (From Kollmann's *Entwickelungsgeschichte*.) (After His.)

and are called *primitive jugular* veins (Fig. 750). The blood from the lower limbs is collected by the iliac veins, which empty themselves into the cardinal veins. In the earlier stages of development the right and left iliac veins open into the corresponding right and left cardinal veins (Fig. 756), but later on a transverse branch connects the lower ends of the two cardinal veins, and through this the blood from the left iliac vein is carried into the right cardinal vein. By the development of a similar transverse branch higher up the blood from the left kidney is also carried into the right cardinal vein (Fig. 755, 2). The portion of the left cardinal vein above the origin of the lower transverse branch becomes atrophied as high as the level of the renal vein, above which it persists as the vena azygos minor. The right cardinal vein, which now receives the blood from both lower extremities, forms a large venous trunk along the posterior

abdominal wall; it receives the renal veins from the kidney
this level, the inferior vena cava. Above the level of the rena
vena cava first makes its appearance as a small vein lying in
the two kidneys. Superiorly it opens into the sinus venosus,

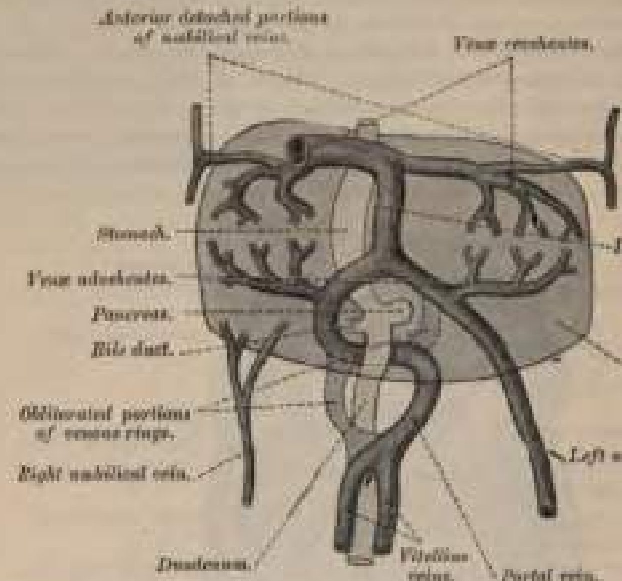

FIG. 754.—The liver, and the veins in connection with it, of a human embryo,
days old, as seen from the ventral surface. (After His.) (Copied from Milnes Marsh

municates with the right cardinal vein near the level of the re
1, 2). This small vein ultimately becomes enlarged, and carri
from the right cardinal vein, and so forms the upper part of th
The portion of the right cardinal vein above the renal veins

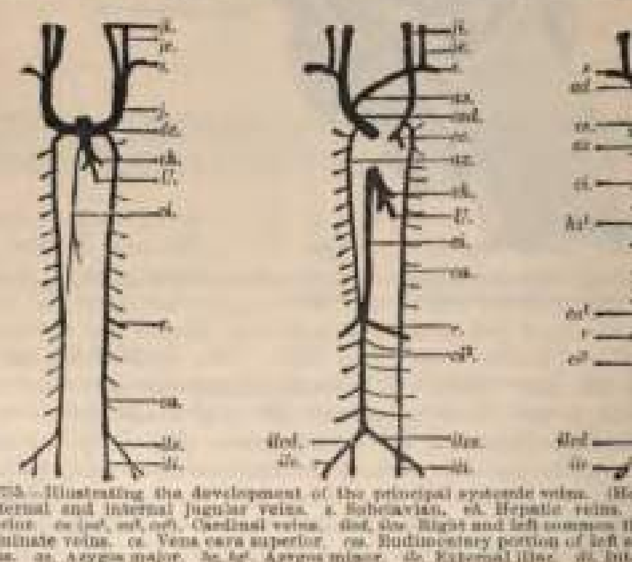

FIG. 755.—Illustrating the development of the principal systemic veins. (Her
je, ji. External and internal jugular veins. s. Subclavian. h. Hepatic veins.
cava inferior. cv (cv¹, cd¹, cd²). Cardinal veins. ilrd, ilre. Right and left common ili
left innominate veins. cs. Vena cava superior. cu. Rudimentary portion of left su
nary sinus. az. Azygos major. hz, hz¹. Azygos minor. ile. External iliac. ili. Inter

azygos major, and receives the right intercostal veins, while th
is brought into communication with it by the development of
in front of the spinal column (Fig. 755, 2, 3).

In consequence of the atrophy of the Wolffian bodies the cardinal veins diminish in size; the primitive jugular veins, on the other hand, become enlarged, owing to the rapid development of the head and brain. They are further augmented by receiving the vein (*subclavian*) from the upper extremity, and so come to form the chief veins of the Cuvierian ducts; these ducts gradually assume an

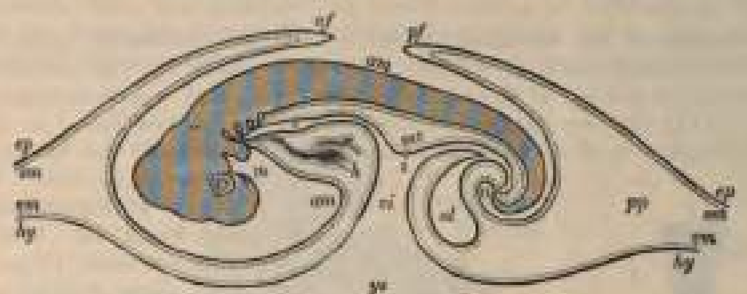

FIG. 756.—Diagrammatic outline of a longitudinal vertical section of the chick on the fourth day. *ep.* Epiblast. *sm.* Somatic mesoblast. *hy.* Hypoblast. *vm.* Visceral mesoblast. *cf.* Cephalic fold. *pf.* Caudal fold. *am.* Cavity of true amnion. *ys.* Yolk-sac. *i.* Intestine. *s.* Foregut. *a.* Future anus, still closed. *m.* The mouth. *me.* The mesentery. *al.* The allantoic vesicle. *pp.* Space between inner and outer folds of amnion. (From Quain's *Anatomy*, Allen Thomson.)

almost vertical position in consequence of the descent of the heart into the thorax. The right and left Cuvierian ducts are originally of the same diameter, and are frequently termed the *right and left superior venæ cavæ.* By the development of a transverse branch (the future *left innominate vein*) between the

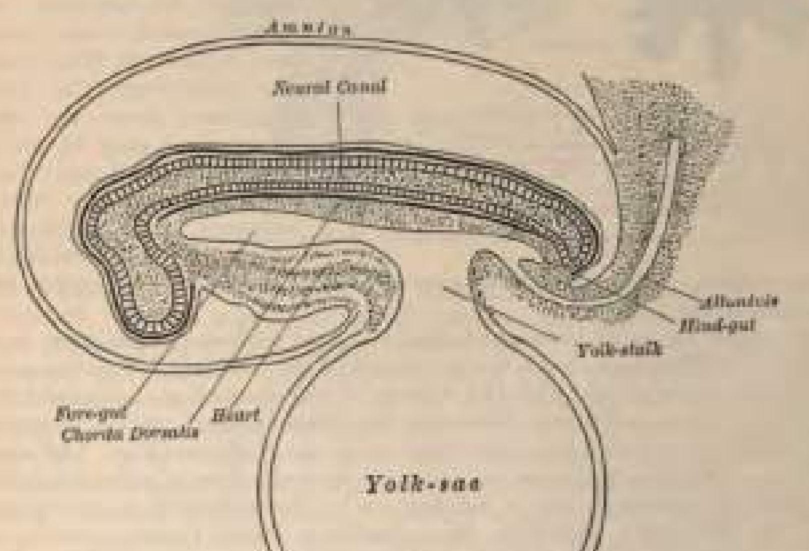

FIG. 757.—Diagram of a longitudinal section of a mammalian embryo. Very early. (After Quain.)

two ducts the blood is carried from the left duct into the right, which thus becomes much enlarged and forms the permanent *superior vena cava*, and into which the vena azygos major opens. The left duct atrophies; its upper part remains pervious as a small vein, which receives the *left superior intercostal vein;* its intermediate portion is represented by the *vestigial fold* of Marshall; its lower part persists as a small vein, the oblique vein of Marshall, which runs downward across the back of the left auricle to join the coronary sinus; this sinus, as has been indicated, represents the persistent left horn of the sinus venosus. The primitive jugular veins become the internal jugular veins of the adult; the lower part of the right primitive jugular vein forms also the right innominate veins (Figs. 755, 1, 2, 3).

The fœtal circulation has been described in the section on the **Blood-Vascular System.**

Development of the Alimentary Canal.—As already indicated (page 1157), the primitive alimentary canal is formed, at an early stage, by the enclosure within the embryo of a portion of the blastodermic vesicle, and is seen to consist of three parts, viz.: (1) the *fore-gut*, within the cephalic flexure and dorsal to the heart; (2) the *mid-gut*, opening freely into the yolk-sac; and (3) the *hind-gut*, within the caudal flexure. The fore-gut and hind-gut end blindly, there being at first neither mouth nor anus (Figs. 756 and 757). The formation of the mouth or stomodæum, and the subsequent communication between it and the cephalic end of the fore-gut, have already been considered; the manner in which the anus is formed will presently be discussed.

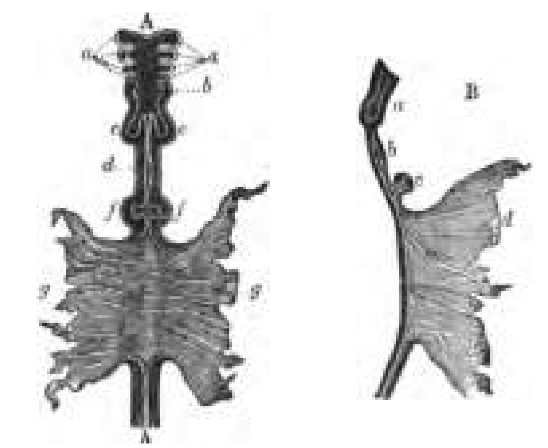

FIG. [illegible].—Early form of the alimentary canal. (From Kölliker, after Bischoff.) In A a front view and in B an antero-posterior section are represented. a. Four pharyngeal or visceral plates. b. The pharynx. c, c. The commencing lungs. d. The stomach. f, f. The diverticula connected with the formation of the liver. g. The yolk-sac into which the middle intestinal groove opens. h. The posterior part of the intestine.

From the fore-gut are developed the pharynx, œsophagus, stomach, and duodenum, and further, as diverticula from the duodenum, the liver and pancreas; from the hind-gut, the greater part of the rectum, and as a tubular outgrowth from it the hollow stalk of the allantois; the mid-gut gives origin to the remainder, or longest section, of the alimentary tube—*i. e.*, the portion which reaches from the duodenum to the rectum.

The upper part of the fore-gut becomes dilated to form the *pharynx*, in relation to which the branchial arches are developed (Figs. 716 and 759); the succeeding part remains tubular, and with the descent of the stomach is elongated to form the œsophagus. Soon a fusiform dilatation, the future stomach, makes its appearance, and beyond this the mid-gut opens freely into the yolk-sac (Figs. 759 and 760).

This opening is at first wide, but, as the body-walls close in around the umbilicus, it is gradually narrowed into a tubular stalk, the *yolk-stalk* or *vitello-intestinal duct*. At this stage, therefore, the alimentary canal forms a nearly straight tube in front of the notochord and primitive aortæ (Fig. 757). From the stomach to the rectum it is attached to the notochord by a band of mesoblast, from which the common mesentery of the gut is subsequently developed. The stomach undergoes a further dilatation, and its two curvatures can be recognized (Figs. 760 and 764), the greater directed toward the vertebral column and the lesser toward the anterior wall of the abdomen, while of its two surfaces one looks to the right and the other to the left. The mid-gut also undergoes great elongation, and forms a V-shaped loop which projects downward and forward; from the bend or angle of the loop the vitello-intestinal duct passes to the umbilicus (Fig. 764). For a time a part of the loop extends beyond the abdominal cavity into the umbilical cord, but by the end of the third month this is withdrawn. With the lengthening of the tube, the mesoblast, which attaches it to the future vertebral column and which carries the blood-vessels for the supply of the gut, is thinned and drawn out to form the *primitive* or *common mesentery*. The portion of this mesentery which is attached to the greater curvature of the stomach is named the *mesogastrium*, and the parts which suspend the colon and rectum are respectively termed the *mesocolon* and *mesorectum* (Fig. 764). About the sixth week a lateral diverticulum makes its appearance a short distance beyond the vitello-intestinal duct, and indicates the future cæcum or boundary between the small and the large intestine. This cæcal diverticulum has at first a uniform calibre, but its blind extremity remains rudimentary and forms the vermiform

FIG. 759.—Human embryo, about fifteen days old. Brain and heart represented from right side; alimentary canal and yolk-sac in mesial section. (After His.)

appendix (Figs. 764, 765). Changes also take place in the position and direction of the stomach. It falls over on to its right surface, which henceforth is directed backward, while its original left surface looks forward; further, its greater curvature is drawn downward and to the left, away from the vertebral column, while its lesser curvature is directed upward, and the commencement of the duodenum is pushed over to the right side of the middle line. The mesogastrium, being attached to the greater curvature, must necessarily follow its movements, and hence it becomes greatly elongated and drawn outward from the vertebral column, and, like the stomach, what was originally its right surface is now directed backward and its left forward. In this way a pouch, the *bursa omentalis*, is formed behind the stomach; this pouch is the future lesser sac of the peritoneum, and it increases in size as the alimentary tube undergoes further development; the entrance to the pouch constitutes the future *foramen of Winslow* (Figs. 761, 765, and 768). The remainder of the canal becomes greatly increased in length, so that the tube is coiled on itself, and this increase in length demands a corresponding increase in the width of the intestinal attachment of the mesentery, so that it becomes plaited or folded.

At this stage the small and the large intestine are attached to the vertebral column by a common mesentery, the coils of the small intestine falling to the right of the middle line, while the large intestine lies on the left side.[1]

[1] Sometimes this condition persists throughout life, and it is then found that the duodenum does not cross from the right to the left side of the vertebral column, but lies entirely on the right side of the mesial plane, where it is continued into the jejunum; the arteries to the small intestine (rami intestini tenuis) also arise from the right instead of the left side of the superior mesenteric artery.

The gut now becomes rotated upon itself, so that the large intestine is carried over in front of the small intestine, and the cæcum is placed immediately below

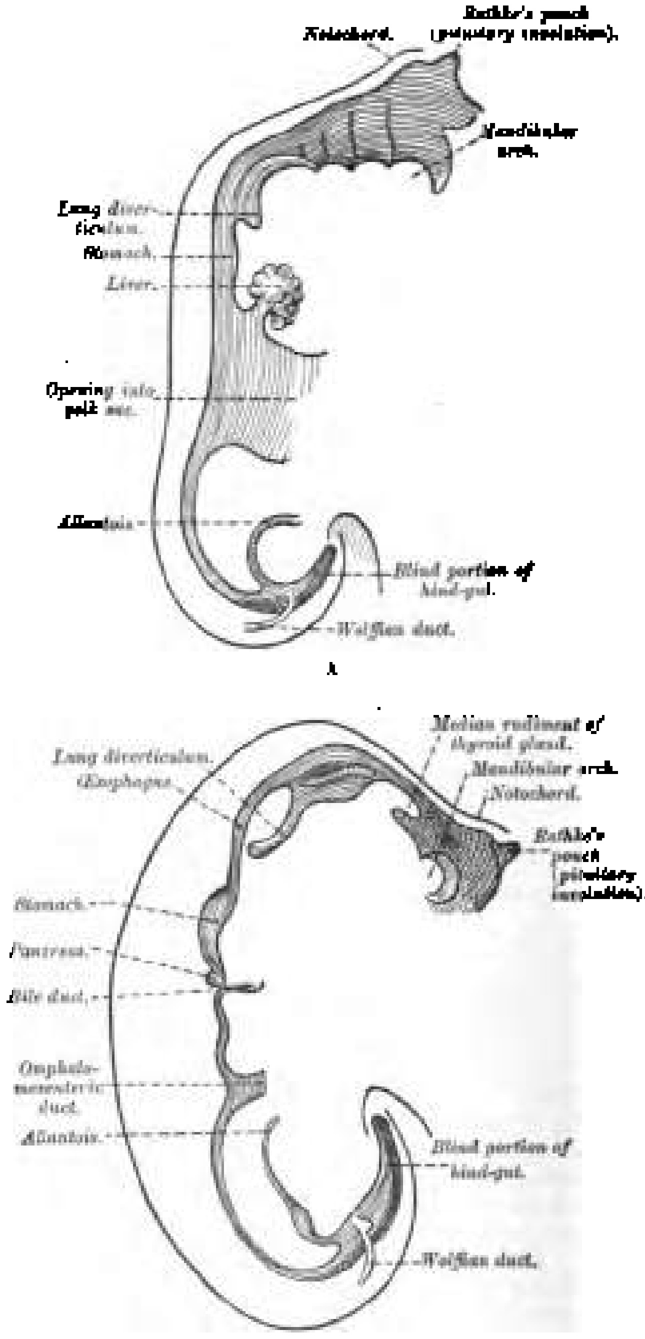

Fig. 780.—Sketches in profile of two stages in the development of the human alimentary canal. (His.) Fig. A × 30. Fig. B × 20.

the liver; about the sixth month the cæcum descends into the right iliac fossa and the large intestine now forms an arch consisting of the ascending, transverse, and descending portions of the colon—the transverse portion crossing in front of the duodenum and lying just below the greater curvature of the stomach; within this arch the coils of the small intestine are disposed (Fig. 765). Some-

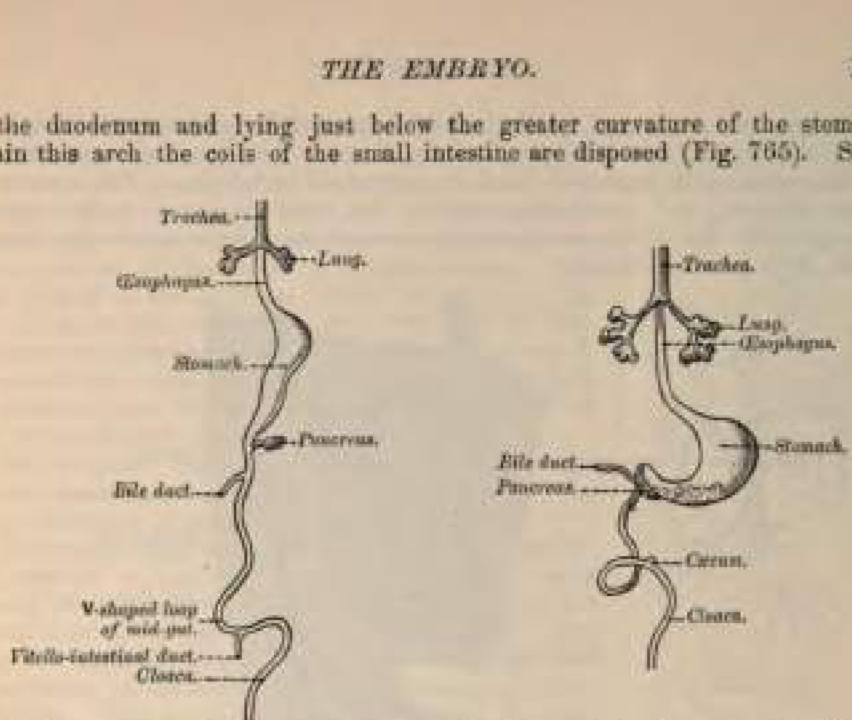

FIG. 761.—Front view of two successive stages in the development of the alimentary canal. (His.)

times the downward progress of the cæcum is arrested, so that in the adult it may be found lying immediately below the liver instead of in the right iliac region.

Further changes take place in the bursa omentalis and in the common mesentery, and give rise to the peritoneal relations seen in the adult. The bursa omentalis, which at first reaches only as far as the greater curvature of the

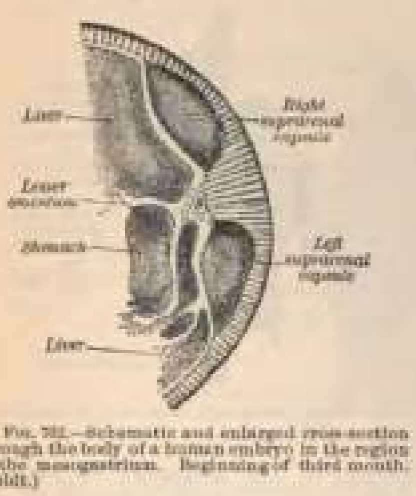

FIG. 762.—Schematic and enlarged cross-section through the body of a human embryo in the region of the mesogastrium. Beginning of third month. (Toldt.)

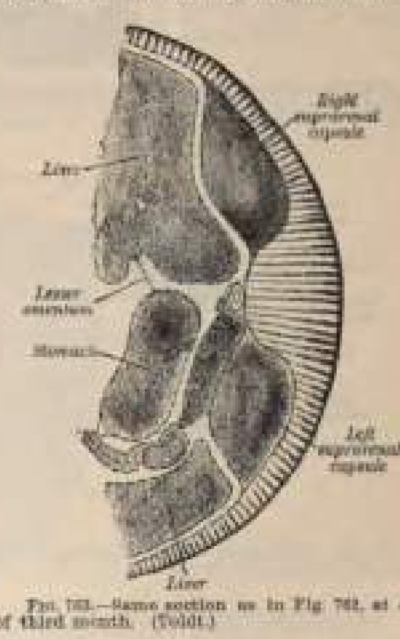

FIG. 763.—Same section as in Fig. 762, at end of third month. (Toldt.)

stomach, grows downward to form the great omentum, and this downward extension lies in front of the transverse colon and the coils of the small intestine. The anterior layer of the transverse mesocolon is at first quite distinct from the posterior wall of the bursa omentalis, but ultimately the two blend, and hence the great omentum appears as if attached to the transverse colon (Figs. 768, 769, and 770). The

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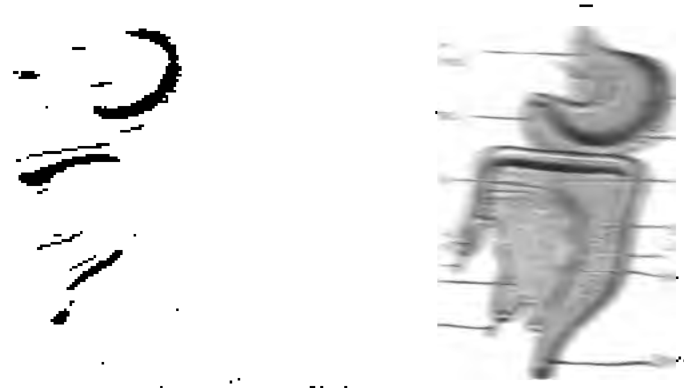

in front of the posterior end of the hind-gut. This invagination is termed the *proctodæum;* the mesoblast between it and the hypoblastic lining of the hind-gut is thinned, and ultimately the septum breaks down and disappears, and the hind-gut opens on the surface; into this part of the hind-gut the urinary and generative organs open for a time, and so it constitutes a *common cloaca.* The small portion of the hind-gut behind the orifice of the anus is named the *caudal* or *post-anal* gut; it communicates with the neural tube by means of a canal, the *neurenteric canal*, already referred to. Ultimately the post-anal gut becomes obliterated, and it, together with the neurenteric canal, finally disappears.

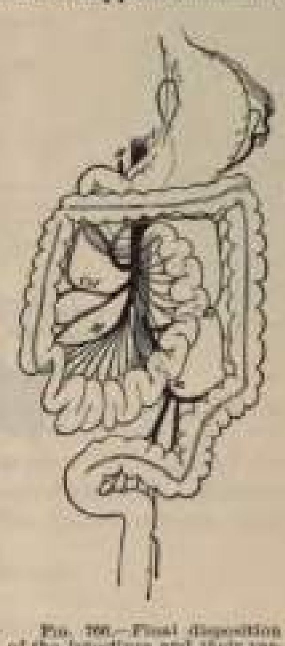

Fig. 766.—Final disposition of the intestines and their vascular relations. (Jonnesco.) *A.* Aorta. *H.* Hepatic artery. *S.* Splenic artery. *M. Col.* Branches of superior mesenteric artery. *m, m'.* Branches of inferior mesenteric artery.

The peritoneal cavity is the space left between the visceral and parietal layers of the mesoblast, and the serous membrane is developed from these layers.

The tongue originates from the floor of the pharynx. The anterior or papillary portion first appears as a rounded elevation, the *tuberculum impar*, between the ventral ends of the mandibular and hyoid arches. Between the third and fourth arches a second larger elevation arises, in the centre of which is a median groove or furrow. This second elevation is termed the *furcula*, and from it the epiglottis is developed, while the median furrow becomes the entrance to the larynx (Fig. 771). The tuberculum impar and the furcula are at first in apposition, but are soon separated by a ridge produced by the forward growth of the second and third arches. This ridge gives rise to the posterior part of the tongue and extends forward in the form of a V, so as to embrace between its two limbs the tuberculum impar. At the apex of the V there is a pit-like invagination to form the middle thyroid rudiment, and this depression persists as the foramen cæcum of the adult. The union of the two parts of the tongue is indicated even

Fig. 767.—The primitive mesentery of a six weeks' human embryo, half schematic. (Kollmann.)

in the adult by a V-shaped depression, the apex of which is at the foramen cæcum, while the two limbs run outward and forward parallel to but a little behind the circumvallate papillæ, which are therefore developed from the tuberculum impar (Figs. 772, 773). The tonsils are developed from the second branchial cleft, and make their appearance between the fourth and fifth months.

The *liver* arises in the form of two diverticula or hollow outgrowths from the ventral surface of that portion of the fore-gut which afterward becomes the

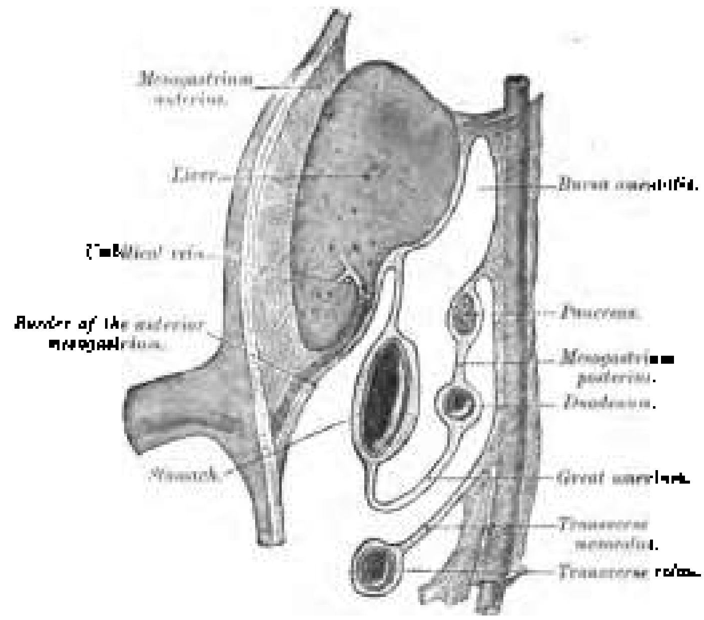

FIG. 759.—Schematic figure of the bursa omentalis, etc. Human embryo of eight weeks. (Kollmann.)

duodenum (Figs. 759, 760). The outgrowths, which represent the right and the left lobes, respectively, of the adult liver, give off solid buds of cells, which grow into columns or cylinders; these unite with one another in every direction to form a close network, in the meshes of which are contained the capillary blood-vessels. Some of these columns become hollowed out and form the bile-ducts, while the

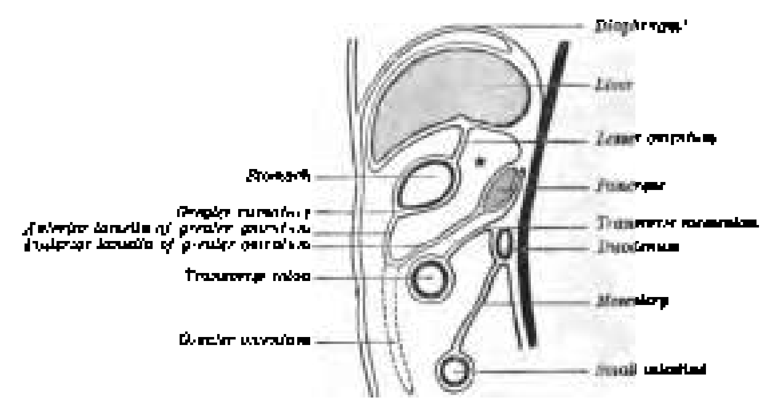

FIG. 760.—Illustrating the development of the bursa omentalis, cavity of the great omentum or lesser sac. Fœtal stage. * Lesser sac. (Hertwig.)

remainder constitute the secreting structure. The minute ducts thus produced unite to form the right and left hepatic ducts; while the common bile-duct is developed as a protrusion from the duodenal wall, and as it grows the liver becomes shifted away from the duodenum. The gall-bladder and cystic duct are formed by a hollow evagination from the wall of the common bile-duct. About the third month the liver almost fills the abdominal cavity. From this period the relative development of the liver is less active, more especially that of the left lobe, which now becomes smaller than the right; but up to the end of fœtal life the liver remains relatively larger than in the adult.

The *pancreas* is also an early formation, being far advanced in the second

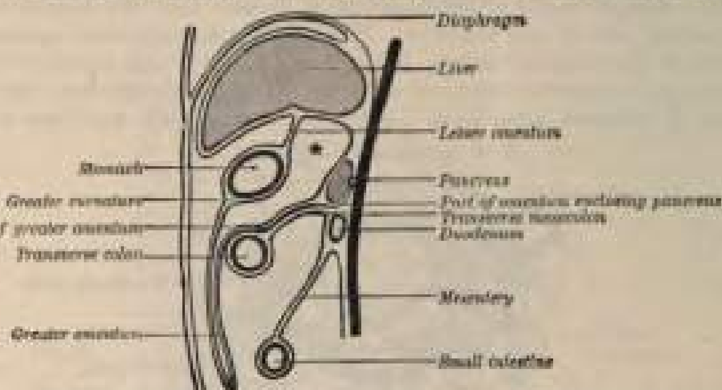

FIG. 770.—Development of bursa omentalis. Infantile stage. Great omentum covers the intestines and has fused with the transverse mesocolon. Pancreas is free from peritoneum posteriorly. (Hertwig.)

month. It originates as a hollow projection from the hypoblast of the dorsal wall of the duodenum (Figs. 760 and 761), opposite the hepatic diverticula, which, as we have already seen, spring from its ventral wall. This hollow process grows

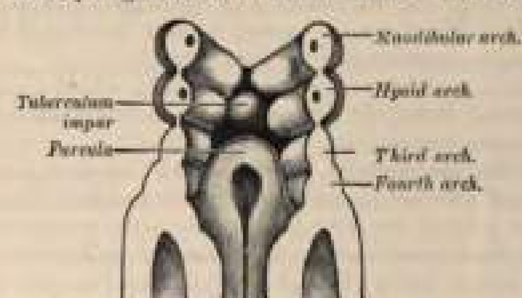

FIG. 771.—The floor of the pharynx of a human embryo about fifteen days old; × 50. (From His.)

between the two layers of the dorsal mesentery and sends out offshoots, which branch abundantly and form a complicated tubular gland. As torsion of the stomach takes place, the pancreas assumes a transverse position and becomes fixed

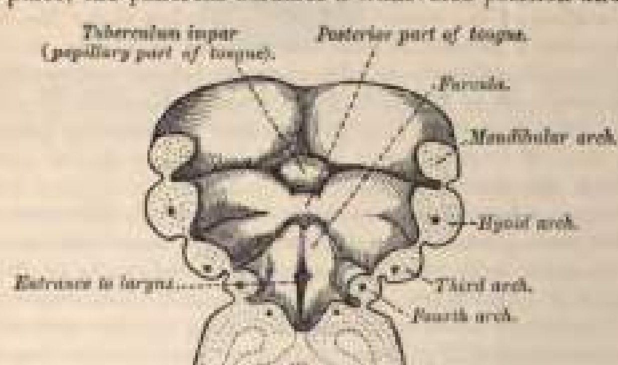

FIG. 772.—The floor of the pharynx of a human embryo about twenty-three days old; × 30. (From His.)

across the dorsal wall of the abdomen, the posterior layer of its mesentery undergoing absorption. Its duct ultimately opens into the duodenum together with the common bile-duct.

The *spleen*, on the other hand, is of mesoblastic origin, for there is never any connection between the intestinal cavity and the substance of this organ. It originates in the mesenteric fold which connects the stomach to the vertebral column (mesogastrium) (Fig. 764).

The thyroid body is developed as a median and two lateral diverticula from the ventral wall of the pharynx. The median diverticulum appears first; it commences at the foramen cæcum, between the anterior and posterior rudiments of the tongue, and extends backward as a tubular duct, the *ductus thyro-glossus*. The lateral diverticula arise from the fourth visceral cleft and fuse with the median

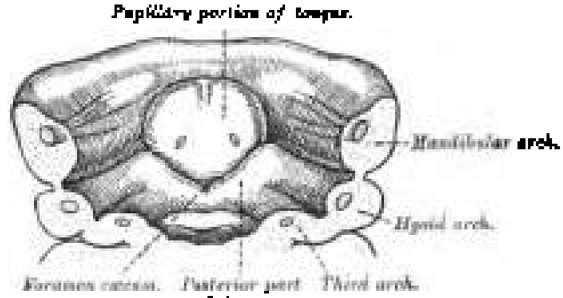

FIG. 773.—Floor of mouth of an embryo slightly older than that shown in Fig. 772. × 16. (From His.)

part to form the thyroid body. The connection of the lateral diverticula with the pharynx disappears early, but the remains of the ductus thyro-glossus may persist as a tube leading from the foramen cæcum toward the hyoid bone, the *pyramid* of the thyroid probably representing its lower part.[1]

The thymus is developed from bilateral diverticula, which are principally derived from the third visceral cleft. It increases in size until the second year of life, after which it undergoes atrophy.

Development of the Respiratory Organs.—The lungs appear somewhat later than the liver. They are developed from a small median *cul-de-sac* or diverticulum from the upper part of the fore-gut, immediately behind the fourth visceral cleft. During the fourth week a pouch is formed on either side of the central diverticulum, and opens freely through it into the fore-gut (pharynx). These lateral pouches soon become subdivided—the right into three and the left into two parts, these subdivisions being the early indications of the lobes of the lungs (Figs. 716 and 761). The two primary pouches have thus a common tube of communication with the pharynx. This common tube becomes the larynx and trachea, the latter rapidly elongating as development proceeds. The larynx first becomes evident as a dilatation of the upper part of the trachea about the end of the fifth week. The epiglottis is developed from the anterior or median portion of the furcula, and the aryteno-epiglottidean folds from its lateral ridges (Fig. 772). The vocal cords and ventricles of the larynx are formed about the fourth month.

As the lungs grow backward they project into the anterior part of the cœlum, which becomes shut off from the rest of the body-cavity by the pericardium and Diaphragm to form the pleural cavities.

The Diaphragm is formed in two parts: (*a*) ventral, (*b*) dorsal. The ventral part appears first, and consists of a thick septum of mesoblast, the *septum transversum*, which projects from the anterior and lateral walls of the embryo, and which ends behind in a free edge. The sinus venosus, which receives the vitelline, umbilical, and Cuvierian veins is placed originally in this septum, and into the posterior part of it also the liver diverticula grow from the duodenum. The sinus separates itself above from the septum, and the greater part of it is incorporated with the right auricle. The liver also becomes separated from it below, except where the veins pass through into the heart. The septum transversum shuts

[1] Kanthack (*Journal of Anat. and Physiol.*, vol. xxv., p. 155) disputed this view. He examined 100 subjects, 60 of which were fetuses or infants, and found that in many cases there was no trace of foramen cæcum and that, when it was present, it formed a short canal near the surface and was lined with stratified squamous, not columnar, epithelium. Further, after careful microscopical examination he found no trace of a tubular lumen in the pyramid of the thyroid body.

off the greater part of the thoracic from the abdominal cavity, but posteriorly there remain two channels of communication, one on each side of the alimentary tube: these channels subsequently become the pleural cavities, and are shut off from the abdomen by folds which grow from the lateral and posterior parts of

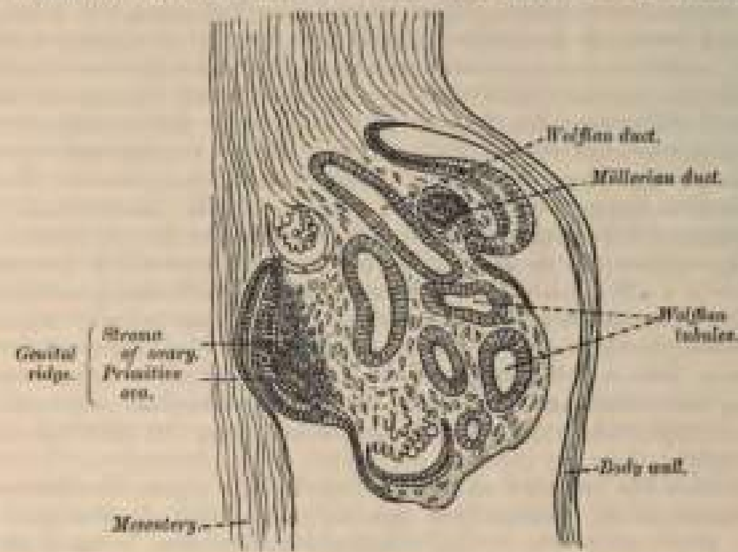

FIG. 774.—Section of the urogenital area of a chick embryo of the fourth day. (Waldeyer.)

the trunk and which fuse with the posterior edge of the septum transversum. Sometimes the fusion is incomplete, thus leaving a permanent communication between the abdominal and one or other of the pleural cavities, and through which some of the abdominal contents may pass, forming what is termed a *diaphragmatic hernia.*

Development of the Urinary and Generative Organs.—The urinary organs are

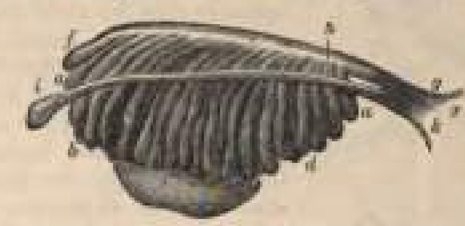

FIG. 775.—Enlarged view from the front of the left Wolffian body before the establishment of the distinction of sex. (From Farre, after Kobelt.) *a, a, b, d,* Tubular structure of the Wolffian body; *e,* Wolffian duct; *f,* Its upper extremity; *g,* Its termination in *x,* the urogenital sinus; *h,* The duct of Müller; *i,* Its upper funnel-shaped extremity; *k,* Its lower end, terminating in the urogenital sinus; *l,* The mass of blastema for the reproductive organ, ovary or testicle.

developed from a ridge of mesoblast at the point where this layer separates into somatopleure and splanchnopleure. As this ridge is situated close to the epiblast, between the paraxial mesoblast and the common pleuro-peritoneal cavity, it has been named the "intermediate cell-mass." It is at first solid, and in it is formed a cord-like arrangement of some of the cells, which extends longitudinally from just below the heart to the posterior extremity of the body-cavity. In this cord-like structure a tube is hollowed out; it gradually becomes separated from the rest of the intermediate cell-mass, and is then named the *Wolffian duct* (Fig. 700).[1] Its posterior end becomes connected with and eventually opens into the hind-gut. Its anterior end becomes connected with pit-like involutions of the peritoneal epithelium, and in the mesoblastic tissue between these invaginations a vascular glomerulus is formed which projects into the peritoneal cavity. It is known as the *head-kidney*

[1] By some embryologists the Wolffian duct is regarded as being of epiblastic origin and formed by a longitudinal invagination of the epiblast.

or *pronephros* (Lankester), and is a very rudimentary organ which speedily disappears. Behind this body and to the inner side of the Wolffian duct, between it and the body-cavity, a number of tubes are formed, which communicate by one extremity with the Wolffian duct, and, passing transversely toward the body-cavity, terminate in cæcal extremities. These tubes are called segmental tubes, and the whole mass is known as the *mid-kidney*, *Wolffian body*, or *mesonephros* (Lankester) (Fig. 775). After a time the cæcal extremities become dilated and enclose a tuft or glomerulus of capillary blood-vessels. As soon as the permanent kidneys are formed, the Wolffian body for the most part disappears. In the male, however, the vasa efferentia and rete testis of the testicle are formed as outgrowths from it. In the female traces of it are left as the *parovarium* and *epoöphoron*. In the male the Wolffian duct becomes the epididymis and vas deferens; in the female it undergoes atrophy, and is represented only by the functionless duct of Gärtner.

Finally, in that portion of the intermediate cell-mass which lies behind the Wolffian body, a differentiation of cells takes place which results in the formation of a number of convoluted tubes; into this a hollow protrusion of the lower end of the Wolffian duct grows up, and thus is formed the *hind-kidney* or *metanephros* (Lankester). This is the permanent kidney. The uriniferous convoluted tubes and Malpighian corpuscles are formed from the intermediate cell-mass, and the collecting tubules and ureter from the protrusion from the posterior end of the Wolffian duct.

Shortly after the formation of the Wolffian body, a second duct becomes developed. It arises on the outer side of this body as a slight thickening of the cells lining the pleuro-peritoneal cavity. This thickening then becomes invaginated into the mesoblast and extends as a cord along the outer side of the Wolffian body, to the posterior extremity of the embryo. It speedily acquires a lumen, and is then known as the *Müllerian duct* (Fig. 774). In its passage to the posterior extremity of the embryo it comes into close relation with the Wolffian duct, and the two ducts on either side become connected with their fellows on the opposite side by their cellular substance into a single cord, the *genital cord* (Fig. 776, *gc*), in which the Wolffian ducts lie side by side in front, and the ducts of Müller behind. These latter tubes in the substance of the genital cord become fused together, and open by a single orifice into the hind-gut (cloaca). At their anterior extremities the ducts of Müller open by a somewhat funnel-shaped orifice into the pleuro-peritoneal cavity. In the female the greater part of the Müllerian duct is developed into the Fallopian tube, but the posterior fused portion of the two ducts is converted into the uterus and vagina (Fig. 777). In the male the greater part of the ducts disappears; the posterior fused portion is believed to be represented by the *sinus pocularis* (*uterus masculinus*) of the urethra.

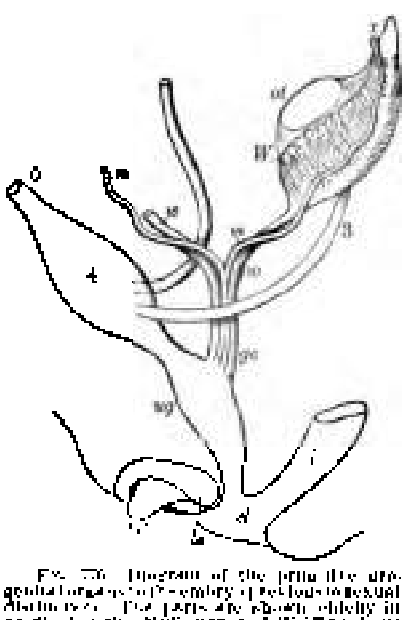

FIG. 776.—Diagram of the primitive urogenital organs in the embryo previous to sexual distinction. The parts are shown chiefly in profile, but the Müllerian and Wolffian ducts are seen from the front. 3. Ureter. 4. Urinary bladder. 5. Urachus. ot. The mass of blastema from which ovary or testicle is afterward formed. W. Left Wolffian body. w, w. Right and left Wolffian ducts. m, m. Right and left Müllerian ducts uniting together and with the Wolffian ducts in gc, the genital cord. ug. Sinus urogenitalis. i. Lower part of the intestine. cl. Common opening of the intestine and urogenital sinus. cp. Elevation which becomes clitoris or penis. ls. Ridge from which the labia majora or scrotum are formed.

It has been seen that the Wolffian and Müllerian ducts open into the common cloaca, which is the termination of the intestinal cavity, and into which the allantois also opens in front (Fig. 776). As the allantois expands into the urinary bladder this common cavity is divided into two by a septum, to form the urogenital sinus in front and the rectum behind, and the Wolffian and Müllerian ducts now open into the urogenital sinus.

The *urinary bladder*, as before stated, is formed by a dilatation of a part of the intra-embryonic portion of the allantois. At the end of the second month the middle part of this portion of the allantois becomes dilated into a spindle-shaped cavity, which persists as the *urinary bladder*. Between the lower extremity of the spindle-shaped dilatation and the intestine is the *urogenital sinus*, into which the Müllerian and Wolffian ducts now open, and which becomes the first part of the urethra. The upper part of the intra-embryonic portion of the allantois, which is not dilated, forms the *urachus* (Fig. 776); this extends into the umbilical cord, and at an early period of embryonic existence forms a tube of communication with the allantois. It is obliterated before the termination of fœtal life, but the cord formed by its obliteration is perceptible throughout life, passing from the upper part of the bladder to the umbilicus. It occasionally remains patent after birth, constituting a well-known malformation.

The *suprarenal* bodies are developed from two different sources. The medullary part of the organ is of epiblastic origin, and is derived from the tissues forming the sympathetic ganglia of the abdomen, while the cortical portion is of mesoblastic origin, and originates as an outgrowth from the upper part of the Wolffian body. The two parts are at first quite distinct, but become combined in the process of development. The suprarenal capsules are at first larger than the kidneys; about the tenth week they equal them in size, and from that time decrease relatively to the kidney, though they remain, throughout fœtal life, proportionally much larger than in the adult.

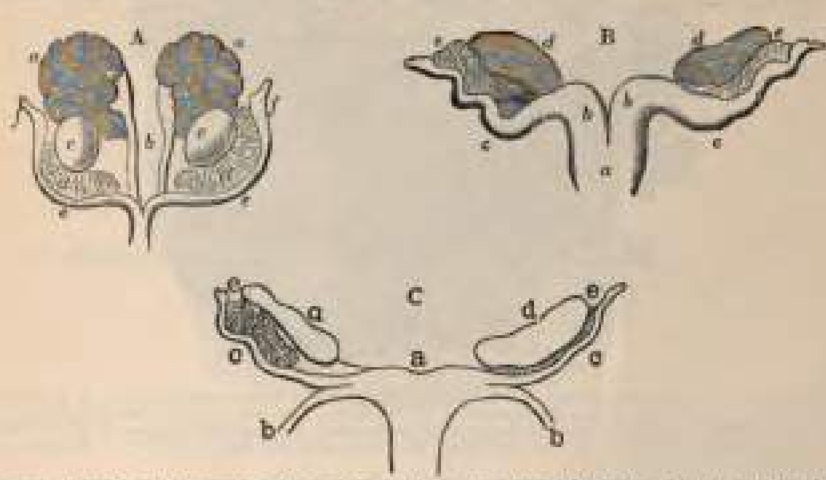

Fig. 777.—Female genital organs of the embryo, with the remains of the Wolffian bodies. (After J. Müller.) A. From a fœtal sheep; a. The kidneys. b. The ureters. c. The ovaries. d. Remains of the Wolffian bodies. e. Fallopian tubes. f. Their abdominal openings. B. More advanced, from a fœtal deer; a. Body of the uterus. b. Cornua. c. Tubes. d. Ovaries. e. Remains of the Wolffian bodies. C. Still more advanced, from the human fœtus of three months; a. The body of the uterus. b. The round ligament. c. The Fallopian tubes. d. The ovaries. e. Remains of the Wolffian bodies.

Ovaries and Testicles.—The first appearance of the reproductive organs is essentially the same in the two sexes, and consists in a thickening of the epithelial layer which lines the peritoneal or body-cavity close to the inner side of the Wolffian body. Beneath this thickened epithelium an increase in the mesoblast takes place, forming a distinct projection or ridge. This is termed the *genital ridge* (Fig. 774), and from it the testicle in the one sex, and the ovary in the other, are developed. As the embryo grows the genital ridge gradually becomes pinched off from the Wolffian body, with which it is at first continuous, though it still remains connected to the remnant of this body by a fold of peritoneum, the *mesorchium* or *mesovarium*. About the seventh week the distinction of sex begins to be perceptible.

The ovary, thus formed from the genital ridge, consists of a central part of connective tissue covered by a layer or layers of epithelium, the *germinal epithelium*. Columns of this epithelium, termed *egg-tubes*, grow down into the stroma, and simultaneously with this an upward growth of the connective tissue takes place between the columns of epithelial cells. It results from this that the columns of cells become enclosed in meshes of connective tissue (Fig. 784). Each egg-tube or nest represents a primitive Graafian follicle, one cell of which becomes enlarged to form the ovum; the remainder form the epithelium of the follicle. The remains of the germinal epithelium on the surface of the ovary form the permanent epithelial covering of this organ. According to Beard, the primitive ova are early set apart during the segmentation of the ovum and migrate into the germinal ridge.

The testicle is developed in a very similar way to the ovary, but the processes are not so well marked. Like the ovary, in its earliest stages it consists of a central mass of connective tissue covered by germinal epithelium. A downward growth of columns of this epithelium into the central connective tissue takes place. From these the seminiferous tubules are developed and become connected with outgrowths from the Wolffian body, which, as before mentioned, form the rete testis and vasa efferentia.

With regard to the other parts of the internal female organs, the Fallopian tube, as has been mentioned, is developed from the upper part of the duct of Müller, while the lower parts of the two ducts approach each other, and, lying

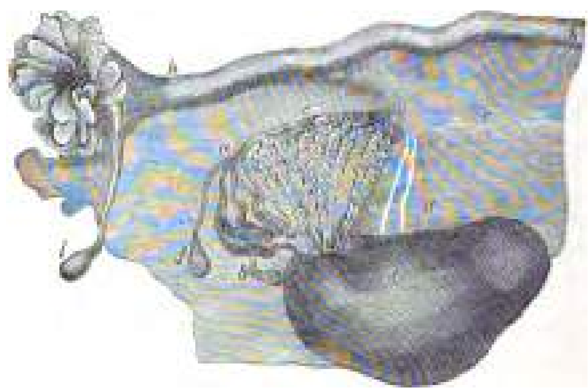

FIG. 778.—Adult ovary, parovarium, and Fallopian tube. (From Farre, after Kobelt.) *a, a.* Epoöphoron formed from the upper part of the Wolffian body. *b.* Remains of the uppermost tubes sometimes forming hydatids. *c.* Middle set of tubes. *d.* Some lower atrophied tubes. *e.* Atrophied remains of the Wolffian duct. *f.* The terminal bulb or hydatid. *h.* The Fallopian tube, originally the duct of Müller. *i.* Hydatid attached to the extremity. *l.* The ovary.

side by side, finally coalesce to form the cavity of the uterus and vagina. This coalescence commences in the middle of the genital cord, and corresponds to the body of the uterus. With regard to the further changes in the female organs, the only remains of the Wolffian body in the complete condition are two rudimentary or vestigial structures, which can be found, on careful search, in the broad ligament near the ovary: the *parovarium* or *organ of Rosenmüller* and the *epoöphoron* (Fig. 778). The organ of Rosenmüller consists of a number of tubes which converge to a transverse portion, the epoöphoron, and this is sometimes prolonged into a distinct duct, running transversely, the *duct of Gärtner*, which is much more conspicuous and extends further in some of the lower animals. This, as has been pointed out, is the remains of the Wolffian duct. About the fifth month an annular constriction marks the position of the neck of the uterus, and after the sixth month the walls of the uterus begin to thicken. The round ligament is derived from a band containing involuntary muscular fibres, which runs downward from the lower part of the Wolffian body to the groin, and which in the male forms the gubernaculum testis; the peritoneum constitutes the broad ligament; the superior ligament of the Wolffian body, which serves to connect it with the Diaphragm, disappears with that body.

With regard to the other parts of the male organs, the Müllerian ducts disappear, with the exception of their lower ends. These unite in the middle line, and open by a common orifice into the urogenital sinus. This constitutes the *utriculus hominis* or *sinus prostaticus*. Frequently, however, the upper end of the duct of Müller remains visible in the male as a little pedunculated body, called the hydatid of Morgagni, in the neighborhood of the epididymis,[1] between the testis and globus major.

The epididymis, the vas deferens, and ejaculatory duct are formed from the Wolffian duct. One or more of the tubes of the Wolffian body form the vas aberrans and a structure described by Giraldès, and called, after him, "the organ of Giraldès," which bears some resemblance to the organ of Rosenmüller in the other sex. It consists of a number of convoluted tubules, lying in the cellular tissue in front of the cord, and close to the head of the epididymis.

Descent of the Testes.—The testes, at an early period of fœtal life, are placed at the back part of the abdominal cavity, behind the peritoneum and a little below the kidneys. The anterior surface and sides are invested by peritoneum. At about the third month of intra-uterine life a peculiar structure, the *gubernaculum testis*, makes its appearance. This structure is at first a slender band, extending

FIG. 779.—Section of the ovary of a newly born child. (Waldeyer.)

from that part of the skin of the groin which afterward forms the scrotum through the inguinal canal to the body and epididymis of the testicle, and is then continued upward in front of the kidney toward the Diaphragm. As development advances the peritoneum covering the testicle encloses it and forms a mesentery, the *mesorchium*, which also encloses the gubernaculum and forms two folds, one above the testicle and the other below it. The one above the testicle is the *plica vascularis*, and contains ultimately the spermatic vessels; the one below, the *plica gubernatrix*, contains the lower part of the gubernaculum, which has now grown into a thick cord; it terminates below at the internal ring in a tube of peritoneum, the processus vaginalis, which protrudes itself down the inguinal canal. The lower part of the gubernaculum by the fifth month has become a thick cord, while the upper part has disappeared. The lower part can now be seen to consist of a central core of unstriped muscle-fibre, and outside this of a firm layer of striped elements, connected, behind the peritoneum, with the abdominal wall. As the scrotum

[1] Mr. Osborn, in the *St. Thomas's Hospital Reports*, 1875, has written an interesting paper pointing out the probable connection between this fœtal structure and one form of hydrocele.

develops, the lower end of the gubernaculum is carried with t
is attached to the bottom of this pouch. The fold of peritoneu
processus vaginalis, projects itself downward into the inguinal
at the external abdominal ring, pushing before it a part of t
muscle and the aponeurosis of the external oblique, which for
cremaster muscle and the external spermatic fascia. It form
gating depression or *cul-de-sac*, which eventually reaches the bot
and into this the testicle is drawn by the growth of the body o
gubernaculum does not grow commensurately with the growth
therefore the testicle, being attached by the gubernaculum to
scrotum, is prevented from rising as the bottom grows, and is
inguinal canal and eventually into the scrotum. It seems ce
gubernacular cord becomes shortened as development proceeds,
causing the testicle to reach the bottom of the scrotum. By th
testicle has reached the scrotum, preceded by the lengthened p
the processus vaginalis, which communicates by its upper extre
toneal cavity. Just before birth the upper part of the pou
closed, and this obliteration extends gradually downward to wit
of the testis. The process of peritoneum surrounding the t
entirely cut off from the general peritoneal cavity, constitutes t

In the female there is also a gubernaculum, which effects a
in the position of the ovary, though not so extensive a change a
in the male. The gubernaculum in the female, as it lies on e
with the fundus of the uterus formed by the union of the M
tracts adhesions to this organ, and thus the ovary is prevent
below this level. The remains of the gubernaculum—that
below the attachment of the cord to the uterus to its termi
majora—ultimately forms the round ligament of the uterus. A
accompanies it along the inguinal canal, analogous to the pr
the male; it is called the *canal of Nuck*. In rare cases the
fail to contract adhesions to the uterus, and then the ovary de
inguinal canal into the labia majora, extending down the
under these circumstances resembles in position the testicles in

Surgical Anatomy.—Abnormalities in the formation and in the
may occur. The testicle may fail to be developed; or the testicle may
the vas deferens may be undeveloped in whole or part; or, again, both te
may be fully developed, but the duct may not become connected to th
may fail in its descent, or it may descend into some abnormal position. T
in the position where it was primarily developed, below the kidney; or
internal abdominal ring, but fail to pass through this opening; it may be
canal, which is perhaps the most common position; or it may pass throu
inal ring and remain just outside it, failing to pass to the bottom of the s
hand, it may get into some abnormal position: it may pass the scrotu
neum, or it may fail to enter the inguinal canal, and may find its way th
into the crural canal, and present itself on the thigh at the saphenous op
third class of cases of abnormality of the testicle: where the organ has
into the scrotum, but is malplaced. The most common form of this i
inverted; that is to say, the organ is rotated so that the epididymis is co
the scrotum, and the body, surrounded by the tunica vaginalis, is directe
cases the vas deferens is to be felt in the front of the cord. The condit
connection with hydrocele and hæmatocele, and the position of the tes
carefully ascertained before performing any operation for these affection
the testicle may be *reversed*. This is a condition in which the top of th
the globus major of the epididymis, is at the bottom of the scrotum,
comes off from the summit of the organ. Cases sometimes occur, gener
in which the spermatic cord becomes twisted. In consequence of this th
is partially or completely arrested; if the latter, the testicle becomes gan
it may undergo atrophy.

The **external organs of generation** (Fig. 780), like the int

[1] The obliteration of the process of peritoneum which accompanies the
the *funicular process*, is often incomplete. See section on Inguinal Hernia.

a stage in which there is no distinction of sex. It is therefore necessary to describe this stage, and then follow the development of the female and male organs respectively.

As stated above, the anal depression, or proctodæum, at an early period is formed by an involution of the epiblast, and the intestine is still closed at its lower end. When the septum between the two opens, which is about the fourth week, the urachus in front and the intestine behind both communicate with the anal

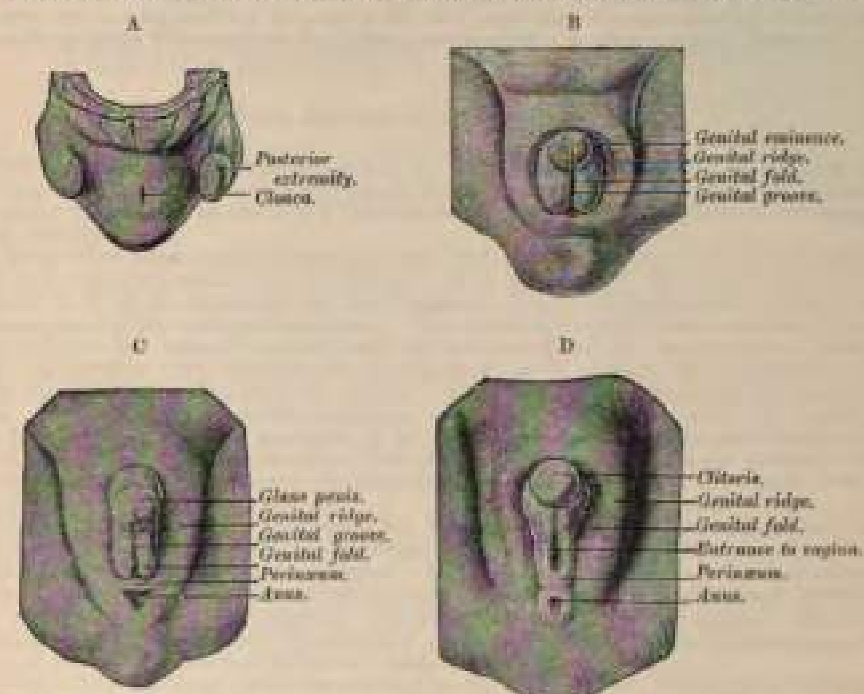

FIG. [illegible].—Stages in the development of the external sexual organs in the male and female. (After the Ecker-Ziegler wax models.) (From Hertwig's *Entwickelungsgeschichte*.)

depression. This, which is now called the *cloaca*, is afterward divided by a transverse septum, the *perinæum*, which appears about the second month. Two tubes are thus formed: the posterior becomes the lower part of the rectum, the anterior is the urogenital sinus. In the sixth week a tubercle, the *genital eminence*, is formed in front of the cloaca, and this is soon surrounded by two folds of skin, the *genital ridges*. Toward the end of the second month the genital tubercle presents, on its lower aspect, a groove, the *genital groove*, which extends downward toward the cloaca. This groove becomes deeper, and is bounded laterally by projecting folds of skin, the *genital folds*. All these parts are well developed by the second month, yet no distinction of sex is possible.

Female Organs.—The female organs are developed by an easy transition from the above. The urogenital sinus persists as the vestibule of the vagina and the urethra. The genital eminence forms the clitoris, the genital ridges the labia majora, and the lips of the genital groove the labia minora, which remain open. An innovation of the epithelium takes place on either side close to the root of the genital tubercle, which becomes the glands of Bartholin.

Male Organs.—In the male the changes are greater. The genital eminence is developed into the penis, the glans appearing in the third month, the prepuce and corpora cavernosa in the fourth. The genital groove closes and thus forms a canal, the spongy portion of the urethra. The urogenital sinus becomes elongated and forms the membranous urethra. The genital ridges unite in the middle line to form the scrotum, at about the same time as the genital groove closes, viz., between the third and fourth month. A similar involution of epithelium to that which in the female forms the glands of Bartholin takes place in the male and becomes the glands of Cowper.

The following table is translated from the work of Beaunis and Bouchard, with some alterations, especially in the earlier weeks. It will serve to present a *résumé* of the above facts in an easily accessible form.[1]

[1] It will be noticed that the time assigned in this table for the appearance of the first rudiment of some of the bones varies in some cases from that assigned in the description of the various bones in the sequel. This is a point on which anatomists differ, and which probably varies in different cases.

CHRONOLOGICAL TABLE

OF

THE DEVELOPMENT OF THE FŒTUS.

(FROM BEAUNIS AND BOUCHARD.)

First Week.—During this period the ovum is in the Fallopian tube. Having been fertilized in the upper part of the tube, it slowly passes down, undergoing segmentation, and reaches the uterus probably about the end of the first week. During this time it does not undergo much increase in size.

Second Week.—The ovum rapidly increases in size and becomes imbedded in the decidua, so that it is completely enclosed in the decidua reflexa by the end of this period. An ovum believed to be of the thirteenth day after conception is described by Reichert. There was no appearance of any embryonic structure. The equatorial margins of the ovum were beset with villi, but the surface in contact with the uterine wall and the one opposite to it were bare. In another ovum, described by His, believed to be of about the fourteenth day, there was a distinct indication of an embryo. There was a medullary groove bounded by folds. In front of this a slightly prominent ridge, the rudimentary heart. The amnion was formed and the embryo was attached by a stalk, the allantois, to the inner surface of the chorion. It may be said, therefore, that these parts, the amnion and the allantois, and the first rudiments of the embryo, the medullary groove, and the heart, are formed at the end of the second week.

Third Week.—By the end of the third week the flexures of the embryo have taken place, so that it is strongly curved. The protovertebral disks, which begin to be formed early in the third week, present their full complement. In the nervous system the primary divisions of the brain are visible, and the primitive ocular and auditory vesicles are already formed. The primary circulation is established. The alimentary canal presents a straight tube communicating with the yolk-sac. The branchial arches are formed. The limbs have appeared as short buds. The Wolffian bodies are visible.

Fourth Week.—The umbilical vesicle has attained its full development. The caudal extremity projects. The upper and the lower limbs and the cloacal aperture appear. The heart separates into a right and left heart. The special ganglia and anterior roots of the spinal nerves, the olfactory fossæ, the lungs and the pancreas can be made out.

Fifth Week.—The allantois is vascular in its whole extent. The first traces of the hands and feet can be seen. The primitive aorta divides into aorta and pulmonary artery. The duct of Müller and genital gland are visible. The ossification of the clavicle and the lower jaw commences. The cartilage of Meckel occupies the first post-oral arch.

Sixth Week.—The activity of the umbilical vesicle ceases. The pharyngeal clefts disappear. The vertebral column, primitive cranium, and ribs assume the cartilaginous condition. The posterior roots of the nerves, the membranes of the nervous centres, the bladder, kidney, tongue, larynx, thyroid body, the germs of teeth, and the genital tubercle and folds are apparent.

Seventh Week.—The muscles begin to be perceptible. The points of ossification of the ribs, scapula, shaft of humerus, femur, tibia, palate, and upper jaw appear.

Eighth Week.—The distinction of arm and forearm, and of thigh and leg, is apparent, as well as the interdigital clefts. The capsule of the lens and pupillary membrane, the interventricular and commencement of the interauricular septum, the salivary glands, the spleen, and suprarenal capsules are distinguishable. The larynx begins to become cartilaginous. All the vertebral bodies are cartilaginous. The points of ossification for the ulna, radius, fibula, and ilium make their appearance. The two halves of the hard palate unite. The sympathetic nerves are now for the first time to be discerned.

[1] [Eternod (*Anat. Anzeiger*, Band xv., 1898) described an ovum which he reconstructed. It had a precise history, from which he concluded that it must have belonged to the end of the second or the beginning of the third week. Including the villi it measured 10 × 8.2 × 6 mm. It was flattened on its embryonal side, and the embryo measured 1.3 mm. The amnion was completely formed and the allantois existed as a long canal. The vitelline circulation was established and the villi of the chorion were beginning to be vascularized. The blastopore still opened into the amniotic cavity, with the primitive groove behind it and the rudimentary groove in front. The notochord was closing in and all three layers of the blastoderm were distinct, except around the blastopore, where they formed an undivided mass.—EDS.]

Ninth Week.—The corpus striatum and the pericardium are first apparent. The ovary and testicle can be distinguished from each other. The genital furrow appears. The osseous nuclei of the bodies and arches of the vertebræ, of the frontal, vomer, and malar bones, of the shafts of the metacarpal and metatarsal bones, and of the phalanges appear. The union of the hard palate is completed. The gall-bladder is seen.

Third Month.—The formation of the fœtal placenta advances rapidly. The projection of the caudal extremity disappears. It is possible to distinguish the male and female organs from each other. The cloacal aperture is divided into two parts. The cartilaginous arches on the dorsal region of the spine close. The points of ossification for the occipital, sphenoid, lachrymal, nasal, squamous portion of temporal and ischium appear, as well as the orbital centre of the superior maxillary. The pons Varolii and fissure of Sylvius can be made out. The eyelids, the hair, and the nails begin to form. The mammary gland, the epiglottis and prostate are beginning to develop. The union of the testicle with the canals of the Wolffian body takes place.

Fourth Month.—The closure of the cartilaginous arches of the spine is complete. Osseous points for the first sacral vertebra and os pubis appear. The ossification of the malleus and incus takes place. The corpus callosum, the membrana lamina spiralis, the cartilage of the Eustachian tube, and the tympanic ring are seen. Fat is first developed in the subcutaneous cellular tissue. The tonsils are seen, and the closure of the genital furrow and the formation of the scrotum and prepuce take place.

Fifth Month.—The two layers of the decidua begin to coalesce. Osseous nuclei of the axis and odontoid process, of the lateral points of the first sacral vertebra, of the median points of the second, and of the lateral masses of the ethmoid make their appearance. Ossification of the stapes and the petrous bone and ossification of the germs of the teeth take place. The germs of the permanent teeth and the organ of Corti appear. The eruption of hair on the head commences. The sudoriferous glands, Brunner's glands, the follicles of the tonsil and base of the tongue, and the lymphatic glands appear at this period. The differentiation between the uterus and vagina becomes apparent.

Sixth Month.—The points of ossification for the anterior root of the transverse process of the seventh cervical vertebra, the lateral points of the second sacral vertebra, the median points of the third, the manubrium sterni and the os calcis appear. The sacro-vertebral angle forms. The cerebral hemispheres cover the cerebellum. The papillæ of the skin, the sebaceous glands, and Peyer's patches make their appearance. The free border of the nail projects from the corium of the dermis. The walls of the uterus thicken.

Seventh Month.—The additional points of the first sacral vertebra, the lateral points of the third, the median point of the fourth, the first osseous point of the body of the sternum, and the osseous point for the astragalus appear. Meckel's cartilage disappears. The cerebral convolutions, the island of Reil, and the tubercula quadrigemina are apparent. The pupillary membrane atrophies. The testicle passes into the vaginal process of the peritoneum.

Eighth Month.—Additional points for the second sacral vertebra, lateral points for the fourth and median points for the fifth sacral vertebra, can be seen.

Ninth Month.—Additional points for the third sacral vertebra, lateral points for the fifth, osseous points for the middle turbinated bone, for the body and great cornu of the hyoid, for the second and third pieces of the body of the sternum, and for the lower end of the femur appear. Ossification of the bony lamina spiralis and axis of the cochlea takes place. The eyelids open, and the testicles are in the scrotum.

INDEX.

A.

B.

D.

G.

H.

I.

M.

N.

O.

P.

T.

W.

X.

Y.

Z.

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