Plan of the Relations of the Posterior Tibial Artery.

In front.
Tibialis posticus.
Flexor longus digitorum.
Tibia.
Ankle-joint.

Inner side.
Posterior tibial nerve,
upper third.

Posterior Tibial.

Outer side.
Posterior tibial nerve,
lower two-thirds.

Behind.
Integument and fascia.
Gastrocnemius.
Soleus.
Deep transverse fascia.
Posterior tibial nerve.
Abductor hallucis.

Behind the Inner ankle the tendons and blood-vessels are arranged, under cover of the internal annular ligament, in the following order, from within outward: First, the tendons of the Tibialis posticus and Flexor longus digitorum, lying in the same groove, behind the inner malleolus, the former being the most internal. External to these is the posterior tibial artery, having a vein on either side: and, still more externally, the posterior tibial nerve. About half an inch nearer the heel is the tendon of the *Flexor longus hallucis.*

Peculiarities in Size.—The posterior tibial is not unfrequently smaller than usual, or absent, its place being supplied by a large peroneal artery which passes inward at the lower end of the tibia, and either joins the small tibial artery or continues alone to the sole of the foot.

Surface Marking.—The course of the posterior tibial artery is indicated by a line drawn from a point one inch below the centre of the popliteal space to midway between the tip of the internal malleolus and the centre of the convexity of the heel.

Surgical Anatomy.—The *application of a ligature* to the posterior tibial may be required in cases of wound of the sole of the foot attended with great hæmorrhage, when the vessel should be tied at the inner ankle. In cases of wound of the posterior tibial it will be necessary to enlarge the opening so as to expose the vessel at the wounded point, excepting where the vessel is injured by a punctured wound from the front of the leg. In cases of aneurism from wound of the artery low down, the vessel should be tied in the middle of the leg. But in aneurism of the posterior tibial high up it would be better to tie the femoral artery.

To tie the posterior tibial artery at the ankle, a semilunar incision, convex backward, should be made through the integument, about two inches and a half in length, midway between the heel and inner ankle or a little nearer the latter. The subcutaneous cellular tissue having been divided, a strong and dense fascia, the internal annular ligament, is exposed. This ligament is continuous above with the deep fascia of the leg, covers the vessels and nerves, and is intimately adherent to the sheaths of the tendons. This having been cautiously divided upon a director, the sheath of the vessels is exposed, and, being opened, the artery is seen with one of the venæ comites on each side. The aneurism needle should be passed round the vessel from the heel toward the ankle, in order to avoid the posterior tibial nerve, care being at the same time taken not to include the venæ comites.

The vessel may also be tied in the lower third of the leg by making an incision, about three inches in length, parallel with the inner margin of the tendo Achillis. The internal saphenous vein being carefully avoided, the two layers of fascia must be divided upon a director, when the artery is exposed along the outer margin of the Flexor longus digitorum, with one of its venæ comites on either side and the nerve lying external to it.

To tie the posterior tibial in the middle of the leg is a very difficult operation, on account of the great depth of the vessel from the surface. The patient being placed in the recumbent position, the injured limb should rest on its outer side, the knee being partially bent and the foot extended, so as to relax the muscles of the calf. An incision about four inches in length should then be made through the integument a finger's breadth behind the inner margin of the tibia, taking care to avoid the internal saphenous vein. The deep fascia having been divided, the margin of the Gastrocnemius is exposed, and must be drawn aside, and the tibial attachment of the Soleus divided, a director being previously passed beneath it. The artery may now be felt pulsating beneath the deep fascia about an inch from the margin of the tibia. The fascia having been divided, and the limb placed in such a position as to relax the muscles of the calf as much as possible, the veins should be separated from the artery, and the aneurism needle passed round the vessel from without inward, so as to avoid wounding the posterior tibial nerve.

The branches of the posterior tibial artery are—the

Peroneal.	Nutrient.
Muscular.	Communicating.
Internal Calcanean.	

The **Peroneal Artery** lies, deeply seated, along the back part of the fibular side of the leg. It arises from the posterior tibial about an inch below the lower border of the Popliteus muscle, passes obliquely outward to the fibula, and then descends along the inner border of that bone, contained in a fibrous canal between the Tibialis posticus and the Flexor longus hallucis, or in the substance of the latter muscle to the lower third of the leg, where it gives off the *anterior peroneal*. It then passes across the articulation between the tibia and fibula to the outer side of the os calcis, where it gives off its terminal branches, the *external calcanean*.

Relations.—This vessel rests at first upon the Tibialis posticus, and then, for the greater part of its course, in a fibrous canal between the origins of the Flexor longus hallucis and Tibialis posticus, covered or surrounded by the fibres of the Flexor longus hallucis. It is *covered*, in the upper part of its course, by the Soleus and deep transverse fascia; *below*, by the Flexor longus hallucis.

PLAN OF THE RELATIONS OF THE PERONEAL ARTERY.

In front.

Tibialis posticus.
Flexor longus hallucis.

Outer side.

Fibula.
Flexor longus hallucis.

Inner side.

Flexor longus hallucis.

Behind.

Soleus.
Deep transverse fascia.
Flexor longus hallucis.

Peculiarities in Origin.—The peroneal artery may arise three inches below the Popliteus, or from the posterior tibial high up, or even from the popliteal.

Its size is more frequently increased than diminished; and then it either reinforces the posterior tibial by its junction with it, or altogether takes the place of the posterior tibial in the lower part of the leg and foot, the latter vessel only existing as a short muscular branch. In those rare cases where the peroneal artery is smaller than usual a branch from the posterior tibial supplies its place, and a branch from the anterior tibial compensates for the diminished anterior peroneal artery. In one case the peroneal artery has been found entirely wanting.

The anterior peroneal is sometimes enlarged, and takes the place of the dorsal artery of the foot.

The branches of the peroneal are—the

Muscular.	Communicating.
Nutrient.	Posterior Peroneal.
Anterior Peroneal.	External Calcanean.

Muscular Branches.—The **peroneal artery** in its course gives off branches to the Soleus, Tibialis posticus, Flexor longus hallucis, and Peronei muscles.

The *nutrient artery* supplies the fibula.

The *Anterior peroneal* pierces the interosseous membrane, about two inches above the outer malleolus, to reach the fore part of the leg, and, passing down beneath the Peroneus tertius to the outer ankle, ramifies on the front and outer side of the tarsus, anastomosing with the external malleolar and tarsal arteries.

The *communicating* is given off from the peroneal about an inch from its lower end, and, passing inward, joins the communicating branch of the posterior tibial.

The *Posterior peroneal* passes down behind the outer ankle to the back of the external malleolus, to terminate in branches which ramify on the outer surface and back of the os calcis.

The *External calcanean* are the terminal branches of the peroneal artery; they pass to the outer side of the heel, and communicate with the external malleolar, and, on the back of the heel, with the internal calcanean arteries.

The **nutrient artery** of the tibia arises from the posterior tibial near its origin, and, after supplying a few muscular branches, enters the nutrient canal of that bone, which it traverses obliquely from above downward. This is the largest nutrient artery of bone in the body.

The **muscular branches** of the posterior tibial are distributed to the Soleus and deep muscles along the back of the leg.

The **communicating branch**, to join a similar branch of the peroneal, runs transversely across the back of the tibia, about two inches above its lower end, passing beneath the Flexor longus hallucis.

The **internal calcanean** are several large arteries which arise from the posterior

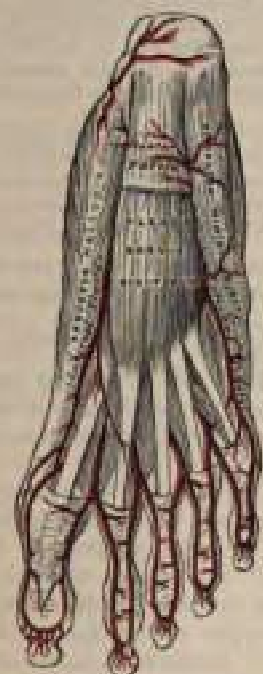

FIG. 322.—The plantar arteries. Superficial view.

FIG. 323.—The plantar arteries. Deep view.

tibial just before its division: they are distributed to the fat and integument behind the tendo Achillis and about the heel, and to the muscles on the inner side of the sole, anastomosing with the peroneal and internal malleolar, and, on the back of the heel, with the external calcanean arteries.

The **Internal Plantar Artery** (Figs. 322, 323), much smaller than the external, passes forward along the inner side of the foot. It is at first situated above[1] the Abductor hallucis, and then between it and the Flexor brevis digitorum, both of which it supplies. At the base of the first metatarsal bone, where it has become much diminished in size, it passes along the inner border of the great toe, inosculating with its digital branch. Small superficial digital branches accompany the digital branches of the internal plantar nerve and join the plantar digital arteries of the three inner spaces.

The **External Plantar Artery**, much larger than the internal, passes obliquely outward and forward to the base of the fifth metatarsal bone. It then turns obliquely inward to the interval between the bases of the first and second

[1] This refers to the erect position of the body. In the ordinary position for dissection the artery is deeper than the muscle.

metatarsal bones, where it anastomoses with the communicating branch from the dorsalis pedis artery, thus completing the *plantar arch*. As this artery passes outward, it is first placed between the os calcis and Abductor hallucis, and then between the Flexor brevis digitorum and Flexor accessorius, and as it passes forward to the base of the little toe, it lies more superficially between the Flexor brevis digitorum and Abductor minimi digiti, covered by the deep fascia and integument. The remaining portion of the vessel is deeply situated: it extends from the base of the metatarsal bone of the little toe to the back part of the first interosseous space, and forms the plantar arch; it is convex forward, lies upon the Interossei muscles opposite the tarsal ends of the metatarsal bones, and is covered by the Adductor obliquus hallucis, the flexor tendons of the toes, and the Lumbricales.

Surface Marking.—The course of the internal plantar artery is represented by a line drawn from the mid-point between the tip of the internal malleolus and the centre of the convexity of the heel to the middle of the under surface of the great toe; the external plantar by a line from the same point to within a finger's breadth of the tuberosity of the fifth metatarsal bone. The plantar arch is indicated by a line drawn from this point; *i. e.* a finger's breadth internal to the tuberosity of the fifth metatarsal bone transversely across the foot to the back of the first interosseous space.

Surgical Anatomy.—Wounds of the plantar arch are always serious, on account of the depth of the vessel and the important structures which must be interfered with in an attempt to ligate it. They must be treated on similar lines to those of wounds of the palmar arches (see page 545). Delorme has shown that it may be ligated from the dorsum of the foot in almost any part of its course by removing a portion of one of the three middle metatarsal bones.

Branches.—The plantar arch, besides distributing numerous branches to the muscles, integument, and fasciæ in the sole, gives off the following branches:

Posterior Perforating. Digital—Anterior Perforating.

The **Posterior Perforating** are three small branches which ascend through the back part of the three outer interosseous spaces, between the heads of the Dorsal interossei muscles, and anastomose with the interosseous branches from the metatarsal artery.

The **Digital Branches** are four in number, and supply the three outer toes and half the second toe. The *first* passes outward from the outer side of the plantar arch, and is distributed to the outer side of the little toe, passing in its course beneath the Abductor and short Flexor muscles. The *second, third*, and *fourth* run forward along the interosseous spaces, and on arriving at the clefts between the toes divide into collateral branches, which supply the adjacent sides of the three outer toes and the outer side of the second. At the bifurcation of the toes each digital artery sends upward, through the fore part of the corresponding interosseous space, a small branch, which inosculates with the interosseous branches of the metatarsal artery. These are the *anterior perforating branches.*

From the arrangement already described of the distribution of the vessels to the toes it will be seen that both sides of the three outer toes and the outer side of the second toe are supplied by branches from the plantar arch; both sides of the great toe and the inner side of the second are supplied by the communicating branch of the dorsalis pedis.

THE VEINS.

The Veins are the vessels which serve to return the blood from the capillaries of the different parts of the body to the heart. They consist of two distinct sets of vessels, the *pulmonary* and *systemic*.

The **Pulmonary Veins** are concerned in the circulation in the lungs. Unlike other vessels of this kind, they contain arterial blood, which they return from the lungs to the left auricle of the heart.

The **Systemic Veins** are concerned in the general circulation; they return the venous blood from the body generally to the right auricle of the heart.

The **Portal Vein,** an appendage to the systemic venous system, is confined to the abdominal cavity, returning the venous blood from the viscera of digestion, and carrying it to the liver by a single trunk of large size, the *vena portæ*. This vessel ramifies in the substance of the liver and breaks up into a minute network of capillaries. These capillaries then re-collect to form the hepatic veins, by which the blood is conveyed to the inferior vena cava.

The veins, like the arteries, are found in nearly every tissue of the body. They commence by minute plexuses which receive the blood from the capillaries. The branches which have their commencement in these plexuses unite together into trunks, and these, in their passage toward the heart, constantly increase in size as they receive tributaries or join other veins. The veins are larger and altogether more numerous than the arteries; hence the entire capacity of the venous system is much greater than that of the arterial, the pulmonary veins excepted, which only slightly exceed in capacity the pulmonary arteries. From the combined area of the smaller venous branches being greater than the main trunks, it results that the venous system represents a cone, the summit of which corresponds to the heart, its base to the circumference of the body. In form the veins are perfectly cylindrical, like the arteries, their walls being collapsed when empty, and the uniformity of their surface being interrupted at intervals by slight constrictions, which indicate the existence of valves in their interior. They usually retain, however, the same calibre as long as they receive no branches.

The veins communicate very freely with one another, especially in certain regions of the body, and this communication exists between the larger trunks as well as between the smaller branches. Thus, in the cavity of the cranium and between the veins of the neck, where obstruction would be attended with imminent danger to the cerebral venous system, we find that the sinuses and larger veins have large and very frequent anastomoses. The same free communication exists between the veins throughout the whole extent of the spinal canal, and between the veins composing the various venous plexuses in the abdomen and pelvis, as the spermatic, uterine, vesical, and prostatic.

Veins have thinner walls than arteries, the difference in thickness being due to the small amount of elastic and muscular tissues which the veins contain. The superficial veins usually have thicker coats than the deep veins, and the veins of the lower limb are thicker than those of the upper.

The minute structure of these vessels will be described in the section on General Anatomy.

The systemic veins are subdivided into three sets: superficial, deep, and sinuses.

The **Superficial** or **Cutaneous Veins** are found between the layers of the superficial fascia, immediately beneath the integument; they return the blood from these structures, and communicate with the deep veins by perforating the deep fascia.

The **Deep Veins** accompany the arteries, and are usually enclosed in the same sheath with those vessels. With the smaller arteries—as the radial, ulnar, brachial, tibial, peroneal—they exist generally in pairs, one lying on each side of the vessel, and are called *venæ comites*. The larger arteries—as the axillary, subclavian, popliteal, and femoral—have usually only one accompanying vein. In certain organs of the body, however, the deep veins do not accompany the arteries; for instance, the veins in the skull and spinal canal, the hepatic veins in the liver, and the larger veins returning blood from the osseous tissue.

Sinuses are venous channels which, in their structure and mode of distribution, differ altogether from the veins. They are found only in the interior of the skull, and consist of channels formed by a separation of the two layers of the dura mater, their outer coat consisting of fibrous tissue, their inner of an endothelial layer continuous with the lining membrane of the veins.

THE PULMONARY VEINS.

The *Pulmonary Veins* return the arterial blood from the lungs to the left auricle of the heart. They are four in number, two for each lung. The pulmonary differ from other veins in several respects: 1. They carry arterial instead of venous blood. 2. They are destitute of valves. 3. They are only slightly larger than the arteries they accompany. 4. They accompany those vessels singly. They commence in a capillary network upon the walls of the air-cells, where they are continuous with the capillary ramifications of the pulmonary artery, and, uniting together, form one vessel for each lobule. These vessels, uniting successively, form a single trunk for each lobe, three for the right and two for the left lung. The vein from the middle lobe of the right lung generally unites with that from the upper lobe, forming two trunks on each side, which open separately into the left auricle. Occasionally they remain separate; there are then three veins on the right side. Not unfrequently the two left pulmonary veins terminate by a common opening.

Within the lung, the branches of the pulmonary artery are *in front*, the veins *behind*, and the bronchi *between* the two.

At the root of the lung, the veins are *in front*, the artery *in the middle*, and the bronchus *behind*.

Within the pericardium, their anterior surface is invested by the serous layer of this membrane. The right pulmonary veins pass behind the right auricle and ascending aorta and superior vena cava; the left pass in front of the thoracic aorta with the left pulmonary artery.

THE SYSTEMIC VEINS.

The systemic veins may be arranged into three groups: 1. Those of the head and neck, upper extremity, and thorax, which terminate in the superior vena cava. 2. Those of the lower extremity, abdomen, and pelvis, which terminate in the inferior vena cava. 3. The cardiac veins, which open directly into the right auricle of the heart.

VEINS OF THE HEAD AND NECK.

The veins of the head and neck may be subdivided into three groups: 1. The veins of the exterior of the head and face. 2. The veins of the neck. 3. The veins of the diploë and interior of the cranium.

Veins of the Exterior of the Head and Face.

The veins of the exterior of the head and face are—the

Frontal.	Temporal.
Supra-orbital.	Internal Maxillary.
Angular.	Temporo-maxillary.
Facial.	Posterior Auricular.

Occipital.

The **frontal vein** commences on the anterior part of the skull by a venous plexus which communicates with the anterior tributaries of the temporal vein. The veins converge to form a single trunk, which runs downward near the middle line of the forehead parallel with the vein of the opposite side, and unites with it at the root of the nose by a transverse branch called the *nasal arch*. Occasionally the frontal veins join to form a single trunk, which bifurcates at the

FIG. 324.—Veins of the head and neck.

root of the nose into the two angular veins. At the root of the nose the veins diverge and join the *supra-orbital vein*, at the inner angle of the orbit, to form the *angular vein*.

The **supra-orbital vein** commences on the forehead, communicating with the anterior temporal vein, and runs downward and inward, superficial to the Occipito-frontalis muscle, receiving tributaries from the neighboring structures, and joins the frontal vein at the inner angle of the orbit to form the *angular vein*.

The **angular vein**, formed by the junction of the frontal and supra-orbital veins, runs obliquely downward and outward on the side of the root of the nose, and receives the veins of the ala nasi on its inner side and the superior palpebral veins on its outer side; it moreover communicates with the ophthalmic vein, thus establishing an important anastomosis between this vessel and the cavernous sinus. Some small veins from the dorsum of the nose terminate in the nasal arch.

The **Facial Vein** commences at the side of the root of the nose, being a direct continuation of the angular vein. It lies behind and follows a less tortuous course than the facial artery. It passes obliquely downward and outward, beneath the Zygomaticus major and minor muscles, descends along the anterior border of the Masseter, crosses over the body of the lower jaw, with the facial artery, and, passing obliquely outward and backward, beneath the Platysma and cervical fascia, unites with the anterior division of the temporo-maxillary vein, to form a trunk of large size (*common facial vein*), which enters the internal jugular. From near its termination a communicating branch often runs down the anterior border of the Sterno-mastoid to join the lower part of the anterior jugular.

Tributaries.—The facial vein receives, near the angle of the mouth, communicating tributaries of considerable size (the *deep facial* or *anterior internal maxillary vein*) from the pterygoid plexus. It is also joined by the inferior palpebral, the superior and inferior labial veins, the buccal veins from the cheek, and the masseteric veins. Below the jaw it receives the submental; the inferior palatine, which returns the blood from the plexus around the tonsil and soft palate; the submaxillary vein, which commences in the submaxillary gland; and, generally, the ranine vein.

Surgical Anatomy.—There are some points about the facial vein which render it of great importance in surgery. It is not so flaccid as are most superficial veins, and, in consequence of this, remains more patent when divided. It has, moreover, no valves. It communicates freely with the intracranial circulation, not only at its commencement by its tributaries, the angular and supra-orbital veins, communicating with the ophthalmic vein, a tributary of the cavernous sinus, but also by its deep branch, which communicates through the pterygoid plexus with the cavernous sinus by branches which pass through the foramen ovale and foramen lacerum medium (see page 606). These facts have an important bearing upon the surgery of some diseases of the face, for on account of its patency the facial vein favors septic absorption, and therefore any phlegmonous inflammation of the face following a poisoned wound is liable to set up thrombosis in the facial vein, and detached portions of the clot may give rise to purulent foci in other parts of the body. And on account of its communications with the cerebral sinuses these thrombi are apt to extend upward into them and so induce a fatal issue.

The **Temporal Vein** commences by a minute plexus on the side and vertex of the skull, which communicates with the frontal and supra-orbital veins in front, the corresponding vein of the opposite side, and the posterior auricular and occipital veins behind. From this network anterior and posterior branches are formed which unite above the zygoma, forming the trunk of the vein. This trunk is joined in this situation by a large vein, the *middle temporal*, which receives the blood from the substance of the Temporal muscle and pierces the fascia at the upper border of the zygoma. The temporal vein then descends between the external auditory meatus and the condyle of the jaw, enters the substance of the parotid gland, and unites with the internal maxillary vein to form the temporo-maxillary vein.

Tributaries.—The temporal vein receives in its course some parotid veins, an articular branch from the articulation of the jaw, anterior auricular veins from the external ear, and a vein of large size, the *transverse facial*, from the side of the face. The middle temporal vein, previous to its junction with the temporal vein, receives a branch, the *orbital vein*, which is formed by some external palpebral branches, and passes backward between the layers of the temporal fascia.

The **Internal Maxillary Vein** is a vessel of considerable size, receiving branches which correspond with those of the internal maxillary artery. Thus it receives the middle meningeal veins, the deep temporal, the pterygoid, masseteric, buccal, alveolar, some palatine veins, and the inferior dental. These branches form a large plexus, the *pterygoid*, which is placed between the Temporal and External pterygoid and partly between the Pterygoid muscles. This plexus communicates very freely with the facial vein and with the cavernous sinus by branches through the foramen Vesalii, foramen ovale, and foramen lacerum medium, at the base of the skull. The trunk of the vein then passes backward behind the neck of the lower jaw, and unites with the temporal vein, forming the temporo-maxillary vein.

The **Temporo-maxillary Vein**, formed by the union of the temporal and internal maxillary veins, descends in the substance of the parotid gland on the outer surface of the external carotid artery, between the ramus of the jaw and the Sterno-mastoid muscle, and divides into two branches, an anterior, which passes inward to join the facial vein, and a posterior, which is joined by the posterior auricular vein and becomes the external jugular.

The **Posterior Auricular Vein** commences upon the side of the head by a plexus which communicates with the tributaries of the temporal and occipital veins. The vein descends behind the external ear and joins the posterior division of the temporo-maxillary vein, forming the external jugular. This vessel receives the stylo-mastoid vein and some tributaries from the back part of the external ear.

The **Occipital Veins** commence at the back part of the vertex of the skull by a plexus in a similar manner to the other veins. These unite and form one or two veins, which follow the course of the occipital artery, passing deeply beneath the muscles of the back part of the neck, and terminate in the internal jugular, occasionally in the external jugular vein. As these veins pass across the mastoid portion of the temporal bone, one of them receives the mastoid vein, which thus establishes a communication with the lateral sinus.

The Veins of the Neck.

The veins of the neck, which return the blood from the head and face, are—the

External Jugular. Anterior Jugular.
Posterior External Jugular. Internal Jugular.
Vertebral.

The **External Jugular Vein** receives the greater part of the blood from the exterior of the cranium and deep parts of the face, being formed by the junction of the posterior division of the temporo-maxillary and posterior auricular veins. It commences in the substance of the parotid gland, on a level with the angle of the lower jaw, and runs perpendicularly down the neck in the direction of a line drawn from the angle of the jaw to the middle of the clavicle. In its course it crosses the Sterno-mastoid muscle, and runs parallel with its posterior border as far as its attachment to the clavicle, where it perforates the deep fascia, and terminates in the subclavian vein, on the outer side of or in front of the Scalenus anticus muscle. In the neck it is separated from the Sterno-mastoid by the investing layer of the deep cervical fascia, and is covered by the Platysma, the superficial fascia, and the integument. This vein is crossed about its middle by the superficialis colli nerve, and its upper half is accompanied by the auricularis magnus nerve. The external jugular vein varies in size, bearing an inverse proportion to that of the other veins of the neck; it is occasionally double. It is provided with two pairs of valves, the lower pair being placed at its entrance into the subclavian vein, the upper pair in most cases about an inch and a half above the clavicle. The portion of vein between the two sets of valves is often dilated, and is termed the *sinus*. These valves do not prevent the regurgitation of the blood or the passage of injection from below upward.[1]

Surgical Anatomy.—Venesection used formerly to be performed on the external jugular vein, but is now probably never resorted to. The anatomical point to be remembered in performing this operation is to cut across the fibres of the Platysma myoides in opening the vein, so that by their contraction they will expose the orifice in the vein and so allow the flow of blood.

Tributaries.—This vein receives the occipital occasionally, the posterior external jugular, and near its termination, the suprascapular and transverse cervical veins.

[1] The student may refer to an interesting paper by Dr. Struthers, "On Jugular Venesection in Asphyxia, anatomically and experimentally considered, including the Demonstration of Valves in the Veins of the Neck," in the *Edinburgh Medical Journal* for November, 1856.

It communicates with the anterior jugular, and, in the substance of the parotid, receives a large branch of communication from the internal jugular.

The **Posterior External Jugular Vein** commences in the occipital region, and returns the blood from the integument and superficial muscles in the upper and back part of the neck, lying between the Splenius and Trapezius muscles. It runs down the back part of the neck, and opens into the external jugular just below the middle of its course.

The **Anterior Jugular Vein** commences near the hyoid bone from the convergence of several superficial veins from the submaxillary region. It passes down between the median line and the anterior border of the Sterno-mastoid, and at the lower part of the neck passes beneath that muscle to open into the termination of the external jugular or into the subclavian vein (Fig. 331). This vein varies considerably in size, bearing almost always an inverse proportion to the external jugular. Most frequently there are two anterior jugulars, a right and left, but occasionally only one. This vein receives some laryngeal veins, and occasionally a small thyroid vein. Just above the sternum the two anterior jugular veins communicate by a transverse trunk, which receives tributaries from the inferior thyroid veins. It also communicates with the internal jugular. There are no valves in this vein.

The **Internal Jugular Vein** collects the blood from the interior of the cranium, from the superficial parts of the face, and from the neck. It commences just external to the jugular foramen, at the base of the skull, being formed by the coalescence of the lateral and inferior petrosal sinuses (Fig. 329). At its origin it is somewhat dilated, and this dilatation is called the *sinus*, or *gulf*, of the internal jugular vein. It runs down the side of the neck in a vertical direction, lying at first on the outer side of the internal carotid, and then on the outer side of the common carotid, and at the root of the neck unites with the subclavian vein to form the innominate vein. The internal jugular vein, at its commencement, lies upon the Rectus capitis lateralis, and behind the internal carotid artery and the nerves passing through the jugular foramen; lower down, the vein and artery lie upon the same plane, the glosso-pharyngeal and hypoglossal nerves passing forward between them; the pneumogastric descends between and behind them in the same sheath, and the spinal accessory passes obliquely outward, behind or in front of, the vein. At the root of the neck the vein of the right side is placed at a little distance from the artery; on the left side it usually lies over the artery at its lower part. The right internal jugular vein crosses the first part of the subclavian artery. The vein is of considerable size, but varies in different individuals, the left one being usually the smaller. It is provided with a pair of valves, which are placed at its point of termination or from half to three-quarters of an inch above it.

Tributaries.—This vein receives in its course the facial, lingual, pharyngeal, superior and middle thyroid veins, and sometimes the occipital. At its point of junction with the common facial vein it becomes greatly increased in size.

The **lingual veins** commence on the dorsum, sides, and under surface of the tongue, and, passing backward, following the course of the lingual artery and its branches, terminate in the internal jugular. Sometimes the ranine vein, which is a branch of considerable size commencing below the tip of the tongue, joins the lingual. Generally, however, it passes backward, crosses the Hyo-glossus muscle in company with the hypoglossal nerve, and joins the facial.

The **pharyngeal vein** commences in a minute plexus, the *pharyngeal*, at the back part and sides of the pharynx, and, after receiving meningeal tributaries and the Vidian and spheno-palatine veins, terminates in the internal jugular. It occasionally opens into the facial, lingual, or superior thyroid vein.

The **superior thyroid vein** commences in the substance and on the surface of the thyroid gland by tributaries corresponding with the branches of the superior thyroid artery, and terminates in the upper part of the internal jugular vein. It receives the superior laryngeal and crico-thyroid veins.

The **middle thyroid vein** collects the blood from the lower part of the lateral lobe of the thyroid gland, and, being joined by some veins from the larynx and trachea, terminates in the lower part of the internal jugular vein.

The **facial** and **occipital veins** have been described above.

Surgical Anatomy.—The internal jugular vein occasionally requires ligature in cases of septic thrombosis of the lateral sinus from suppuration in the middle ear, in order to prevent septic emboli being carried into the general circulation. This operation has been performed recently in several cases, with the most satisfactory results. The cases are generally those of chronic disease of the middle ear, with discharge of pus which perhaps has existed for many years. The patient is seized with acute septic inflammation, spreading to the mastoid cells, and consequent on this, septic thrombosis of the lateral sinus extending to the internal jugular vein. Such cases are always extremely grave, for there is a danger of a portion of the septic clot being detached and causing septic embolism in the thoracic viscera. If the condition is suspected, the sinus should be at once explored by trephining at a point an inch behind the centre of the external auditory meatus and a quarter of an inch above Reid's base line. The condition of the sinus is then investigated, and if it is found to be thrombosed, the surgeon should at once proceed to ligate the internal jugular vein, by an incision along the anterior border of the sterno-mastoid, the centre of which is on a level with the greater cornu of the hyoid bone. The vein should be ligated in two places and divided between. After the vessel has been secured and divided, the lateral sinus is to be thoroughly cleared out, and by removing the ligature from the upper end of the divided vein, all septic clots removed by syringing from the sinus through the vein. If hemorrhage occurs from the distal end of the sinus, it can be arrested by careful plugging with antiseptic gauze.

The **Vertebral Vein** commences in the occipital region by numerous small tributaries from the deep muscles at the upper and back part of the neck; these pass outward and enter the foramen in the transverse process of the atlas, and descend, forming a dense plexus around the vertebral artery in the canal formed by the foramina in the transverse processes of the cervical vertebræ. This plexus unites at the lower part of the neck into two main trunks, one of which emerges from the foramen in the transverse process of the sixth cervical vertebra, and the other through that of the seventh, and, uniting, form a single vessel, which terminates at the root of the neck in the back part of the innominate vein near its origin, its mouth being guarded by **a pair of valves. On the right side** it crosses the first part of the subclavian artery.

Tributaries.—The vertebral vein receives in its course a vein from the inside of the skull through the posterior condyloid foramen; muscular veins from the muscles in the prevertebral region; dorsi-spinal veins, from the back part of the cervical portion of the spine; meningo-rachidian veins, from the interior of the spinal canal; the anterior and posterior vertebral veins; and close to its termination it is joined by a *small vein* from the *first intercostal space* which accompanies the superior intercostal artery.

The **anterior vertebral vein** commences in a plexus around the transverse processes of the upper cervical vertebræ, descends in company with the ascending cervical artery between the Scalenus anticus and Rectus capitis anticus major muscles, and opens into the vertebral vein just before its termination.

The **posterior vertebral vein** (the **deep cervical**) accompanies the profunda cervicis artery, lying between the Complexus and Semispinalis colli. It commences in the suboccipital region by communicating branches from the occipital vein and tributaries from the deep muscles at the back of the neck. It receives tributaries from the plexuses around the spinous processes of the cervical vertebræ, and terminates in the lower end of the vertebral vein.

The Veins of the Diploë.

The diploë of the cranial bones is channelled in the adult by a number of tortuous canals, which are lined by a more or less complete layer of compact tissue.

The veins they contain are large and capacious, their walls being thin, and formed only of endothelium resting upon a layer of elastic tissue, and they present at irregular intervals pouch-like dilatations, or *culs-de-sac*, which serve as reservoirs for the blood. These are the veins of the diploë; they can only be displayed by removing the outer table of the skull.

In adult life, as long as the cranial bones are distinct and separable, these veins are confined to the particular bones; but in old age, when the sutures are united, they communicate with each other and increase in size. These vessels communicate, in the interior of the cranium, with the meningeal veins and with the sinuses of the dura mater, and on the exterior of the skull with the veins of the pericranium. They are divided into the *frontal*, which opens into the supra-orbital vein by an aperture in the supra-orbital notch; the *anterior temporal*, which is confined chiefly to the frontal bone, and opens into one of the deep temporal veins, after escaping by an aperture in the great wing of the sphenoid;

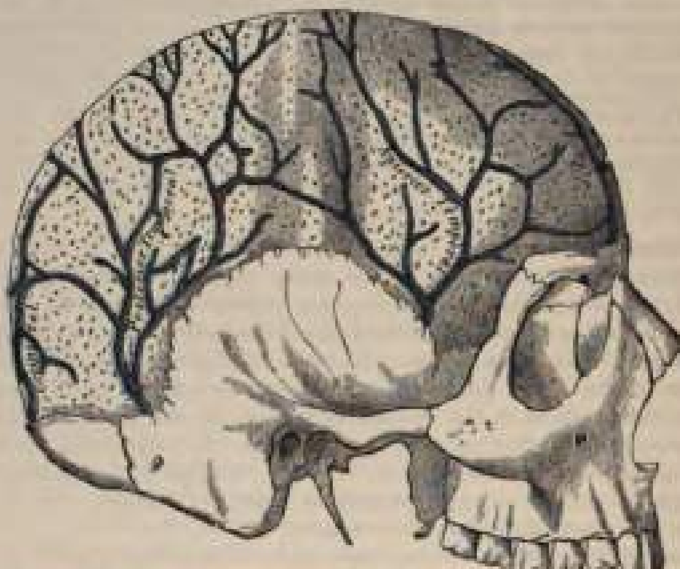

FIG. [illegible].—Veins of the Diploë as displayed by the removal of the outer table of the skull.

the *posterior temporal*, which is confined to the parietal bone, and terminates in the lateral sinus by an aperture at the posterior inferior angle of the parietal bone; and the *occipital*, the largest of the four, which is confined to the occipital bone, and opens either into the occipital vein or internally into the lateral sinus or torcular Herophili.

The Cerebral Veins.

The **Cerebral Veins** are remarkable for the extreme thinness of their coats in consequence of the muscular tissue in them being wanting, and for the absence of valves. They may be divided into two sets: the superficial, which are placed on the surface, and the deep veins, which occupy the interior of the organ.

The **Superficial Cerebral Veins** ramify upon the surface of the brain, being lodged in the sulci between the convolutions, a few running across the convolutions. They receive branches from the substance of the brain and terminate in the sinuses. They are named, from the position they occupy, superior, median, and inferior cerebral veins.

The **Superior Cerebral Veins**, eight to twelve in number on each side, return the blood from the convolutions on the superior surface of the hemisphere; they pass forward and inward toward the great longitudinal fissure, where they receive the *median cerebral veins;* near their termination they become invested with a tubular sheath of the arachnoid membrane, and open into the superior longitudinal sinus in the opposite direction to the course of the current of the blood.

The **Median Cerebral Veins** return the blood from the convolutions of the mesial surface of the corresponding hemisphere; they open into the superior cerebral veins, or occasionally into the inferior longitudinal sinus.

The **Inferior Cerebral Veins** ramify on the lower part of the outer and on the under surface of the cerebral hemisphere. Some, collecting tributaries from the under surface of the anterior lobes of the brain, terminate in the cavernous sinus. One vein of large size, the *middle cerebral vein*, commences on the under surface of the temporal lobe, and, running along the fissure of Sylvius, opens into the cavernous sinus. Another large vein, the *great anastomotic vein of Trolard*, commences on the parietal lobe, runs along the horizontal limb of the fissure of Sylvius, and opens into the anterior part of the cavernous sinus under the lesser wing of the sphenoid. Others commence on the under surface of the base of the brain, and unite to form from three to five veins, which open into the superior petrosal and lateral sinuses from before backward.

The **Deep Cerebral**, or **Ventricular Veins** (*venæ Galeni*), are two in number. They are formed by the union of two veins, the *vena corporis striati*, and the *choroid vein*, on either side. They run backward, parallel with one another, between the layers of the velum interpositum, and pass out of the brain at the great transverse fissure, between the posterior extremity, or *splenium*, of the corpus callosum and the tubercula quadrigemina, to enter the straight sinus. The two veins usually unite to form one, *the vena magna Galeni*, before opening into the straight sinus, just before their union they receive the basilar vein.

The **vena corporis striati** commences in the groove between the corpus striatum and thalamus opticus, receives numerous veins from both of these parts, and unites behind the anterior pillar of the fornix with the choroid vein to form one of the venæ Galeni.

The **choroid vein** runs along the whole length of the outer border of the choroid plexus, receiving veins from the hippocampus major, the fornix and corpus callosum, and unites, at the anterior extremity of the choroid plexus, with the vein of the corpus striatum.

The **Basilar vein** commences at the anterior perforated space at the base of the brain by the union of a small anterior cerebral vein, which courses backward between the anterior lobes of the cerebrum, with the deep Sylvian vein, which descends through the lower part of the Sylvian fissure. It passes backward round the crus cerebri, receiving the inferior striate vein from the corpus striatum, interpeduncular veins from the interpeduncular space, ventricular veins from the middle cornu of the lateral ventricles, and tributaries from the uncinate convolution, and enters the vein of Galen just before its junction with the vein of the opposite side.

The **Cerebellar veins** occupy the surface of the cerebellum, and are disposed in three sets, superior, inferior, and lateral. The *superior* pass partly forward and inward, across the superior vermiform process, to terminate in the straight sinus and the venæ Galeni, partly outward to the lateral and superior petrosal sinuses. The *inferior cerebellar veins*, of large size, terminate in the lateral, superior petrosal, and occipital sinuses.

The perivascular lymphatics alluded to in the section on General Anatomy are especially found in connection with the vessels of the brain. These vessels are enclosed in a sheath, which acts as a lymphatic channel, through which the lymph is carried to the subarachnoid and subdural spaces, from which it is returned into the general circulation.

The Sinuses of the Dura Mater.

The sinuses of the dura mater are venous channels, analogous to the veins, their outer coat being formed by the dura mater; their inner, by a continuation of the lining membrane of the veins. They are fourteen in number, and are divided into two sets: 1, those situated at the upper and back part of the skull; 2, those at the base of the skull. The former are—the

Superior Longitudinal Sinus.	Straight Sinus.
Inferior Longitudinal Sinus.	Lateral Sinuses.
Occipital Sinus.	

The **Superior Longitudinal Sinus** occupies the attached margin of the falx cerebri. Commencing at the foramen cæcum, through which, in the child, it constantly communicates by a small branch with the veins of the nasal fossæ, it runs from before backward, grooving the inner surface of the frontal, the adjacent margins of the two parietal, and the superior division of the crucial ridge of the occipital bone, and terminates by opening into the torcular Herophili. The sinus is triangular in form, narrow in front, and gradually increases in size as it passes backward. On examining its inner surface it presents the internal openings of the superior cerebral veins, which run, for the most part, from behind forward, and open chiefly at the back part of the sinus, their orifices being concealed by fibrous folds; numerous fibrous bands (*chordæ Willisii*) are also seen, extending transversely across the inferior angle of the sinus: and, lastly, some small, white, projecting bodies, the *glandulæ Pacchioni*. This sinus receives the superior cerebral veins, numerous veins from the diploë and dura mater, and, at the posterior extremity of the sagittal suture, veins from the pericranium, which pass through the parietal foramina.

The *torcular Herophili*, or *confluence of the sinuses*, is the dilated extremity of the superior longitudinal sinus. It is of irregular form, and is lodged on one side (generally the right) of the internal occipital protuberance. From it the lateral sinus of the side to which it is deflected is derived. It receives also the blood from the occipital sinus.

The **Inferior Longitudinal Sinus**, more correctly described as the *inferior longitudinal vein*, is contained in the posterior part of the free margin of the falx cerebri. It is of a cylindrical form, increases in size as it passes backward, and terminates in the straight sinus. It receives several veins from the falx cerebri, and occasionally a few from the mesial surface of the hemispheres.

The **Straight Sinus** is situated at the line of junction of the falx cerebri with the tentorium. It is triangular in form, increases in size as it proceeds backward, and runs obliquely downward and backward from the termination of the inferior longitudinal sinus to the lateral sinus of the opposite side to that into which the superior longitudinal sinus is prolonged. It communicates by a cross branch

FIG. 328.—Vertical section of the skull, showing the sinuses of the dura mater.

with the torcular Herophili. Beside the inferior longitudinal sinus, it receives the venæ Galeni and the superior cerebellar veins. A few transverse bands cross its interior.

The **Lateral Sinuses** are of large size, and are situated in the attached margin of the tentorium cerebelli. They commence at the internal occipital protuberance, one, generally the right, being the direct continuation of the superior longitudinal sinus, the other of the straight sinus. They pass outward and forward, describing a slight curve with its convexity upward, to the base of the petrous portion of the temporal bone, then curve downward and inward on each side to reach the jugular foramen, where they terminate in the internal jugular vein. Each sinus rests, in its course, upon the inner surface of the occipital, the posterior inferior angle of the parietal, the mastoid portion of the temporal, and on the occipital again just before its termination. These sinuses are frequently of unequal size, that formed by the superior longitudinal sinus being the larger, and they increase in size as they proceed from behind forward. The horizontal portion is of a triangular form, the curved portion semicylindrical. Their inner surface is smooth, and not crossed by the fibrous bands found in the other sinuses. These sinuses receive the blood from the superior petrosal sinuses at the base of the petrous portion of the temporal bone, and they unite with the inferior petrosal sinus, just external to the jugular foramen, to form the internal jugular vein (Fig. 329). They communicate with the veins of the pericranium by means of the mastoid and posterior condyloid veins, and they receive some of the inferior cerebral and inferior cerebellar veins and some veins from the diploë. The *petro-squamous sinus*, when present, runs backward along the junction of the petrous and squamous-temporal, and opens into the lateral sinus.

The **Occipital** is the smallest of the cranial sinuses. It is generally single, but occasionally there are two. It is situated in the attached margin of the falx cerebelli. It commences by several small veins around the margin of the foramen magnum, one of which joins the termination of the lateral sinus; it communicates with the posterior spinal veins and terminates in the torcular Herophili.

The sinuses at the base of the skull are—the

Cavernous sinuses.	Superior Petrosal sinuses.
Circular sinus.	Inferior Petrosal sinuses.

Transverse sinus.

The **Cavernous Sinuses** are named from their presenting a reticulated structure, due to their being traversed by numerous interlacing filaments. They are two in number, of irregular form, larger behind than in front, and are placed one on each side

Fig. 327.—Plan showing the relative position of the structures in the right cavernous sinus, viewed from behind.

of the sella turcica, extending from the sphenoidal fissure to the apex of the petrous portion of the temporal bone; they receive anteriorly the ophthalmic vein through the sphenoidal fissure, and open behind into the petrosal sinuses. On the inner wall of each sinus is found the internal carotid artery, accompanied by filaments of the carotid plexus and by the sixth nerve; and on its outer wall, the third, fourth, and ophthalmic division of the fifth nerve. These parts are separated from the blood flowing along the sinus by the lining membrane, which is continuous with the inner coat of the veins. The cavernous sinuses receive some of the cerebral veins, and also a small sinus, the *spheno-parietal*, which extends inward on the under aspect of the lesser wing of the sphenoid; they communicate with the lateral sinuses by means of the superior and inferior petrosal sinuses, and with the facial vein through the ophthalmic vein. They also communicate with each other by means of the circular sinus.

Surgical Anatomy.—An arterio-venous communication may be established between the cavernous sinus and the carotid artery, as it lies in it, giving rise to a pulsating tumor in the orbit. These communications may be the result of injury, such as a bullet wound, a stab, or a blow or fall sufficiently severe to cause a fracture of the base of the skull in this situation, or they may occur idiopathically from the rupture of an aneurism or a diseased condition of the internal carotid artery. The disease begins with sudden noise and pain in the head, followed by exophthalmos, swelling, and congestion of the lids and conjunctivæ, and development of a pulsating tumor at the margin of the orbit, with thrill and the characteristic bruit; accompanying these symptoms there may be impairment of sight, paralysis of the iris and orbital muscles, and pain of varying intensity. In some cases the opposite orbit becomes affected by the passage of the arterial blood into the opposite sinus by means of the circular sinus. Or the arterial blood may find its way through the emissary veins (see page 605) into the pterygoid plexus, and thence into the veins of the face. Pulsating tumors of the orbit may also be due to traumatic aneurism of one of the orbital arteries, and symptoms resembling those of pulsating tumor may be produced by pressure on the ophthalmic vein, as it enters the sinus, by an aneurism of the internal carotid artery.

The **Ophthalmic Veins** are two in number, superior and inferior.

The *superior ophthalmic vein* connects the angular vein at the inner angle of the orbit with the cavernous sinus; it pursues the same course as the ophthalmic artery, and receives tributaries corresponding to the branches derived from that vessel. Forming a short single trunk, it passes through the inner extremity of the sphenoidal fissure, and terminates in the cavernous sinus.

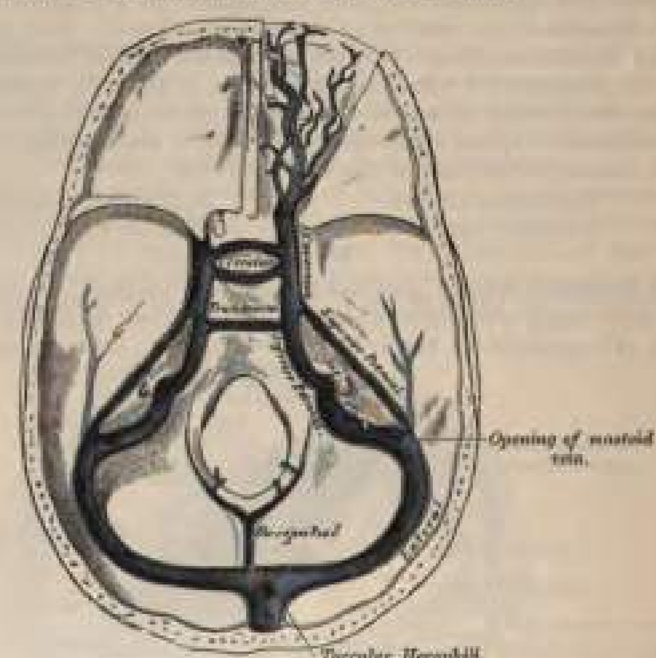

FIG. [illegible].—The sinuses at the base of the skull.

The *inferior ophthalmic vein* receives the veins from the floor of the orbit, and either passes out of the orbit through the spheno-maxillary fissure to join the pterygoid plexus of veins, or else, passing backward through the sphenoidal fissure, it enters the cavernous sinus, either by a separate opening, or, more frequently, in common with the superior ophthalmic vein.

The **Circular sinus** is formed by two transverse vessels, the *anterior* and *posterior intercavernous sinuses*, which connect together the two cavernous sinuses; the one passing in front and the other behind the pituitary body, and thus forming with the cavernous sinuses a venous circle around that body. The anterior one is usually the larger of the two, and one or other is occasionally found to be absent.

The **Superior petrosal sinus** is situated along the superior border of the petrous portion of the temporal bone, in the front part of the attached margin of the tentorium. It is small and narrow, and connects together the cavernous and lateral sinuses at each side. It receives some cerebellar and inferior cerebral veins, and veins from the tympanic cavity.

The **Inferior petrosal sinus** is situated in the groove formed by the junction of the posterior border of the petrous portion of the temporal with the basilar process of the occipital. It commences in front at the termination of the cavernous sinus, and behind joins the lateral sinus after it has passed through the jugular foramen; the junction of these two sinuses forming the commencement of the internal jugular vein. The inferior petrosal sinus receives the veins from the internal ear and also veins from the medulla, pons, and under surface of the cerebellum.

The junction of the two sinuses takes place at the lower border of, or just external to, the jugular foramen. The exact relation of the parts to one another in the foramen is as follows: The inferior petrosal sinus is in front, with the meningeal branch of the ascending pharyngeal artery, and is directed obliquely downward and backward; the lateral sinus is situated at the back part of the fora-

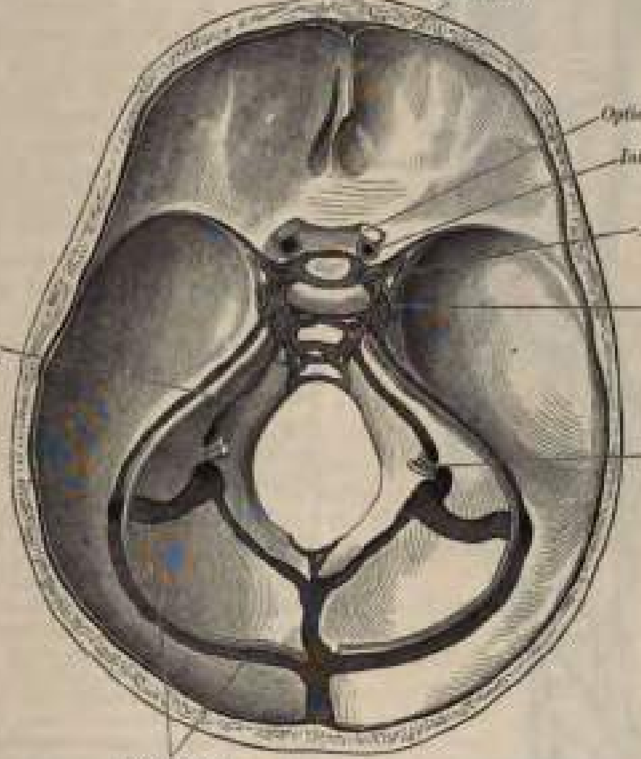

FIG. 329.—Relation of nerves to sinuses in jugular foramen. (Henle.)

men with a meningeal branch of the occipital artery, and between the two are the glosso-pharyngeal, pneumogastric, and spinal accessory nerves. These three sets of structures are divided from each other by two processes of fibrous tissue. The junction of the sinuses takes place superficial to the nerves, so that these latter lie a little internal to the venous channels in the foramen (see Fig. 329). These sinuses are semicylindrical in form.

The **Transverse Sinus**, or **basilar sinus**, consists of several interlacing veins between the layers of the dura mater over the basilar process of the occipital bone, which serve to connect the two inferior petrosal sinuses. With them the anterior spinal veins communicate.

Emissary Veins.—The emissary veins are vessels which pass through apertures in the cranial wall and establish communications between the sinuses inside the skull and the veins external to it. Some of these are always present, others only occasionally so. They vary much in size in different individuals. The principal emissary veins are the following: 1. A vein, almost always present, which passes through the mastoid foramen and connects the lateral sinus with the posterior auricular or with an occipital vein. 2. A vein which passes through the parietal foramen and connects the superior longitudinal sinus with the veins of the scalp. 3. A plexus of minute veins which pass through the anterior condyloid foramen and connect the occipital sinus with the vertebral vein and deep veins of the neck. 4. An inconstant vein which passes through the posterior condyloid foramen and connects the lateral sinus with the deep veins of the neck. 5. One or two veins of considerable size which pass through the foramen ovale and connect the cavernous sinus with the pterygoid and pharyngeal plexuses. 6. Two or three small veins which pass through the foramen lacerum medium and connect the cavernous sinus with the pterygoid and pharyngeal plexuses. 7. There is sometimes a small vein passing through the foramen of Vesalius connecting the same parts. 8. A plexus of veins passing through the carotid canal and connecting the cavernous sinus with the internal jugular vein.

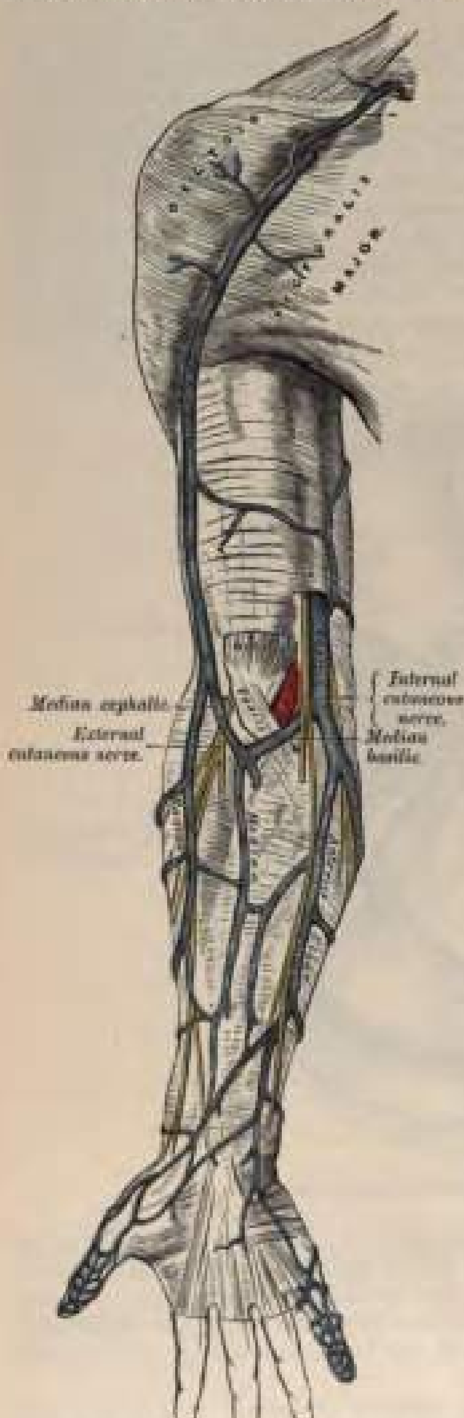

FIG. [illegible].—The superficial veins of the upper extremity.

Surgical Anatomy.—These emissary veins are of great importance in surgery. In addition to them there are, however, other communications between the intra- and extra-cranial circulation, as, for instance, the communication of the angular and supra-orbital veins with the ophthalmic vein at the inner angle of the orbit (page 595), and the communication of the veins of the scalp with the diploic veins (page 599). Through these communications inflammatory processes commencing on the outside of the skull may travel inward, leading to osteo-phlebitis of the diploë and inflammation of the membranes of the brain. To this in former days was to be attributed one of the principal dangers of scalp wounds and other injuries of the scalp.

By means of these emissary veins blood may be abstracted almost directly from the intracranial circulation. For instance, leeches applied behind the ear abstract blood almost directly from the lateral sinus by means of the vein passing through the mastoid foramen. Again, epistaxis in children will frequently relieve severe headache, the blood which flows from the nose being derived from the longitudinal sinus by means of the vein which passes through the foramen cæcum, which is another communication between the intracranial and extracranial circulation which is constantly found in children.

VEINS OF THE UPPER EXTREMITY AND THORAX.

The veins of the Upper Extremity are divided into two sets, *superficial* and *deep*.

The **Superficial Veins** are placed immediately beneath the integument between the two layers of superficial fascia.

The **Deep Veins** accompany the arteries, and constitute the venæ comites of those vessels.

Both sets of vessels are provided with valves, which are more numerous in the deep than in the superficial.

The superficial veins of the upper extremity are—the

Superficial veins of the Hand.	Median.
Anterior Ulnar.	Median Cephalic.
Posterior Ulnar.	Median Basilic.
Common Ulnar.	Basilic.
Radial.	Cephalic.

The **Superficial Veins of the Hand and Fingers** are principally situated on the dorsal surface, and form two plexuses, an inner and outer, on the back of the hand. The inner plexus is formed by the veins from the little finger (*vena salvatella*), the ring finger, and the ulnar side of the middle finger; from it the anterior and posterior ulnar veins are derived. The outer plexus is formed by veins from the thumb, the index finger, and radial side of the middle finger; from it the radial vein is derived. These two plexuses communicate on the back of the hand, forming the superficial arch of veins in this situation. The superficial veins from the palm of the hand form a plexus in front of the wrist, from which the median vein is derived.

The **Anterior Ulnar Vein** commences on the anterior surface of the ulnar side of the hand and wrist, and ascends along the anterior surface of the ulnar side of the forearm to the bend of the elbow, where it joins with the posterior ulnar vein to form the common ulnar. Occasionally it opens separately into the median basilic vein. It communicates with branches of the median vein in front and with the posterior ulnar behind.

The **Posterior Ulnar Vein** commences on the posterior surface of the ulnar side of the wrist. It runs on the posterior surface of the ulnar side of the forearm, and just below the elbow unites with the anterior ulnar vein to form the common ulnar, or else joins the median basilic to form the basilic. It communicates with the deep veins of the palm by a branch which emerges from beneath the Abductor minimi digiti muscle.

The **Common Ulnar** is a short trunk which is not constant. When it exists it is formed by the junction of the two preceding veins, and, passing upward and outward, joins the median basilic to form the basilic vein. When it does not exist the anterior and posterior ulnar veins open separately into the median basilic vein.

The **Radial Vein** commences from the dorsal surface of the wrist, communicating with the deep veins of the palm by a branch which passes through the first interosseous space. It forms a large vessel, which ascends along the radial side of the forearm and receives numerous veins from both its surfaces. At the bend of the elbow it unites with the median cephalic to form the cephalic vein.

The **Median Vein** ascends on the front of the forearm, and communicates with the anterior ulnar and radial veins. At the bend of the elbow it receives a branch of communication from the deep veins, and divides into two branches, the median cephalic and median basilic, which diverge from each other as they ascend.

The **Median Cephalic**, usually the smaller of the two, passes outward in the groove between the Supinator longus and Biceps muscles, and joins with the radial to form the cephalic vein. The branches of the external cutaneous nerve pass beneath this vessel.

The **Left Innominate Vein**, about two and a half inches in length, and larger than the right, passes from left to right across the upper and front part of the chest, at the same time inclining downward, to unite with its fellow of the opposite side, forming the *superior vena cava*. It is in relation, in front, with the first piece of the sternum, from which it is separated by the Sterno-hyoid and Sterno-thyroid muscles, the thymus gland or its remains, and some loose areolar tissue. Behind, it lies across the roots of the three large arteries arising from the arch of the aorta. This vessel is joined by the left vertebral, left internal mammary, left inferior thyroid, and the left superior intercostal veins, and occasionally some thymic and pericardiac veins. There are no valves in the innominate veins.

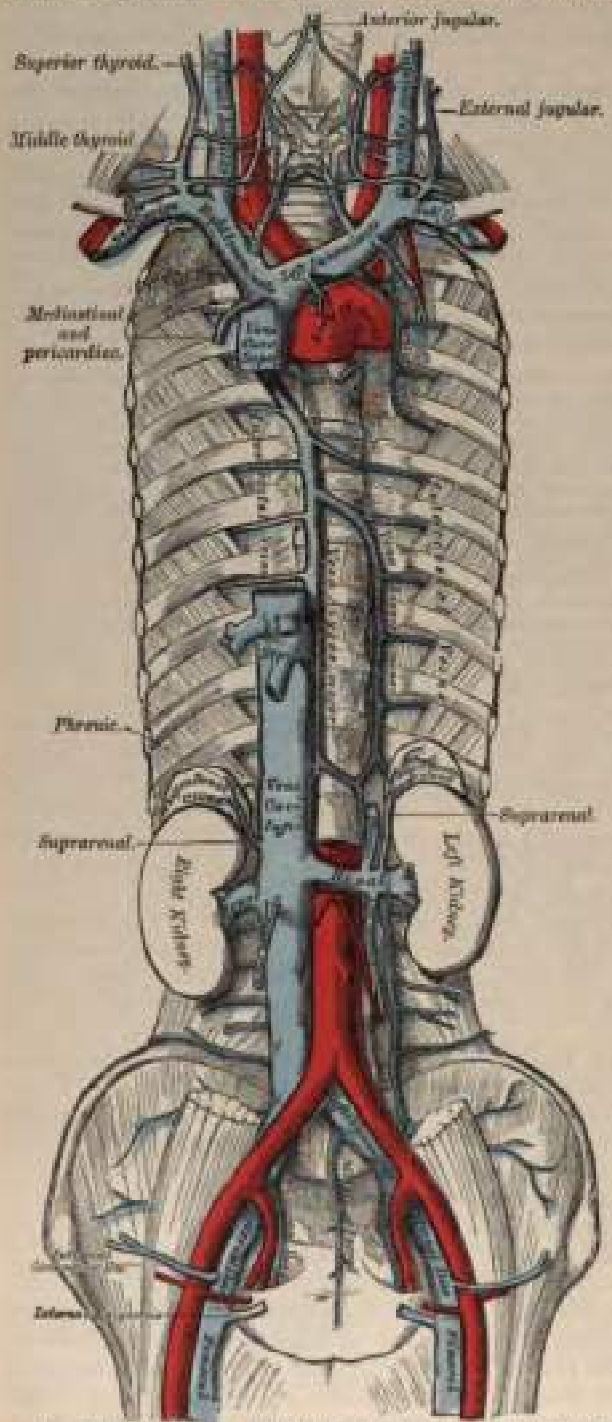

Fig. 331.—The venæ cavæ and azygos veins, with their formative branches.

Peculiarities.—Sometimes the innominate veins open separately into the right auricle; in such cases the right vein takes the ordinary course of the superior vena cava; but the left vein—*left superior vena cava*, as it is termed—after communicating by a small branch with the right one, passes in front of the root of the left lung, and, turning to the back of the heart, receives the cardiac veins, and terminates in the back of the right auricle. This occasional condition in the adult is due to the persistence of the early fœtal condition, and is the normal state of things in birds and some mammalia.

The **internal mammary veins**, two in number to each artery, follow the course of that vessel, and receive branches corresponding with those derived from it. The two veins of each side unite into a single trunk, which terminates in the innominate vein.

The **inferior thyroid veins**, two, frequently three or four, in number, arise in the venous plexus on the thyroid body, communicating with the middle and superior thyroid veins. They form a plexus in front of the trachea, behind the Sterno-thyroid muscles. From this plexus a left vein descends and joins the left innominate trunk, and a right vein passes obliquely downward and outward across the innominate artery to open into the right innominate vein, just at its junction with the superior vena cava. These veins receive œsophageal, tracheal, and inferior laryngeal veins, and are provided with valves at their termination in the innominate veins.

The **Superior intercostal veins** (right and left) drain the blood from two or three intercostal spaces below the first. The *right* vein passes downward and inward and opens into the vena azygos major; the *left* runs across the transverse aorta and opens into the left innominate vein. It usually receives the left bronchial and left superior phrenic vein, and communicates below with the vena azygos minor superior. The *highest intercostal vein*, *i. e.*, from the first space, opens directly into the corresponding vertebral or innominate vein.

The **Superior Vena Cava** receives the blood which is conveyed to the heart from the whole of the upper half of the body. It is a short trunk, varying from two inches and a half to three inches in length, formed by the junction of the two innominate veins. It commences immediately below the cartilage of the first rib close to the sternum on the right side, and, descending vertically, enters the pericardium about an inch and a half above the heart, and terminates in the upper part of the right auricle opposite the upper border of the third right costal cartilage. In its course it describes a slight curve, the convexity of which is turned to the right side.

Relations.—*In front*, with the pericardium and process of cervical fascia which is continuous with it: this separates it from the thymus gland and from the sternum; *behind*, with the root of the right lung; on its *right side*, with the phrenic nerve and right pleura; on its *left side*, with the commencement of the innominate artery and ascending part of the aorta. The portion contained within the pericardium is covered by the serous layer of that membrane in its anterior three-fourths. It receives the vena azygos major just before it enters the pericardium, and several small veins from the pericardium and parts in the mediastinum. The superior vena cava has no valves.

The **Azygos Veins** connect together the superior and inferior venæ cavæ, taking the place of those vessels in that part of the chest occupied by the heart.

The larger, or *right azygos vein* (vena azygos major), commences opposite the first or second lumbar vertebra by a branch from the right lumbar veins (the *ascending lumbar*); sometimes by a branch from the right renal vein or from the inferior vena cava. It enters the thorax through the aortic opening in the Diaphragm, and passes along the right side of the vertebral column to the fourth dorsal vertebra, where it arches forward over the root of the right lung, and terminates in the superior vena cava just before that vessel enters the pericardium. Whilst passing through the aortic opening of the Diaphragm it lies with the thoracic duct on the right side of the aorta, and in the thorax it lies upon the intercostal arteries on the right side of the aorta and thoracic duct, and is partly covered by pleura.

Tributaries.—It receives the lower ten intercostal veins of the right side, the upper two or three of these opening first of all into the right superior intercostal vein. It receives the azygos minor veins, several œsophageal, mediastinal, and pericardial veins; near its termination, the right bronchial vein; and generally the right superior intercostal vein. A few imperfect valves are found in this vein; but its tributaries are provided with complete valves.

The intercostal veins on the left side, below the three upper intercostal spaces, usually form two trunks, named the left lower and the left upper azygos veins.

The *left lower*, or *smaller azygos vein* (vena azygos minor), commences in the lumbar region by a branch from one of the lumbar veins (*ascending lumbar*) or from the left renal. It passes into the thorax through the left crus of the Diaphragm, and, ascending on the left side of the spine as high as the ninth dorsal vertebra, passes across the column, behind the aorta and thoracic duct, to terminate in the right azygos vein. It receives the four or five lower intercostal veins of the left side, and some œsophageal and mediastinal veins.

The *left upper azygos vein* varies inversely with the size of the left superior intercostal. It receives veins from the intercostal spaces between the left superior intercostal vein and highest tributary of the left lower azygos. They are usually three or four in number, and join to form a trunk which ends in the right azygos vein or in the left lower azygos. It sometimes receives the left bronchial vein. When this vein is small or altogether wanting, the left superior intercostal vein will extend as low as the fifth or six intercostal space.

Surgical Anatomy.—In obstruction of the inferior vena cava the azygos veins are one of the principal means by which the venous circulation is carried on, connecting as they do the superior and inferior venæ cavæ, and communicating with the common iliac veins by the ascending lumbar veins, and with many of the tributaries of the inferior vena cava.

The *bronchial veins* return the blood from the substance of the lungs; that of the right side opens into the vena azygos major near its termination; that of the left side, into the left superior intercostal vein or left upper azygos vein.

THE SPINAL VEINS.

The numerous venous plexuses placed upon and within the spine may be arranged into four sets:

1. Those placed on the exterior of the spinal column (the *dorsi-spinal veins*).
2. Those situated in the interior of the spinal canal, between the vertebræ and the theca vertebralis (*meningo-rachidian veins*).
3. The veins of the bodies of the vertebræ (*venæ basis vertebrarum*).
4. The veins of the spinal cord (*medulli-spinal*).

1. The **Dorsi-spinal Veins** commence by small branches which receive their

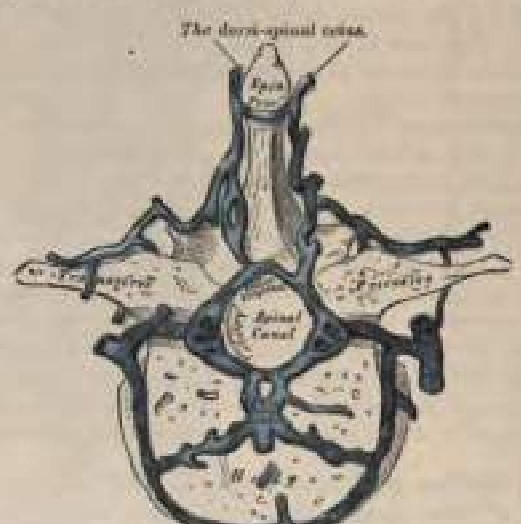

FIG. 332.—Transverse section of a dorsal vertebra, showing the spinal veins.

blood from the integument of the back of the spine and from the muscles in the vertebral grooves. They form a complicated network, which surrounds the spinous processes, the laminæ, and the transverse and articular processes of all the vertebræ. At the bases of the transverse processes they communicate, by means of ascending and descending branches, with the veins surrounding the contiguous vertebræ, and they join with the veins in the spinal canal by branches which perforate the ligamenta subflava. Other branches pass obliquely forward, between the transverse processes, and communicate with the intraspinal veins through the intervertebral foramina. They terminate by joining the vertebral veins in the neck, the intercostal veins in the thorax, and the lumbar and sacral veins in the loins and pelvis.

2. **The Meningo-rachidian Veins.**—The principal veins contained in the spinal canal are situated between the theca vertebralis and the vertebræ. They consist of two longitudinal plexuses, one of which runs along the posterior surface of the bodies of the vertebræ (*anterior longitudinal spinal veins*). The other plexus (*posterior longitudinal spinal veins*) is placed on the inner or anterior surface of the laminæ of the vertebræ.

The *Anterior Longitudinal Spinal Veins* consist of two large, tortuous veins which extend along the whole length of the vertebral column, from the foramen magnum, where they communicate by a venous ring around that opening, to the base of the coccyx, being placed one on each side of the posterior surface of the bodies of the vertebræ along the margin of the posterior common ligament. These veins communicate together opposite each vertebra by transverse trunks which pass beneath the ligament, and receive the large *venæ basis vertebrarum* from the interior of the body of each vertebra. The anterior longitudinal spinal veins are least developed in the cervical and sacral regions. They are not of

FIG. 333.—Vertical section of two dorsal vertebræ, showing the spinal veins.

uniform size throughout, being alternately enlarged and constricted. At the intervertebral foramina they communicate with the dorsi-spinal veins, and with the vertebral veins in the neck, with the intercostal veins in the dorsal region, and with the lumbar and sacral veins in the corresponding regions.

The *Posterior Longitudinal Spinal Veins*, smaller than the anterior, are situated one on each side, between the inner surface of the laminæ and the theca vertebralis. They communicate (like the anterior) opposite each vertebra by transverse trunks, and with the anterior longitudinal veins by lateral transverse branches which pass from behind forward. These veins, by branches which perforate the ligamenta subflava, join with the dorsi-spinal veins. From them branches are given off which pass through the intervertebral foramina and join the vertebral, intercostal, lumbar, and sacral veins.

3. The **Veins of the Bodies of the Vertebræ** (*venæ basis vertebrarum*) emerge from the foramina on their posterior surface, and join the transverse trunk connecting the anterior longitudinal spinal veins. They are contained in large, tortuous channels in the substance of the bones, similar in every respect to those found in the diploë of the cranial bones. These canals lie parallel to the upper and lower surface of the bones. They commence by small openings on the front and sides of the bodies of the vertebræ, through which communicating branches from the veins external to the bone pass into its substance, and converge to the principal canal, which is sometimes double toward its posterior part, and open into the corresponding transverse branch uniting the anterior longitudinal veins. They become greatly developed in advanced age.

4. The **Veins of the Spinal Cord** (*medulli-spinal*) consist of a minute, tortuous,

venous plexus which covers the entire surface of the cord, being situated between the pia mater and arachnoid. These vessels emerge chiefly from the median furrows, and are largest in the lumbar region. Near the base of the skull they unite and form two or three small trunks, which communicate with the vertebral veins, and then terminate in the inferior cerebellar veins or in the inferior petrosal sinuses. Each of the spinal nerves is accompanied by a branch as far as the intervertebral foramina, where it joins the other veins from the spinal canal.

There are no valves in the spinal veins.

VEINS OF THE LOWER EXTREMITY, ABDOMEN, AND PELVIS.

The Veins of the Lower Extremity are subdivided, like those of the upper, into two sets, superficial and deep, the superficial veins being placed beneath the integument, between the two layers of superficial fascia, the deep veins accompanying the arteries and forming the venæ comites of those vessels. Both sets of veins are provided with valves, which are more numerous in the deep than in the superficial set. These valves are also more numerous in the lower than in the upper limb.

The **Superficial Veins of the Lower Extremity** are the *internal* or *long saphenous* and the *external* or *short saphenous*.

On the dorsum of the foot is a venous arch situated in the superficial structures over the anterior extremities of the metatarsal bones. It has its convexity directed forward, and receives digital tributaries from the upper surface of the toes; at its concavity it is joined by numerous small veins which form a plexus on the dorsum of the foot. The arch terminates internally in the long saphenous, externally in a short saphenous vein.

The **internal** or **long saphenous vein** (Fig. 334) commences at the inner side of the arch on the dorsum of the foot; it ascends in front of the inner malleolus and along the inner side of the leg, behind the inner margin of the tibia, accompanied by the internal saphenous nerve. At the knee it passes backward behind the inner condyle of the femur, ascends along the inside 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 in its course cutaneous tributaries from the leg and thigh, and at the saphenous opening the superficial epigastric, superficial circumflex iliac, and external pudic veins. The veins from the inner and back part of the thigh frequently unite to form a large vessel, which enters the main trunk near the saphenous opening; and sometimes those on the outer side of the thigh join to form another large vessel; so that occasionally three large veins are seen converging from different parts of the thigh toward the saphenous opening. The internal saphenous vein communicates in the foot with the internal plantar vein; in the leg, with the posterior tibial veins by branches which perforate the tibial origin of the Soleus muscle, and also with the anterior tibial veins; at the knee, with the articular veins; in the thigh, with the femoral vein by one or more branches. The valves in this vein vary from two to six in number; they are more numerous in the thigh than in the leg.

The **external** or **short saphenous vein** (Fig. 335) commences at the outer side of the arch on the dorsum of the foot; it ascends behind the outer malleolus, and along the outer border of the tendo Achillis, across which it passes at an acute angle to reach the middle line of the posterior aspect of the leg. Passing directly upward, it perforates the deep fascia in the lower part of the popliteal space, and terminates in the popliteal vein, between the heads of the Gastrocnemius muscle.[1] It receives numerous large tributaries from the back part of

[1] Mr. Gay calls attention to the fact that the external saphenous vein often (he says invariably) penetrates the fascia at or about the point where the tendon of the Gastrocnemius commences, and runs below the fascia in the rest of its course, or sometimes among the muscular fibres, to join the popliteal vein. (See Gay on *Varicose Disease of the Lower Extremities*, p. 24, where there is also a careful and elaborate description of the branches of the saphena veins.)

the leg, and communicates with the deep veins on the dorsum of the foot and behind the outer malleolus. Before it perforates the deep fascia it gives off a communicating branch, which passes upward and inward to join the internal saphenous vein. This vein has a variable number of valves, from three to nine (Gay), one of which is always found near its termination in the popliteal vein. The external saphenous nerve lies close beside this vein.

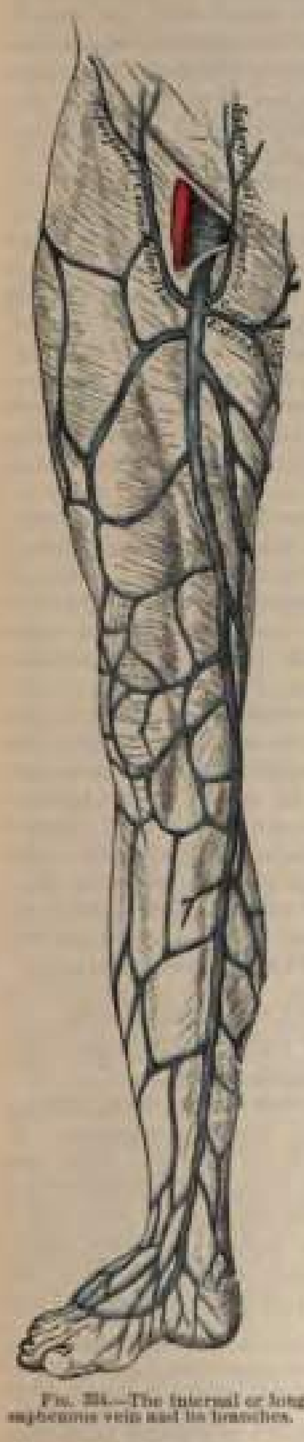

FIG. [illegible].—The internal or long saphenous vein and its branches.

FIG. [illegible].—External or short saphenous vein.

Surgical Anatomy.—The saphena veins are of considerable surgical importance, since a varicose condition of these vessels is more frequently met with than of those in other parts of the body, except perhaps the spermatic and hæmorrhoidal veins. The course of the internal saphenous is in front of the tip of the malleolus, over the subcutaneous surface of the lower end of the tibia, and then along the internal border of this bone to the back part of the internal condyle of the femur, whence it follows the course of the Sartorius muscle, and is represented on the surface by a line drawn from the posterior border of the Sartorius on a level with the internal condyle to the saphenous opening. The short saphenous lies behind the external malleolus, and from this follows the middle line of the calf to just below the ham. It is not generally so apparent beneath the skin as the internal saphenous. Both these veins in the leg are accompanied by nerves, the internal saphenous being joined by its companion nerve just below the level of the knee-joint. No doubt much of the pain of varicose veins in the leg is due to this fact. On the Continent the internal saphenous vein as it rests on the tibia just above the malleolus is sometimes selected for venesection.

The **Deep Veins of the Lower Extremity** accompany the arteries and their branches, and are called the *venæ comites* of those vessels.

The **external** and **internal plantar veins** unite to form the **posterior tibial**. They accompany the posterior tibial artery and are joined by the *peroneal veins*.

The **anterior tibial veins** are formed by a continuation upward of the venæ comites of the dorsalis pedis artery. They pass between the tibia and fibula, through the large oval aperture above the interosseous membrane, and form, by their junction with the posterior tibial, the popliteal vein.

The valves in the deep veins are very numerous.

The **Popliteal Vein** is formed by the junction of the venæ comites of the anterior and posterior tibial vessels; it ascends through the popliteal space to the tendinous aperture in the Adductor magnus, where it becomes the femoral vein. In the lower part of its course it is placed internal to the artery; between the heads of the Gastrocnemius it is superficial to that vessel; but above the knee-joint it is close to its outer side. It receives the sural veins from the Gastrocnemius muscle, the articular veins, and the external saphenous. The valves in this vein are usually four in number.

The **Femoral Vein** accompanies the femoral artery through the upper two-thirds of the thigh. In the lower part of its course it lies external to the artery; higher up it is behind it; and at Poupart's ligament it lies to its inner side and on the same plane. It receives numerous muscular tributaries, and about an inch and a half below Poupart's ligament it is joined by the profunda femoris; near its termination it is joined by the internal saphenous vein. The valves in this vein are four or five in number.

The **External Iliac Vein** commences at the termination of the femoral, beneath the crural arch, and, passing upward along the brim of the pelvis, terminates opposite the sacro-iliac synchondrosis by uniting with the internal iliac to form the common iliac vein. On the right side it lies at first along the inner side of the external iliac artery, but as it passes upward gradually inclines behind it. On the left side it lies altogether on the inner side of the artery. It receives, immediately above Poupart's ligament, the deep epigastric and deep circumflex iliac veins and a small pubic vein, corresponding to the pubic branch of the obturator artery. According to Friedreich, it frequently contains one, and sometimes two valves.

The Deep Epigastric Veins.—Two veins accompany the deep epigastric artery; they usually unite into a single trunk before their termination in the external iliac vein.

The Deep Circumflex Iliac Veins.—Two veins accompany the deep circumflex iliac artery. These unite into a single trunk which crosses the external iliac artery just above Poupart's ligament and terminates in the external iliac vein.

The **Internal Iliac Vein** is formed by the venæ comites of the branches of the internal iliac artery, the umbilical arteries of the fœtus excepted. It receives the blood from the exterior of the pelvis by the gluteal, sciatic, internal pudic, and obturator veins, and from the organs in the cavity of the pelvis by the hæmorrhoidal and vesico-prostatic plexuses in the male, and the uterine and vaginal plexuses in the female. The vessels forming these plexuses are remarkable for their large size, their frequent anastomoses, and the number of valves which they contain. The internal iliac vein lies at first on the inner side, and then behind the internal iliac artery, and terminates opposite the sacro-iliac articulation by uniting with the external iliac to form the common iliac vein. This vessel has no valves.

The **internal pudic veins** (*venæ comites*) have the same course as the internal pudic artery. They receive tributaries corresponding to the branches of the artery, except the tributary corresponding to the dorsal artery of the penis; that is, the dorsal vein of the penis, which opens into the prostatic plexus.

The **hæmorrhoidal plexus** surrounds the lower end of the rectum, being formed by the superior hæmorrhoidal veins, tributaries of the inferior mesenteric. It commences as a series of dilated pouches, about twelve in number, which are arranged circularly at the verge of the anus and are connected by transverse branches. From these pouches veins, about six in number, pass upward in a straight direction in the submucous tissue for about three inches; they then pierce the muscular coat and become arranged in a circular manner at right angles to the long axis of the gut, and eventually unite to form the superior hæmorrhoidal vein.

Surgical Anatomy.—The veins of this plexus are apt to become dilated and varicose, and form piles. This is due to several anatomical reasons: the vessels are contained in very loose, lax connective tissue, so that they get less support from surrounding structures than most other veins, and are less capable of resisting increased blood pressure; the condition is favored by gravitation, being influenced by the erect posture, either sitting or standing, and by the fact that the superior hæmorrhoidal and portal veins have no valves; the veins pass through muscular tissue and are liable to be compressed by its contraction, especially during the act of defecation; they are affected by every form of portal obstruction.

The **vesico-prostatic plexus** surrounds the neck and base of the bladder and prostate gland. It communicates with the hæmorrhoidal plexus behind, and receives the dorsal vein of the penis, which enters the pelvis beneath the subpubic ligament. This plexus is supported upon the sides of the bladder by a reflection of the pelvic fascia. The veins composing it are very liable to become varicose, and often contain hard, earthy concretions, called *phleboliths*.

Surgical Anatomy.—This plexus is wounded in the lateral operation of lithotomy, and it is through it that septic matter finds its way into the general circulation after this operation.

The **dorsal vein of the penis** is a vessel of large size which returns the blood from the body of that organ. At first it consists of two branches, which are contained in the groove on the dorsum of the penis, and it receives veins from the glans penis, the corpus spongiosum, and numerous superficial veins; these unite into a single trunk, which passes between the two parts of the suspensory ligament of the penis, and through an aperture below the subpubic ligament, and divides into two branches, which enter the prostatic plexus.

The **vaginal plexus** surrounds the vagina, being especially developed at the orifice of the canal; it communicates with the vesical plexus in front, and with the hæmorrhoidal plexus behind.

The **uterine plexus** is situated along the sides and superior angles of the uterus, between the layers of the broad ligament, receiving, during pregnancy, large venous canals (the *uterine sinuses*) from the substance of the placenta. The veins composing this plexus anastomose frequently with each other and with the ovarian veins. They are not tortuous like the arteries.

The **Common Iliac Veins** are formed by the union of the external and internal iliac veins in front of the sacro-iliac articulation; passing obliquely upward toward the right side, they terminate upon the intervertebral substance between the fourth and fifth lumbar vertebræ, where the veins of the two sides unite at an acute angle to form the inferior vena cava. The *right common iliac* is shorter than the left, nearly vertical in its direction, and ascends behind and then to the outer side of its corresponding artery. The *left common iliac*, longer and more oblique in its course, is at first situated on the inner side of the corresponding artery, and then behind the right common iliac. Each common iliac receives the ilio-lumbar, and sometimes the lateral sacral, veins. The left receives, in addition, the middle sacral vein. No valves are found in these veins.

The **middle sacral veins** accompany the corresponding artery along the front of the sacrum, and join to form a single vein which terminates in the left common iliac vein; occasionally in the angle of junction of the two iliac veins.

Peculiarities.—The left common iliac vein, instead of joining with the right in its usual position, occasionally ascends on the left side of the aorta as high as the kidney, where, after receiving the left renal vein, it crosses over the aorta, and then joins with the right vein to form the vena cava. In these cases the two common iliacs are connected by a small communicating branch at the spot where they are usually united.[1]

The **Inferior Vena Cava** returns to the heart the blood from all the parts below the Diaphragm. It is formed by the junction of the two common iliac veins on the right side of the fifth lumbar vertebra. It passes upward along the front of the spine on the right side of the aorta, and, having reached the under surface of the liver, is contained in a groove on its posterior surface. It then perforates the central tendon of the Diaphragm, enters the pericardium, where it is covered for a very short distance by its serous layer, and terminates in the lower and back part of the right auricle. At its termination in the auricle it is provided with a valve, the *Eustachian*, which is of large size during fœtal life.

Relations.—*In front*, from below upward, with the mesentery, right spermatic artery, transverse portion of the duodenum, the pancreas, portal vein, and the

[1] See two cases which have been described by Mr. Walsham in the *St. Bartholomew's Hospital Reports*, vols. xvi. and xvii.

posterior surface of the liver, which partly and occasionally completely surrounds it; *behind*, with the vertebral column, the right crus of the Diaphragm, the right renal and lumbar arteries, right semilunar ganglion; on the *left side*, with the aorta.

Peculiarities.—*In Position.*—This vessel is sometimes placed on the left side of the aorta, as high as the left renal veins, after receiving which it crosses over to its usual position on the right side; or it may be placed altogether on the left side of the aorta, as far upward as its termination in the heart: in such cases the abdominal and thoracic viscera, together with the great vessels, are all transposed.

Point of Termination.—Occasionally the inferior vena cava joins the right azygos vein, which is then of large size. In such cases the superior cava receives the whole of the blood from the body before transmitting it to the right auricle, except the blood from the hepatic veins, which passes directly into the right auricle.

Tributaries.—It receives in its course the following veins:

Lumbar.	Suprarenal.
Right Spermatic.	Phrenic.
Renal.	Hepatic.

The **lumbar veins**, four in number on each side, collect the blood by dorsal tributaries from the muscles and integument of the loins and by abdominal tributaries from the walls of the abdomen, where they communicate with the epigastric veins. At the spine they receive veins from the spinal plexuses, and then pass forward, round the sides of the bodies of the vertebræ beneath the Psoas magnus, and terminate at the back part of the inferior cava. The left lumbar veins are longer than the right, and pass behind the aorta. The lumbar veins are connected together by a longitudinal vein which passes in front of the transverse processes of the lumbar vertebræ, and is called the *ascending lumbar*. It forms the most frequent origin of the corresponding vena azygos, and serves to connect the common iliac, ilio-lumbar, lumbar, and azygos veins of the corresponding side of the body.

The **spermatic veins** emerge from the back of the testis, and receive tributaries from the epididymis; they unite and form a convoluted plexus called the *spermatic 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 abdominal ring they unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the internal abdominal ring, coalesce to form two veins, which ascend on the Psoas muscle behind the peritoneum, lying one on each side of the spermatic artery, and unite to form a single vein, which opens on the right side into the inferior vena cava at an acute angle; on the left side into the left renal vein at a right angle. The spermatic veins are provided with valves.[1] The left spermatic vein passes behind the sigmoid flexure of the colon, and is thus exposed to pressure from the contents of that bowel.

Surgical Anatomy.—The spermatic veins are very frequently varicose, constituting the disease known as varicocele. Though it is quite possible that the originating cause of this affection may be a congenital abnormality either in the size or number of the veins of the pampiniform plexus, still it must be admitted that there are many anatomical reasons why these veins should become varicose—viz. the imperfect support afforded to them by the loose tissue of the scrotum; their great length; their vertical course; their dependent position; their plexiform arrangement in the scrotum, with their termination in one small vein in the abdomen; their few and imperfect valves; and the fact that they may be subjected to pressure in their passage through the abdominal wall.

The **ovarian veins** are analogous to the spermatic in the male; they form a plexus near the ovary and in the broad ligament and Fallopian tube, communicating with the uterine plexus. They terminate in the same way as the spermatic veins in the male. Valves are occasionally found in these veins. These vessels, like the uterine veins, become much enlarged during pregnancy.

[1] Rivington has pointed out that a valve is usually found at the orifices of both the right and left spermatic veins. When no valves exist at the opening of the left spermatic vein into the left renal vein, valves are generally present in the left renal vein within a quarter of an inch from the orifice of the spermatic vein (*Journal of Anatomy and Physiology*, vol. vii, p. 163).

The **renal veins** are of large size, and placed in front of the renal arteries.[1] The left is longer than the right, and passes in front of the aorta, just below the origin of the superior mesenteric artery. It receives the left spermatic, the left inferior phrenic, and, generally, the left suprarenal veins. It opens into the vena cava a little higher than the right.

The **suprarenal veins** are two in number: that on the right side terminates in the vena cava; that on the left side, in the left renal or phrenic vein.

The **phrenic veins** follow the course of the phrenic arteries. The *two superior*, of small size, accompany the phrenic nerve and comes nervi phrenici artery, and join the internal mammary. The *two inferior phrenic veins* follow the course of the phrenic arteries, and terminate, the right in the inferior vena cava, the left in the left renal vein.

The **hepatic veins** 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 large veins, which converge toward the posterior surface of the liver and open into the inferior vena cava, whilst 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 inferior vena cava, that from the middle of the organ and lobulus Spigelii having a straight course. The hepatic veins run singly, and are in direct contact with the hepatic tissue. They are destitute of valves.

The Portal System of Veins.

The portal venous system is composed of four large veins which collect the venous blood from the viscera of digestion (stomach, intestine, and pancreas) and from the spleen. The trunk formed by their union (*vena portæ*) enters the liver and ramifies throughout its substance after the manner of an artery and ends in capillaries, from which the blood is collected into the hepatic veins, which terminate in the inferior vena cava. The branches in this vein are in all cases single, and destitute of valves.

The veins forming the portal system are: the

Superior mesenteric.	Inferior mesenteric.
Splenic.	Gastric.

Cystic.

The **superior mesenteric vein** returns the blood from the small intestines and from the cæcum and ascending and transverse portions of the colon, corresponding with the distribution of the branches of the superior mesenteric artery. The large trunk formed by the union of these branches ascends along the right side and in front of the corresponding artery, passes in front of the transverse portion of the duodenum, and unites, behind the upper border of the pancreas, with the splenic vein to form the vena portæ. It receives the right gastro-epiploic vein.

The **splenic vein** commences by five or six large branches which return the blood from the substance of the spleen. These, uniting, form a single vessel, which passes from left to right, grooving the upper and back part of the pancreas below the artery, and terminates at its greater end by uniting at a right angle with the superior mesenteric to form the vena portæ. The splenic vein is of large size, and not tortuous like the artery. It receives the vasa brevia from the left extremity of the stomach, the left gastro-epiploic vein, pancreatic branches from the pancreas, the pancreatico-duodenal vein, and the inferior mesenteric vein.

The **inferior mesenteric vein** returns the blood from the rectum, sigmoid flexure, and descending colon, corresponding with the ramifications of the branches of the inferior mesenteric artery. It lies to the left of the artery, and ascends beneath the peritoneum in the lumbar region; it passes behind the transverse portion

[1] The student may observe that all veins above the Diaphragm, which do not lie on the same plane as the arteries which they accompany, lie in front of them, and that all veins below the Diaphragm, which do not lie on the same plane as the arteries which they accompany, lie behind them, except the renal and profunda femoris vein.

of the duodenum and pancreas, and terminates in the splenic vein. Its hæmorrhoidal branches inosculate with those of the internal iliac, and thus establish a communication between the portal and the general venous system.[1]

The **gastric veins** are two in number: one, a small vein, corresponds to the pyloric branch of the hepatic artery; the other, considerably larger, corresponds to the gastric artery. The former (*pyloric*, Walsham) runs along the lesser cur-

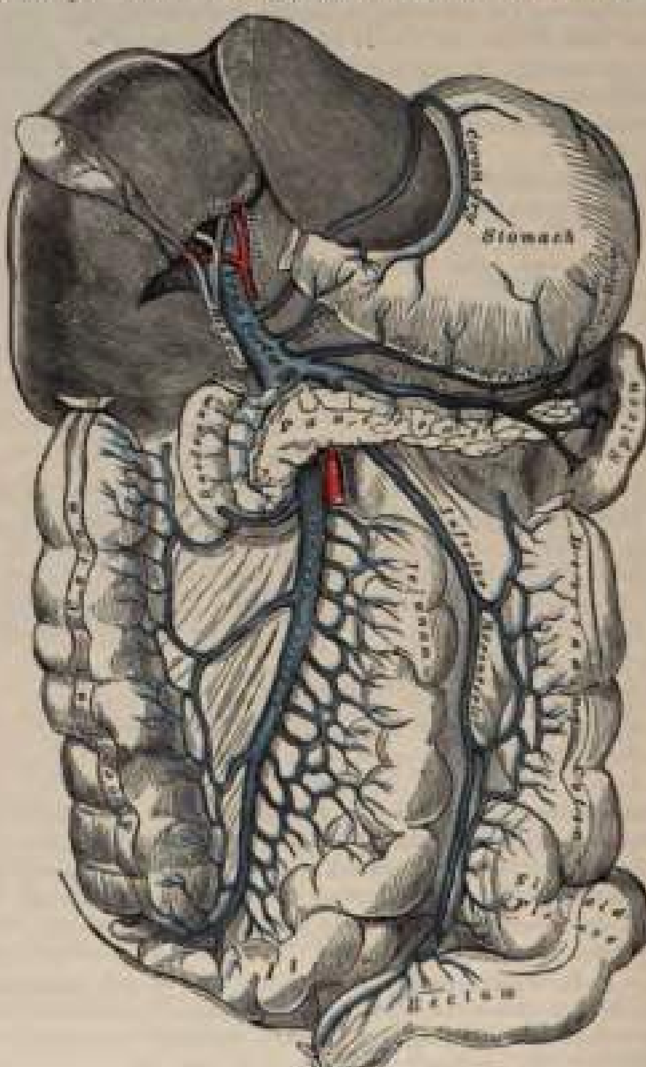

FIG. 336.—Portal vein and its branches.

NOTE.—In this diagram the right *gastro-epiploic* vein opens into the splenic vein; generally it empties itself into the superior mesenteric, close to its termination.

vature of the stomach toward the pyloric end, receives branches from the pylorus and duodenum, and ends in the vena portæ. The latter (*coronary*, Walsham) begins near the pylorus, runs along the lesser curvature of the stomach toward the

[1] Besides this anastomosis between the portal vein and the branches of the vena cava, other anastomoses between the portal and systemic veins are formed by the communication between the gastric veins and the œsophageal veins, which empty themselves into the vena azygos minor; between the left renal vein and the veins of the intestines, especially of the colon and duodenum; between the veins of the round ligament of the liver and the portal veins; and between the superficial branches of the portal veins of the liver and the phrenic veins, as pointed out by Mr. Kiernan. (See *Physiological Anatomy*, by Todd and Bowman, 1859, vol. ii. p. 348.)

œsophageal opening, and then passes across the front of the spine from left to right to end in the vena portæ, at a point a little above the junction of the pyloric vein.

The **Portal Vein** is formed by the junction of the superior mesenteric and splenic veins, their union taking place in front of the vena cava and behind the upper border of the head of the pancreas. Passing upward through the right border of the lesser omentum to the under surface of the liver, it enters the transverse fissure, where it is somewhat enlarged, forming the *sinus* of the portal vein, and divides into two branches which accompany the ramifications of the hepatic artery and hepatic duct throughout the substance of the liver. Of these two branches, the right is the larger, but the shorter, of the two. The portal vein is about three or four inches in length, and, whilst contained in the lesser omentum, lies behind and between the common bile duct and the hepatic artery, the former being to the right, the latter to the left. These structures are accompanied by filaments of the hepatic plexus of nerves and numerous lymphatics, surrounded by a quantity of loose areolar tissue (*capsule of Glisson*), and placed between the layers of the lesser omentum.

The Cystic Vein.—The vena portæ generally receives the cystic vein, although it sometimes terminates in the right branch of the vena portæ.

The portal vein divides, in the substance of the liver, like an artery, and its minute ramifications end in capillaries, from which the blood is carried to the inferior vena cava by the hepatic veins; these veins also collect the blood which has been brought to the liver by the hepatic artery. It will therefore be seen that the blood which is carried to the liver by the portal vein passes through two sets of capillary vessels, viz.: (1) the capillaries in the stomach, intestine, pancreas, and spleen, and (2) the capillaries of the portal vein in the liver.

THE CARDIAC VEINS.

The veins which return the blood from the substance of the heart are: the

Great cardiac vein.	Anterior cardiac veins.
Posterior cardiac vein.	Right or small coronary vein.
Left cardiac veins.	Coronary sinus.

Venæ Thebesii.

The **Great Cardiac Vein** (sometimes called the *Coronary vein*) is a vessel of considerable size, which commences at the apex of the heart, and ascends along the anterior interventricular groove to the base of the ventricles. It then curves to the left side, around the auriculo-ventricular groove, between the left auricle and ventricle, to the back part of the heart, and opens into the left extremity of the coronary sinus, its aperture being guarded by two valves. It receives, in its course, tributaries from both ventricles, but especially the left, and also from the left auricle; one of these, ascending along the thick margin of the left ventricle, is of considerable size. The vessels joining it are provided with valves.

The **Posterior Cardiac Vein** (sometimes called the *Middle cardiac vein*) commences by small tributaries, at the apex of the heart, communicating with those of the preceding. It ascends along the posterior interventricular groove to the base of the heart, and terminates in the coronary sinus, its orifice being guarded by a valve. It receives the veins from the posterior surface of both ventricles.

The **Left Cardiac Veins** are three or four small vessels, which collect the blood from the posterior surface of the left ventricle, and open into the lower border of the coronary sinus.

The **Anterior Cardiac Veins** are three or four small vessels, which collect the blood from the anterior surface of the right ventricle. One of these (the *vein of Galen*), larger than the rest, runs along the right border of the heart. They open separately into the lower part of the right auricle.

The **Right** or **Small Coronary Vein** runs along the groove between the right auricle and ventricle, to open into the right extremity of the coronary sinus. It receives blood from the back part of the right auricle and ventricle.

The **Coronary Sinus** is that portion of the anterior or great cardiac vein which is situated in the posterior part of the left auriculo-ventricular groove. It is about an inch in length, presents a considerable dilatation, and is covered by the muscular fibres of the left auricle. It receives the veins enumerated above, and an *oblique vein* from the back part of the left auricle, the remnant of the obliterated left Cuvierian duct of the fœtus, described by Mr. Marshall. The great coronary sinus terminates in the right auricle, between the inferior vena cava and the auriculo-ventricular aperture, its orifice being guarded by a semilunar fold of the lining membrane of the heart, the *Thebesian valve*. All the veins joining this vessel, excepting the oblique vein above mentioned, are provided with valves.

The **Venæ Thebesii** (*venæ cordis minimæ*) are numerous minute veins, which return the blood directly from the muscular substance, without entering the venous current. They open by minute orifices (*foramina Thebesii*) on the inner surface of the right auricle.

THE LYMPHATIC SYSTEM.

THE Lymphatic System includes not only the lymphatic vessels and the glands through which they pass, but also the *lacteal* or *chyliferous vessels*. The lacteals are the lymphatic vessels of the small intestine, and differ in no respect from the lymphatics generally, excepting that they contain a milk-white fluid, the *chyle*, during the process of digestion, and convey it into the blood through the thoracic duct.

The lymphatics have derived their name from the appearance of the fluid contained in their interior (*lympha*, water). They are also called *absorbents*, from the property they possess of absorbing certain materials from the tissues and conveying them into the circulation.

The lymphatics are exceedingly delicate vessels, the coats of which are so transparent that the fluid they contain is readily seen through them. They retain a nearly uniform size, being interrupted at intervals by constrictions, which give them a knotted or beaded appearance. These constrictions are due to the presence of valves in their interior. Lymphatics have been found in nearly every texture and organ of the body which contain blood-vessels. Such non-vascular structures as cartilage, the nails, cuticle, and hair have none, but with these exceptions it is probable that eventually all parts will be found to be permeated by these vessels.

The lymphatics are arranged into a superficial and deep set. The superficial lymphatics, on the surface of the body, are placed immediately beneath the integument, accompanying the superficial veins; they join the deep lymphatics in certain situations by perforating the deep fascia. In the interior of the body they lie in the submucous areolar tissue throughout the whole length of the gastro-pulmonary and genito-urinary tracts, and in the subserous tissue in the cranial, thoracic, and abdominal cavities. The method of their origin will be described later, along with the other details of their minute anatomy. Here it will be sufficient to say that a plexiform network of minute lymphatics may be found interspersed among the proper elements and blood-vessels of the several tissues, the vessels composing which, as well as the meshes between them, are much larger than those of the capillary plexus. From these networks small vessels emerge, which pass either to a neighboring gland or to join some larger lymphatic trunk. The deep lymphatics, fewer in number and larger than the superficial, accompany the deep blood-vessels. Their mode of origin is probably similar to that of the superficial vessels. The lymphatics of any part or organ exceed the veins in number, but in size they are much smaller. Their anastomoses also, especially those of the large trunks, are more frequent, and are effected by vessels equal in diameter to those which they connect, the continuous trunks retaining the same diameter.

The **lymphatic** or **absorbent glands**, named also *conglobate glands*, are small, solid, glandular bodies situated in the course of the lymphatic and lacteal vessels. In size they vary from a hemp-seed to an almond, and their color, on section, is of a pinkish-gray tint, excepting the bronchial glands, which in the adult are mottled with black. Each gland has a layer or capsule of cellular tissue investing it, from which prolongations dip into its substance, forming partitions. The lymphatic and lacteal vessels pass through these bodies in their passage to the thoracic and lymphatic ducts. A lymphatic or lacteal vessel, previous to entering a gland, divides into several small branches, which are named *afferent vessels*. As they enter their external coat becomes continuous with the capsule of the gland, and the vessels, much thinned, and consisting only of their internal or endothelial coat, pass into the gland, and branch out upon and in the tissue of the capsule, these branches opening into the lymph-sinuses of the gland. From these sinuses fine branches proceed to form a plexus, the vessels of which unite to form a single *efferent vessel*, which, on emerging from the gland, is again invested with an external coat. (Further details on the minute anatomy of the lymphatic vessels and glands will be found in the section on General Anatomy.)

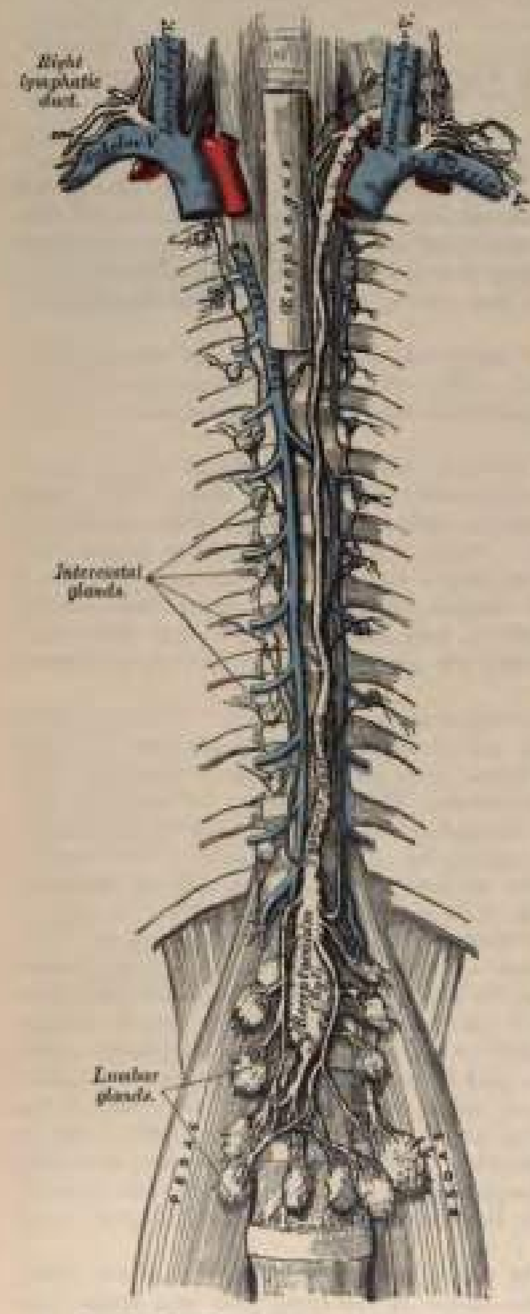

Fig. 337.—The thoracic and right lymphatic duct.

THE THORACIC DUCT.

The **thoracic duct** (Fig. 337) conveys the great mass of lymph and chyle into the blood. It is the common trunk of all the lymphatic vessels of the body, excepting those of the right side of the head, neck, and thorax, and right upper extremity, the right lung, right side of the heart, and the convex surface of the liver. It varies in length from fifteen to eighteen inches in the adult, and extends from the second lumbar vertebra to the root of the neck. It commences in the abdomen by a triangular dilatation, the *receptaculum chyli* (*reservoir* or *cistern of Pecquet*), which is situated upon the front of the body of the second lumbar vertebra, to the right side and behind the aorta, by the side of the right crus of the Diaphragm. It ascends into the thorax through the aortic opening in the Diaphragm, lying to the right of the aorta, and is placed in the posterior mediastinum in front of the vertebral column, lying between the aorta and vena azygos major. Opposite the fourth dorsal vertebra it inclines toward the left side, and ascends behind the arch of the aorta on the left side of the œsophagus, and behind the first portion of the left subclavian artery, to the upper orifice of the thorax. Opposite the seventh cervical vertebra it turns outward and then curves downward over the subclavian artery and in front of the Scalenus anticus muscle, so as to form an arch, and terminates in the left subclavian vein at its angle of junction with the left internal jugular vein. The thoracic duct, at its commencement, is about equal in size to the diameter of a goosequill, diminishes considerably in its calibre in the middle of the thorax, and is again dilated just before its termination. It is generally flexuous in its course, and constricted at intervals so as to present a varicose appearance. The thoracic duct not unfrequently divides in the middle of its course into two branches of unequal size, which soon reunite, or into several branches, which form a plexiform interlacement. It occasionally divides, at its upper part, into two branches, of which the one on the left side terminates in the usual manner, while that on the right opens into the right subclavian vein, in connection with the right lymphatic duct. The thoracic duct has numerous valves throughout its whole course, but they are more numerous in the upper than in the lower part: at its termination it is provided with a pair of valves, the free borders of which are turned toward the vein, so as to prevent the passage of venous blood into the duct.

Tributaries.—The thoracic duct, at its commencement, receives four or five large trunks from the abdominal lymphatic glands, and also the trunk of the lacteal vessels. Within the thorax it is joined by the lymphatic vessels from the left half of the wall of the thoracic cavity, the lymphatics from the sternal and intercostal glands, those of the left lung, left side of the heart, trachea, and œsophagus; and, just before its termination, it receives the lymphatics of the left side of the head and neck and left upper extremity.

Structure.—The thoracic duct is composed of three coats, which differ in some respects from those of the lymphatic vessels. The *internal coat* consists of a single layer of flattened lanceolate-shaped endothelial cells with serrated borders; of a subendothelial layer, similar to that found in the arteries; and an elastic fibrous coat, the fibres of which run in a longitudinal direction. The *middle coat* consists of a longitudinal layer of white connective tissue with elastic fibres, external to which are several laminæ of muscular tissue, the fibres of which are for the most part disposed transversely, but some are oblique or longitudinal and intermixed with elastic fibres. The *external coat* is composed of areolar tissue, with elastic fibres and isolated fasciculi of muscular fibres.

The **Right Lymphatic Duct** is a short trunk, about half an inch in length and a line or a line and a half in diameter. It terminates in the right subclavian vein at its angle of junction with the right internal jugular vein. Its orifice is guarded by two semilunar valves, which prevent the passage of venous blood into the duct.

Tributaries.—It receives the lymph from the right side of the head and neck, the right upper extremity, the right side of the thorax, the right lung and right side of the heart, and from part of the convex surface of the liver.

LYMPHATICS OF THE HEAD, FACE, AND NECK.

The **Lymphatic Glands of the Head** (Fig. 338) are arranged in the following groups: (1) The *occipital*, one or two in number, placed at the back of the head, close to the occipital artery. (2) The *posterior auricular* or *mastoid*, usually two in number, situated on the insertion of the Sterno-mastoid to the mastoid process. Both these sets of glands are affected in cutaneous eruptions and other diseases of the scalp. (3) The *parotid* or *pre-auricular*, some of which are superficial to, and others are imbedded in, the substance of the parotid gland. (4) The *buccal*, one or more, placed on the surface of the Buccinator muscle. (5) The *internal maxillary*, beneath the ramus of the jaw. (6) The *lingual*, two or three in number, lying on the Hyo-glossus and Genio-hyo-glossus. (7) The *retro-pharyngeal*, lying one on each side of the middle line in front of the Rectus capitis anticus major.

The **lymphatic vessels of the scalp** are divided into an *anterior* and a *posterior set*, which follow the course of the temporal and occipital vessels. The *temporal* accompany the temporal artery in front of the ear, to the parotid lymphatic glands, from which they proceed to the lymphatic glands of the neck. The *occipital* follow the course of the occipital artery, descend to the occipital and posterior auricular lymphatic glands, and finally join the cervical glands.

The **Lymphatic Vessels of the Face** are divided into two sets, *superficial* and *deep*.

The **superficial lymphatic vessels of the face** are more numerous than those of the head, and commence over its entire surface. Those from the frontal region accompany the frontal vessels; they then pass obliquely across the face, running

Fig. [illegible].—The superficial lymphatics and glands of the head, face, and neck.

with the facial vein, pass through the buccal glands on the surface of the Buccinator muscle, and join the submaxillary lymphatic glands. The latter receive the lymphatic vessels from the lips, and are often found enlarged in cases of malignant disease of those parts.

The **lymphatic vessels of the cranium** consist of two sets, the *meningeal* and *cerebral*. The *meningeal lymphatics* accompany the meningeal vessels, escape through foramina at the base of the skull, and join the deep cervical lymphatic glands. The *cerebral lymphatics* are described by Eshmann as being situated between the arachnoid and pia mater, as well as in the choroid plexuses of the lateral ventricles; they accompany the trunks of the carotid and vertebral arteries, and probably pass through foramina at the base of the skull to terminate in the deep cervical glands. They have not at present been demonstrated in the dura mater or in the substance of the brain.

The lymphatics of the orbit and of the temporal and zygomatic fossæ run with the branches of the internal maxillary artery to the maxillary glands, and afterward to the deep cervical.

The lymphatics of the nose can be injected from the subdural and subarachnoid spaces. They terminate in the retro-pharyngeal and supra-hyoid glands. The lymphatics of the tongue chiefly accompany the ranine vein first to the lingual glands and from these to the deep cervical. Those from the anterior part of the tongue and floor of the mouth pierce the Mylo-hyoid muscles and so reach the submaxillary glands. From the upper part of the pharynx the lymphatics pass to the retro-pharyngeal glands; from the lower part, to the deep cervical glands. From the larynx two sets of vessels arise: an upper, piercing the thyro-hyoid

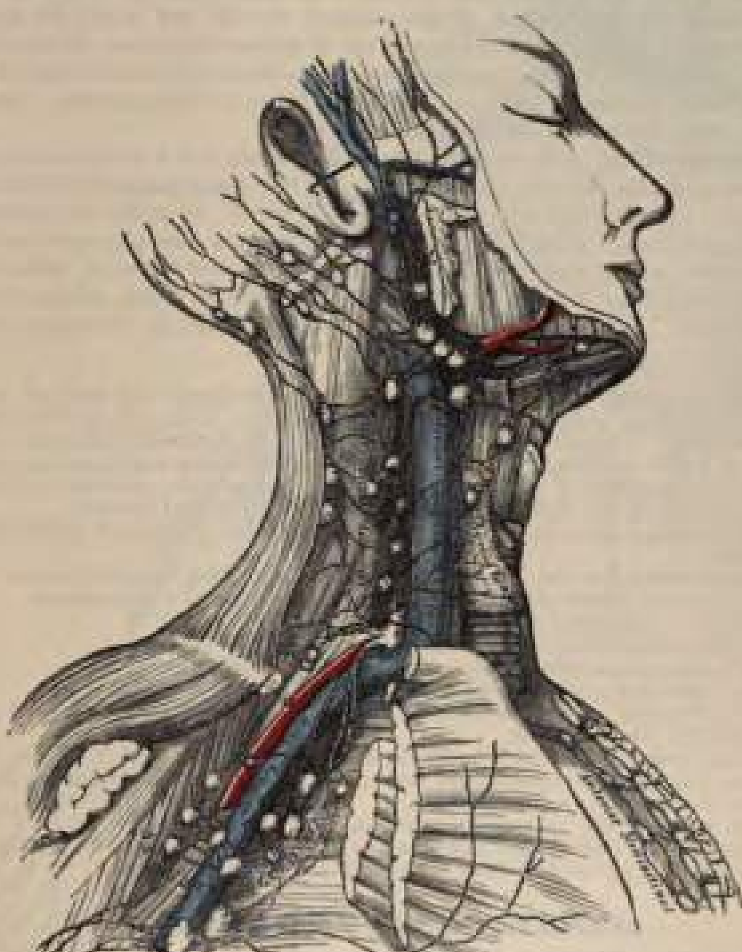

Fig. 339.—The deep lymphatics and glands of the neck and thorax.

membrane and joining the superior set of deep glands; and a lower, perforating the crico-thyroid membrane to join the lower set of deep cervical glands. The lymphatics of the thyroid body accompany the superior and inferior thyroid arteries, and open partly into the upper and partly into the lower set of deep cervical glands.

The **Lymphatic Glands of the Neck** are divided into two sets, *superficial* and *deep*.

The **superficial cervical glands** may be arranged in three sets: (1) The *submaxillary*, eight to ten in number, situated beneath the body of the lower jaw in the submaxillary triangle; (2) *suprahyoid*, one or two in number, situated in the middle line of the neck, between the anterior bellies of the two digastric muscles; and (3) *cervical*, placed in the course of the external jugular vein between the Platysma and deep fascia. They are most numerous at the root of the neck, in the triangular interval between the clavicle, the Sterno-mastoid, and the Trapezius, where they are continuous with the axillary glands. A few small glands are also found on the front and sides of the larynx.

The **deep cervical glands** (Fig. 339) are numerous and of large size; they form a chain along the sheath of the carotid artery and internal jugular vein, lying by the side of the pharynx, œsophagus, and trachea, and extending from the base of the skull to the thorax, where they communicate with the lymphatic glands in that cavity. They are subdivided into two sets: an *upper*, ten to twenty in number, situated about the bifurcation of the common carotid and along the upper part of the internal jugular vein; and a *lower*, ten to fifteen in number, clustered around the lower part of the internal jugular vein, and extending outward into the supraclavicular fossa, where they are continuous with the axillary glands. Internally, this set is continuous with the mediastinal glands.

The **superficial** and **deep cervical lymphatic vessels** are a continuation of those already described on the cranium and face. After traversing the glands in those regions, they pass through the chain of glands which lie along the sheath of the carotid vessels, being joined by the lymphatics from the pharynx, œsophagus, larynx, trachea, and thyroid gland. At the lower part of the neck, after receiving some lymphatics from the thorax, they unite into a single trunk, which terminates, on the left side, in the thoracic duct; on the right side, in the right lymphatic duct.

Surgical Anatomy.—The cervical glands are very frequently the seat of tuberculous disease. This condition is most usually set up by some lesion in those parts from which they receive their lymph. This excites some inflammation, which subsequently takes on a tuberculous character. It is very desirable, therefore, for the surgeon, in dealing with these cases, to possess a knowledge of the relation of the respective groups of glands to the periphery. The following table is extracted from Mr. Treves's work on *Scrofula and its Gland Diseases*:

Scalp.—Posterior part = suboccipital and mastoid glands. Frontal and parietal portions = parotid glands.

Lymphatic vessels from the scalp also enter the superficial cervical set of glands.

Skin of face and neck = submaxillary, parotid, and superficial cervical glands.

External ear = superficial cervical glands.

Lower lip = submaxillary and suprahyoid glands.

Buccal cavity = submaxillary and upper set of deep cervical glands.

Gums of lower jaw = submaxillary glands.

Tongue.—Anterior portion = suprahyoid and submaxillary glands. Posterior portion = upper set of deep cervical glands.

Tonsils and palate = upper set of deep cervical glands.

Pharynx.—Upper part = parotid and retro-pharyngeal glands. Lower part = upper set of deep cervical glands.

Larynx, orbit, and roof of mouth = upper set of deep cervical glands.

Nasal fossæ = retro-pharyngeal glands, upper set of deep cervical glands. Some lymphatic vessels from posterior part of the fossæ enter the parotid glands.

LYMPHATICS OF THE UPPER EXTREMITY.

The **Lymphatic Glands of the Upper Extremity** (Fig. 340) are divided into two sets, *superficial* and *deep*.

The **superficial lymphatic glands** are few and of small size. There are occasionally two or three in front of the elbow, and one or two above the internal condyle of the humerus, near the basilic vein, while one or two may be found lying beside the cephalic vein between the Pectoralis major and Deltoid muscles.

The **deep lymphatic glands** are few in number, and are subdivided into those in the forearm, the arm, and the axilla. In the *forearm* a few small ones are occasionally found in the course of the radial and ulnar vessels. In the *arm* there is a chain of small glands along the inner side of the brachial artery. One, sometimes two, fairly constant glands are situated a little above and in front of the inner condyle of the humerus. In the *axilla* they are of large size, and usually ten or twelve in number. A chain of these glands surrounds the axillary vessels, imbedded in a quantity of loose areolar tissue; they receive the lymphatic vessels from the arm; others are dispersed in the areolar tissue of the axilla; the remainder are arranged in two series, a small chain running along the lower border of the Pectoralis major, receiving the lymphatics from the front of the chest and mamma; and others are placed along the lower margin of the posterior wall of the axilla, which receive the lymphatics from the integument of the back.

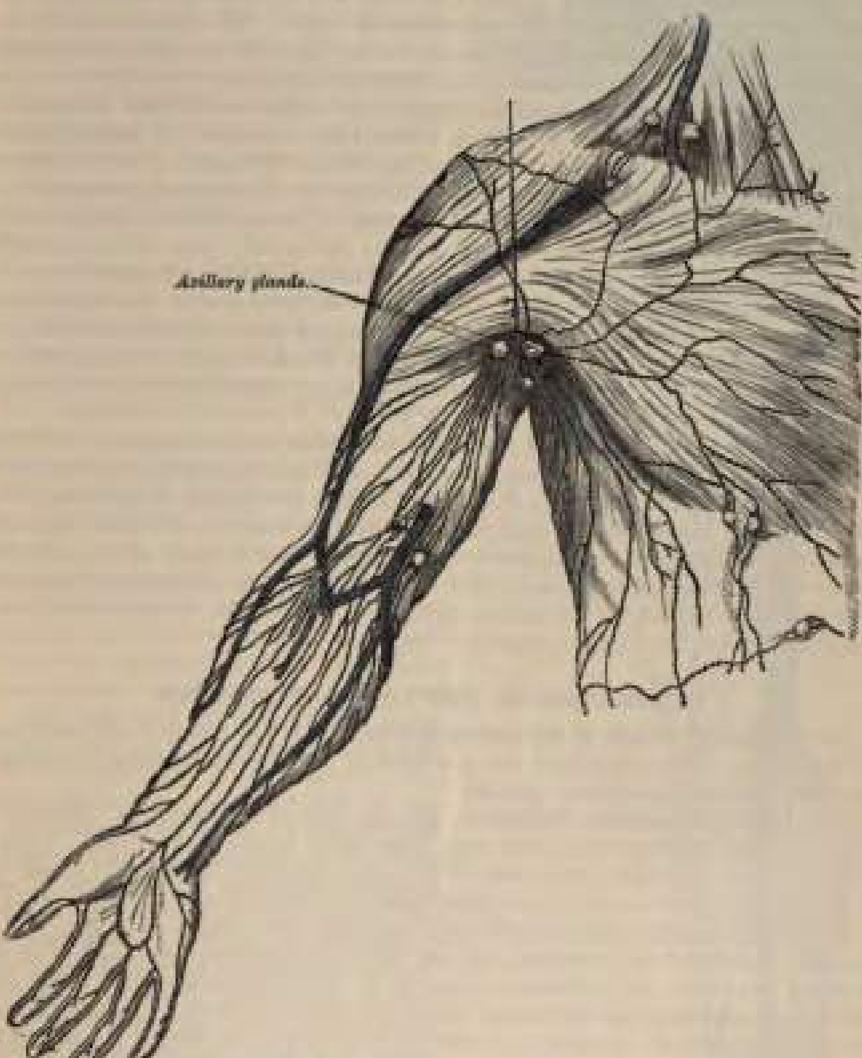

FIG. 340.—The superficial lymphatics and glands of the upper extremity.

Two or three subclavian or infra-clavicular lymphatic glands are placed immediately beneath the clavicle; it is through these that the axillary and deep cervical glands communicate with each other. The efferent vessels from the axillary glands may be from one to three or four in number. They accompany the subclavian vein into the neck, and end, on the right side, by joining the right lymphatic duct, on the left side by opening into the thoracic duct.

Surgical Anatomy.—In malignant diseases, tumors, or other affections implicating the upper part of the back and shoulder, the front of the chest and mamma, the upper part of the in the middle line of the neck, between the anterior bellies of the two digastric muscles; and (3) *cervical*, placed in the course of the external jugular vein between the Platysma and deep fascia. They are most numerous at the root of the neck, in the triangular interval between the clavicle, the Sterno-mastoid, and the Trapezius, where they are continuous with the axillary glands. A few small glands are also found on the front and sides of the larynx.

The **deep cervical glands** (Fig. 339) are numerous and of large size; they form a chain along the sheath of the carotid artery and internal jugular vein, lying by the side of the pharynx, œsophagus, and trachea, and extending from the base of the skull to the thorax, where they communicate with the lymphatic glands in that cavity. They are subdivided into two sets: an *upper*, ten to twenty in number, situated about the bifurcation of the common carotid and along the upper part of the internal jugular vein; and a *lower*, ten to fifteen in number, clustered around the lower part of the internal jugular vein, and extending outward into the supraclavicular fossa, where they are continuous with the axillary glands. Internally, this set is continuous with the mediastinal glands.

The **superficial** and **deep cervical lymphatic vessels** are a continuation of those already described on the cranium and face. After traversing the glands in those regions, they pass through the chain of glands which lie along the sheath of the carotid vessels, being joined by the lymphatics from the pharynx, œsophagus, larynx, trachea, and thyroid gland. At the lower part of the neck, after receiving some lymphatics from the thorax, they unite into a single trunk, which terminates, on the left side, in the thoracic duct; on the right side, in the right lymphatic duct.

Surgical Anatomy.—The cervical glands are very frequently the seat of tuberculous disease. This condition is most usually set up by some lesion in those parts from which they receive their lymph. This excites some inflammation, which subsequently takes on a tuberculous character. It is very desirable, therefore, for the surgeon, in dealing with these cases, to possess a knowledge of the relation of the respective groups of glands to the periphery. The following table is extracted from Mr. Treves's work on *Scrofula and its Gland Diseases*:

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Gums of lower jaw = submaxillary glands.

Tongue.—Anterior portion = suprahyoid and submaxillary glands. Posterior portion = upper set of deep cervical glands.

Tonsils and palate = upper set of deep cervical glands.

Pharynx.—Upper part = parotid and retro-pharyngeal glands. Lower part = upper set of deep cervical glands.

Larynx, orbit, and roof of mouth = upper set of deep cervical glands.

Nasal fossæ = retro-pharyngeal glands, upper set of deep cervical glands. Some lymphatic vessels from posterior part of the fossæ enter the parotid glands.

LYMPHATICS OF THE UPPER EXTREMITY.

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The **deep lymphatic glands** are few in number, and are subdivided into those in the forearm, the arm, and the axilla. In the *forearm* a few small ones are occasionally found in the course of the radial and ulnar vessels. In the *arm* there is a chain of small glands along the inner side of the brachial artery. One, sometimes two, fairly constant glands are situated a little above and in front of the inner condyle of the humerus. In the *axilla* they are of large size, and usually ten or twelve in number. A chain of these glands surrounds the axillary vessels, imbedded in a quantity of loose areolar tissue; they receive the lymphatic vessels from the arm; others are dispersed in the areolar tissue of the axilla; the remainder are arranged in two series, a small chain running along the lower border of the Pectoralis major, receiving the lymphatics from the front of the chest and mamma; and others are placed along the lower margin of the posterior wall of the axilla, which receive the lymphatics from the integument of the back.

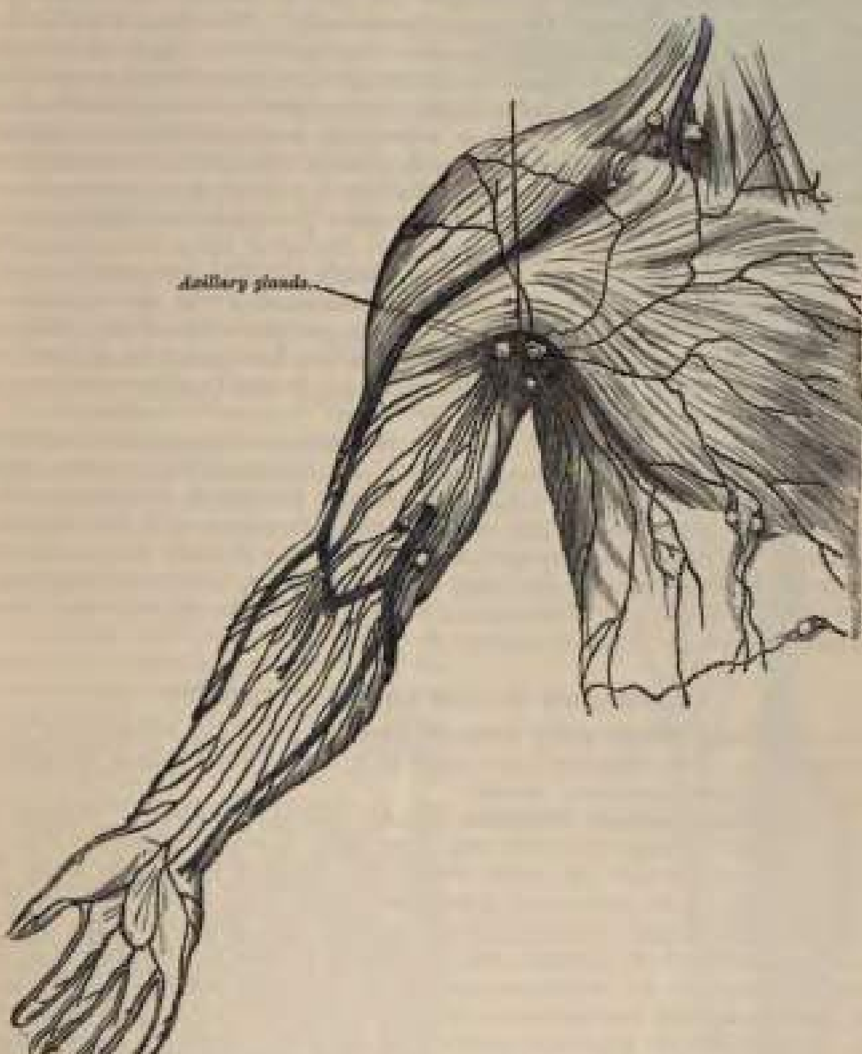

Fig. 340.—The superficial lymphatics and glands of the upper extremity.

Two or three subclavian or infra-clavicular lymphatic glands are placed immediately beneath the clavicle; it is through these that the axillary and deep cervical glands communicate with each other. The efferent vessels from the axillary glands may be from one to three or four in number. They accompany the subclavian vein into the neck, and end, on the right side, by joining the right lymphatic duct, on the left side by opening into the thoracic duct.

Surgical Anatomy.—In malignant diseases, tumors, or other affections implicating the upper part of the back and shoulder, the front of the chest and mamma, the upper part of the front and side of the abdomen, or the hand, forearm, and arm, the axillary glands are liable to be found enlarged.

The **lymphatic vessels of the upper extremity** are divided into two sets, *superficial* and *deep*.

The **superficial lymphatic vessels of the upper extremity** commence on the fingers, two vessels running along either side of each finger, one on the palmar and the other on the dorsal surface. Those on the palmar surface form an arch in the palm of the hand, from which are derived two sets of vessels, which pass up the forearm, taking the course of the subcutaneous veins. The lymphatics from the dorsal surface of the fingers form a plexus on the back of the hand, and, winding around the inner and outer borders of the forearm, unite with those in front. Those from the inner border of the hand accompany the ulnar veins along the inner side of the forearm to the bend of the elbow, where they are joined by some lymphatics from the outer side of the forearm: they then follow the course of the basilic vein, communicate with the glands immediately above the elbow, and terminate in the axillary glands, joining with the deep lymphatics. The superficial lymphatics from the outer and back part of the hand accompany the radial veins to the bend of the elbow. They are less numerous than the preceding. At the bend of the elbow the greater number join the basilic group; the rest ascend with the cephalic vein on the outer side of the arm, some crossing the upper part of the Biceps obliquely, to terminate in the axillary glands, whilst one or two accompany the cephalic vein in the cellular interval between the Pectoralis major and Deltoid, and enter the subclavian lymphatic glands.

The **deep lymphatic vessels of the upper extremity** accompany the deep blood-vessels. In the forearm they consist of four sets, corresponding with the radial, ulnar, and interosseous arteries; they pass through the glands occasionally found in the course of those vessels, and communicate at intervals with the superficial lymphatics. In their course upward some of them pass through the glands which lie upon the brachial artery; they then enter the axillary and subclavian glands, and at the root of the neck terminate on the left side in the thoracic duct, and on the right side in the right lymphatic duct.

LYMPHATICS OF THE LOWER EXTREMITY.

The **Lymphatic Glands of the Lower Extremity** are divided into two sets, *superficial* and *deep*. The superficial are confined to the inguinal region, forming the *superficial inguinal lymphatic glands*.

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 *oblique* set, 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 *vertical* set, two to five in number, 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 receives the superficial lymphatic vessels from the lower extremity. Leaf[1] figures some of the efferent vessels from these glands as terminating directly in the veins of this region.

Surgical Anatomy.—These glands frequently become enlarged in diseases implicating the parts from which their lymphatics originate. Thus in malignant or syphilitic affections of the prepuce and penis, or of the labia majora in the female, in cancer scroti, in abscess in the perineum, or in any other diseases affecting the integument and superficial structures in those parts, or the subumbilical part of the abdominal wall or the gluteal region, the upper chain of glands is almost invariably enlarged, the lower chain being implicated in diseases affecting the lower limb.

The **deep lymphatic glands** are the anterior tibial, popliteal, deep inguinal, gluteal, and ischiatic.

[1] *The Surgical Anatomy of the Lymphatic Glands*, 1898.

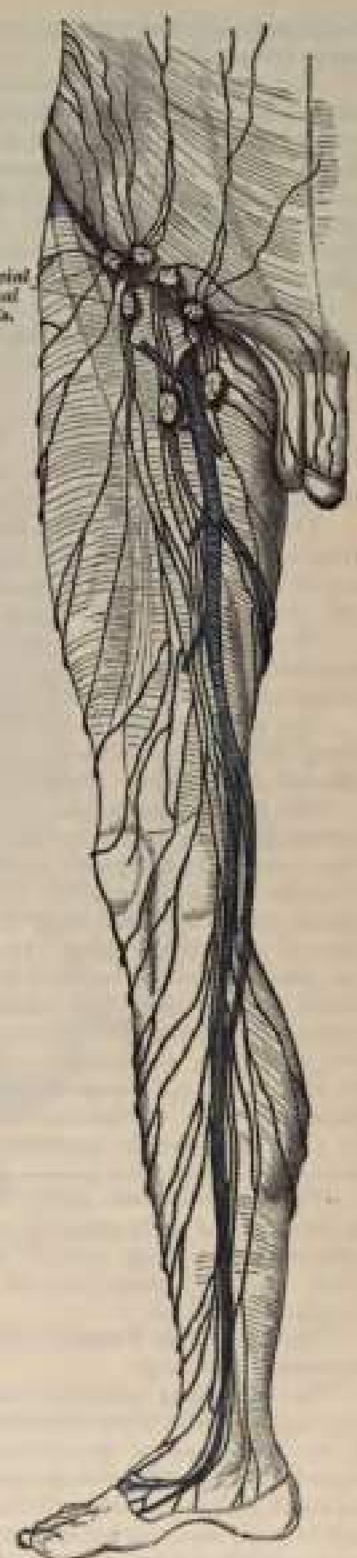

FIG. 341.—The superficial lymphatics and glands of the lower extremity.

The **anterior tibial gland** is not constant in its existence. It is generally found by the side of the anterior tibial artery, upon the interosseous membrane at the upper part of the leg. Occasionally, two glands are found in this situation.

The **popliteal glands**, four or five in number, are of small size; they surround the popliteal vessels, imbedded in the cellular tissue and fat of the popliteal space.

The **deep inguinal glands** are placed beneath the deep fascia around the femoral artery and vein. They are of small size, and communicate with the superficial inguinal glands through the saphenous opening.

The **gluteal** and **ischiatic glands** are placed, the former above, the latter below, the Pyriformis muscle, resting on their corresponding vessels as they pass through the great sacro-sciatic foramen.

The **Lymphatic Vessels of the Lower Extremity,** like the veins, may be divided into two sets, *superficial* and *deep*.

The **superficial lymphatic vessels** are placed beneath the integument in the superficial fascia, and are divisible into two groups: an internal group, which follow the course of the internal saphenous vein; and an external group, which accompany the external saphenous. The *internal group*, the larger, commence on the inner side and dorsum of the foot; they pass, some in front and some behind, the inner ankle, run up the leg with the internal saphenous vein, pass with it behind the inner condyle of the femur, and accompany it to the groin, where they terminate in the group of superficial inguinal lymphatic glands which surround the saphenous opening. Some of the efferent vessels from these glands pierce the cribriform fascia and sheath of the femoral vessels, and terminate in a lymphatic gland contained in the femoral canal, thus establishing a communication between the lymphatics of the lower extremity and those of the trunk; others pierce the fascia lata and join the deep inguinal glands. The *external group* arise from the outer side of the foot, ascend in front of the leg, and, just below the knee, cross the tibia from without inward, to join the lymphatics on the inner side of the thigh. Others commence on the outer side of the foot, pass behind the outer malleolus, and accompany the external saphenous vein along the back of the leg, where they enter the popliteal glands.

The **deep lymphatic vessels of the lower extremity** are few in number and accompany the deep blood-vessels. In the leg they consist of three sets, the anterior tibial, peroneal, and posterior tibial, which accompany the corresponding blood-vessels, two or three to each artery; they ascend with the blood-vessels and enter the lymphatic glands in the popliteal space; the efferent vessels from these glands accompany the femoral vein and join the deep inguinal glands; from these, the vessels pass beneath Poupart's ligament and communicate with the chain of glands surrounding the external iliac vessels.

The deep lymphatic vessels of the gluteal and ischiatic regions follow the course of the blood-vessels, and join the gluteal and ischiatic glands at the great sacro-sciatic foramen.

LYMPHATICS OF THE PELVIS AND ABDOMEN.

The **Lymphatic Glands in the Pelvis** are the external iliac, the internal iliac, and the sacral. Those of the abdomen are the lumbar and cœliac glands.

The **external iliac glands** form an uninterrupted chain round the external iliac vessels, three being placed round the commencement of the vessels just behind the crural arch. They communicate below with the deep inguinal lymphatic glands, and above with the lumbar glands.

The **internal iliac glands** surround the internal iliac vessels; they receive the lymphatic vessels corresponding to the branches of the internal iliac artery, and communicate with the lumbar glands.

The **sacral glands** occupy the sides of the anterior surface of the sacrum, some being situated in the meso-rectal fold. These and the internal iliac glands are affected in malignant disease of the bladder, rectum, or uterus.

The **lumbar glands** are very numerous; they are situated on the front of the lumbar vertebræ, surrounding the common iliac vessels, the aorta, and vena cava; they receive the lymphatic vessels from the lower extremities and pelvis, as well as from the testes and some of the abdominal viscera: the efferent vessels from these glands unite into a few large trunks, which, with the lacteals, form the commencement of the thoracic duct. In addition to these there are a few small *lateral lumbar glands* which lie between the transverse processes of the vertebræ, behind the Psoas muscle, and receive lymphatics from the back. In some cases of malignant disease these glands become enormously enlarged, completely surrounding the aorta and vena cava, and occasionally greatly contracting the calibre of those vessels. In all cases of malignant disease of the testes and in malignant disease of the lower limb, before any operation is attempted, careful examination of the abdomen should be made, in order to ascertain if any enlargement exists; and if any should be detected, all operative measures should be avoided as fruitless.

The **Cœliac Glands,** nearly twenty in number, surround the cœliac axis and lie in front of the aorta near the origin of that vessel. They receive the lymphatic vessels from a large part of the liver, from the spleen, pancreas, and stomach. Their efferent vessels join the lacteals from the intestine and open into the receptaculum chyli.

The **Lymphatic Vessels of the Abdomen and Pelvis** may be divided into two sets, *superficial* and *deep*.

The **superficial lymphatic vessels of the walls of the abdomen and pelvis** follow the course of the superficial blood-vessels. Those derived from the integument of the lower part of the abdomen below the umbilicus follow the course of the superficial epigastric vessels and converge to the superior group of the superficial inguinal glands; a deeper set accompany the deep epigastric vessels, and communicate with the external iliac glands. The superficial lymphatics from the sides of the lumbar part of the abdominal wall wind round the crest of the ilium, accompanying the superficial circumflex iliac vessels, to join the superior group of the superficial inguinal glands; the greater number, however, run backward along with the ilio-lumbar and lumbar vessels, to join the lateral lumbar glands.

The **superficial lymphatic vessels of the gluteal region** turn horizontally round the outer side of the nates, and join the superficial inguinal glands.

The **superficial lymphatic vessels of the scrotum and perinæum** follow the course of the external pudic vessels, and terminate in the superficial inguinal glands.

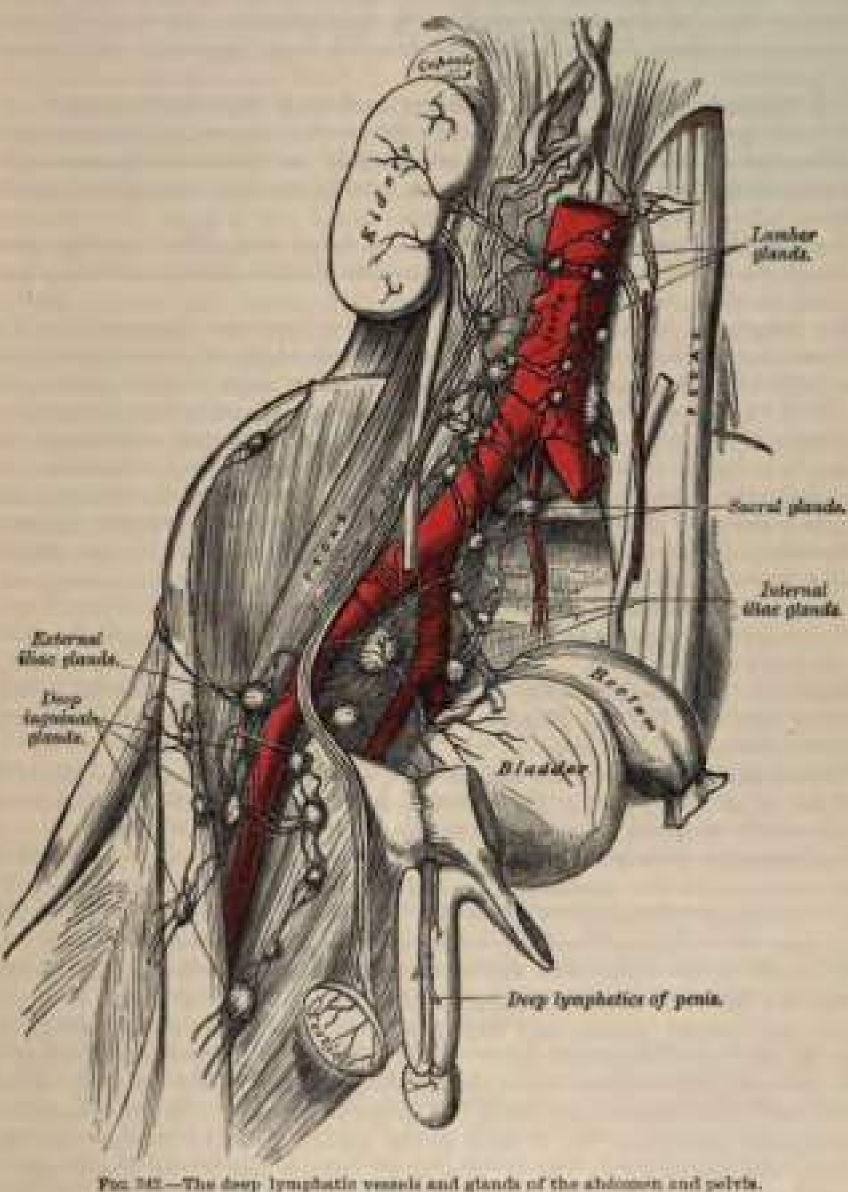

FIG. 342.—The deep lymphatic vessels and glands of the abdomen and pelvis.

The **superficial lymphatic vessels of the penis** occupy the sides and dorsum of the organ, the latter receiving the lymphatics from the skin covering the glans penis; they all converge to the upper chain of the superficial inguinal glans. The **deep lymphatic vessels of the penis** follow the course of the internal pudic vessels, and join the internal iliac glands.

In the female the lymphatic vessels of the mucous membrane of the labia, nymphæ, and clitoris terminate in the upper chain of the inguinal glands.

The **deep lymphatic vessels of the abdomen and pelvis** take the course of the principal blood-vessels. Those of the parietes of the pelvis, which accompany the gluteal, ischiatic, and obturator vessels, follow the course of the internal iliac artery, and ultimately join the lumbar lymphatics.

The efferent vessels from the inguinal glands enter the pelvis beneath Poupart's ligament, where they lie in close relation with the femoral vein; they then pass through the chain of glands surrounding the external iliac vessels, and finally terminate in the lumbar glands. They receive the deep epigastric and circumflex iliac lymphatics.

The **lymphatic vessels of the bladder** arise from the entire surface of the organ;[1] the greater number run beneath the peritoneum on its posterior surface, and, after passing through the lymphatic glands in that situation, join with the lymphatics from the prostate and vesiculæ seminales, and enter the internal iliac glands.

The **lymphatic vessels of the rectum** are of large size; after passing through some small glands that lie upon its outer wall and in the meso-rectum they pass to the sacral glands.

The **lymphatic vessels of the uterus** consist of two sets, *superficial* and *deep*, the former being placed beneath the peritoneum, the latter in the substance of the organ. The lymphatics of the cervix uteri, together with those from the greater part of the vagina, enter the internal iliac and sacral glands; those from the body and fundus of the uterus pass outward in the broad ligaments, and, being joined by the lymphatics from the ovaries, broad ligaments, and Fallopian tubes, ascend with the ovarian vessels to open into the lumbar glands; the lymphatics from the lower part of the vagina join those of the external genitals and pass to the superficial inguinal glands. In the unimpregnated uterus they are small, but during gestation they become very greatly enlarged.

The **lymphatic vessels of the testicle** consist of two sets, *superficial* and *deep*: the former commence on the surface of the tunica vaginalis, the latter in the epididymis and body of the testis. They form several large trunks which ascend with the spermatic cord, and, accompanying the spermatic vessels into the abdomen, terminate into the lumbar glands; hence the enlargement of these glands in malignant disease of the testis.

The **lymphatic vessels of the kidney** arise on the surface, and also in the interior of the organ; they join at the hilum, and, after receiving the lymphatic vessels from the ureter and suprarenal capsules, open into the lumbar glands.

The **lymphatic vessels of the liver** are divisible into two sets, *superficial* and *deep*. The former arise in the subperitoneal areolar tissue over the entire surface of the organ. Those on the convex surface may be divided into four groups: 1. Those which pass from behind forward, consisting of three or four branches, which ascend in the falciform ligament and unite to form a single trunk, which passes up between the fibres of the Diaphragm, behind the ensiform cartilage, to enter the anterior mediastinal glands, and finally ascends to the root of the neck, to terminate in the right lymphatic duct. 2. Another group, which also incline from behind forward, are reflected over the anterior margin of the liver to its under surface, and from thence pass along the longitudinal fissure to the glands in the gastro-hepatic omentum. 3. A third group incline outward to the right lateral ligament, and, uniting into one or two large trunks, pierce the Diaphragm, and run along its upper surface to enter the anterior mediastinal glands, or, instead of entering the thorax, turn inward across the crus of the Diaphragm and open into the commencement of the thoracic duct. 4. The fourth group incline outward from the surface of the left lobe of the liver to the left lateral ligament, pierce the Diaphragm, and, passing forward, terminate in the glands in the anterior mediastinum.

[1] Curnow states that they are confined to the base of the organ.

The *superficial lymphatics on the under surface of the liver* are divided into three sets: 1. Those on the right side of the gall-bladder enter the lumbar glands. 2. Those surrounding the gall-bladder form a remarkable plexus; they accompany the hepatic vessels, and open into the glands in the gastro-hepatic omentum. 3. Those on the left of the gall-bladder pass to the œsophageal glands and to the glands which are situated along the lesser curvature of the stomach.

The *deep lymphatics* accompany the branches of the portal vein and the hepatic artery and duct through the substance of the liver; passing out at the transverse fissure, they enter the lymphatic glands along the lesser curvature of the stomach and behind the pancreas, or join with one of the lacteal vessels previous to its termination in the thoracic duct.

The **lymphatic glands of the stomach** are of small size; they are placed along the upper part of the lesser and toward the pyloric end of the greater curvature.

The **lymphatic vessels of the stomach** consist of two sets, *superficial* and *deep*; the former originating in the subserous, and the latter in the submucous coat. They follow the course of the blood-vessels, and may consequently be arranged into three groups. The *first group* accompany the gastric vessels along the lesser curvature to the cardiac orifice, receiving branches from both surfaces of the organ, and pass to the cœliac glands. The *second group* pass from the great end of the stomach, accompanying the vasa brevia, and enter the splenic lymphatic glands. The *third group* run along the greater curvature with the right gastro-epiploic vessels toward the pylorus, and, receiving the lymphatics from the upper part of the duodenum, terminate in the cœliac glands.

The **lymphatic glands of the spleen** occupy the hilum. Its *lymphatic vessels* consist of two sets, superficial and deep; the former are placed beneath its peritoneal covering, the latter in the substance of the organ; they accompany the blood-vessels, passing through a series of small glands, and, after receiving the lymphatics from the pancreas, ultimately pass into the cœliac glands.

The *lymphatics of the pancreas* also enter the cœliac glands.

THE LYMPHATIC SYSTEM OF THE INTESTINES.

The **lymphatic glands of the small intestine** are placed between the layers of the mesentery, occupying the meshes formed by the superior mesenteric vessels, and hence called *mesenteric glands*. They vary in number from a hundred to a hundred and fifty, and in size from that of a pea to that of a small almond.[1] These glands are most numerous and largest above, the glands of the jejunum, being more numerous than those of the ileum. This latter group becomes enlarged and infiltrated with deposit in cases of fever accompanied with ulceration of the intestines.

The **lymphatic glands of the large intestine** are much less numerous than the mesenteric glands; they are situated along the vascular arches formed by the arteries previous to their distribution, and even sometimes upon the intestine itself. They are fewest in number along the transverse colon, where they form an uninterrupted chain with the mesenteric glands.

The **lymphatic vessels of the small intestine** are called **lacteals**, from the milk-white fluid they usually contain: they consist of two sets, superficial and deep, the former lie between the layers of the muscular coat and between the muscular and peritoneal coats, taking a longitudinal course along the outer side of the intestine; the latter occupy the submucous tissue, and course transversely round the intestine, accompanied by the branches of the mesenteric vessels; they pass between the layers of the mesentery, enter the mesenteric glands, and finally unite to form two or three large trunks which terminate separately in the receptaculum chyli; frequently, however, they first unite to form a single large trunk, termed the *intestinal lymphatic trunk*.

The **lymphatic vessels of the large intestine** consist of two sets: those of the

[1] Leaf (*op. cit.*) says it is very common to find not more than forty or fifty.

cæcum, ascending and transverse colon, which, after passing through their proper glands, enter the mesenteric glands; and those of the descending colon, sigmoid flexure, and rectum, which pass to the lumbar glands.

THE LYMPHATICS OF THE THORAX.

The **Lymphatic Glands of the Thoracic Wall** are the intercostal, internal mammary, anterior mediastinal, and posterior mediastinal.

The **intercostal glands** are small, and situated on each side of the spine, near the costo-vertebral articulations; they vary from one to three in each space.

The **sternal** or **internal mammary glands** are placed at the anterior extremity of each intercostal space, by the side of the internal mammary vessels.

The **anterior mediastinal glands** are placed in the loose areolar tissue of the anterior mediastinum, some lying upon the Diaphragm in front of the pericardium, and others round the great vessels at the base of the heart.

The **posterior mediastinal glands** are situated in the areolar tissue in the posterior mediastinum, forming a continuous chain by the side of the aorta and œsophagus; they communicate on each side with the intercostal, below with the lumbar, and above with the deep cervical glands.

The **Superficial Lymphatic Vessels of the Front of the Thorax** run across the great Pectoral muscle, and those on the back part of this cavity lie upon the Trapezius and Latissimus dorsi; they all converge to the axillary glands. The lymphatics from the greater part of the mammary gland pass outward to the lower border of the Pectoralis major muscle, where they enter a chain of small glands situated in the axillary space along the lower border of its anterior boundary. Some few lymphatics from the inner side of the mammary gland pass through the intercostal spaces to reach the anterior mediastinal glands.

The **Deep Lymphatic Vessels of the Thoracic Wall** are the intercostal, internal mammary, and diaphragmatic.

The **intercostal lymphatic vessels** follow the course of the intercostal vessels, receiving lymphatics from the intercostal muscles and pleura; they pass backward to the spine, and unite with lymphatics from the back part of the thorax and spinal canal. After traversing the intercostal glands, they pass down the spine and terminate in the thoracic duct.

The **internal mammary lymphatic vessels** follow the course of the internal mammary vessels; they commence in the muscles of the abdomen above the umbilicus, communicating with the epigastric lymphatics, ascend between the fibres of the Diaphragm at its attachment to the ensiform appendix, and in their course behind the costal cartilages are joined by the intercostal lymphatics; they terminate on the right side in the right lymphatic duct, on the left side in the thoracic duct.

The **lymphatic vessels of the Diaphragm** follow the course of their corresponding vessels, and terminate, some in front in the anterior mediastinal and internal mammary glands, some behind, in the intercostal and posterior mediastinal lymphatics.

The **Lymphatic Glands of the Viscera of the Thorax** are the bronchial glands.

The **bronchial glands** are situated round the bifurcation of the trachea and roots of the lungs. They are ten or twelve in number, the largest being placed opposite the bifurcation of the trachea, the smallest round the bronchi and their primary divisions for some little distance within the substance of the lungs. In infancy they present the same appearance as lymphatic glands in other situations; in the adult they assume a brownish tinge, and in old age a deep black color. Occasionally they become sufficiently enlarged to compress and narrow the canal of the bronchi, and they are often the seat of tuberculous deposits.

The **superior mediastinal** or **cardiac glands** lie in front of the transverse aorta and left innominate vein; this group consists of numerous large glands. They receive the lymph from the pericardium, heart, and thymus gland.

The **lymphatic vessels of the lung** consist of two sets, *superficial* and *deep*: the former are placed beneath the pleura, forming a minute plexus which covers the outer surface of the lung; the latter accompany the blood-vessels and run along the bronchi: they both terminate at the root of the lungs in the bronchial glands. The efferent vessels from these glands, two or three in number, ascend upon the trachea to the root of the neck, traverse the tracheal and œsophageal glands, and terminate on the left side in the thoracic duct and on the right side in the right lymphatic duct.

The **cardiac lymphatic vessels** consist of two sets, *superficial* and *deep*: the former arise in the subserous areolar tissue of the surface, and the latter in the deeper tissues of the heart. They follow the course of the coronary vessels: those of the right side unite into a trunk at the root of the aorta, which, ascending across the arch of that vessel, communicates with one or more of the cardiac glands, and passes backward to the trachea, upon which it ascends, to terminate at the root of the neck in the right lymphatic duct. Those of the left side unite into a single vessel at the base of the heart, which, passing along the pulmonary artery and traversing some glands at the root of the aorta, ascends on the trachea to terminate in the thoracic duct.

The **thymic lymphatic vessels** arise from the under surface of the thymus gland, and enter the superior mediastinal glands, from which they emerge as two vessels: these terminate, one on each side, in the corresponding internal jugular vein.

The **lymphatic vessels of the œsophagus** form a plexus round that tube, traverse the glands in the posterior mediastinum, and, after communicating with the pulmonary lymphatic vessels near the roots of the lungs, terminate in the thoracic duct.

THE NERVOUS SYSTEM.

THE Nervous System is composed: 1. Of a series of large centres of nerve-matter, called, collectively, the *cerebro-spinal centres* or *cerebro-spinal axis*. 2. Of smaller centres, termed *ganglia*. 3. Of nerves connected either with the cerebro-spinal axis or the ganglia. And 4. Of certain modifications of the peripheral terminations of the nerves forming the organs of the external senses.

The **Cerebro-spinal axis** consists of the brain or encephalon and the spinal cord, which are contained within the skull and spinal canal. The brain and its membranes will be first considered, and then the spinal cord and its coverings.

THE MEMBRANES OF THE BRAIN.

Dissection.—To examine the brain with its membranes, the skull-cap must be removed. In order to effect this, saw through the external table, the section commencing, in front, about an inch above the margin of the orbit, and extending, behind, to a little above the level with the occipital protuberance. Then break the internal table with the chisel and hammer, to avoid injuring the investing membranes or brain; loosen and forcibly detach the skull-cap, when the dura mater will be exposed. The adhesion between the bone and the dura mater is very intimate, and much more so in the young subject than in the adult.

The membranes of the brain are: the dura mater, arachnoid membrane, and pia mater.

The Dura Mater.

The **Dura Mater** is a thick and dense inelastic fibrous membrane which lines the interior of the skull. Its outer surface is rough and fibrillated, and adheres closely to the inner surface of the bones, forming their internal periosteum, this adhesion being most marked opposite the sutures and at the base of the skull. Its inner surface is smooth and lined by a layer of endothelium. It sends four processes inward, into the cavity of the skull, for the support and protection of the different parts of the brain, and is prolonged to the outer surface of the skull through the various foramina which exist at the base, and thus becomes continuous with the pericranium; its fibrous layer forms sheaths for the nerves which pass through these apertures. At the base of the skull it sends a fibrous prolongation into the foramen cæcum; it sends a series of tubular prolongations round the filaments of the olfactory nerves as they pass through the cribriform plate, and also round the nasal nerve as it passes through the nasal slit; a prolongation is also continued through the sphenoidal fissure into the orbit, and another is continued into the same cavity through the optic foramen, forming a sheath for the optic nerve, which is continued as far as the eyeball. In the posterior fossa it sends a process into the internal auditory meatus, ensheathing the facial and auditory nerves; another through the jugular foramen, forming a sheath for the structures which pass through this opening; and a third through the anterior condyloid foramen. Around the margin of the foramen magnum it is closely adherent to the bone, and is continuous with the dura mater lining the spinal canal. In certain situations, as already mentioned (page 594), the fibrous layers of this membrane separate, to form sinuses for the passage of venous blood. Upon the outer surface of the dura mater, in the situation of the longitudinal sinus, may be seen numerous small whitish bodies, the *glandulæ Pacchioni*.

Structure.—The dura mater consists of white fibrous tissue with connective-tissue cells and elastic fibres arranged in flattened laminæ which are imperfectly separated by lacunar spaces and blood-vessels into two layers, *endosteal* and *meningeal*. The endosteal layer is the internal periosteum for the cranial bones, and contains the blood-vessels for their supply. At the margin of the foramen magnum it becomes continuous with the periosteum lining the spinal canal. The meningeal or supporting layer is lined on its inner surface by a layer of nucleated endothelium, similar to that found on serous membranes: these cells were formerly regarded as belonging to the arachnoid membrane. By its reduplication the meningeal layer forms the falx cerebri, the tentorium and falx cerebelli, and the diaphragma sellæ. The two layers are connected by fibres which intersect each other obliquely.

Its *arteries* are very numerous, but are chiefly distributed to the bones. Those found in the anterior fossa are the anterior meningeal branches of the anterior and posterior ethmoidal and internal carotid, and a branch from the middle meningeal. In the middle fossa are the middle and small meningeal branches of the internal maxillary, a branch from the ascending pharyngeal, which enters the skull through the foramen lacerum medium basis cranii, branches from the internal carotid, and a recurrent branch from the lachrymal. In the posterior fossa are meningeal branches from the occipital, one of which enters the skull through the jugular foramen, and the other through the mastoid foramen; the posterior meningeal, from the vertebral; occasionally meningeal branches from the ascending pharyngeal, which enter the skull, one at the jugular foramen, the other at the anterior condyloid foramen, and a branch from the middle meningeal.

The *veins*, which return the blood from the dura mater, and partly from the bones, anastomose with the diploic veins. These vessels terminate in the various sinuses, with the exception of two which accompany the middle meningeal artery, and pass out of the skull at the foramen spinosum to join the internal maxillary vein; above they communicate with the superior longitudinal sinus. Many of the meningeal veins do not open directly into the sinuses, but indirectly through a series of ampullæ termed *venous lacunæ*. These are found on each side of the superior longitudinal sinus, especially near its middle portion, and are often invaginated by Pacchionian bodies; they also exist near the lateral and straight sinuses. They communicate with the underlying cerebral veins, and also with the diploic and emissary veins.

The *nerves* of the dura mater are filaments from the Gasserian ganglion, from the ophthalmic, superior maxillary, inferior maxillary, vagus, and hypoglossal nerves, and from the sympathetic.

Processes of the Dura Mater.—The processes of the dura mater, sent inward into the cavity of the skull, are four in number: the falx cerebri, the tentorium cerebelli, the falx cerebelli, and the diaphragma sellæ.

The *falx cerebri*, so named from its sickle-like form, is a strong arched process of the dura mater, which descends vertically in the longitudinal fissure between the two hemispheres of the brain. It is narrow in front, where it is attached to the crista galli of the ethmoid bone, and broad behind, where it is connected with the upper surface of the tentorium. Its upper margin is convex, and attached to the inner surface of the skull, in the middle line, as far back as the internal occipital protuberance; it contains the superior longitudinal sinus. Its lower margin is free, concave, and presents a sharp curved edge, which contains the inferior longitudinal sinus.

The *tentorium cerebelli* is an arched lamina of dura mater, elevated in the middle and inclining downward toward the circumference. It covers the upper surface of the cerebellum, and supports the occipital lobes of the brain, and prevents them pressing upon the cerebellum. It is attached, behind, by its convex border to the transverse ridges upon the inner surface of the occipital bone, and there encloses the lateral sinuses; in front, to the superior margin of the petrous portion of the temporal bone on either side, enclosing the superior petrosal sinuses; and at the apex of this bone the free or internal border and the attached or external border meet, and, crossing one another, are continued forward, to be attached to the anterior and posterior clinoid processes respectively. Along the middle line of its upper surface the posterior border of the falx cerebri is attached, the straight sinus being placed at their point of junction. Its anterior border is free and concave, and bounds a large oval opening for the transmission of the crura cerebri.

The *falx cerebelli* is a small triangular process of dura mater received into the indentation between the two lateral lobes of the cerebellum behind. Its base is attached, above, to the under and back part of the tentorium; its posterior margin, to the lower division of the vertical crest on the inner surface of the occipital bone. As it descends it sometimes divides into two smaller folds, which are lost on the sides of the foramen magnum.

The *diaphragma sellæ* is a horizontal process formed by a reduplication of the meningeal layer of the dura mater. It forms a small circular fold, which constitutes a roof for the sella turcica. This almost completely covers the pituitary body, presenting merely a small central opening for the infundibulum to pass through.

The Arachnoid Membrane.

The arachnoid (ἀράχνη εἶδος, like a spider's web), so named for its extreme thinness, is a delicate membrane which envelops the brain, lying between the pia mater internally and the dura mater externally; from this latter membrane it is separated by a space, the *subdural space*.

It invests the brain loosely, being separated from direct contact with the cerebral substance by the pia mater, and a quantity of loose areolar tissue, the *subarachnoidean*. On the upper surface of the cerebrum the arachnoid is thin and transparent, and may be easily demonstrated by injecting a stream of air beneath it by means of a blowpipe; it passes over the convolutions without dipping down into the sulci between them. At the base of the brain the arachnoid is thicker, and slightly opaque toward the central part; it covers the anterior lobes, and extends across between the two temporal lobes so as to leave a considerable interval between it and the brain, the *anterior subarachnoidean space* (Cisterna pontis); it is in contact with the pons and under surface of the cerebellum; but between the hemispheres of the cerebellum and the medulla oblongata another considerable interval is left between it and the brain, called the *posterior subarachnoidean space* (Cisterna magna). These two spaces communicate together across the crura cerebelli. Other smaller cisternæ are found in various positions; and all communicate freely with one another. The arachnoid membrane surrounds the nerves which arise from the brain, and encloses them in loose sheaths as far as their point of exit from the skull.

The *subarachnoid space* is the interval between the arachnoid and pia mater. It is not, properly speaking, a *space*, for it is occupied everywhere by a spongy tissue consisting of trabeculæ of delicate connective tissue, which pass from the pia mater to the arachnoid, and in the meshes of which the subarachnoid fluid is contained. This so-called space is small on the surface of the hemispheres; but at the base of the brain the subarachnoid tissue is less abundant and its meshes larger, where it forms the Cisternæ pontis et magna mentioned above. In addition to these two large spaces, a third is formed on the upper surface of the corpus callosum, for the arachnoid stretches across from one cerebral hemisphere to the other immediately beneath the free border of the falx cerebri, and thus leaves a space in which the anterior cerebral arteries are contained. Another space is found in the fissure of Sylvius, for the arachnoid stretches across from the anterior to the middle lobe of the brain, without dipping down to the bottom of the fissure, and in this space the middle cerebral artery ramifies. The subarachnoid space communicates with the general ventricular cavity of the brain by means of three openings: one of these is in the middle line at the inferior boundary of the fourth ventricle, where an opening in the pia-matral covering of this cavity, the *foramen of Magendie*, exists and permits the passage of fluid from the one space to the other. The other two communications are at the extremities of the lateral recesses of the fourth ventricle, behind the upper roots of the glosso-pharyngeal nerves; they are named the *foramina of Key and Retzius.* It is stated by Merkel that the lateral ventricles also communicate with the subarachnoid space at the apices of their descending horns.

The subdural space also contains fluid; this is, however, small in quantity compared with the cerebro-spinal fluid and is probably of the nature of lymph.

The *cerebro-spinal fluid* fills up the subarachnoid space. It is a clear, limpid fluid, having a saltish taste and a slightly alkaline reaction. According to Lassaigne, it consists of 98.5 parts of water, the remaining 1.5 per cent. being solid matters, animal and saline. It varies in quantity, being most abundant in old persons, and is quickly reproduced. Its chief use is probably to afford mechanical protection to the nervous centres, and to prevent the effects of concussions communicated from without.

Structure.—The arachnoid consists of bundles of white fibrous and elastic tissue intimately blended together. Its outer surface is covered with a layer of endothelium. Vessels of considerable size, but few in number, and, according to Bochdalek, a rich plexus of nerves derived from the motor division of the fifth, the facial, and the spinal accessory nerves, are found in the arachnoid.

Glandulæ Pacchioni or Arachnoid Villi.

The **glandulæ Pacchioni** are numerous small whitish granulations usually collected into clusters of variable size, which are found in the following situations: 1. Upon the outer surface of the dura mater, in the vicinity of the superior longitudinal sinus, being received into little depressions on the inner surface of the calvarium. 2. On the inner surface of the dura mater. 3. In the superior longitudinal sinus. 4. On the pia mater, near the margin of the hemispheres.

These bodies are not glandular in structure, but simply enlarged normal villi of the arachnoid. In their growth they appear to perforate the dura mater, and when of large size they cause absorption of the bone, and come to be lodged in pits or depressions on the inner table of the skull. Their manner of growth is as follows: at an early period they project through minute holes in the inner layer of the dura mater, which open into large venous spaces situated in the tissues of the membrane, on either side of the longitudinal sinus and communicating with it. In their onward growth the villi push the outer layer of the dura mater before them, and this forms over them a delicate membranous sheath. In structure they consist of spongy trabecular tissue, covered over by a membrane, which is continuous with the arachnoid. The space between these two coverings, derived from the dura mater and arachnoid respectively, corresponds to and is continuous with the subdural space. The spongy tissue of which they are composed is continuous with the trabecular tissue of the subarachnoid space; so that fluid injected into the subarachnoid space finds its way into the Pacchionian bodies; and through their coverings filters into the superior longitudinal sinus. They are supposed to be the means by which excess of cerebro-spinal fluid is got rid of, when its quantity is increased above normal.

These bodies are not found in infancy, and very rarely until the third year. They are usually found after the seventh year; and from this period they increase in number as age advances. Occasionally they are wanting.

The Pia Mater.

The pia mater is a vascular membrane, and derives its blood from the internal carotid and vertebral arteries. It consists of a minute plexus of blood-vessels, held together by an extremely fine areolar tissue. It invests the entire surface of the brain, dipping down between the convolutions and laminæ, and is prolonged into the interior, forming the velum interpositum and choroid plexuses of the lateral and fourth ventricles. Upon the surfaces of the hemispheres, where it covers the gray matter of the convolutions, it is very vascular, and gives off from its inner surface a multitude of minute vessels, which extend perpendicularly for some distance into the cerebral substance. At the base of the brain, in the situation of the anterior and posterior perforated spaces, a number of long straight vessels are given off, which pass through the white matter to reach the gray substance in the interior. On the cerebellum the membrane is more delicate, and the vessels from its inner surface are shorter. The pia mater of the spinal cord is thicker, firmer, and less vascular than that of the brain, and as it is traced upward over the medulla it is seen to preserve these characters. At the upper border of the medulla it is prolonged over the lower half of the fourth ventricle, forming a covering for it (tela choroidea inferior) before it is reflected on to the under surface of the cerebellum.

According to Fohmann and Arnold, this membrane contains numerous lymphatic vessels. Its nerves are derived from the sympathetic, and also from the third, fifth, sixth, facial, glosso-pharyngeal, pneumogastric, and spinal accessory. They accompany the branches of the arteries.

THE BRAIN.

GENERAL CONSIDERATIONS AND DIVISIONS.

The **encephalon** or **brain** is that portion of the cerebro-spinal axis which is contained in the cavity of the cranium. For purposes of description it may be divided into five parts, as follows: (1) the two cerebral hemispheres; (2) the inter-brain; (3) the mid-brain; (4) the pons Varolii and cerebellum; and (5) the medulla oblongata. If the student will refer to the section on the Development of the Brain he will find that these five portions correspond fairly accurately to the five secondary cerebral vesicles, of which the brain at an early period of embryonal life consisted: the prosencephalon, or *first* vesicle, by means of a protrusion from its front part on either side, forms the cerebral hemispheres and the lateral ventricles; the remainder of the prosencephalon, together with the *second* vesicle, the thalamencephalon, form the inter-brain and third ventricle: the *third* vesicle, the mesencephalon, forms the mid-brain, or that portion which connects the inter-brain and hemispheres above with the pons Varolii below, and the cavity of the vesicle forms the aqueduct of Sylvius, or iter a tertio ad quartum ventriculum; the *fourth* vesicle, the epencephalon, becomes the future pons Varolii and cerebellum, and its cavity forms the upper half of the fourth ventricle; and, finally, the *fifth* vesicle, the metencephalon, develops into the medulla oblongata, and its cavity forms the lower half of the fourth ventricle. It will thus be seen that the five divisions of the encephalon mentioned above correspond to the five secondary cerebral vesicles, with the exception of the first two, which together form the cerebral hemispheres and the inter-brain. In consequence of this these two portions of the brain are sometimes grouped together as the *cerebrum*.

I. The Hemispheres of the Brain.

General Considerations.—The two hemispheres constitute the largest portion of the encephalon, and, together with the parts derived from the thalamencephalon, form what is called by some writers the *fore-brain*. They occupy the whole of the vault of the skull, and consist of a central cavity, in either hemisphere, surrounded by exceedingly thick and convoluted walls of nervous tissue. The under surface or base of the cerebrum is of an irregular form, resting in front on the anterior and middle fossæ of the skull and behind upon the tentorium cerebelli. The upper surface is of an ovoid form, broader behind than in front, convex in general outline, and divided into two lateral halves or hemispheres, right and left, by the *great longitudinal fissure*, which extends throughout the entire length of the cerebrum in the middle line, reaching down to the base of the brain in front and behind, but interrupted in the middle by a broad transverse commissure of white matter, the *corpus callosum*, which connects the two hemispheres together.

The Surface of the Cerebrum.—Each hemisphere presents an outer convex surface, filling the concavity of the corresponding half of the vault of the cranium;

an inner, flattened surface, which is vertical and directed toward the corresponding surface of the opposite hemisphere (the two forming the sides of the longitudinal fissure); and an under surface or base, of an irregular form, which rests in front on the anterior and middle fossæ of the base of the skull, and behind upon the tentorium cerebelli. The hemispheres are composed of an outer stratum of gray matter, called the *cortical substance.* It is thrown into a number of creases or infoldings, which are termed *fissures* and *sulci*, and these separate the surface into a number of irregular eminences, named *convolutions* or *gyri.*

The infoldings or creases are of two kinds, *fissures* and *sulci.* The fissures are of large size, and appear early in fœtal life; they are few in number, nearly constant in their arrangement, and are produced by infoldings of the entire thickness

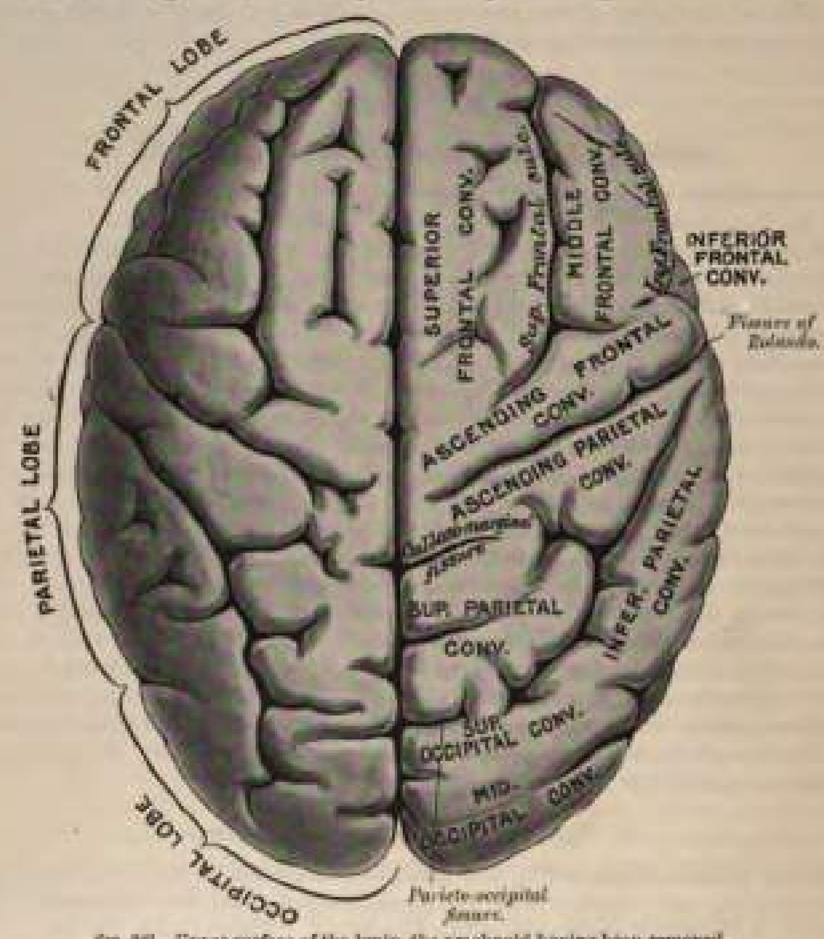

FIG. 361.—Upper surface of the brain, the arachnoid having been removed.

of the wall of the prosencephalon, producing corresponding elevations in the interior of the ventricle, and hence are termed *complete fissures.* They comprise (*a*) the hippocampal, or dentate fissure; (*b*) the anterior part of the calcarine fissure; (*c*) the collateral fissure. The *sulci* are more numerous; they are superficial depressions of the gray matter, which is folded inward and only indents the central white substance. They produce no corresponding elevations in the interior of the ventricle, and are therefore spoken of as *incomplete fissures.* They are fairly constant in their arrangement, and have received names indicative of their position and direction, but at the same time vary, within certain limits, in different individuals. They are similar, without being absolutely identical, on the two sides of the brain. It therefore follows that the gyri or convolutions which lie between these sulci are fairly constant in their general arrangement.

The number and extent of the convolutions, as well as the depth of the intervening sulci, appear to bear a close relation to the intellectual power of the individual, as is shown in their increasing complexity of arrangement as one ascends from the lowest mammalia up to man, where they present a most complex arrangement. Again, in the child, at birth, before the intellectual faculties are exercised, the convolutions are simpler, and the sulci between them shallower, than in the adult. In old age, when the mental faculties have diminished in activity, they become less prominently marked. By their arrangement the convolutions are adapted to increase the amount of gray matter without occupying much additional space, while they also afford a greater extent of surface for the termination of white fibres in gray matter.

It will be convenient, in the first instance, to describe the fissure which separates the two hemispheres from each other, and those which divide each hemisphere into its larger divisions.

The Longitudinal Fissure (Fig. 343).—This great fissure separates the cerebrum into two hemispheres, and reaches from the front to the back of the organ : it contains a vertical process of the dura mater, the falx cerebri (page 640). In front and behind it extends from the top to the bottom of the cerebrum, and completely sepa-

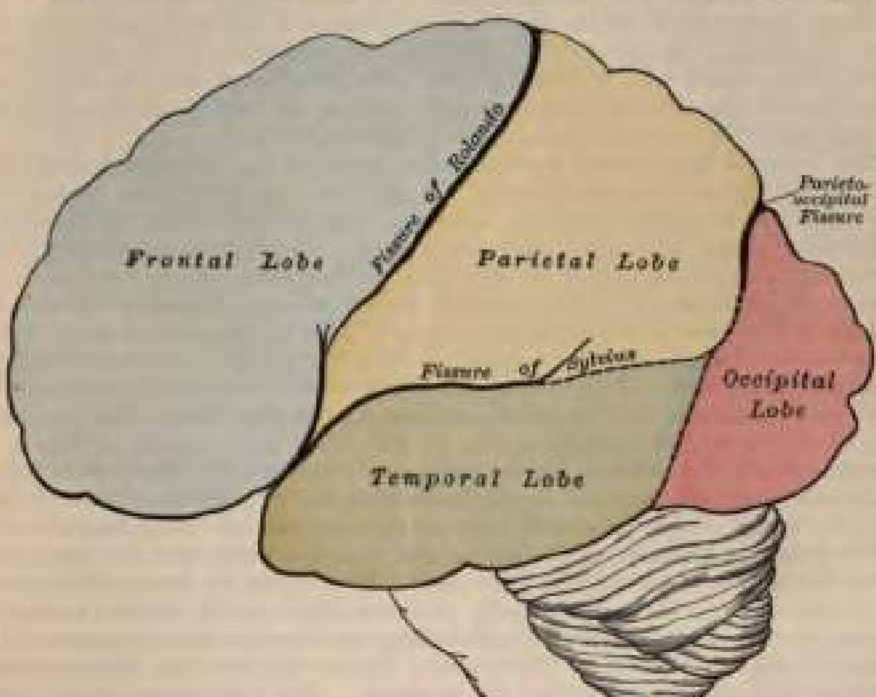

FIG. 344.—Fissures and lobes on the external surface of the cerebral hemispheres.

rates the two hemispheres, but its middle portion only separates the hemispheres for about half their vertical extent, the floor of this part of the fissure being formed by the great central white commissure, the *corpus callosum*, which connects the two hemispheres together.

The remaining fissures are situated in one or other of the two hemispheres, with the exception of the transverse fissure, one-half of which is contained in each hemisphere.

Sylvian Fissure (Fig. 344).—This fissure is a well-marked cleft on the base and side of the hemisphere. Starting at the base of the brain in a depression, the *vallecula Sylvii*, in which is situated the anterior perforated space, it passes outward to the external surface of the hemisphere. It here gives off a short *anterior* *limb*, which passes forward, and a short *ascending limb*, which passes upward into the inferior frontal convolution. It is then continued backward as the *horizontal limb*, which terminates by an upward inflexion in the parietal lobe. It occupies the middle third of the lateral surface of the hemisphere.

The **Fissure of Rolando** is situated about the middle of the outer surface of the hemisphere, and, coursing obliquely downward and forward, divides the surface of the hemisphere into approximately equal parts. It commences at or near the longitudinal fissure, a little behind its mid-point, and runs sinuously downward and forward, to terminate a little above the horizontal limb of the fissure of Sylvius, and about half an inch behind the ascending limb of the same fissure. It forms two chief curves: the upper or *superior genu* is concave forward and upward, while the lower or *inferior genu* has its concavity directed backward.

The **parieto-occipital fissure** is only seen to a slight extent on the outer surface of the hemisphere, being situated for the most part on its mesial aspect. The portion on the outer surface is called the *external parieto-occipital fissure*, to distinguish it from the part continued on to the internal surface, which is termed the *internal parieto-occipital fissure*. The external parieto-occipital fissure commences about midway between the posterior extremity or occipital pole of the brain and the fissure of Rolando, and runs downward and outward for about an inch.

These three fissures divide the external surface of the hemisphere into four lobes: the *frontal*, the *parietal*, the *occipital*, and the *temporal*. To these must be added (1) the central lobe, or island of Reil, which is situated deeply in the Sylvian fissure, and (2) the olfactory lobe, which is found at the base of the brain and was formerly described under the name of the olfactory nerve.

The Lobes on the External Surface.—The lobes on the external surface have received their names from the bones of the skull with which they are most nearly in relation, but it must be borne in mind that they do not correspond in shape or limit with the bone after which they are named. The division is, moreover, to a certain extent artificial, as will be seen from the following description. If a line is drawn in continuation of the external parieto-occipital fissure downward and outward to the lower border of the hemisphere, it will impinge on a slight notch, the *pre-occipital notch*, and if a second line is prolonged backward from the horizontal part of the fissure of Sylvius to join the first, the division of the outer surface of the hemisphere into four lobes will be accomplished (Fig. 344). The portion in front of the fissure of Rolando is the *frontal* lobe; that behind the fissure of Rolando and above the fissure of Sylvius is the *parietal* lobe; the portion behind the parieto-occipital fissure and its continuation is the *occipital* lobe; and the part below the fissure of Sylvius and in front of the occipital lobe is the *temporal* lobe.

The Fissures and Lobes of the Mesial and Tentorial Surfaces.—The mesial surface of the cerebrum can only be fully viewed by dividing the corpus callosum and the structures beneath it longitudinally in the middle line; in order to expose the tentorial surface, the pons Varolii, cerebellum, and medulla must be removed, by division of the crus cerebri on either side. When this has been done, a section such as is represented in Fig. 345 will be shown. The parts in the centre, below the corpus callosum, belong to the interior of the brain, and will be disregarded for the present, while the lobes and fissures of the remaining portion of the hemisphere are considered. The fissures are five in number, in addition to a small part of the fissure of Sylvius, the commencement of which is seen, separating the frontal and temporal lobes. These fissures are named the *calloso-marginal*, the *internal parieto-occipital*, the *calcarine*, the *collateral*, and the *dentate* or *hippocampal*.

The **calloso-marginal fissure** commences below the anterior extremity of the corpus callosum; it at first runs forward and upward, parallel with the rostrum of the corpus callosum, and, winding round in front of the genu of that body, it continues from before backward, between the upper margin of the hemisphere and the convolution of the corpus callosum, to about midway between the anterior and posterior extremities of the brain, where it ascends to reach the upper margin of the hemisphere, a short distance behind the superior extremity of the fissure of Rolando.

The **internal parieto-occipital** extends in an oblique direction downward and forward to join the calcarine fissure, on a level with the hinder end of the corpus callosum.

The **calcarine fissure** commences, usually by two branches, close to the posterior extremity of the hemisphere. These soon unite, and the fissure runs nearly horizontally forward, and is joined by the parieto-occipital fissure, and continues as far as the posterior extremity of the corpus callosum, a little below the level of which it terminates. Its anterior part causes the prominence in the interior of the brain, known as the hippocampus minor or calcar avis.

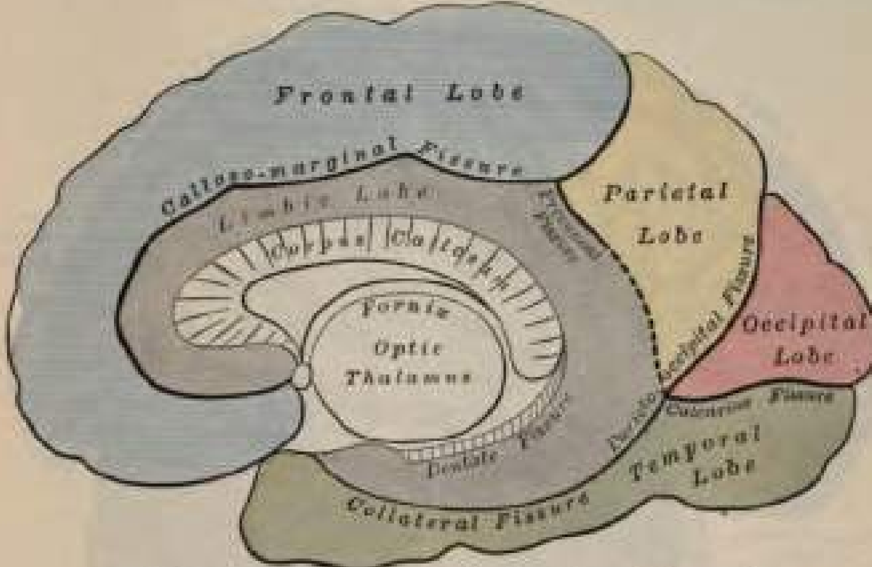

FIG. 343.—Fissures and lobes on the internal surface of the cerebral hemispheres.

The **collateral fissure** is situated on the tentorial surface, below and external to the preceding, being separated from it by the sub-collateral or uncinate gyrus. It runs forward, from the posterior extremity of the brain, nearly as far as the tip of the temporal lobe. It lies below the posterior and descending horns of the lateral ventricle, and its middle part causes the prominence in the interior of the brain, known as the eminentia collateralis.

The **dentate** or **hippocampal fissure** commences immediately behind the posterior extremity of the corpus callosum, and runs forward to terminate at the recurved part of the hippocampal gyrus. It causes the prominence of the hippocampus major in the descending horn of the lateral ventricle. In addition to these fissures, which are constant, there is frequently an irregular broken fissure, which appears to be a continuation backward of the posterior part of the calloso-marginal fissure, before it ascends to reach the upper edge of the hemisphere. This has been termed the *post-limbic fissure*. These fissures map off portions of the internal and tentorial surfaces of the hemispheres, which form parts of the lobes found on the external surface. That portion which lies in front and above the calloso-marginal fissure belongs almost entirely to the frontal lobe; its posterior extremity, which extends for a short distance behind the upper end of the fissure of Rolando, forms a small part of the parietal lobe; that portion which lies above the internal parieto-occipital fissure and behind the calloso-marginal fissure forms a part of the parietal lobe; that between the parieto-occipital fissure above and the calcarine fissure below is a portion of the occipital lobe; and all the region below the calcarine fissure behind and the collateral fissure in front belongs to the temporal lobe. The remainder of the mesial and tentorial surfaces of the hemisphere constitute what Broca termed the *limbic lobe*, which is subsequently referred to (page 652).

The surface of the hemisphere has thus been divided into its different parts, viz.: the frontal, the parietal, the occipital, the temporal, the limbic, the olfactory lobes, and the island of Reil. Each of these lobes is further subdivided into convolutions or gyri by smaller fissures, which, though less constant in their arrangement than the fissures already described, have a fairly definite course.

1. The Frontal Lobe.—On its *external* surface the frontal lobe presents three sulci, which divide it into four convolutions (Fig. 346). The *precentral sulcus* runs upward through this lobe, parallel to the lower half of the fissure of

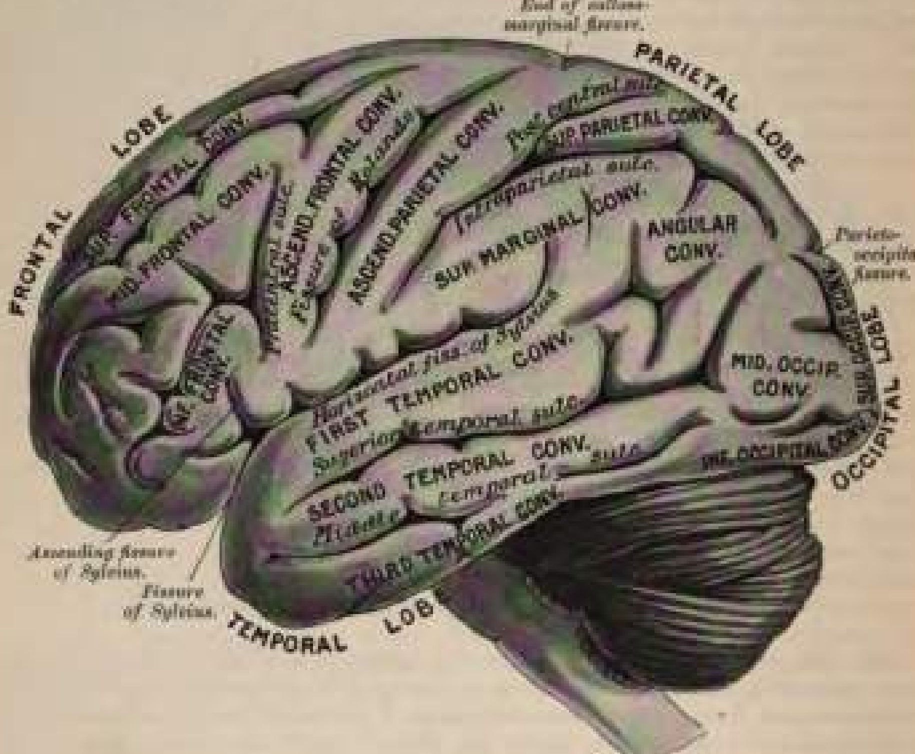

Fig. 346.—Convolutions and sulci on the external surface of the cerebral hemisphere.

Rolando. It is frequently broken or interrupted by annectant gyri. It limits a convolution, which lies between it and the fissure of Rolando, and which is called the *ascending frontal convolution*. From it two sulci, the *superior* and *inferior frontal*, run forward and downward, and divide the remainder of the outer surface of the lobe into three parallel principal convolutions, named respectively the *superior*, *middle*, and *inferior frontal convolutions*.

The *ascending frontal convolution* is a simple convolution, bounded in front by the precentral sulcus, behind by the fissure of Rolando, and extending from the upper margin of the hemisphere above to a little behind the bifurcation of the fissure of Sylvius below.

The *superior frontal convolution* is situated between the margin of the longitudinal fissure and the superior frontal sulcus. It extends above on to the inner aspect of the hemisphere, forming the greater part of the marginal convolution, and in front on to the orbital surface, forming the internal orbital convolution. It is usually more or less completely subdivided into two by an antero-posterior sulcus, the ***sulcus frontalis mesialis*** of Cunningham, which, however, is frequently interrupted and broken into several parts by bridging convolutions.

The *middle frontal convolution* is situated between the superior and inferior frontal sulci, and extends from the precentral sulcus on to the orbital surface of the lobe, where it forms the anterior orbital convolution. The middle frontal convolution is frequently subdivided into two by a sagittally directed sulcus, the *sulcus frontalis medius* of Eberstaller.

The *inferior frontal convolution* is situated below the inferior frontal sulcus, and extends forward from the lower part of the precentral sulcus, on to the under surface of the lobe, where it forms the posterior orbital convolution. The inferior frontal convolution is subdivided by the anterior and ascending limbs of the fissure of Sylvius into three parts, viz.: (1) *anterior* or *pars orbitalis*, below the

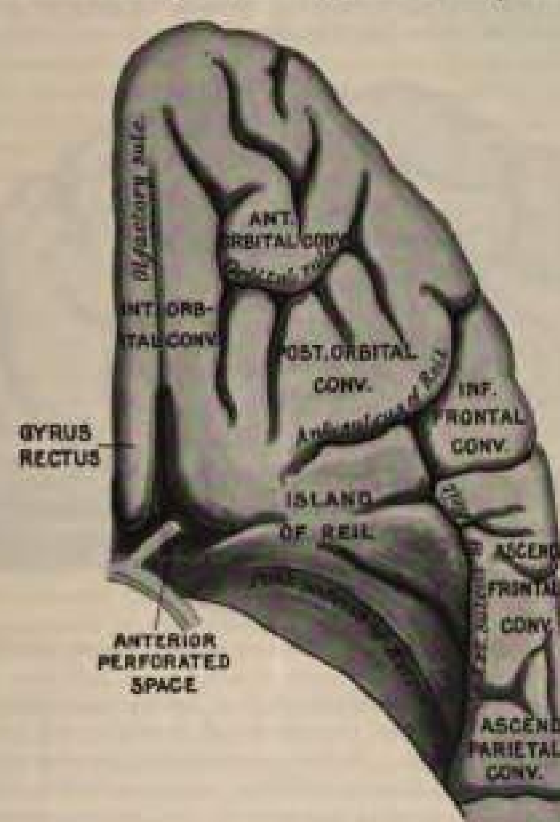

FIG. 347.—Convolutions and sulci on the under surface of the anterior lobe.

anterior limb of the fissure; (2) *middle* or *pars triangularis* ("cap" of Broca), between the two limbs; and (3) *posterior* or *pars basalis*, behind the ascending limb.

The left inferior frontal convolution is, as a rule, more highly developed than the right, and is named the *convolution of Broca*, from the fact that in 1861 Broca discovered that it was the centre for language.

The *under surface* of the frontal lobe rests on the orbital plate of the frontal bone, and is sometimes named the *orbital lobe* (Fig. 347). It is divided into three convolutions by a well-marked sulcus, the *orbital* or *tri-radiate sulcus*. These are named, from their position, the *internal, anterior*, and *posterior orbital convolutions*, and are the continuations respectively of the superior, middle, and inferior frontal convolutions of the external surface. The internal orbital convolution presents a well-marked antero-posterior groove or sulcus, the *olfactory sulcus*, for the olfactory tract; and the portion internal to this is named the *gyrus rectus*, and is continuous with the marginal gyrus, presently to be described. The *mesial* or *internal surface* of the frontal lobe is occupied by a single curved convolution, which from its situation is termed the *marginal gyrus* (Fig. 348). It commences in front of the anterior perforated space, runs along the margin of the longitudinal fissure on the mesial surface of the orbital lobe, where it is continuous with the internal orbital convolution; it then ascends, and runs backward to the point where the calloso-marginal fissure turns upward to reach the superior border of the hemisphere. An oval portion at the posterior part of this convolution is sometimes marked off by a vertical fissure, and is distinguished as the *paracentral gyrus*, because it is continuous with the convolutions in front and behind the central fissure or fissure of Rolando.

2. **The Parietal Lobe.**—On its external surface the parietal lobe presents for examination two sulci and three convolutions.

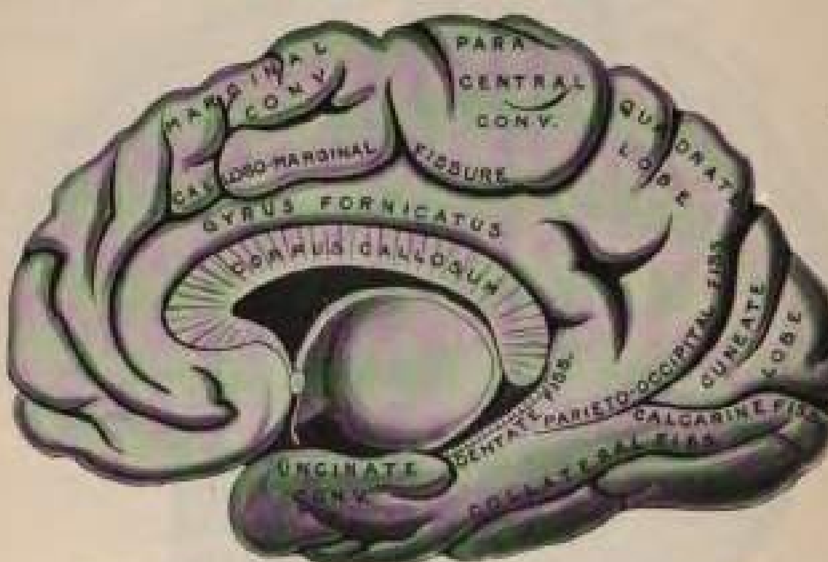

Fig. 348.—Convolutions and sulci on the internal surface of cerebral hemisphere.

The *intra-parietal sulcus* commences close to the horizontal limb of the fissure of Sylvius, about midway between the fissure of Rolando and the upturned extremity of the fissure of Sylvius. It first runs upward parallel to and behind the lower half of the fissure of Rolando, and then turns backward, extending nearly to the termination of the external parieto-occipital fissure, where it sometimes becomes continuous with the superior occipital sulcus. The ascending portion of this sulcus separates off a convolution, the *ascending parietal*, which lies between it and the fissure of Rolando, while the horizontal portion divides the remainder of the external surface of the parietal lobe into two other convolutions, the *superior* and *inferior parietal*.

The *post-central sulcus* is a slightly marked groove, which is sometimes a branch of the intra-parietal sulcus, being given off where the ascending portion of this sulcus turns backward. It lies parallel to and behind the upper part of the fissure of Rolando, and separates the ascending from the superior parietal convolution.[1]

[1] Professor Cunningham describes these two sulci, the intra-parietal and post-central, somewhat differently. He regards them as both belonging to the intra-parietal sulcus, which he divides into three parts: the ascending portion of the intra-parietal, as described above, he terms the *ramus verticalis inferior*; the horizontal portion as the *ramus horizontalis*; while the post-central sulcus he denominates the *ramus verticalis superior*. He states that considerable variability is exhibited in the relation to each other of these different parts of the intra-parietal sulcus, but that the one in which the three parts of the sulcus are confluent is by far the most constant condition. Sometimes, however,

The *ascending parietal convolution* is bounded in front by the fissure of Rolando, behind by the ascending portion of the intra-parietal sulcus and by the post-central sulcus. It extends from the great longitudinal fissure above to the horizontal limb of the fissure of Sylvius below. It lies parallel with the ascending frontal convolution, with which it is connected below, and also, sometimes, above the termination of the fissure of Rolando.

The *superior parietal convolution* is bounded in front by the post-central sulcus, which lies between it and the previous convolution, but with which it is usually connected above the upper extremity of the sulcus; behind, it is bounded by the external parieto-occipital fissure, below the termination of which it is joined to the occipital lobe by a narrow convolution, the *first annectant gyrus*; below, it is separated from the inferior parietal convolution by the horizontal portion of the intra-parietal sulcus; and above, it is continuous on the inner surface of the hemisphere with the quadrate lobe.

The *inferior parietal convolution* is that portion of the parietal lobe which is situated between the ascending portion of the intra-parietal sulcus in front, the horizontal portion of the same sulcus above, the horizontal limb of the fissure of Sylvius below, and the posterior boundary of the parietal lobe behind. It is divided into two convolutions by an indistinct groove. One, the *supra-marginal*, lies behind the ascending part of the intra-parietal sulcus and above the horizontal limb of the fissure of Sylvius, over the extremity of which it arches. It is connected in front with the ascending parietal convolution below the intra-parietal sulcus, and behind with the superior temporal convolution round the posterior extremity of the fissure of Sylvius. The other, the *angular*, is united anteriorly with the foregoing, while posteriorly it is continuous with the middle temporal convolution by a process which curves round the superior temporal or parallel sulcus. It is connected with the occipital lobe by the *second annectant gyrus*.

The *internal* or *mesial* surface of the parietal lobe is continuous with the external surface over the upper edge of the hemisphere. It is of small size, and forms one square-shaped convolution, which from its shape is termed the *quadrate lobe*. From its situation above the cuneate lobe it is sometimes named *precuneus*.

3. The Occipital Lobe.—The occipital lobe is divided on its *external* surface into three convolutions by two indistinct sulci, the *superior* and *middle occipital sulci*. They are directed backward across the lobe, being frequently small and ill marked; the superior is sometimes continuous with the horizontal portion of the intra-parietal sulcus.

The *superior occipital convolution* is situated above the superior sulcus, and is connected to the superior parietal convolution by the *first annectant gyrus*.

The *middle occipital convolution* is situated between the superior and middle occipital sulci, and is connected to the angular convolution by the *second annectant gyrus*, and to the middle temporal convolution by the *third annectant gyrus*.

The *inferior occipital convolution* is situated below the middle occipital sulcus, and is sometimes separated from the external occipito-temporal convolution on the under surface of the hemisphere by an inconstant sulcus, the *inferior occipital sulcus*. It is connected to the inferior temporal convolution by the *fourth annectant gyrus*.

The *internal* or *mesial* surface of the occipital lobe presents a triangular convolution, which is known as the *cuneus* or *cuneate lobule*. It is situated between the internal parieto-occipital and calcarine fissures, which, as already mentioned, meet some distance behind the posterior extremity of the corpus callosum.

the three parts of the sulcus may be separate, or the ramus horizontalis confluent with the ramus verticalis inferior, the ramus verticalis superior remaining separate; or, again, the vertical limbs may be confluent and the horizontal limb separate; or, finally, the ramus horizontalis may be joined to the lower end of the ramus verticalis superior, while the lower vertical ramus is separate. The prolongation of the intra-parietal sulcus into the occipital lobe, which sometimes exists, he calls the *ramus occipitalis*. In the majority of cases, however, the occipital ramus is separated from the main portion of the intra-parietal sulcus by a superficial or deep bridging convolution. (*Journal of Anatomy and Physiology*, vol. xxiv., part ii., p. 135.)

4. The **temporal lobe**, sometimes called the temporo-sphenoidal lobe, presents an outer and an inferior surface. The *outer surface* is subdivided by two fissures, named respectively the first and second temporal sulci. The *first temporal sulcus* is well marked, and runs from before backward through the temporal lobe parallel with, but some little distance below, the horizontal limb of the fissure of Sylvius, and hence is often termed the *parallel sulcus*. The *second temporal sulcus* takes the same direction as the first, but is situated at a lower level, and is often interrupted by one or more bridging convolutions. These two sulci subdivide this surface of the temporal lobe into three convolutions. The *first* or *superior temporal convolution* is situated between the horizontal limb of the fissure of Sylvius and the first temporal sulcus, and is continuous behind with the supra-marginal convolution. The *second* or *middle temporal convolution* lies between the first and second temporal sulci, and is continued behind into the angular and middle occipital convolutions. The *third* or *inferior temporal convolution* is placed below the second temporal sulcus: it is connected posteriorly with the inferior occipital convolution, and is also prolonged on to the under or tentorial surface of the temporal lobe, where it is limited internally by the third temporal sulcus, about to be described.

The inferior or tentorial surface presents two fissures, viz.: the third temporal sulcus and the collateral fissure—the latter of which has already been described (page 647). The *third temporal sulcus* extends from near the occipital pole behind, to near the anterior extremity of the temporal lobe in front, but is, however, frequently subdivided by bridging gyri. The convolutions on the inferior surface are (1) the *fourth temporal* or *subcollateral convolution* (sometimes called the *external occipito-temporal*), situated between the third temporal sulcus and the collateral fissure; and (2) the *subcalcarine convolution* or *lingual lobule*, lying between the calcarine fissure above and the posterior part of the collateral fissure below and continuous in front with the hippocampal convolution, the latter forming part of the limbic lobe.[1]

The **central lobe** or **island of Reil** (Fig. 349) lies deeply in the Sylvian fissure, and can only be seen when the lips of that fissure are widely separated, since it is overlapped and hidden by the convolutions which bound the fissure. These convolutions are termed the *opercula of the insula;* they are separated from each other by the three limbs of the Sylvian fissure, and named the orbital, frontal, fronto-parietal, and temporal opercula. It is almost surrounded by a deep *limiting sulcus*, which separates it from the frontal, parietal, and temporal lobes. When the opercula have been removed, the insula presents the form of a triangular eminence; its apex is directed downward and inward toward the anterior perforated space, and is continuous in front with the posterior orbital convolution and behind with the hippocampal convolution. It is divided into a *pre-central* and a *post-central* lobe by the *sulcus centralis*, which runs backward and upward from the apex of the insula. The pre-central lobe is further subdivided by shallow sulci into three or four short convolutions, the *gyri breves*, while the post-central lobe is named the *gyrus longus* and is often bifurcated at its upper extremity. The gray matter of the insula is continuous with that of the different opercula, while its mesial surface corresponds with the lenticular nucleus of the corpus striatum.

Limbic Lobe.—The term limbic lobe (*grande lobe limbique*) was introduced by Broca in 1878, and under it he included two convolutions, viz., the callosal and hippocampal, which together arch round the corpus callosum and the hippocampal fissure. These he separated on the morphological ground that they are well developed in animals possessing a keen sense of smell (osmatic

[1] It will be seen from this description that the tentorial surface of the occipital lobe is regarded as forming part of the same surface as the temporal lobe. The boundary between the occipital and temporal lobes on the tentorial surface is purely artificial, and if represented by a line drawn upward and inward from the pre-occipital notch, would cut both the subcollateral and subcalcarine gyri.

animals), such as the dog and fox. To the lobe thus defined the following parts must be added, viz.: the laminæ of the septum lucidum, together with the fornix and its fimbriæ, which may be regarded as forming an inner or deep arch; the peduncles and longitudinal striæ of the corpus callosum, together with the gyrus dentatus, which form a middle arch, while the outer arch is constituted by the callosal and hippocampal convolutions: the first two arches are separated from each other by the corpus callosum.

Convolutions of the Limbic Lobe.—(1) The *callosal convolution, gyrus fornicatus*, or *gyrus cinguli* is an arch-shaped convolution, lying in close relation to the superficial surface of the corpus callosum, from which it is separated by a slit-like fissure, the *callosal fissure*. It commences below the rostrum of the corpus callosum, curves round in front of the genu, extends along the upper surface of the body, and finally turns downward behind the splenium, where it is connected by a narrow isthmus with the gyrus hippocampi. It is separated from the marginal convolution by the calloso-marginal sulcus, from the quadrate lobe by the post-limbic sulcus, and from the subcalcarine convolution by the calcarine fissure.

(2) The *hippocampal convolution* (gyrus hippocampi) is bounded above by the hippocampal or dentate fissure, and below by the anterior part of the collateral

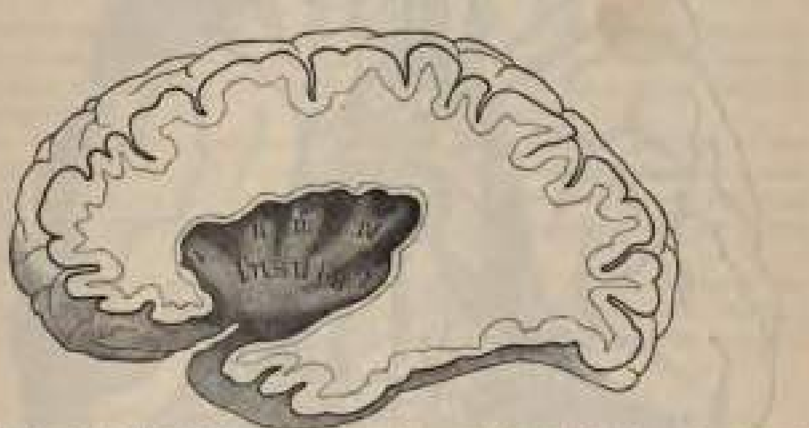

FIG. [illegible].—The Island of Reil. Left side. The overlapping parts of the hemisphere have been removed. (Dalton.) 1, 2, 3, gyri breves; 4, 5, gyrus longus, bifurcated at its upper extremity.

fissure. Behind, it is continuous superiorly, through the isthmus, with the callosal convolution, and inferiorly with the subcalcarine or lingual convolution. Its anterior extremity is recurved in the form of a hook, and is named the *uncus*. Running in the substance of the callosal and hippocampal convolutions, and connecting them together, is a tract of arched fibres, named the *cingulum*. The outer root of the olfactory tract passes into the anterior extremity of the hippocampal convolution, and the inner root into the commencement of the callosal convolution, so that these two convolutions, with the addition of the olfactory tract, present a racquet-like appearance—the olfactory tract constituting the handle and the two convolutions the circumference of the blade.

(3) The *dentate convolution* (formerly named the *dentate fascia*) is situated above the gyrus hippocampi, from which it is separated by the hippocampal or dentate fissure. It is covered by the fimbria, and is a narrow, elongated convolution, the free surface of which presents a notched or toothed appearance, hence its name. Posteriorly it is prolonged as a delicate lamina, the *fasciola cinerea*, around the splenium of the corpus callosum, and becomes continuous on the upper surface of that body with its mesial and lateral longitudinal striæ. Anteriorly it is prolonged into the notch produced by the recurving of the uncus, where it forms a sharp curve; from here it can be traced as a delicate band (*band of Giacomini*) over the uncus, on the outer surface of which it is lost.

The remaining structures which contribute to the formation of the limbic lobe will be subsequently described.

The **olfactory lobe** is situated on the under surface of the frontal lobe. It is rudimentary in man and some other mammals, but in vertebrates generally it is well developed, and consists of a distinct extension of the cerebral hemisphere, enclosing a portion of the anterior horn of the lateral ventricle. In man it is long and slender, and may be described as consisting of two parts, the *anterior* and *posterior olfactory lobules*.

The *anterior olfactory lobule* is made up of: (1) the olfactory bulb; (2) the olfactory tract; (3) the trigonum olfactorium; and (4) the area of Broca.

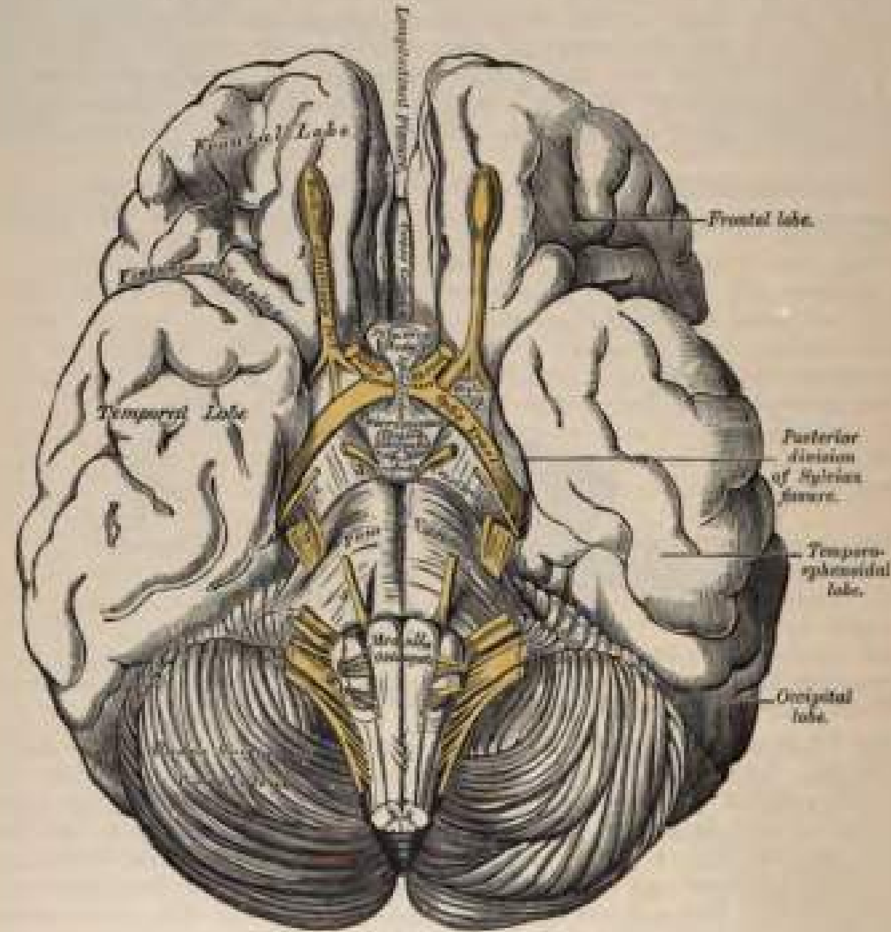

FIG. 555.—Base of the brain.

(1) The *olfactory bulb* is an oval mass of a reddish-gray color, which rests on the cribriform plate of the ethmoid bone, and forms the anterior expanded extremity of the olfactory tract. Its under surface receives the olfactory nerves, which pass upward through the cribriform plate from the olfactory region of the nose. Its minute structure will be subsequently described.

(2) The *olfactory tract* is a band of white matter, triangular on section, the apex being directed upward. It lies in the olfactory sulcus on the under surface of the frontal lobe. Traced backward, it is seen to divide into two roots, an outer and an inner. The *outer root* passes across the outer part of the anterior perforated space to the nucleus amygdalæ and the anterior part of the gyrus hippocampi. The *inner root* turns sharply inward, and ends partly in Broca's area and partly in

the callosal convolution; in other words, the inner root is continuous with one extremity and the outer root with the other extremity of the limbic lobe.

(3) The *trigonum olfactorium* is situated between the diverging roots of the olfactory tract, and is sometimes described at the *middle* or *gray root* of the tract. It is part of an area of gray matter, which forms the base of the anterior olfactory lobule; another portion of it is termed (4) the *area of Broca;* and a third portion, of no special significance, is situated external to the outer root of the olfactory tract. This area of gray matter is bounded internally and posteriorly by a fissure (*fissura prima*) which separates it from the peduncle of the corpus callosum and from the posterior olfactory lobule. The area of Broca is continuous with the gyrus fornicatus.

The *posterior olfactory lobule* or *anterior perforated space* is marked off from the anterior lobule by the fissura prima, and is situated at the commencement of the fissure of Sylvius. Internally, it is bounded by the peduncle of the corpus callosum, and is continuous with the lamina cinerea. Posteriorly it is bounded by the optic tract, and it is partially concealed by the temporal lobe which overlaps it. It has received the name of anterior perforated space from its being perforated by numerous openings, which transmit blood-vessels to the interior of the brain, and it corresponds to the under surface of the lenticular nucleus and part of the claustrum.

Under Surface or Base of the Encephalon (Fig. 350).—Having considered the surface of the hemispheres, the student should direct his attention to the base of the brain, before commencing the study of the component parts which make up the two hemispheres.

The base of the brain presents for examination the under surfaces of the frontal and temporal lobes; the structures contained in the interpeduncular space, with the crura cerebri or cerebral peduncles; the under surfaces of the pons Varolii, cerebellum, and medulla oblongata; and the superficial origins of the cranial nerves.

The various objects exposed to view (with the exception of the origins of the cranial nerves, which will be considered in another section) in the middle line and on either side of the middle line, are here arranged in the order they are met with from before backward.

In the Middle Line.	*On Each Side of the Middle Line.*
Longitudinal fissure.	Frontal lobe.
Rostrum and peduncles of corpus callosum.	Olfactory lobe.
Lamina cinerea.	Fissure of Sylvius.
Optic commissure.	Optic tracts.
Tuber cinereum.	Crus cerebri.
Infundibulum.	Temporal lobe.
Pituitary body.	Hemisphere of cerebellum.
Corpora albicantia.	
Posterior perforated space.	
Pons Varolii.	
Medulla oblongata.	

The **longitudinal fissure** partially separates the two hemispheres from each other. It divides completely the anterior portions of the two frontal lobes; and on raising the cerebellum and pons, it will be seen to separate completely the two occipital lobes; of these two portions of the longitudinal fissure, that which separates the occipital lobes is the longer. The intermediate part of the fissure is filled up by the great transverse band of white matter, the *corpus callosum.* In the fissure between the two frontal lobes the anterior cerebral arteries ascend on the corpus callosum.

The **corpus callosum** terminates at the base of the brain by a concave margin, which is connected with the tuber cinereum through the intervention of a thin layer of gray substance, the *lamina cinerea*. This may be exposed by gently raising and drawing back the optic commissure. A white band may be observed on each side, passing backward from the under surface of the corpus callosum, across the posterior margin of the anterior perforated space to the hippocampal gyrus, where each meets the corresponding outer root of the olfactory tract: these bands are called the *peduncles of the corpus callosum*. They may be traced upward around the genu to become continuous with the *striæ longitudinales* on its upper surface. Laterally, this portion of the corpus callosum extends into the frontal lobe.

The **lamina cinerea** is a thin layer of gray substance, extending backward from the termination of the corpus callosum above the optic commissure to the tuber cinereum; it is continuous on each side with the gray matter of the anterior perforated space, and forms the anterior part of the inferior boundary of the third ventricle.

The **optic commissure** is situated in the middle line, immediately in front of the tuber cinereum and below the lamina cinerea; that is to say, the commissure is superficial to the lamina in the order of dissection when the base is uppermost. It is the point of junction between the two optic tracts, and will be described with the cranial nerves. Immediately behind the diverging optic tracts, and between them and the peduncles of the cerebrum (*crura cerebri*), is a lozenge-shaped interval, the *interpeduncular space*, which is bounded behind by the pons Varolii, and in which are found the following parts: the tuber cinereum, infundibulum, pituitary body, corpora albicantia, and the posterior perforated space.

The **tuber cinereum** is an eminence of gray matter, situated between the optic tracts, and extending from the corpora albicantia to the optic commissure, to which it is attached; it is connected with the surrounding parts of the cerebrum, forms part of the floor of the third ventricle, and is continuous with the gray substance in that cavity. From the middle of its under surface a conical tubular process of gray matter, about two lines in length, is continued downward and forward to be attached to the posterior lobe of the pituitary body. This is the **infundibulum**, and its canal, which is funnel-shaped, communicates with the third ventricle.

The **pituitary body** (*hypophysis cerebri*) is a small, reddish-gray, vascular mass, weighing from five to ten grains, and of an oval form, situated in the sella turcica, where it is retained by a process of dura mater, named the diaphragma sellæ. This process covers in the sella turcica, and has a small hole in its centre through which the infundibulum passes.

Structure.—The pituitary body is very vascular, and consists of two lobes, separated from one another by a fibrous lamina. Of these, the anterior is the larger, of an oblong form, and somewhat concave behind, where it receives the posterior lobe, which is round. The two lobes differ both in development and structure. The *anterior lobe*, of a dark, reddish-brown color, is developed from the epiblast of the buccal cavity, and resembles to a considerable extent, in microscopic structure, the thyroid body. It consists of a number of isolated vesicles and slightly convoluted tubules, lined by epithelium and united together by a very vascular connective tissue. The epithelium is columnar and occasionally ciliated. The alveoli sometimes contain a colloid material, similar to that found in the thyroid body, and their walls are surrounded by a close network of lymphatic and capillary blood-vessels. The *posterior lobe* is developed as an outgrowth from the embryonic brain, and during fœtal life contains a cavity which communicates through the infundibulum with the cavity of the third ventricle. In the adult it becomes firmer and more solid, and consists of a sponge-like connective tissue arranged in the form of reticulating bundles, between which are branched cells, some of them containing pigment. In the lower animals the two lobes are quite distinct, and it is only in the mammalia that they become fused together.

The **corpora albicantia** or **mammillaria** are two small, round, white masses, each about the size of a pea, placed side by side immediately behind the tuber cinereum, and connected with each other across the mesial plane. They are mainly formed by the anterior crura of the fornix, which, after descending to the base of the brain, are twisted upon themselves to form loops, and constitute the white covering of the corpora albicantia. A second fasciculus, the *bundle of Vicq d'Azyr*, converges from the optic thalamus, and enters the anterior part of each body on its dorso-mesial surface. They are composed externally of white substance, and internally of gray matter; the nerve-cells of the gray matter are arranged in two sets, inner and outer, the cells of the former set being the smaller. They are also connected to the tegmentum by a small bundle of fibres, the peduncle of the mammillary body. At an early period of fœtal life they are blended together into one large mass, but become separated about the seventh month. In most vertebrates there is only one median corpus albicans.

The **posterior perforated space** (*pons Tarini*) corresponds to a whitish-gray fossa placed between the corpora albicantia in front, the pons Varolii behind, and the crus cerebri on either side. It forms the posterior part of the floor of the third ventricle, and is perforated by numerous small orifices for the passage of the postero-median ganglionic branches of the posterior cerebral and posterior communicating arteries.

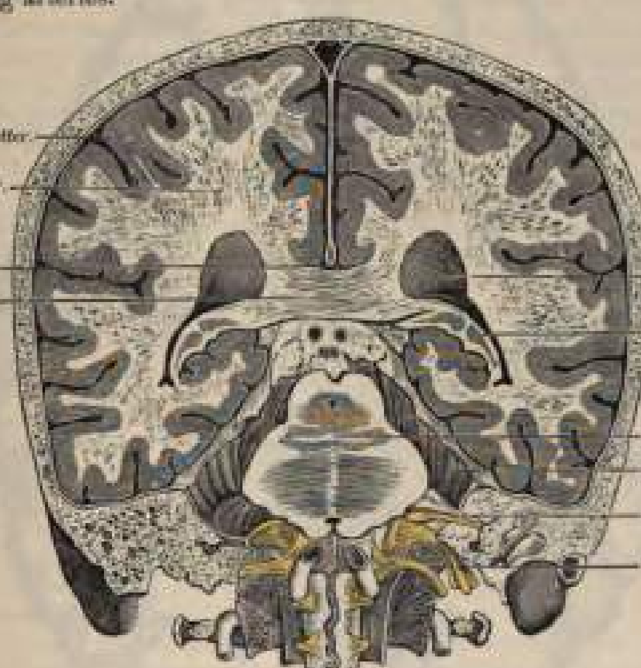

FIG. 351.—Transverse vertical section of the brain, through the fore part of the foramen magnum, looked at from the front. (After Hirschfeld and Leveillé.)

The **pons Varolii** is situated immediately behind the two crura of the cerebrum. It consists of a broad band of white fibres, which pass transversely from one cerebellar hemisphere to the other; the band becoming narrower as it enters the cerebellum. In the middle line on its under surface a narrow groove runs from before backward and accommodates the basilar artery.

The **medulla oblongata** emerges from the posterior border of the pons Varolii; it is pyramidal in form, and is continuous below with the cervical portion of the spinal cord. It is marked on its ventral surface by a median fissure, continuous below with the anterior median fissure of the cord, and on either side by secondary fissures and columns, which will be described in the sequel.

The Frontal Lobe.—The under surface of the frontal lobe, sometimes named the orbital lobe, is seen on the anterior part of the base of the brain on either side of the median line. It has already been described (page 649).

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The **fissure of Sylvius** at the base of the brain separates the frontal from the temporal lobe, and lodges the middle cerebral artery. It has also been described (page 645).

The **optic tracts** are well-marked flattened bands of fibres, which run obliquely across the crus cerebri on either side, and unite anteriorly to form the optic commissure. They will be described in connection with the cranial nerves.

The **crura cerebri** (*peduncles of the cerebrum*) are two thick cylindrical bundles of white matter, which appear in front of the anterior border of the pons, and diverge as they pass forward and outward to enter the under surface of each hemisphere. Each crus is about three-quarters of an inch in length, and is about the same in breadth anteriorly, but somewhat less posteriorly. They are marked upon their surface with longitudinal striæ, and each is crossed, just before entering the hemisphere, by the fourth nerve and the optic tract, the latter of which is adherent by its upper surface to the peduncle.

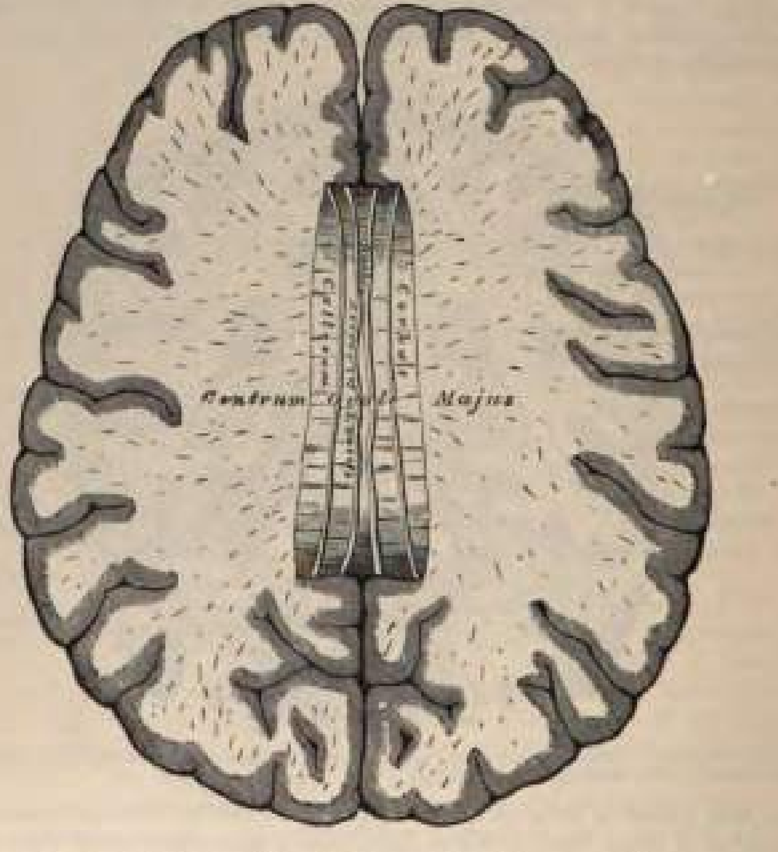

FIG. 352.—Section of the brain. Made on a level with the corpus callosum.

The Temporal Lobe.—The under surface of the temporal lobe is visible at the base of the brain, on either side of the crura and the structures contained in the interpeduncular space. It is separated anteriorly from the frontal lobe by the fissure of Sylvius, and behind is limited by the anterior border of the lateral hemispheres of the cerebellum. The fissures and lobes on its surface have already been described (page 652).

The **hemispheres of the cerebellum** are situated on either side of the middle line, and cover the occipital lobes of the cerebrum, when viewed from the base. The cerebellum differs much in appearance from the rest of the encephalon, being of a darker color, while its convolutions are smaller and narrower, and arranged like the leaves of a book, and hence called *folia*.

General Arrangement of the Parts Composing the Cerebrum.—Each hemisphere, as already stated, consists of a central cavity, the *lateral ventricle*, surrounded by thick and convoluted walls of nervous tissue.

Interior of the Cerebrum.—If the upper part of either hemisphere is removed with a knife, about half an inch above the level of the corpus callosum, its internal white matter will be exposed. It is an oval-shaped centre, of white substance, surrounded on all sides by a narrow convoluted margin of gray matter, which presents an equal thickness in nearly every part. This white central mass has been called the *centrum ovale minus*. Its surface is studded with numerous minute red dots (*puncta vasculosa*), produced by the escape of blood from divided blood-vessels. In inflammation or great congestion of the brain these are very numerous and of a dark color. If the remaining portion of one hemisphere is slightly separated from the other, a broad band of white substance will be observed, connecting them at the bottom of the longitudinal fissure; this is the *corpus callosum*. The margins of the hemispheres which overlap this portion of the brain are called the *labii cerebri*. Each labium is part of the callosal convolution already described; and the space between it and the upper surface of the corpus callosum is termed the *callosal fissure* (Fig. 348). The hemispheres should now be sliced off to a level with the upper surface of the corpus callosum, when the white substance of that structure will be seen connecting the two hemispheres. The large expanse of medullary matter now exposed, surrounded by the convoluted margin of gray substance, is called the *centrum ovale majus of Vieussens* (Fig. 352).

The Corpus Callosum.—The corpus callosum is a thick stratum of transversely directed nerve-fibres, by which probably almost every part of one hemisphere is connected with the corresponding part of the other hemisphere. The fibres of this body, when they pass from it into the hemispheres radiate in various directions, to terminate in the gray matter of the periphery. It thus connects the two hemispheres of the brain, forming their great transverse commissure, and at the same time roofs in the lateral ventricles. The best conception of its size and form is obtained by making an anterior posterior vertical section through the centre of the brain (Fig. 353). It is then seen to be a long, thick, irregularly flattened arch; in front taking a sharp bend, the *genu*, and dipping downward and backward to the base of the brain by a reflected portion, the *rostrum*, which is connected with the lamina cinerea; behind it terminates by a rounded end, which is folded over and is named the *splenium*. It is about four inches in length, and extends to within an inch and a half of the anterior, and two inches and a half of the posterior extremity of the cerebrum. It is somewhat broader behind than in front, and is thicker at either end than in its central part, being thickest behind. The reflected anterior portion of the corpus callosum is called the *beak* or *rostrum*; it becomes gradually thinner as it descends, and is attached by its lateral margins to the frontal lobes. At its termination, in addition to joining the lamina cinerea, the corpus callosum gives off two bands of white substance, the peduncles of the corpus callosum, already described (page 656).

Posteriorly, the corpus callosum forms a thick rounded fold, called the *splenium* or *pad*, which is free for a little distance as it curves forward, and is then continuous by its under surface with the fornix. The splenium overlaps the mesencephalon, but is separated from it by the pia mater, which is prolonged forward to form the velum interpositum. On its upper surface, the structure of the corpus callosum is very apparent, being collected into coarse transverse bundles. Along the middle line is a longitudinal depression, the so-called *raphé*, bounded laterally by two or more slightly elevated longitudinal bands, called the *striæ longitudinales* or *nerves of Lancisi*; and, still more externally, other longitudinal striæ are seen, beneath the callosal convolutions. These are the *striæ longitudinales laterales*, or *tænia tectæ*. On each side of the middle line the under surface of the corpus callosum forms the roof of the lateral ventricles, while in the mesial plane it is continuous behind with the fornix, being separated from it in front by the septum lucidum, which forms a vertical partition between the two ventricles. On each side the fibres of the corpus callosum extend into the substance of the hemispheres, connecting them together. The greater thickness of the two extremities of this commissure is explained by the fact that the fibres from the anterior and posterior parts of each hemisphere cannot pass directly across, but have to take a curved direction.

FIG. 353.—Vertical median section of the encephalon, showing the parts in the middle line.

1. Convolution of the corpus callosum. Above it is the calloso-marginal fissure.
2. Fissure of Rolando.
3. The parieto-occipital fissure.
4, 4, point to the calcarine fissure, which is just above the numbers. Between 2 and 3 are the convolutions of the quadrate lobe. Between 3 and 4 is the cuneate lobe.
5. The corpus callosum.
6. The septum lucidum.
7. The fornix.
8. Anterior crus of the fornix, descending to the base of the brain, and turning on itself to form the corpus albicans. The bundle of Vicq d'Azyr is indicated by a dotted line.
9. The optic thalamus. Behind the anterior crus of the fornix a shaded part indicates the foramen of Monro; in front of the number an oval mark shows the position of the gray or middle commissure.
10. The velum interpositum.
11. The pineal gland.
12. The corpora quadrigemina.
13. The crus cerebri.
14. The valve of Vieussens (to the right of the number).
15. The pons Varolii.
16. The third nerve.
17. The pituitary body.
18. The optic nerve.
19 points to the anterior commissure, indicated by the oval outline behind the number.

The part of the corpus callosum which curves forward on each side from the genu into the frontal lobe and covers the front part of the anterior cornu of the lateral ventricle is called the *forceps anterior* or *minor*. The part which curves backward from each side of the splenium into the occipital lobe is known as the *forceps posterior* or *major*. Between these two parts on each side is the main body of the fibres, which extend laterally into the temporal lobe and cover in the body of the lateral ventricle. These are known as the *tapetum* or *mat*.

An incision should now be made through the corpus callosum, on either side of the raphé, when two large irregular cavities will be exposed, which extend through a great part of the length of each hemisphere. These are the lateral ventricles.

The Lateral Ventricles (Fig. 354).—The lateral ventricles, two in number, right and left, are irregular cavities situated in the lower and inner parts of the cerebral hemisphere, one on either side of the middle line. They are separated from each other by a mesial vertical partition, the *septum lucidum*, but communicate with the third ventricle and indirectly with each other through the *foramen of Monro*. They are lined by a thin, diaphanous membrane, the *ependyma*, which is covered by ciliated epithelium, and are moistened by a serous fluid, which, even in health, may be secreted in considerable amount. Each lateral ventricle consists of a central cavity or *body*, and three prolongations from it, termed *cornua*. The *anterior* cornu curves forward and outward into the frontal lobe; the *posterior* backward and inward into the occipital lobe; and the *middle* descends into the *temporal* lobe.

The **central cavity** or **body** of the lateral ventricle is situated in the lower part of the parietal lobe. It is an irregularly curved cavity, triangular in shape on

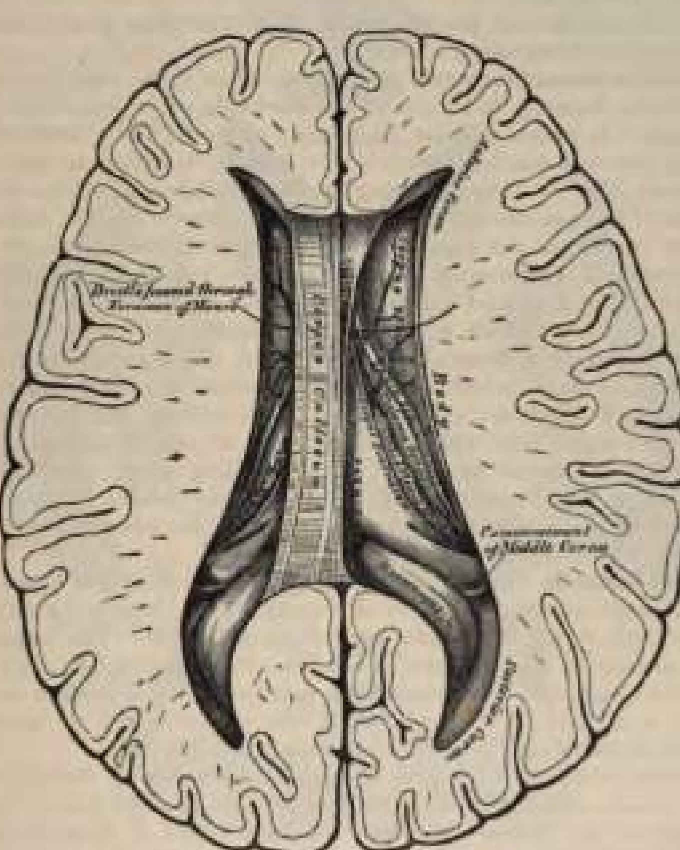

FIG. 254.—The lateral ventricles of the brain.

transverse section, and presents a roof, a floor, and an inner wall. Its *roof* is formed by the under surface of the corpus callosum; its *inner wall* is the septum lucidum, which separates it from the opposite ventricle and connects the under surface of the corpus callosum with the fornix; its *floor* is formed by the following parts, enumerated in their order of position, from before backward: the *caudate nucleus* of the *corpus striatum*, *tænia semicircularis*, *optic thalamus*, *choroid plexus*, one-half of the *fornix* and its *posterior pillar*.

The **anterior cornu** passes forward and outward, with a slight inclination downward, from the foramen of Monro into the frontal lobe, curving round the anterior extremity of the caudate nucleus. It is bounded above by the corpus callosum, and below by the upper surface of its reflected portion, the rostrum. It is bounded internally by the anterior portion of the septum lucidum, and externally by the head of the caudate nucleus of the corpus striatum. Its apex reaches the posterior surface of the genu of the corpus callosum.

The **posterior cornu** curves backward into the substance of the occipital lobe, its direction being backward and outward, and then inward; its concavity is therefore directed inward. Its roof is formed by the fibres of the corpus callosum passing to the temporal and occipital lobes. On its inner wall is seen a longitudinal eminence, which is in an involution of the ventricular wall produced by the calcarine sulcus; this is called the *hippocampus minor*, or *calcar avis*. Just above this the forceps major of the corpus callosum, sweeping round to enter the occipital lobe, causes another projection, which is known as the *bulb of the posterior horn*. The hippocampus minor and bulb of the posterior horn are extremely variable in their degree of development, being in some cases ill defined, while in others they are unusually prominent.

Between the middle and posterior cornu is a triangular area, called the *trigonum ventriculi* (see Descending Horn).

The **middle** or **descending cornu**, the largest of the three, traverses the temporal lobe of the brain, forming in its course a remarkable curve round the back of the optic thalamus. It passes at first backward, outward, and downward, and then curves round the crus cerebri, forward and inward, to within an inch of the apex of the temporal lobe, its direction being fairly well indicated on the surface of the brain by that of the parallel sulcus. Its upper boundary, or roof, is formed chiefly by the under surface of the tapetum of the corpus callosum, but the tail of the nucleus caudatus of the corpus striatum and the tænia semicircularis are also prolonged into it, and extend forward in the roof of the descending horn to its extremity, where they end in a mass of gray matter, the *amygdaloid nucleus*; this nucleus is merely a localized thickening of the adjacent gray cortex. Its lower boundary, or floor, presents for examination the following parts: the *hippocampus major*, *pes hippocampi*, *eminentia collateralis* or *pes accessorius*, *corpus fimbriatum*, prolonged from the posterior pillar of the fornix, and the *choroid plexus*. Along the mesial aspect of the descending cornu there is a cleft-like opening, which is the lower part of the *transverse fissure*, through which the choroid plexus of the pia mater is invaginated into the ventricle, but covered by the ependyma, which is pushed in before it.

The **corpus striatum** has received its name from the striped appearance which its section presents, in consequence of diverging white fibres being mixed with the gray matter which forms the greater part of its substance. The larger portion of this body is embedded in the white substance of the hemisphere, and is therefore external to the ventricle. It is termed the *extra-ventricular portion* or the *nucleus lenticularis*; a part, however, is visible in the ventricle and its anterior cornu: this is the *intra-ventricular portion*, or the *nucleus caudatus*.

The **nucleus caudatus** (Fig. 355) is a pear-shaped, highly arched mass of gray matter; its broad extremity is directed forward into the fore part of the body and anterior cornu of the lateral ventricle; its narrow end is directed outward and backward on the outer side of the optic thalamus; it is continued downward into the roof of the descending cornu, where it terminates in the *nucleus amygdalæ*, a collection of gray matter in the apex of the temporal lobe. It is covered by the lining of the ventricle, and crossed by some veins of considerable size. It is separated from the extra-ventricular portion, in the greater part of its extent, by a lamina of white matter, which is called the *internal capsule*, but the two portions of the corpus striatum are united in front.

The **nucleus lenticularis**, or extra-ventricular portion of the corpus striatum, is only seen in sections of the hemisphere. When divided horizontally, it presents, to some extent, the appearance of a biconvex lens, while a vertical transverse section of it gives a somewhat triangular outline. It does not extend as far forward or backward as the nucleus caudatus. It is bounded externally by a lamina of white matter called the *external capsule*, on the outer surface of which is a thin layer of gray matter termed the *claustrum*. The claustrum presents ridges and furrows on its outer surface, corresponding to the convolutions and sulci of the island of Reil, from which it is separated by a thin white lamina.

Upon making a transverse vertical section through the middle of the nucleus lenticularis it is seen to present two white lines, parallel with its lateral border, which divide it up into three zones, of which the outer and largest is of a reddish color, and is known as the *putamen*, while the two inner are paler and of a yellowish tint, and are termed the *globus pallidus*. All three zones are marked by fine radiating white fibres, which are most distinct in the putamen. The gray matter of the corpus striatum is traversed by nerve-fibres, some of which are believed to originate in it. The cells are multipolar, both large and small; those of the lenticular nucleus containing yellow pigment.

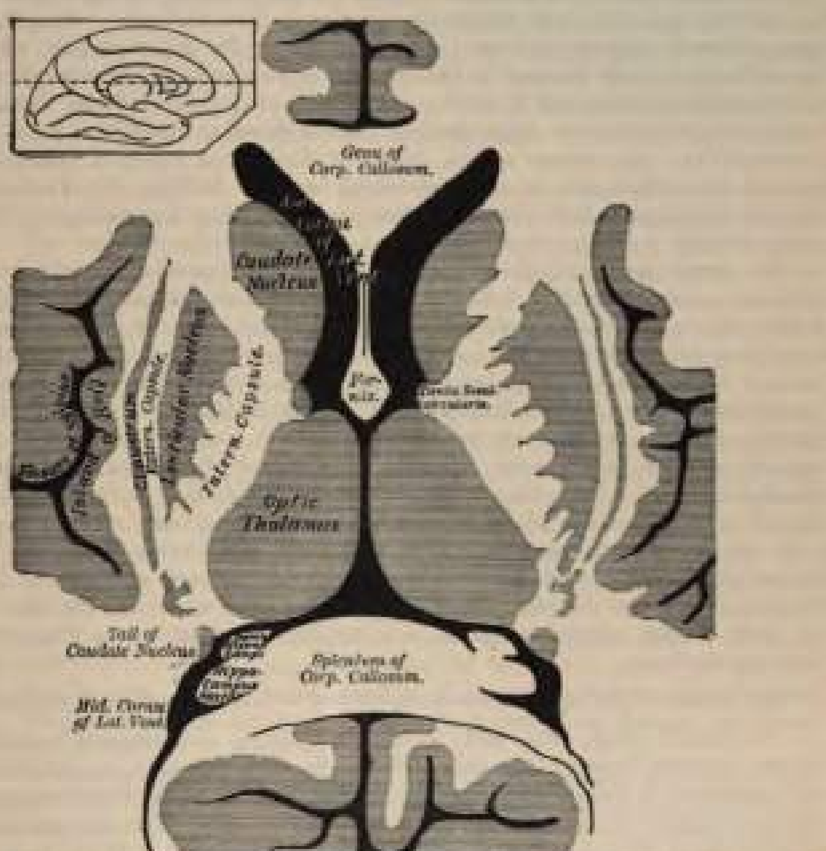

Fig. 355.—Middle part of a horizontal section through the cerebrum at the level of the dotted line in the small figure of one hemisphere. (From Ellis, after Dalton.)

The **internal capsule** is formed by fibres of the crusta of the crus cerebri, supplemented by fibres derived from the corpus striatum and optic thalamus on each side. In horizontal section (Fig. 355) it is seen to be somewhat abruptly curved, with its convexity inward; the prominence of the curve is called the *genu*, and projects between the caudate nucleus and the optic thalamus. The portion in front of the genu is termed the *anterior limb*, and separates the lenticular from the caudate nucleus; the portion behind the genu is the *posterior limb*, and separates the lenticular nucleus from the optic thalamus. The internal capsule is composed largely of fibres, which, derived from the crusta of the crus cerebri, are continued through it to the cortex of the cerebral hemispheres, the fibres of the anterior limb passing to the frontal region; those from the genu and the anterior two-thirds of the posterior limb pass to the Rolandic area of the cortex, while those in the hindermost third of the same limb pass to the temporo-occipital region. In addition to these, there are fibres which terminate in the corpus striatum and the optic thalamus; and other fibres derived from the gray matter of these two bodies, from the subthalamic region,[1] and from the hemisphere of the opposite side through the corpus callosum, which pass through the internal capsule to the cerebral cortex.

The **external capsule** is a lamina of white matter, situated on the outer side of the lenticular nucleus, between it and the claustrum, and is continuous with the internal capsule below and behind the lenticular nucleus. It is made up of fibres derived partly from the anterior white commissure and partly from the subthalamic region.

The **claustrum** is a thin layer of gray matter, situated on the outer surface of the external capsule. On transverse section it is seen to be triangular, with its apex directed upward and its base downward. Its inner surface, which is contiguous to the outer capsule, is smooth, but its outer surface presents ridges and furrows which correspond with the convolutions and sulci of the island of Reil, with which it is in close relationship. The claustrum is regarded as a detached portion of the gray matter of the island of Reil, from which it is separated by a layer of white fibres, the *capsula extrema* or *band of Baillarger*. Its cells are small and spindle-shaped, and contain yellow pigment; they are similar to those found in the deepest layer of the cortex.

The **tænia semicircularis** is a narrow, whitish band of medullary substance, situated in the depression between the caudate nucleus and the optic thalamus. Anteriorly its fibres are partly continued into the anterior pillar of the fornix; some, however, pass over the anterior commissure to the gray matter between the caudate nucleus and septum lucidum, while others penetrate the caudate nucleus. Posteriorly it is continued into the roof of the middle or descending horn of the lateral ventricle, at the extremity of which it enters the *nucleus amygdalæ*, an oval mass of gray matter, situated in the roof of the lower extremity of the descending horn. Like the corpus striatum, it is formed by a localized thickening of the gray matter of the cortex cerebri. Superficial to it is a large vein, *vena corporis striati*, which receives numerous small veins from the surface of the corpus striatum and optic thalamus; it runs forward and passes through the foramen of Monro to join the corresponding vena Galeni. On the surface of the vein of the corpus striatum is a narrow band of white fibres, named the *lamina cornea*.

The remains of the corpus callosum should now be removed in order to expose the fornix.

The **fornix** (Figs. 353, 354) is a longitudinal, arch-shaped lamella of white matter, situated beneath the corpus callosum, with which it is continuous behind, but separated in front by the septum lucidum. It may be described as consisting of two symmetrical halves, one for either hemisphere. The two portions are not united to each other in front and behind, but their central parts are joined together in the middle line. The two anterior, separated parts are called the *anterior pillars* (*columnæ fornicis*); the intermediate united portions constitute the *body of the fornix*; and the posterior parts, which are also separated from each other, are called the *posterior pillars* (*crura fornicis*).

The *body of the fornix* is triangular, narrow in front, broad behind. Its upper surface is connected, in the median line, to the septum lucidum in front, and the corpus callosum behind; laterally this surface forms part of the floor of each lateral ventricle. Its under surface rests upon the velum interpositum, which separates it from the third ventricle and the inner portion of the upper surface of the optic thalami. Its outer edge, on each side, is free, and is connected with the choroid plexuses.

The *anterior pillars* arch downward toward the base of the brain, separated

[1] The *subthalamic region* is the mass upon which the optic thalamus rests, and is an extension forward of the tegmentum of the mesencephalon (see page 674).

from each other by a narrow interval. They are composed of white fibres, which descend through the gray matter in the lateral wall of the third ventricle, and are placed immediately behind the anterior commissure. At the base of the brain, each pillar becomes twisted upon itself to form a loop, somewhat resembling the figure of 8. The lowest part of the loop constitutes the white matter of the corresponding *corpus albicans*, from which the fibres can apparently be traced upward and backward, as the *bundle of Vicq d'Azyr*, into the substance of the corresponding optic thalamus (Fig. 353). It must be stated, however, that there is probably no direct continuity between this bundle and the anterior pillar of the fornix—the latter possibly ending in the gray matter of the corpus albicans. The anterior crura of the fornix are joined in their course by the peduncles of the pineal gland and the superficial fibres of the tænia semicircularis, and receive fibres from the septum lucidum. Zuckerkandl describes an *olfactory fasciculus*, which becomes detached from the main portion of the anterior pillar of the fornix, and passes downward, in front of the anterior commissure, to the base of the brain, where it divides into two bundles, one joining the inner root of the olfactory tract; the other, the peduncle of the corpus callosum, and through it reaching the hippocampal convolution.

Between the anterior pillars of the fornix and the anterior extremity of the optic thalamus, an oval aperture is seen on each side; this is the foramen of Monro (Fig. 359). The two openings descend toward the middle line, and lead into the upper part of the third ventricle. Through this foramen the lateral ventricles communicate with the third ventricle, and consequently with each other; through it also the two choroid plexuses become joined with each other across the middle line. The boundaries of the opening are, above and in front, the anterior pillars of the fornix; behind, the anterior extremity of the optic thalamus.

The *posterior pillars* are the backward prolongations of the two halves of the body of the fornix. They are flattened bands, and, at their commencement, are intimately connected by their upper surfaces with the corpus callosum. Diverging from one another, each curves round the posterior extremity of the optic thalamus, and then passes downward and forward into the descending horn of the lateral ventricle. Here it lies along the concavity of the hippocampus major, on the surface of which some of its fibres are spread out, while the remainder are continued, as the *corpus fimbriatum* or *tænia hippocampi*, into the hook or uncus of the hippocampal convolution. Upon examining the under surface of the fornix, between its diverging posterior pillars, a triangular portion of the under surface of the corpus callosum may be seen. On it are a number of curved or oblique lines passing between the two pillars of the fornix. This portion has been termed the *lyra*, from the fancied resemblance it bears to a harp.

The **anterior commissure** is a bundle of white fibres, placed in front of the anterior pillars of the fornix, and appears to connect together the corpora striata. On transverse section it is seen to be oval in shape, its long diameter being vertical in direction and measuring about one-fifth of an inch. Its fibres can be traced backward and downward through the globus pallidus and below the putamen on each side into the substance of the temporal lobe. It serves in this way to connect the two temporal lobes, but it also contains fibres from the olfactory tract of the opposite side, the decussation of which in the anterior commissure may serve to explain the condition of crossed anosmia, *e. g.*, where there is a lesion in one temporal lobe with a loss of smell in the olfactory area of the opposite side of the nose.

The **septum lucidum** is a thin, double, vertically placed partition, which forms the internal boundary of the body and anterior horn of the lateral ventricle. It consists of two distinct laminæ, separated in part of their extent by a narrow chink or interval, called the *fifth ventricle*. It is a thin, semitransparent septum, attached, above, to the under surface of the corpus callosum; below, to the anterior part of the fornix behind, and the reflected portion of the corpus callosum in front. It is triangular in form, broad in front and narrow behind; its inferior angle corresponds with the upper part of the anterior commissure. The outer surface of each lamina is directed toward the lateral ventricle, and is covered by the ependyma of that cavity, while its mesial surface bounds the cavity of the fifth ventricle.

Fifth Ventricle.—The fifth ventricle was originally a part of the great longitudinal fissure, which has become shut off by the union of the hemispheres in the formation of the corpus callosum above and the fornix below. Each half of the septum is therefore formed by the median wall of the hemisphere, and consists of an internal layer of gray matter, derived from the gray matter of the cortex, and an external layer of white substance continuous with the white matter of the cerebral hemispheres. The fifth ventricle differs from the other ventricles of the brain, inasmuch as it is not developed from the cavity of the cerebral vesicles, it is not lined by ciliated epithelium but by altered pia mater, and it does not communicate with the general ventricular cavity; further, the fluid it contains is of the nature of lymph.

The structures on the floor of the descending horn of the lateral ventricle will now be described.

The **hippocampus major**, or **cornu Ammonis** (Fig. 356), is a white eminence, about two inches in length, of a curved elongated form, extending throughout the

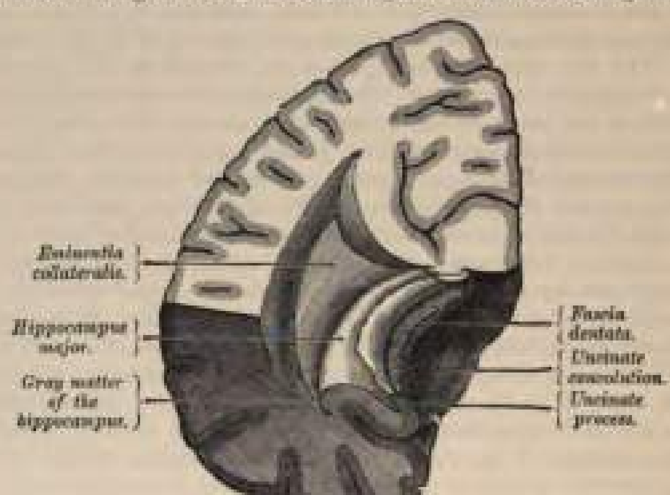

FIG. 356.—Transverse section of the middle horn of the lateral ventricle. (From a drawing by Mr. F. A. Barton.)

entire length of the floor of the descending horn of the lateral ventricle. At its lower extremity it becomes enlarged, and presenting two or three rounded elevations with intervening depressions, it resembles the paw of an animal, and is called the *pes hippocampi*. If a transverse section is made through the hippocampus major, it will be seen that this eminence is produced by the folding of the cortex of the brain to form the dentate (hippocampal) sulcus. To the outer side and parallel with the hippocampus major an elongated eminence, the *eminentia collateralis*, is frequently recognized. It corresponds with the middle part of the collateral fissure, and its size depends on the direction and depth of this fissure. The main mass of the hippocampus major consists of gray matter, but on its ventricular surface is a thin layer of white matter, known as the *alveus*, which is continuous with the corpus fimbriatum of the fornix and is covered by the ependyma of the ventricle. Dr. J. G. Macarthy, of McGill University, Montreal, has shown[1] that, if the alveus and superficial strata of gray matter be reflected from the surface of the hippocampus by an incision carried along its convexity, the "core" of the hippocampus, as he terms it, presents in many cases a corrugated or crimped appearance.

[1] *Journal of Anat. and Phys.*, vol. xxiii., 1899.

The **corpus fimbriatum** or **fimbria** (*tænia hippocampi*) has already been mentioned as a part of the posterior pillar of the fornix. It consists of a narrow white band, which is placed immediately below the choroid plexus, and is attached by its deep surface to the white matter (alveus) of the hippocampus major as it courses through the descending cornu of the lateral ventricle. It can be traced as far as the uncus or hook of the hippocampal gyrus. Its inner margin is free, and rests upon the dentate convolution, from which it is separated by a slit-like fissure, the *fimbrio-dentate fissure*. Its outer margin is attenuated and irregular, and forms the line along which the ependyma is reflected over the choroid plexus as the latter is invaginated through the inferior part of the transverse fissure. When the choroid plexus is pulled away it carries the ependyma with it, and the descending horn opens on to the surface of the brain through the transverse fissure. If now the inner border of the corpus fimbriatum be raised, a notched band of gray matter, the gyrus dentatus, will be exposed; this has already been described as forming part of the limbic lobe (page 653).

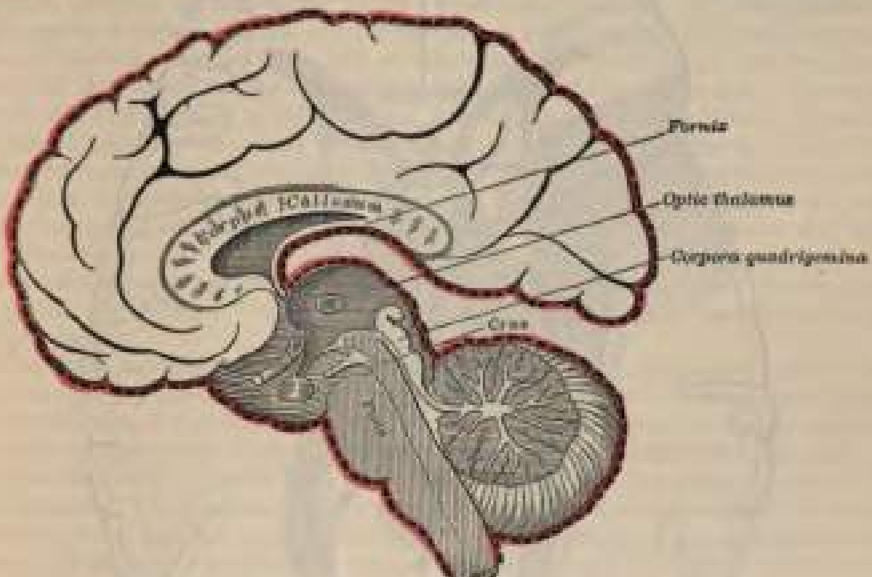

FIG. 357.—Diagram showing the mode of formation of the velum interpositum.

The **choroid plexus** is a highly vascular, fringe-like structure, which is situated partly in the body and partly in the descending cornu of the lateral ventricle. It will be desirable to consider these two portions separately, in order to get a just conception of how they are formed.

The portion in the body of the ventricle is the vascular, fringed border of a triangular fold of pia mater, the *velum interpositum*, which lies on the under surface of the fornix and forms the roof of the third ventricle. It will be remembered that the developing brain vesicles are covered by pia mater. As the prolongation from the first vesicle, which is to form the cerebral hemispheres, increases in size, it grows backward and downward and covers the other vesicles, with the result that the pia mater covering the hemisphere comes in contact with that covering the upper surface of the second vesicle (Fig. 357).[1] A portion of the two layers which are in contact forms the velum interpositum. Immediately above is the body of the fornix, which is formed by the fusion of the cerebral hemispheres in the middle line and below is the cavity of the second vesicle (the third ventricle), with the optic thalamus on either side (Fig. 359). Just beyond the free lateral border of the fornix, between it and the tænia semicircularis, is a portion of the

[1] In the diagram the two layers are represented as being separated from each other, for the sake of clearness.

first cerebral vesicle, which is not developed into nervous matter but is made up only of ependyma covered by pia mater. The vessels of this portion of the highly vascular pia mater become dilated and prolonged, and grow into the ventricle, pushing the ependyma before them, and forming an irregular congeries of vessels, apparently encroaching on the cavity of the lateral ventricle, but in reality being external to it, because they are separated from it by the lining membrane of the cavity, the ependyma. This vascular structure is the choroid plexus of the body of the ventricle.

The part of the choroid plexus seen in the descending cornu is formed in exactly the same way, viz., by an ingrowth of the vessels of the pia mater into the cavity, pushing the ependyma before it, at a part of the wall of the horn where

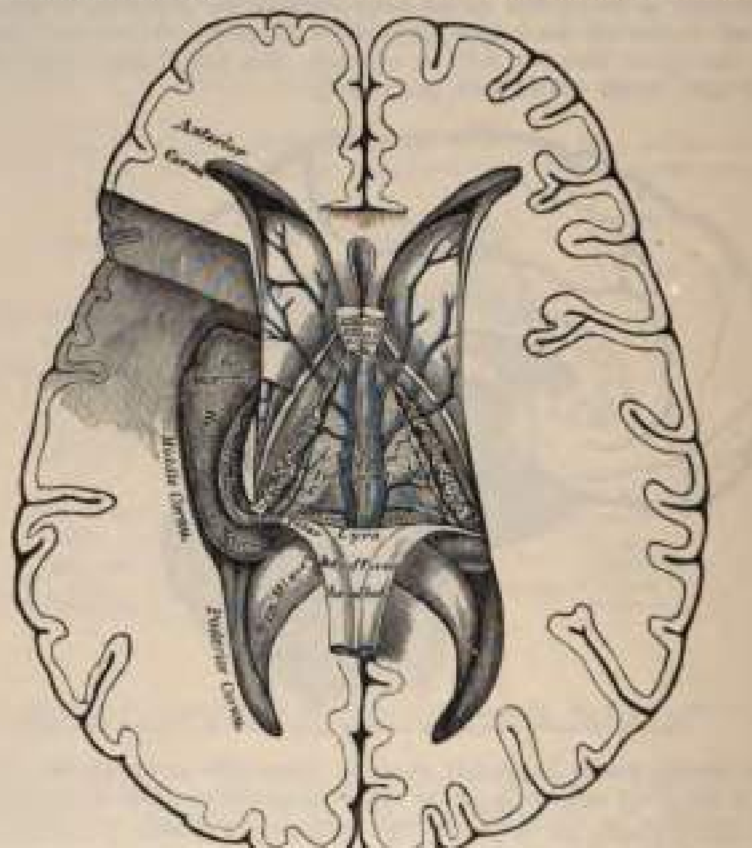

FIG. 356.—The fornix, velum interpositum, and middle or descending cornu of the lateral ventricle.

there is a similar absence of nervous tissue and where it consists simply of pia mater and ependyma in close contact. This portion lies between the corpus fimbriatum in the floor and the tænia semicircularis in the roof of the descending horn. This area, destitute of nervous matter, is continuous with the area in the body of the ventricle, from which the choroid plexus of this region originated, and in it the vessels of its pia mater increase, and, invaginating the ependyma, appear in the descending horn as its choroid plexus. In the body of the ventricle the choroid plexus is really the vascular fringed margin of the velum; beyond the posterior margin of the velum the plexus of the descending horn is continuous with the pia mater on the surface of the gyrus hippocampi; the two portions of the plexus are, however, directly continuous with each other. The gap or cleft through which the invagination of the pia mater takes place is called the *transverse fissure*.

In front, the choroid plexus of the lateral ventricle is small and tapering, and communicates with that of the opposite side through the *foramen of Monro*. In structure it consists of minute and highly vascular villous processes, containing an afferent and efferent vessel, and covered by a single layer of flattened epithelium, the cells of which often contain a yellowish fat molecule. The anterior choroidal artery is derived from the internal carotid, and enters the ventricle at the extremity of the descending cornu, and, after ramifying in the plexus, sends branches into the adjacent parts of the brain. The posterior choroidal arteries, one or two in number, are derived from the posterior cerebral artery, and reach the plexus by passing forward under the splenium of the corpus callosum. The veins of the choroid plexus unite to form a prominent vein, which courses from behind forward to the foramen of Monro, and joins with the vein of the corpus striatum to form the corresponding vein of Galen.

The **transverse fissure** is not a real fissure or cleft, because it is filled by the invagination of the pia mater, forming the velum interpositum and the choroid plexuses, covered by the lining of the ventricular cavities. If this involution of pia mater is pulled out, the ventricular lining will necessarily be torn away with it, and a cleft-like space will be left on either side, extending from the foramen of Monro to the bottom of the descending horn of the lateral ventricle. The upper part of this cleft, that is to say, the part nearest the foramen of Monro, is between the lateral border of the body of the fornix and the optic thalamus; below this, at the commencement of the middle horn, it is between the commencing corpus fimbriatum of the fornix and the pulvinar of the optic thalamus; and lower still, in the descending horn, between the corpus fimbriatum on the floor and the tænia semicircularis in the roof of the cornu. Posteriorly the transverse fissure opens between the splenium of the corpus callosum above, and the corpora quadrigemina and pineal gland below. Through the fissure the venæ Galeni emerge to join the straight sinus.

The **velum interpositum** or **tela choroidea superior** (Fig. 358) is a vascular membrane, and is a prolongation of the pia mater into the interior of the brain through the middle part of the transverse fissure. It is of a triangular form, and separates the under surface of the body and posterior pillars of the fornix from the cavity of the third ventricle. Laterally it covers the inner part of the upper surface of the optic thalamus. Its posterior border or base lies beneath the splenium of the corpus callosum above, and the optic thalamus, the corpora quadrigemina, and pineal body below. Its anterior extremity, or apex, ends just behind the anterior pillars of the fornix, where it is connected with the anterior extremities of the choroid plexuses, which are here united through the foramen of Monro, and are then prolonged backward on the under surface of the velum as the *choroid plexuses of the third ventricle*; in front, these plexuses of the third ventricle lie close to the middle line, but diverge from each other behind. The lateral margins of the velum interpositum form the choroid plexuses of the lateral ventricles. It is supplied by the anterior and posterior choroidal arteries, already described. The veins of the velum interpositum, the *venæ Galeni*, two in number, run between its layers, each being formed by the union of the vein of the corpus striatum with the choroid vein. The venæ Galeni unite posteriorly into a single trunk, the *vena magna Galeni*, which terminates in the straight sinus (Fig. 326).

II. The Inter-brain.

The **inter-brain** (thalamencephalon) is the region of the third ventricle, and comprises the parts developed from the second cerebral vesicle, together with that portion of the first vesicle which is not concerned in the formation of the cerebral hemispheres.

The inter-brain is connected above and in front with the cerebral hemispheres; behind, with the mid-brain or mesencephalon. On its upper surface it is entirely concealed from view, as it is covered by those portions of the internal surfaces of the cerebral hemispheres which have fused together to form the corpus callosum and the fornix, and is separated from the latter by the two layers of pia mater which form the velum interpositum. Inferiorly it reaches the base of the brain, forming the structures contained in the interpeduncular space.

The third ventricle is the cavity of the inter-brain (Fig. 359). It is a narrow median crevice between the two optic thalami, which constitute the side walls of the inter-brain. Its roof is formed by the velum interpositum, from which are suspended the choroid plexuses of the third ventricle. Its floor, somewhat oblique in its direction, is formed, from before backward, by the tuber cinereum, with its infundibulum and pituitary body; the corpora albicantia; the posterior perforated space; and the tegments of the crura cerebri. Its sides are formed by the optic thalami, and are limited above by a delicate band of white fibres, the *stria pinealis*,

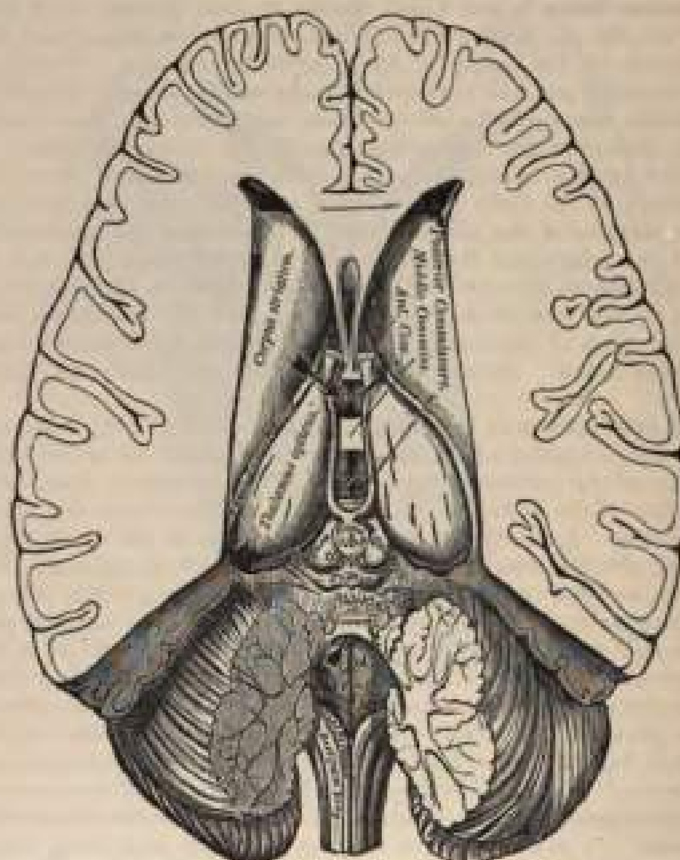

FIG. 359.—The third and fourth ventricles. An arrow has been placed in the position of the foramen of Monro.

which runs along the junction of the mesial and upper surfaces of the optic thalamus to join the anterior pillars of the fornix. Its sides are somewhat convex, so that in the middle of the ventricle the two lateral walls are almost in contact, and are here united across the middle line by a band of gray nervous matter, the *middle, gray*, or *soft* commissure. The ventricle is bounded in front by the anterior pillars of the fornix and the lamina cinerea; behind by the pineal gland, the posterior commissure, and the upper end of the iter a tertio ad quartum ventriculum. The cavity is much deeper in front than behind, and presents a recess at its anterior part, which lies over the optic commissure and is therefore termed the *optic recess*. Behind and below this is the conical depression of the infundibulum, passing downward and forward to the pituitary body. At its posterior extremity the cavity forms another and smaller recess, which extends into the stalk of the pineal gland, and is termed the *pineal recess*. At its upper and anterior part, immediately behind the anterior pillars of the fornix and in front of the optic thalamus, is an opening, the *foramen of Monro*, by which this ventricle communicates with the lateral ventricle on either side. The roof of the cavity is limited in front and behind by transverse bands of white matter, known respectively as the *anterior* and *posterior commissures*. The former has already been described in connection with the corpus striatum (page 665).

The *middle* or *soft commissure* consists almost entirely of gray matter. It connects the two optic thalami, and is continuous with the gray matter lining the anterior part of the third ventricle. It is frequently broken in examining the brain, and might then be supposed to be wanting; it is sometimes double.

The *posterior commissure* is a rounded band of white fibres, which stretches across from one optic thalamus to the other, overlying the upper end of the aqueduct of Sylvius, or iter a tertio ad quartum ventriculum. It is usually described as belonging to the inter-brain, but would appear to belong in part to the mid-brain, since some of its fibres are commissural and connect the anterior corpora quadrigemina to the fillet of the opposite side (see below). In addition there are other decussating fibres, which come from the tegmentum of the crus cerebri on one side and decussate with those of the opposite side in the posterior commissure, and passing through the optic thalamus reach the cerebral hemispheres. Fibres have also been described as taking their origin in the pineal body and ganglion habenulæ, and passing across to the posterior longitudinal bundle and oculomotor nucleus of the opposite side; these fibres occupy the ventral part of the commissure, and receive their myelin sheath before those in its dorsal part. But to a certain extent the posterior commissure belongs to the inter-brain, since it contains fibres which serve as commissural fibres between the two optic thalami.

The **optic thalami** are two large oblong masses, situated on either side of the third ventricle, and lying between the diverging portions of the corpora striata. They are composed mainly of gray matter, but their free surfaces are coated with a thin layer of white nervous tissue. They present outer and under surfaces, which are not free, but are blended with contiguous parts of the brain, and upper, inner, and posterior surfaces, which are free. The anterior extremity is narrow, and forms the posterior boundary of the foramen of Monro. The outer surface is in contact with the posterior limb of the internal capsule, which separates it from the lenticular nucleus. The *inferior* surface rests upon and is continuous with the tegmentum of the crus cerebri. Its upper surface is free, and is separated from the caudate nucleus by a furrow which lodges the lamina cornea, the vein of the corpus striatum, and the tænia semicircularis. It is divided into an outer and an inner part by a groove which runs from behind, forward and inward. The outer part forms a portion of the floor of the lateral ventricle, and is covered by the ependyma of that cavity; it terminates in front in a tubercle, the *anterior tubercle* of the optic thalamus. The inner part is covered by the velum interpositum, which separates it from the fornix, and is excluded from both the lateral and third ventricles by the reflection of the lining of these cavities, and is therefore destitute of an ependymal covering.

The *internal* surface forms the lateral wall of the third ventricle, and running along its upper border is the peduncle of the pineal gland, from which the ependyma of the third ventricle is reflected on to the under surface of the velum interpositum. The *posterior* surface projects beyond the level of the corpora quadrigemina, and forms a well-marked rounded prominence, the *posterior tubercle* or *pulvinar*. The pulvinar is continued externally into a second eminence, the *external geniculate body*, which is placed above and to the outer side of the *internal geniculate body*, and from which it is separated by the superior brachium, one of the roots of the optic tract.

The optic thalamus is formed chiefly of gray matter, which is arranged in two masses, the *outer* and *inner nuclei*, and these are partially separated from each other by an S-shaped vertical lamina of white matter, called the *internal medullary lamina*. This is named internal in contradistinction to a second or *external medullary lamina* of white matter, which coats the outer surface of the optic thalamus and connects it with the internal capsule. The inner nucleus is connected with the corresponding nucleus of the opposite side through the middle commissure of the third ventricle. The external nucleus, which is the larger of the two, extends backward into the pulvinar. The gray matter of the optic thalamus contains large multipolar and fusiform cells, and is traversed in every direction by numerous nerve-fibres.

The optic thalamus is intimately connected with the following structures:

1. It constitutes a relay for the greater number of the fibres of the tegmentum of the crus cerebri.

2. The pulvinar receives many of the fibres of the optic tract.

3. It is connected with the cerebral cortex, (*a*) through the *anterior stalk of the optic thalamus*, which passes from the anterior extremity of the thalamus through the anterior limb of the internal capsule to the frontal lobe; (*b*) through the *posterior stalk* or *optic radiations*, consisting of fibres which take their origin in the pulvinar and are transmitted through the extreme posterior part of the internal capsule to the occipital lobe; (*c*) through the *inferior stalk* or *ansa peduncularis*, made up of fibres which leave the inferior surface of the thalamus and end in the temporal lobe; (*d*) through fibres which pass from the external surface of the thalamus to the parietal lobe.

4. With the corpus striatum. The fibres destined for the caudate nucleus leave the external surface; those for the lenticular nucleus, the inferior aspect of the thalamus.

5. With the corpus albicans through the bundle of Vicq d'Azyr.

In connection with the optic thalamus two small nuclei of gray matter require consideration: (1) One of these, the *anterior nucleus*, is situated in the *anterior tubercle* of the optic thalamus. This nucleus receives the fibres (bundle of Vicq d'Azyr) which take origin in the cells of the corpus albicans (see page 657). Though this bundle of fibres appears to be the direct continuation of the anterior pillar of the fornix through the corpus albicans to the optic thalamus, it is believed to have no histological continuity with it. The fibres of the anterior pillar of the fornix form synapses in the corpus albicans around the cells which give origin to the bundle of Vicq d'Azyr, and thus an indirect communication only is established between the fornix and the optic thalamus. (2) The second gray nucleus lies in a depressed space, the *trigonum habenulæ*, situated between the pulvinar and the posterior part of the peduncle of the pineal gland. It is termed the *ganglion of the habenula*. It receives fibres from the peduncles of the pineal body, and sends off others which pass to a small collection of gray matter, situated between the diverging crura cerebri, and named the *ganglion interpedunculare*.

The **pineal gland** (*epiphysis cerebri*), so named from its peculiar shape (pinus, a *fir-cone*), is a small reddish gray body, conical in shape (hence its synonym, *conarium*), placed immediately above and behind the posterior commissure and between the anterior corpora quadrigemina, on which it rests. It is covered by the velum interpositum, which intervenes between it and the splenium of the corpus callosum. It is an upgrowth from the second cerebral vesicle (hence the name epiphysis), and is at first hollow, but soon becomes solid and loses its connection with the ventricular cavity. It is retained in its position by a duplicature of pia mater, derived from the under surface of the velum interpositum, which almost completely invests it. The pineal gland is about four lines in length and from two to three in width at its base, and is said to be larger in the child than in the adult, and in the female than in the male. It is attached on either side by a flattened stalk of white matter, the *pedunculus conarii*. This stalk consists of two laminæ, upper and lower, separated by a little recess, the *pineal recess* (see page 671). The lower lamina is prolonged into the posterior commissure. The upper divides into two strands, the *peduncles of the pineal gland*, or *striæ pinealis ;* these extend on either side along the optic thalamus at the junction of its mesial and upper surfaces (see page 671) to the anterior pillars of the fornix, with which they blend. The two stalks join together at their posterior extremity, in front of the pineal gland, forming a sort of festoon, and the base of the gland is connected to their posterior margin at the point of junction.

Structure.—The pineal gland consists of a number of follicles, lined by epithelium, and connected together by ingrowths of connective tissue. The follicles contain a transparent viscid fluid and a quantity of sabulous matter named *acervulus cerebri*, composed of phosphate and carbonate of lime, phosphate of magnesia and ammonia, with a little animal matter. These concretions are almost constant in their existence, and are present at all periods of life. They are found upon the surface of the pineal body and occasionally upon its peduncles.

Morphologically the pineal gland is regarded as the homologue of the structure termed the *pineal eye* of the lizards. In these reptiles the epiphysis cerebri is attached by an elongated stalk and projects through the parietal foramen. Its extremity lies immediately under the epidermis, and on microscopic examination presents, in a rudimentary fashion, structures similar to those found in the eyeball.

III. The Mid-Brain.

The **mid-brain, or mesencephalon,** is the constricted portion of the brain which connects the pons Varolii with the inter-brain and hemispheres, and hence it is frequently called the *isthmus cerebri*. It is developed from the third cerebral vesicle, the cavity of which becomes the aqueduct of Sylvius. It comprises the crura cerebri, the corpora quadrigemina, the geniculate bodies, and the Sylvian aqueduct. Its direction is from before backward and downward. In front and above it is continuous with the inter-brain; below with the pons. Its two surfaces are ventral and dorsal. They are free, but concealed: the ventral surface by the apices of the temporal lobes which overlap it; the dorsal, by the overhanging cerebral hemispheres. The *ventral* surface when exposed by drawing aside the temporal lobes, is seen to consist of two cylindrical bundles of white matter which emerge from the pons and diverge as they pass forward and outward to enter the inner and under part of either hemisphere. They are the *crura cerebri* or *cerebral peduncles*, and between them is a triangular area, already described as part of the interpeduncular space (see page 653); near the point of divergence of the crura the roots of the third nerve are seen to emerge in several bundles from a groove, the *sulcus oculomotorius*. The *dorsal* surface is not visible until a considerable portion of the cerebral hemispheres and other overlying structures have been removed. It then presents four rounded eminences placed in pairs, two in front and two behind, and separated from one another by a crucial depression. These are termed the *corpora* or *tubercula quadrigemina*. The ventral and dorsal surfaces meet on the side of the mid-brain, and are separated from each other by a furrow, the *lateral groove*, which runs from below upward and forward (Fig. 359).

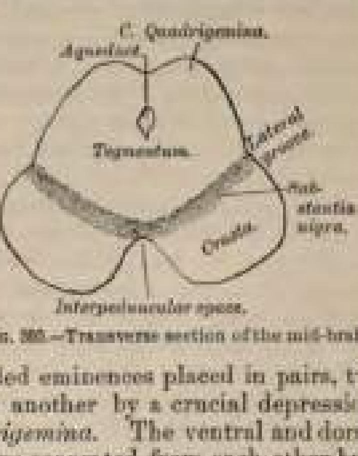

Fig. 360.—Transverse section of the mid-brain.

If a cross-section be made through the mesencephalon (Fig. 360) it will be seen that each lateral half is divided into two unequal portions by a lamina of deeply pigmented gray matter, named the *substantia nigra ;* of these the postero-superior portion is named the *tegmentum*, and the antero-inferior the *crusta* or *pes*. The substantia nigra is curved on section with its concavity upward, and extends from the lateral groove externally to the oculomotor sulcus internally. The two crustæ are quite separate from one another, but the two halves of the tegmentum are joined to each other in the mesial plane by a prolongation forward of the raphé or median septum of the pons. Laterally the tegmenta are free, but dorsally they blend with the corpora quadrigemina.

Crustæ.—The crustæ, which are two in number, separated by the interpeduncular space, are semilunar in section, and consist of longitudinal bundles of white fibres, which may be divided into three principal sets: (1) Those occupying the outer third of the crusta are believed to arise from the cells of the nuclei pontis, gray nuclei in the pons Varolii, and pass through the posterior part of the internal capsule to the cerebral cortex of the occipital and temporal lobes. (2) The fibres occupying the middle third of the crusta take their origin in the cells of the Rolandic area of the cortex, and, converging to the internal capsule, pass down through its genu and through the anterior two-thirds of its posterior limb to the crusta, from which they are prolonged through the pons into the anterior pyramid of the medulla oblongata. (3) The origin, from below, of the fibres occupying the inner third of the crusta is uncertain, though by some they are believed to arise in the crusta itself, from the cells of the locus niger. Above, they pass through the anterior part of the internal capsule to the cerebral cortex of the frontal lobe. In addition to these three sets of longitudinal fibres, a well-marked bundle, defined by having an oblique direction, must be noted. This is named the *mesial fillet*. It arises from the fillet (see below), and at the lower part of the crusta is situated at its mesial border; as it ascends it courses obliquely outward to reach the lateral border of the middle group of fibres (pyramidal tract) and becomes lost in the subthalamic region.

The **tegmentum**, or that portion of the mid-brain which is superior to the substantia nigra, consists of longitudinally directed strands of white fibres, which are separated from each other by transversely arched fibres. There is also a considerable quantity of gray matter. It thus forms a peculiar reticulated structure, which has been named *formatio reticularis*, and is similar to a like structure in the pons and medulla, with which it is continuous. In some parts of the tegmentum the longitudinal fibres are arranged in fairly well-defined tracts, which are as follows: 1. The *posterior longitudinal bundle*, which is composed of large nerve-fibres, and lies on either side of the median line, just below the aqueduct. These fibres are continued upward from the anterior column of the cord, in which they probably form short longitudinal commissures between its different segments. They pass through the pyramid of the medulla, then form the posterior longitudinal bundle of the pons, and enter the tegmentum; here they give off fibres to the nuclei of the third and fourth cranial nerves. At the front of the mid-brain some of the fibres of the posterior longitudinal bundle enter the posterior commissure and there decussate (see page 671); others pass upward to the subthalamic region. 2. Fibres from the superior cerebellar peduncle. These lie on either side of the middle line of the tegmentum, and, as they pass through it, decussate with each other, so that the fibres of one half of the cerebellum pass to the opposite half of the cerebrum. Having crossed to the opposite side, the bundle of fibres passes upward and forward, enclosing a mass of gray matter, the *red nucleus*, or *nucleus of the tegmentum*, from which it probably receives fibres, and eventually passes into the optic thalamus. 3. The *fillet*. This takes its chief origin in the medulla, and passes through the pons to the mid-brain, as will be described in the sequel. It forms a considerable bundle of longitudinal fibres in the ventral part of the tegmentum, and divides into three parts—the *upper*, *mesial*, and *lower fillet*. The *upper* fillet passes to the upper pair of corpora quadrigemina and the occipital region of the cerebral hemisphere. The *mesial* fillet has already been alluded to in the description of the crusta. After separating from the rest of the fillet its fibres assume an oblique direction, and are eventually lost in the subthalamic region. The *lower* fillet, also called *lemniscus*, is situated in the ventral part of the tegmentum, through which it passes obliquely and emerges at its side, and after crossing the superior peduncle of the cerebellum, passes to the inferior quadrigeminal bodies. It is reinforced by some fibres from the superior medullary velum. 4. Fibres from the olivary nucleus, which pass in a longitudinal direction through the reticular formation of the tegmentum and are continued onward into the internal capsule.

The *red nucleus* or *nucleus of the tegmentum*, is a tract of gray matter situated on either side of the middle line, and is composed of numerous large cells, which are deeply pigmented. It is pierced by the fibres of the third nerve, and prolonged above into the posterior part of the subthalamic region.

The Substantia Nigra.—This, as already stated, is a layer of deeply pigmented gray matter, which separates the crusta from the tegmentum. It is thicker internally than externally, where it is partially divided up by the mesial fillet passing from the tegmentum to the crusta. It is traversed at its inner part by some of the fibres of origin of the third cranial nerve. The cells are small and multipolar, and are characterized by containing a large amount of dark pigment granules.

The **corpora** or **tubercula quadrigemina** are four rounded eminences placed in pairs, two in front and two behind, and separated from one another by a crucial depression. They are situated on the dorsal surface of the mid-brain, immediately behind the third ventricle and posterior commissure, and beneath the splenium of the corpus callosum. The *anterior* or *upper* pair, sometimes called the *nates*, are the larger. They are oval, their long diameter being directed forward and outward, and are of a gray color. The *posterior* or *lower* pair, called the *testes*, are hemispherical in form, and lighter in color than the preceding. From the outer side of each of these eminences, a prominent white band, termed *brachium*, is continued forward and outward. Those from the nates (*brachia anteriora*) pass obliquely outward between the pulvinar and the inner geniculate bodies into the external geniculate bodies. Those from the testes (*brachia posteriora*) lose themselves beneath an oval prominence on either side of the corpora quadrigemina, called the *internal geniculate body*. The corpora quadrigemina are larger in the lower animals than in man. In fishes, reptiles, and birds they are hollow, and only two in number (*corpora bigemina*); they represent the anterior quadrigeminals of mammals. In these lower animals the corpora bigemina are frequently termed the *optic lobes*, because of their connection with the optic tracts. In the mammalia they are four in number, and solid. In the human fœtus all four bodies are differentiated by the fifth month, and form at this time a considerable proportion of the brain.

The corpora quadrigemina are composed of white matter externally, and gray matter within. The *posterior* pair consist almost entirely of gray matter, covered over by a very thin stratum of white substance. Beneath the gray matter is a thin layer of white fibres, forming a part of the lower fillet. This separates the gray matter of the posterior corpora quadrigemina from the central gray matter of the aqueduct. The *anterior* pair are covered superficially by a thin stratum of white matter, the *stratum zonale*, the fibres of which are fine and arranged transversely. Beneath this is the *stratum cinereum*, a layer of gray matter which resembles a cup, semilunar in shape, thicker in the centre, and thinning off toward the margins, and consisting of numerous multipolar cells, for the most part of small size, embedded in a fine network of nerve-fibres. Below this again is the *stratum opticum*, or *upper gray-white layer*, characterized by the large amount of fine nerve-fibres which intersect the gray matter. These fibres vary in size in different parts of the layer, but have for the most part a longitudinal direction. The nerve-cells between the fibres are larger, and send their axis-cylinder processes into the next stratum. Finally there is the *stratum lemnisci*, or *deep gray-white layer*, which separates the rest of the body from the gray matter around the aqueduct. It consists of fibres partly derived from the upper fillet and partly from the cells of the preceding layer. Interspersed among these fibres are nerve-cells of large size.

In close relationship with the corpora quadrigemina are the **superior peduncles of the cerebellum**. They emerge from the upper and mesial part of the hemispheres of the cerebellum, and run upward and forward to the corpora quadrigemina, with which they come in close contact. They then pass under these bodies, through the tegmentum (*vide supra*), and enter the optic thalamus.

The **corpora geniculata** are two small, oblong masses on each side, situated behind and beneath the posterior end of the optic thalamus, and named, from their position, *corpus geniculatum externum* and *internum*. These two bodies are separated from each other by the brachium anterius of the anterior quadrigeminal body. It is convenient and customary to describe these two bodies together, but the student should bear in mind that the corpus geniculatum externum belongs in reality to the optic thalamus; the corpus geniculatum internum alone being a part of the mid-brain. The *external* geniculate body is of a dark color, and presents a laminated arrangement, consisting of alternate layers of gray and white matter. Its cells are large, multipolar, and pigmented; their processes are intimately related with the visual area in the cerebral cortex of the occipital region. It is believed that the intercellular gray matter of these bodies is composed, to a considerable extent, of the terminations of the optic nerve, which form synapses around the cells. The *internal* geniculate body is smaller in size, lighter in color, and does not present a laminated arrangement. It receives the posterior brachium from the inferior quadrigeminal body, and some of the fibres of the optic tract appear to enter it. The internal geniculate bodies are connected with each other through the optic commissure by a band of fibres named *Gudden's commissure* (see page 721). The anterior quadrigeminal body, the pulvinar, and the external geniculate body are intimately concerned with vision. They constitute the lower cerebral centre for the optic nerve-fibres which end in them. Extirpation of the eyes in newly born animals entails an arrest of their development, but has no effect on the posterior quadrigeminal body or the internal geniculate body. These latter also are well developed in the mole, where the superior quadrigeminal body is rudimentary.

The Aqueduct of Sylvius, or Iter a Tertio ad Quartum Ventriculum.—This is a narrow canal, about half an inch in length, situated between the corpora quadrigemina and the tegmentum, and connecting the third with the fourth ventricle. Its shape on transverse section varies, being T-shaped below, triangular above, and oval about the middle of its course. It is lined by columnar ciliated epithelium, and surrounded by a layer of gray matter, called the *central gray matter of the aqueduct*, which is continuous with the gray matter of the third and fourth ventricles. This gray matter is separated above from that of the corpora quadrigemina by the stratum lemnisci; below it, is the posterior longitudinal bundle and the formatio reticularis of the tegmentum. The central gray matter is more abundant below the canal than above it. Here are certain defined group of cells, which are connected with the roots of the third, fourth, and fifth cranial nerves.

Subthalamic Region.—One other structure, to which allusion has already been made, requires mention in this connection; it is the *subthalamic region*. It is a prolongation forward of the tegmentum of the crus cerebri, which becomes continuous with the lower surface of the optic thalamus. Toward the anterior part of the crus cerebri the tegmentum becomes thinned out, and is blended with the superjacent portion of the optic thalamus. To this region, the name *subthalamic tegmental region* has been given. In front it is lost at the base of the brain in the gray matter of the anterior perforated space, and is continuous with the gray matter of the floor of the third ventricle. The subthalamic tegmental region contains a forward prolongation of the red nucleus, and consists from above downward of three layers: (1) *stratum dorsale*, which is directly applied to the under surface of the optic thalamus, and consists of fine longitudinal fibres; (2) *zona incerta*, a continuation forward of the formatio reticularis of the tegmentum; and (3) the *corpus subthalamicum*, a mass of gray matter which on section presents a lenticular shape, and lies immediately above the substantia nigra.

STRUCTURE OF THE CEREBRUM.

The **cerebrum**, like the other parts of the great nerve centre, is composed of gray and white matter. In order to give some general idea of its construction, at all events in part, it may be compared, for the sake of illustration, to a tree, the trunk of which divides into two main divisions, and these break up into smaller branches, which finally end in twigs, to which are attached the leaves, forming an investment to the branches and covering the whole tree. The trunk is represented by the medulla oblongata as it passes through the foramen magnum; the two main divisions by the crura cerebri, which break up into smaller branches; these diverge from each other, dividing and subdividing, until they reach the surface of the hemispheres, where they terminate in single nerve-fibres, which are continuous with the basal axial cylinder processes of the nerve-cells, the representatives of the leaves. These cells are arranged on the surface, resembling a cap, covering the hemispheres, and constitute the cerebral cortex. But here the analogy ends, for in the cerebrum there are, in addition to this cortex, other masses of gray matter situated in the middle of the brain; and other white fibres besides the diverging ones that have been mentioned, and which serve either to connect the two cerebral hemispheres, or to unite different structures in the same hemisphere.

The **white matter of the cerebrum** consists of medullated fibres, varying in size and arranged in bundles, separated by neuroglia. They may be divided into three distinct systems, according to the course they take. 1. Projection or peduncular fibres, which connect the hemisphere with the medulla oblongata and cord. 2. Transverse or commissural fibres, which unite together the two hemispheres. 3. Association fibres, which connect different structures in the same hemisphere. These are, in many instances, collateral branches of the projection fibres, but others are the axons of independent cells.

1. The **projection** or **peduncular fibres** consist of fibres which pass either to or from the cord. They form the longitudinal fibres of the pons, and at its upper border divide into two main groups, which, diverging from each other, constitute the *crura cerebri* or *cerebral peduncles*. In the crura cerebri, as has been before described, the diverging fibres are arranged in two strata, which are separated by the substantia nigra; the ventral or superficial stratum forming the *crusta* of these bodies, and the dorsal or deeper stratum, the *tegmentum*. The fibres derived from these two sources take a different course, and will have to be separately considered.

The fibres of the *crusta* are derived from the pyramid of the medulla, and are continued upward through the pons; they are reinforced in their passage through the crus by accessory fibres, derived from the central gray nucleus around the Sylvian aqueduct and from the substantia nigra. When they emerge from the crus, most of the fibres pass through the internal capsule, and when they leave it, spread out forward, upward, and backward, forming a series of radiating fibres, the *corona radiata*, which proceed to the cortex. As the fibres pass through the internal capsule they give off branches to the optic thalamus and to the caudate and lenticular nuclei of the striate body, and other fibres, derived especially from the first of these ganglia, form a part of the corona radiata, and pass to the cortex of the cerebral hemispheres. The fibres of the *tegmentum* are continuous with those longitudinal fibres of the pons which are derived from the nucleus gracilis and nucleus cuneatus, and from the formatio reticularis of the medulla. They are reinforced by fibres from the corpora quadrigemina and the corpora geniculata, and from the superior peduncle of the cerebellum. Some of the fibres are continued directly to the cerebral cortex, but the majority pass to the subthalamic region, and either end there or in the substance of the optic thalamus—the connection with the cortex being effected by means of fibres which arise in the optic thalamus. They spread out to form part of the corona radiata, and are distributed especially to the cortex of the temporal and occipital lobes.

2. The **transverse** or **commissural fibres** connect the two hemispheres. They

include: (*a*) the transverse fibres of the corpus callosum; (*b*) the anterior commissure; (*c*) the posterior commissure, and have already been described.

3. **Association Fibres.**—These connect different structures in the same hemisphere, and are of two kinds: (1) Those which unite adjacent convolutions, *short association fibres*; (2) those which pass between more distant parts in the same hemisphere, *long association fibres*.

The *short association fibres* are situated immediately beneath the gray substance of the cortex of the hemispheres, and connect together adjacent convolutions.

The *long association fibres* include the following: (*a*) the uncinate fasciculus; (*b*) the cingulum; (*c*) the superior longitudinal fasciculus; (*d*) the inferior longitudinal fasciculus; (*e*) the perpendicular fasciculus; and (*f*) the fornix.

(*a*) The *uncinate fasciculus* passes across the bottom of the Sylvian fissure, and connects the convolutions of the frontal lobe with the anterior end of the temporal lobe.

(*b*) The *cingulum* is a band of white matter which encircles the hemisphere in an antero-posterior direction, lying in the substance of the convolution of the corpus callosum. Commencing in front at the anterior perforated space, it passes forward and upward parallel with the rostrum, winds round the genu, runs in the convolution from before backward, immediately above the corpus callosum, turns round its posterior extremity, and passes into the hippocampus major, through which it courses to its anterior extremity.

(*c*) The *superior longitudinal fasciculus* runs along the convex surface of the hemisphere, and connects the frontal and occipital and the frontal and temporal lobes.

(*d*) The *inferior longitudinal fasciculus* is a collection of fibres which connects the temporal and occipital lobes, running along the outer wall of the descending and posterior cornua of the lateral ventricle.

(*e*) The *perpendicular fasciculus* runs vertically through the front part of the occipital lobe, and connects the inferior parietal lobule with the fourth temporal convolution.

(*f*) The *fornix* connects the hippocampal convolution with the corpus albicans, and, by means of the bundle of Vicq d'Azyr, with the optic thalamus (see page 672). Through the fibres of the lyra it probably also unites the opposite hippocampal convolutions.

The **gray matter of the cerebrum** is disposed in two great groups: (1) The gray matter of the cerebral cortex. (2) The gray matter of the basal ganglia, the nucleus caudatus and the nucleus lenticularis of the corpus striatum; the claustrum and the amygdaloid nucleus. They are, with the exception of the amygdaloid nucleus, situated to the inner side of the island of Reil, and form with this convolution the oldest part of the hemisphere, for they are the first parts of the encephalon to be differentiated in the development of the individual. They are simply semi-detached local thickenings of the gray cortex. The optic thalamus is not reckoned as a basal ganglion, but as belonging to the thalamencephalon.

GRAY MATTER OF THE CORTEX.

On examining a section through one of the convolutions of the Rolandic area with a lens, it is seen to consist of alternating white and gray layers thus disposed from the surface inward: (1) a thin layer of white substance; (2) a layer of gray substance; (3) a second layer of white substance (outer band of Baillarger or band of Gennari); (4) a second gray layer; (5) a third white layer (inner band of Baillarger); (6) a third gray layer, which rests on the medullary substance of the convolution.

The cortex is made up of nerve-cells which vary in size and shape, and of nerve-fibres, which are either medullated or naked axis-cylinders, embedded in a matrix of neuroglia.

Nerve-cells.—According to Cajal, whose description is now generally accepted, the **nerve-cells** are arranged in four layers, named from the surface inward as follows: (1) the molecular layer; (2) the layer of small pyramidal cells; (3) the layer of large pyramidal cells; (4) the layer of polymorphous cells.

The Molecular Layer.—In this layer the cells are polygonal, triangular, or fusiform in shape. Each polygonal cell gives off some four or five dendrites, while its axon may arise directly from the cell or from one of its dendrites. The axons and dendrites of these cells ramify in the molecular layer. Each triangular cell gives off two or three dendrites, from one of which the axon arises, the dendrites and the axon ramifying in the molecular layer. The fusiform cells are placed with their long axes parallel to the surface and are mostly bipolar, each pole being prolonged into a dendrite, which runs horizontally for some distance and furnishes ascending branches. Their axons, two or three in number, arise from the dendrites, and, like them, take a horizontal course, giving off numerous ascending collaterals. The distribution of the axons and dendrites of all three sets of cells is limited to the molecular layer.

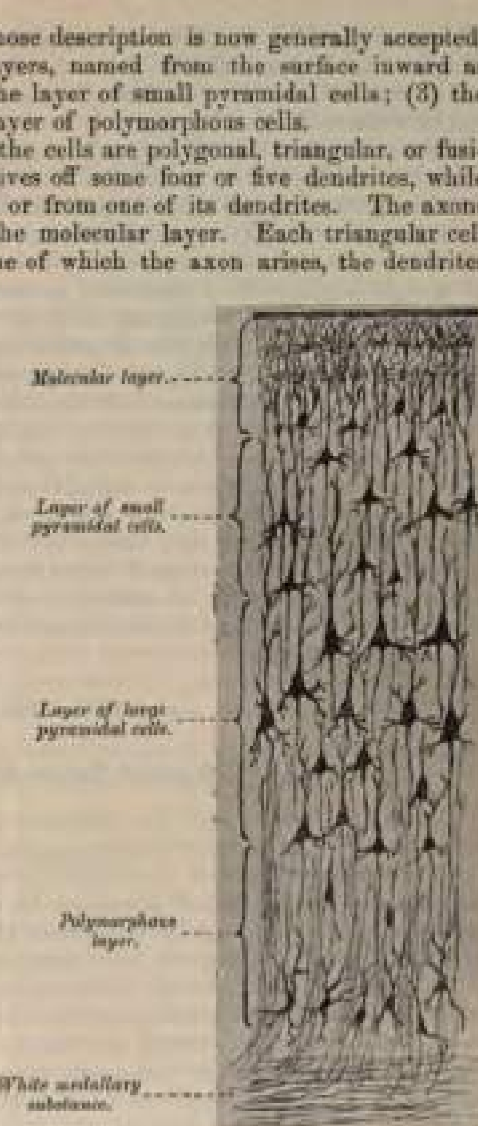

FIG. 581.—The four layers of cells in the cerebral cortex. (After Cajal.) Modified from Testut.

The Layer of Small and the Layer of Large Pyramidal Cells.—The cells in these two layers may be studied together, since, with the exception of the difference in size and the more superficial position of the smaller cells, they resemble each other. The body of each cell is pyramidal in shape, its base being directed to the deeper parts and its apex toward the surface. It contains granular pigment, and stains deeply with ordinary reagents. The nucleus is nucleolated, of large size, and round or oval in shape. The base of the cell gives off the axis-cylinder, and this passes into the central white substance, giving off collaterals in its course, and is distributed as a projection, commissural, or association fibre. Both the apical and basal parts of the cell give off dendrites. The apical dendrite is directed toward the surface, and ends in the molecular layer by dividing into numerous branches, all of which may be seen, when prepared by the silver or methylene-blue method, to be studied with projecting bristle-like processes. The larger pyramidal cells, especially in the Rolandic area, may exceed 50 μ in length and 40 μ in breadth, and are termed *giant cells*.

Layer of Polymorphous Cells.—The cells in this layer, as their name implies, are very irregular in contour, the commonest varieties being of a spindle, star, oval, or triangular shape. Their dendrites are directed outward, toward, but do not reach, the molecular layer; their axons pass into the subjacent white matter.

There are two other kinds of cells in the cerebral cortex, but their axons pass in a direction opposite to that of the pyramidal and polymorphous cells, among which they lie. They are: (*a*) the cells of Golgi, the axons of which do not become medullated, but divide immediately after their origin into a large number of branches, which are directed toward the surface of the cortex; (*b*) the cells of Martinotti, which are chiefly found in the polymorphous layer. Their dendrites are short, and may have an ascending or descending course, while their axons pass out into the molecular layer and form an extensive horizontal arborization.

Nerve-fibres.—These fill up a large part of the intervals between the cells, and may be medullated or non-medullated—the latter comprising the axons of the smallest pyramidal cells and the cells of Golgi. In their direction the fibres may be either transverse (tangential or horizontal) or vertical (radial). The *transverse fibres* run parallel to the surface of the hemisphere, intersecting the vertical fibres at a right angle. They consist of several strata, of which the following are the most important: (1) a stratum of white fibres covering the superficial aspect of the molecular layer; (2) the external band of Baillarger, or band of Gennari, which runs through the layer of large pyramidal cells; (3) the internal band of Baillarger, which intervenes between the layer of large pyramidal cells and the polymorphous layer. According to Cajal, the transverse fibres consist of (*a*) the collaterals of the pyramidal and polymorphous cells and of the cells of Martinotti; (*b*) the arborizations of the axons of Golgi's cells; (*c*) the collaterals and terminal arborizations of the projection, commissural, or association fibres. The *vertical fibres.*—Some of these, viz., the axons of the pyramidal and polymorphous cells, are directed toward the central white matter, while others, the terminations of the commissural, projection, or association fibres, pass outward to end in the cortex. The axons of the cells of Martinotti are also ascending fibres.

In certain parts of the cortex this typical structure is departed from. The chief of these regions are: (1) the occipital lobe, (2) the hippocampus major, (3) the dentate convolution, and (4) the olfactory bulb.

Special Types of Gray Matter.

1. In the cuneus and the calcarine fissure of the occipital lobe, Cajal has recently described as many as nine layers. Here the inner band of Baillarger is absent; the outer band of Baillarger (band of Gennari) is, on the other hand, of considerable thickness. If a section be examined microscopically, an additional layer is seen to be interpolated between the molecular layer and the layer of small pyramidal cells. This extra layer consists of two or three strata of fusiform cells, the long axes of which are at right angles to the surface. Each cell gives off two dendrites, external and internal, from the latter of which the axon arises and passes into the white central substance. In the layer of small pyramidal cells, fusiform cells, identical with the above, are seen, as well as ovoid or star-like cells with ascending axons (cells of Martinotti). This area of the cortex forms the visual centre, and it has been shown by Dr. J. S. Bolton[1] that in old standing cases of optic atrophy the thickness of Gennari's band is reduced by nearly 50 per cent.

2. In the hippocampus major the molecular layer is very thick and contains a large number of Golgi cells. It has been divided into three strata: (*a*) S. convolutum or S. granulosum, containing many tangential fibres; (*b*) S. lacunosum, presenting numerous lymphatic or vascular spaces; (*c*) S. radiatum, exhibiting a rich plexus of fibrils. The two layers of pyramidal cells are condensed into one, and the cells are mostly of large size. The axons of the cells in the polymorphous layer may run in an ascending, descending, or horizontal direction. Between the polymorphous layer and the ventricular ependyma is the white substance of the alveus.

3. In the rudimentary dentate convolution the molecular layer contains some pyramidal cells, while the layer of pyramidal cells is almost entirely represented by small ovoid cells.

4. **The Olfactory Bulb.**—In many of the lower animals this contains a cavity which communicates through the hollow olfactory stalk with the cavity of the

[1] *Phil. Trans. of Royal Society*, Series B, vol. cxciii, p. 165.

lateral ventricle. In man the original cavity is filled up by neuroglia and its wall becomes thickened, but much more so on its ventral than on its dorsal aspect. Its dorsal part contains a small amount of gray and white matter, but it is scanty and ill defined. A section through the ventral part shows it to consist of the following layers from without inward. (1) A layer of olfactory nerve-fibres, which are the non-medullated axons prolonged from the olfactory cells of the nose, and which reach the bulb by passing through the cribriform plate of the ethmoid bone. At first they cover the bulb, and then penetrate it to end by forming synapses with the dendrons of the mitral cells, presently to be described. (2) *Glomerular layer.*—This contains numerous spheroidal reticulated enlargements, termed *glomeruli*, which are produced by the branching and arborization of the processes of the olfactory nerve-fibres with the descending dendrite of the mitral cells. (3) *Molecular layer.*—This is formed of a matrix of neuroglia, embedded in which are the *mitral cells.* These cells are pyramidal in shape, and the basal part of each gives off a thick dendron which descends into the glomerular layer, where it arborizes as indicated above, and others which interlace with similar dendrites of neighboring mitral cells. The axons pass through the next layer into the white matter of the bulb, from which, after becoming bent on themselves at a right angle, they are continued into the olfactory tract. (4) *Nerve-fibre layer.*—This lies next the central core of neuroglia, and its fibres consist of the axons or afferent processes of the mitral cells which are passing to the brain; some efferent fibres are, however, also present, and terminate in the molecular layer, but nothing is known as to their exact origin.

IV. The Hind-Brain.

The **hind-brain,** or **epencephalon,** comprises those parts which are developed from the fourth cerebral vesicle; namely, the pons, the cerebellum, and the upper half of the fourth ventricle.

PONS VAROLII.

The **pons Varolii** (*tuber annulare*) is the bond of union of the various segments of the encephalon, connecting the cerebrum above, the medulla oblongata below, and the cerebellum behind. It is situated above the medulla oblongata, below the crura cerebri, and between the hemispheres of the cerebellum. It is about an inch in length and in thickness, and about an inch and a half in width. It presents four surfaces: *superior*, which is attached, by direct continuation of fibres, to the mid-brain; *inferior*, which is continuous with the medulla oblongata; while the *anterior* or *ventral* and the *posterior* or *dorsal* surfaces are free.

The *anterior or ventral* surface is very prominent, markedly convex from side to side, and less so from before backward. It consists of transverse white fibres, which arch like a bridge across the middle line, and on either side are gathered together into a compact mass, forming the *middle peduncle of the cerebellum.* Above and below it presents a well-defined border; below, its transverse fibres slightly overlap the pyramidal bodies of the medulla, which disappear into its substance; above, the transverse fibres slightly overlap the crura cerebri which emerge from it. This surface rests upon the clivus of the sphenoid bone, and presents in the middle line a longitudinal groove, wider in front than behind, in which rests the basilar artery.

The *posterior* or *dorsal* surface of the pons is free, but is concealed from view by the cerebellum. It forms the upper part of the floor of the fourth ventricle, and will be described with this cavity.

Structure.—Transverse sections of the pons Varolii show that it consists of two parts, which differ in appearance and structure from each other: the anterior or *ventral* portion consists for the most part of fibres arranged in transverse and longitudinal bundles with a small amount of gray matter; the posterior or dorsal portion is a continuation of the reticular formation of the medulla, and is called the *tegmental* portion, as most of its constituents are continued into the tegmentum of the crus cerebri.

The anterior or ventral part consists of three layers of fibres: 1. superficial transverse fibres; 2. longitudinal fibres; 3. deep transverse fibres. These three layers are not, however, completely differentiated from each other, for some transverse fibres may be seen between the bundles of the longitudinal fibres (Fig. 362).

1. The *superficial transverse fibres*, consisting of a rather thick layer on the ventral surface of the pons, cross the middle line, and proceeding laterally are collected into a large rounded bundle of fibres on each side. This bundle, with the addition of some transverse fibres from the deeper part of the pons, forms the *middle peduncle* of the cerebellum of the corresponding side.

2. The *longitudinal fibres* enter the pons below as a single mass, which forms the continuation upward of the fibres of the pyramids of the medulla; as they ascend they become broken up into bundles by some of the transverse fibres, and

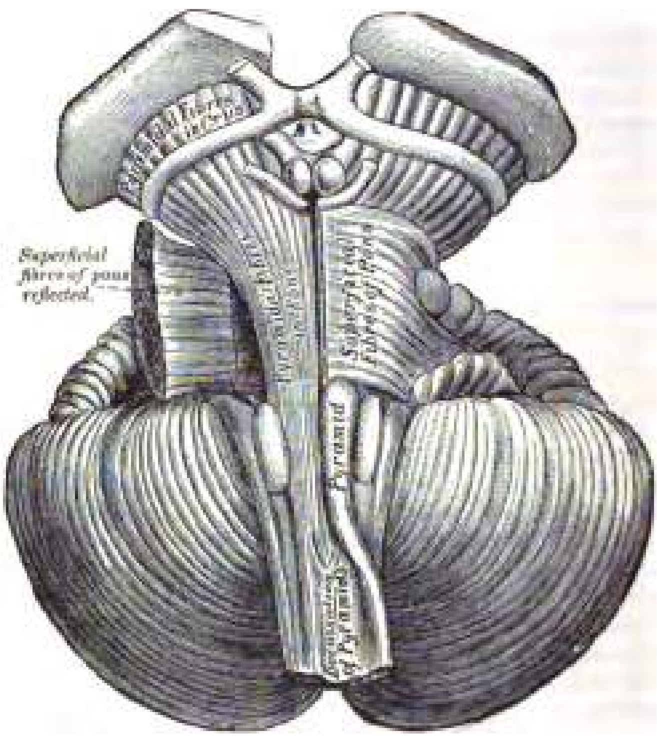

FIG. 362.—Superficial dissection of the medulla oblongata and pons. (Testut.)

are continued into the crusta of the mid-brain. They lie on either side of the middle line, and cause a bulging of the superficial transverse fibres on the ventral surface of the pons, with a longitudinal mesial groove between them. This is the groove, mentioned above, in which the basilar artery is received. As the fibres ascend they are increased in number, being reinforced by others derived from the nerve-cells in the deep transverse strata.

3. The *deep transverse fibres* form a thicker layer than the superficial set, and there is much gray matter between them. The fibres pass from the middle line, where they interlace with those from the opposite side, and, coursing to the lateral borders of the pons, they, for the most part, curve dorsally, and assist the superficial transverse fibres in forming the middle peduncle of the cerebellum. Some of the fibres join the nerve-cells which are situated in the gray matter of this layer, and in addition nerve-fibres derived from others of these cells pass off to join the longitudinal fibres (see above).

The *tegmental* or *dorsal portion* of the pons is chiefly constituted by a continuation upward of the reticular formation and gray matter of the medulla. It is subdivided into lateral halves by a median raphé continuous with that of the medulla, but this does not extend into the ventral half of the pons, being here obliterated by the transverse fibres.

The dorsal portion of the pons, like the ventral, contains both transverse and longitudinal fibres. The transverse fibres are collected into a distinct bundle, which, from its shape, is sometimes termed the *trapezium* or *corpus trapezoides*. It consists of fibres which proceed laterally to become connected with the cells of the accessory auditory nucleus. The longitudinal fibres, which are continuous with those of the medulla, are mostly collected into two bundles on either side. One of these lies between the corpus trapezoides and the formatio reticularis of the pons, and is a continuation upward of the sensory tracts; it is termed the *fillet*. The other bundle is situated more dorsally, near the floor of the fourth ventricle; it is the *posterior longitudinal bundle*, and contains both ascending and descending fibres. Other longitudinal fibres, which are more diffusely distributed, arise from the cells of the gray matter of the pons itself. The greater part of the dorsal portion of the pons is, as stated above, a continuation upward of the formatio reticularis of the medulla, and, like it, presents, on transverse section, viewed under a moderate magnifying power, a reticular appearance. In addition to the gray matter, which presents a number of small reticularly arranged masses, with nerve-cells, there are some important collections of nerve-cells which require mention.

1. The **superior olivary nucleus** is a small isolated collection of gray matter, situated on the dorsal surface of the outer part of the trapezium. In structure it resembles the inferior olivary nucleus of the medulla, presently to be described, and is situated immediately above it. The nerve-fibres derived from its cells pass into the trapezium, and, as stated above, cross the middle line and enter the accessory auditory nucleus of the other side. The other collections of nerve-cells in the formatio reticularis of the pons are nuclei from which some of the cranial nerves arise.

2. **Nuclei of the Fifth Nerve.**—The nuclei of the fifth nerve in the pons are two in number: one for the motor root and the other for the sensory. The *motor* nucleus is situated in the higher portion of the pons, close under the dorsal surface and along the line of the lateral margin of the fourth ventricle. The *sensory* nucleus lies external to the motor one, beneath the superior peduncle of the cerebellum, which forms the lateral boundary of the upper half of the fourth ventricle. Some of the fibres from these nuclei pass to the raphé of the pons, and thence probably to the higher parts of the brain; the rest form the nerve-roots of the motor and sensory parts of the fifth nerve respectively. They pass through the pons to emerge on its ventral surface at its lateral and constricted portion, nearer its superior than its inferior margin. It must be mentioned that the whole of the roots of the fifth nerve are not formed from these nuclei. The sensory root is partly formed by a long tract of fibres, known as the *ascending* root, which can be traced through the pons and medulla to the upper part of the spinal cord. The motor root, in like manner, is partly formed by a long tract of fibres, which passes downward from the gray matter in the floor of the Sylvian aqueduct and which is termed the *descending* root.

3. The **nucleus of the sixth nerve** is situated beneath the floor of the fourth ventricle, on either side of the middle line. It lies close to the root of the facial nerve, immediately to be described, being a little external to and beneath it, and corresponds to the upper half of the fasciculus teres of the floor of the fourth ventricle (Fig. 371). The fibres pass through the substance of the pons, and emerge at the lower margin of this structure, between it and the upper end of the medulla.

4. The **nucleus of the facial nerve** is of elongated form, and is situated deeply in the reticular formation below the floor of the fourth ventricle and dorsal to

the *tegmental* portion, as most of its constituents are continued into the tegmentum of the crus cerebri.

The anterior or ventral part consists of three layers of fibres: 1. superficial transverse fibres; 2. longitudinal fibres; 3. deep transverse fibres. These three layers are not, however, completely differentiated from each other, for some transverse fibres may be seen between the bundles of the longitudinal fibres (Fig. 362).

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2. The *longitudinal fibres* enter the pons below as a single mass, which forms the continuation upward of the fibres of the pyramids of the medulla; as they ascend they become broken up into bundles by some of the transverse fibres, and

FIG. [illegible].—Superficial dissection of the medulla oblongata and pons. (Ellis.)

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4. The **nucleus of the facial nerve** is of elongated form, and is situated deeply in the reticular formation below the floor of the fourth ventricle and dorsal to

the superior olivary nucleus. The roots of the nerve derived from it pursue a remarkably tortuous course in the substance of the pons. At first they pass backward and inward till they reach the floor of the fourth ventricle, close to the median groove, where they are collected into a rounded bundle. This passes upward and forward, producing an elevation (*fasciculus teres*) in the floor of the ventricle, and then takes a sharp bend and arches outward through the substance of the pons to emerge at its lower border in the interval between the olivary and restiform bodies of the medulla.

5. The **nuclei of the auditory nerve** are two in number, dorsal and ventral. The *dorsal* nucleus is principally situated in the medulla, but is prolonged upward into the pons, where it lies beneath the upper half of the floor of the fourth ventricle. The *ventral* or accessory nucleus is also partly contained in the medulla and partly in the pons. In the medulla it is situated on the antero-external surface of the restiform body, lying between the vestibular and cochlear divisions of the auditory nerve, the latter being to its outer side. In the pons it is seen to lie beyond the boundary of the fourth ventricle on the outer and ventral aspect of the restiform body. A third nucleus (*nucleus of Deiters*) is sometimes termed the outer nucleus of the auditory nerve. It is situated below the outer angle of the fourth ventricle, and contains multipolar nerve-cells of large size. The root of the auditory nerve consists of two portions, lateral and mesial, which pass, one to the outer and the other to the inner side of the restiform body, those from the lateral part arising mainly from the ventral nucleus, those from the mesial part arising from the dorsal auditory nucleus. They emerge at the lower border of the pons, in the groove between the olivary and restiform bodies.

The Nuclei Pontis.—In addition to these nuclei of gray matter, which have been described as being situated in the tegmental or dorsal portion of the pons, there are small masses of gray matter, as mentioned above, in the anterior or ventral portion. These are known as the *nuclei pontis*, and consist of small multipolar nerve-cells, scattered between the bundles of transverse fibres.

THE CEREBELLUM.

The **Cerebellum** is contained in the inferior occipital fossæ, and is situated beneath the occipital lobes of the cerebrum, from which it is separated by the tentorium cerebelli. In form, it is oblong and flattened from above downward, its great diameter being from side to side. It measures from three and a half to four inches transversely, two to two and a half inches from before backward, and is about two inches thick in the centre, and about six lines at the circumference. It consists of gray and white matter: the former, darker than that of the cerebrum, occupies the surface; the latter, the interior. The surface of the cerebellum is not convoluted like that of the cerebrum, but is traversed by numerous curved furrows or sulci, which vary in depth at different parts, and separate the laminæ of which it is composed.

Lobes of the Cerebellum.—The cerebellum consists of three parts or lobes, a median and two lateral. They are all continuous with each other, and are substantially the same in structure. The median portion is called the *worm* or *vermiform process*, from the annulated appearance which it presents, owing to transverse ridges and furrows upon it. On the upper surface of the cerebellum, the worm is only slightly elevated above the level of the lateral portions, but on the under surface it is sunk almost out of sight in a deep depression, which is called the *vallecula*. The lateral parts are called *hemispheres*; they attain a considerable size, overlapping and obscuring the inferior part of the worm. Below and behind they are separated by a deep notch (*posterior cerebellar notch, incisura marsupialis*), and in front by a broader, shallower notch (*anterior cerebellar notch, incisura semilunaris*). The *anterior* notch lies close to the pons and upper part of the medulla, and its upper edge encircles the posterior corpora quadrigemina. The *posterior* notch is free, and contains, in the recent state, the upper part of the falx cerebelli.

The sides of the notches are formed by the margins of the hemispheres, while the bottom of the notches is formed by the anterior and posterior extremities of the worm respectively. The cerebellum is characterized by its laminated or foliated appearance; it is everywhere marked by deep, transverse, somewhat curved fissures, which lie close together, and extend for a considerable depth into the substance of the cerebellum, dividing it into a series of layers or leaves. Upon making sections across the laminæ it will be seen that the folia, though differing in appearance from the convolutions of the cerebrum, are homologous with them, inasmuch as they consist of a central white substance, with a covering or cortex of gray matter.

The largest and deepest fissure is the *great horizontal fissure*. It commences in front at the pons, and passes horizontally round the free margin of the hemisphere to the middle line behind, and divides the cerebellum into an upper and

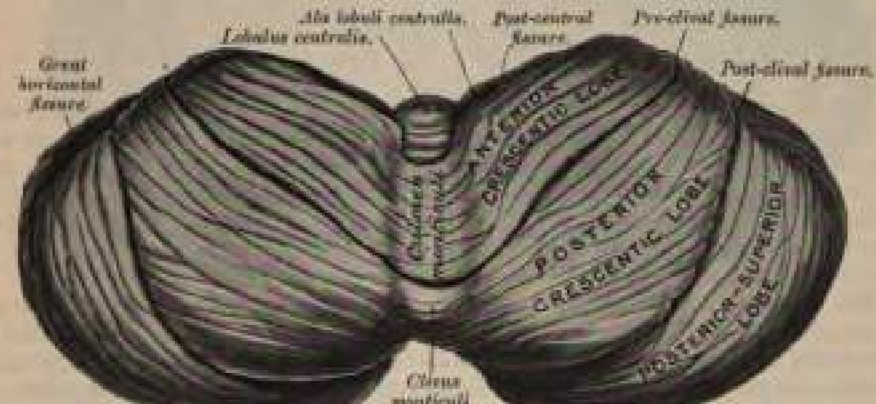

FIG. 363.—Upper surface of the cerebellum. (Schäfer.)

lower portion. Several secondary but deep fissures separate the cerebellum into lobes, and these are further subdivided by shallower sulci, which separate the individual folia or laminæ from each other.

The cerebellum is connected to the cerebrum, pons, and medulla by three pairs of peduncles; which will be described in the sequel; a *superior* pair, connect it with the cerebrum; a *middle* pair, with the pons; and an *inferior* pair, with the medulla.

Upper Surface of Cerebellum (Fig. 363).—The superior surface of the cerebellum is somewhat elevated in the middle line and sloped toward its circumference, its hemispheres being connected together by an elevated median portion or lobe, the *superior worm or superior vermiform process*. The surface is traversed by four curved fissures, which are named from their situation, in front or behind two prominent lobes of the worm, the central lobe and the clivus, (1) the pre-central fissure, (2) the post-central fissure, (3) the pre-clival fissure, and (4) the post-clival fissure. These four fissures divide the entire upper surface of the cerebellum into five lobes, but the portion of the lobe in the worm has received a different name from that in the hemisphere, though the two are continuous with each other. The five lobes in the worm are named from before backward: (1) the *lingula*, (2) the *lobulus centralis*, (3) the *culmen monticuli*, (4) the *clivus monticuli*, and (5) the *folium cacuminis*. The five lobes in the hemispheres are named from before backward: (1) the *frenulum*, (2) the *ala lobuli centralis*, (3) *anterior crescentic*, (4) *posterior crescentic*, and (5) *posterior superior*. The arrangement of these fissures and lobules will be understood by reference to the accompanying schematic arrangement, in which the lobules are named in order from before backward with the fissures which separate them:

UPPER SURFACE OF THE CEREBELLUM.

Worm.		*Hemisphere.*
Lingula.		Frænulum.
	Pre-central fissure.	
Lobulus centralis.		Ala lobuli centralis.
	Post-central fissure.	
Culmen monticuli.		Anterior crescentic lobe.
	Pre-clival fissure.	
Clivus monticuli.		Posterior crescentic lobe.
	Post-clival fissure.	
Folium cacuminis.		Posterior superior lobe.

The **lingula** is a tongue-shaped process of the cerebellum, which lies in front of the lobulus centralis and is partially or completely concealed by it. It is in relation, in front, with the valve of Vieussens, on the dorsal surface of which it rests and with which it is connected; its white matter being continuous with that of the valve. At either side the lingula gradually shades off, and is prolonged only for a short distance into the hemispheres, where it forms the **frænulum**. This does not stretch beyond the superior peduncle of the cerebellum over which it lies.

The Lobulus Centralis.—The lobulus centralis is a small square lobe, situated in the anterior notch. It overlaps the lingula and is in turn partially concealed by the culmen monticuli. Laterally the lobulus centralis extends along the upper and anterior part of each hemisphere, where it forms a wing-like prolongation, the **ala lobuli centralis.**

The **culmen monticuli** is much larger than the two lobes just described, and constitutes, with the succeeding lobe, the clivus, the bulk of the upper worm. In front it partially overlaps and obscures the lobulus centralis, and behind it is separated from the clivus by the *pre-clival fissure.* It forms the most prominent part of the upper worm, and is marked on its surface by three or four secondary fissures, dividing it up into smaller lobules. Laterally it is continuous with the **anterior crescentic lobe** of the hemispheres, which is distinctly differentiated from the posterior crescentic lobe by the pre-clival fissure, though the two were formerly classed together as the quadrate lobe of the lateral hemisphere.

The **clivus monticuli** is of considerable size, and, as stated above, forms with the culmen the major part of the superior worm. It consists of a group of laminæ, which in front are separated from the culmen by the pre-clival fissure and behind appear to be almost continuous with the folium cacuminis, especially in the median line; but it will be found, on careful examination, to be separated from it by a well-defined fissure, the *post-clival* fissure. Laterally this lobe is continued into the hemispheres as the **posterior crescentic lobe,** which is somewhat semilunar in shape, and, with the anterior crescentic lobe, constitutes the greater part of the upper surface of the hemispheres.

The **folium cacuminis** is a short and narrow, concealed band at the posterior extremity of the worm, consisting apparently of a single folium, but in reality marked on its upper and under surfaces by secondary fissures. Laterally it expands in either hemisphere into a considerable lobe, which is semilunar in shape, and is situated at the postero-superior part of the hemisphere and bounded below by the great horizontal fissure. It is named the **posterior superior lobe** and occupies the posterior third of the upper surface of the hemisphere, forming its rounded postero-lateral border.

The **Under Surface of the Cerebellum** (Fig. 364) presents in the middle line the *inferior worm,* buried in the vallecula, and separated from the hemispheres by lateral grooves. Here, as on the upper surface, there are deep fissures, dividing it into separate segments or lobes, but the arrangement is more complicated, and the relation of the segments of the worm to those of the hemisphere is less clearly marked. The fissures are three in number, but are not so regularly disposed as

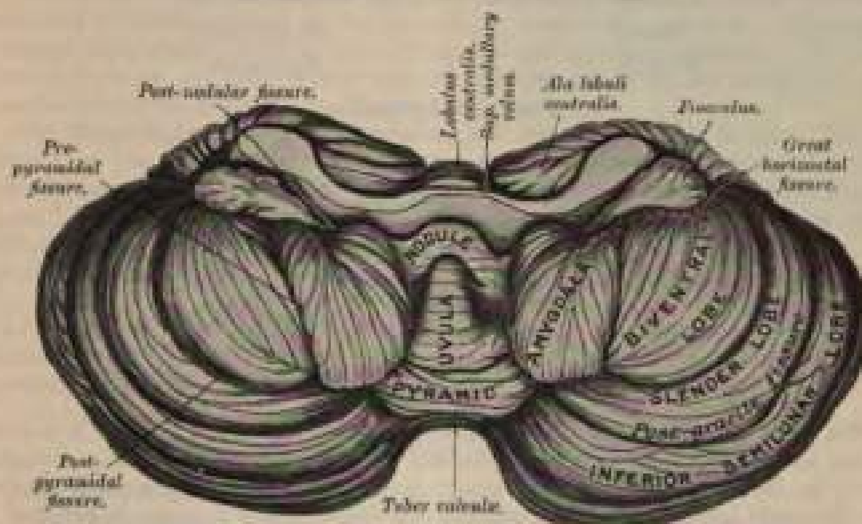

FIG. 364.—Under surface of the cerebellum. (Schäfer.)

those on the upper surface (Fig. 365). They are named, from their relation to the pyramid and nodule, two of the lobes on the under surface of the worm, (1) *post-nodular*, (2) *pre-pyramidal*, and (3) *post-pyramidal fissures*. The part of the worm in front of the post-nodular fissure is termed the *nodule*, and the lobule in the hemisphere corresponding with this is the *flocculus*. The next lobe is situated between

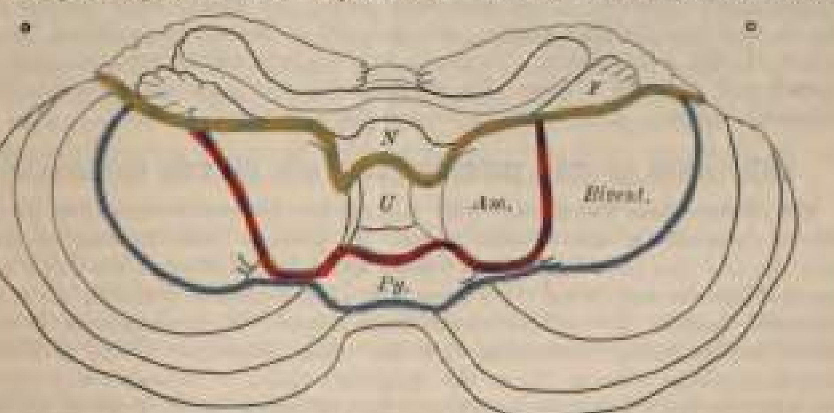

FIG. 365.—Diagram showing fissures on under surface of the cerebellum: F., flocculus; N., nodule; U, uvula; Py., pyramid; Am., amygdala; Bivent., biventral lobe.

the post-nodular and pre-pyramidal fissures. In the vermiform process it is known as the *uvula*, and its lateral expansion in the hemisphere is named the *amygdala* or *tonsil*. The lobule of the worm between the pre- and post-pyramidal fissures is the *pyramid*, and its corresponding part in the hemisphere is the *biventral* or *digastric* lobe. Finally, behind the post-pyramidal fissure in the worm is a small lobe, the *tuber valvulæ* or *tuber posticum*; this, in the hemispheres, expands into a large lobe, which occupies at least two-thirds of the inferior surface of the cerebellum, and is subdivided into two by a secondary fissure, named the *post-gracile* fissure. The anterior of the two subdivisions is named the *slender* lobe; and the posterior, the *inferior semilunar* or *posterior inferior lobe*. These fissures and lobes are here arranged, from before backward, in a schematic form:

UNDER SURFACE OF THE CEREBELLUM.

Worm.	*Hemisphere.*
Nodule.	Flocculus.
Post-nodular fissure.	
Uvula.	Amygdala.
Pre-pyramidal fissure.	
Pyramid.	Biventral lobe.
Post-pyramidal fissure.	
Tuber valvulæ.	Slender lobe. *Post-gracile fissure.* Inferior semilunar lobe.

The **chief fissures of the under surface,** as stated above, are three in number, and are not so regularly disposed as on the upper surface. (1) The *post-nodular fissure* in the worm courses transversely across it, separating the nodule in front from the uvula behind. When it reaches the hemispheres it passes in front of the amygdala, and then crosses between the flocculus in front and the biventral lobe behind, and joins the anterior end of the great horizontal fissure. (2) The *pre-pyramidal fissure* crosses the worm between the uvula in front and the pyramid behind, then curves laterally behind the amygdala, and passes forward along the outer border of this lobe, between it and the biventral lobe, to join the post-nodular sulcus. (3) The *post-pyramidal fissure* passes across the worm behind the pyramid and in front of the tuber valvulæ, and in the hemispheres courses behind the amygdala and biventral lobes, and then along the outer border of the biventral lobe to the post-nodular sulcus. It cuts off at least two-thirds of the inferior surface of the hemisphere. From it a secondary sulcus springs, and coursing forward and outward divides this surface into two parts and falls into the great horizontal fissure. This sulcus is termed the *post-gracile fissure*.

THE LOBES OF THE INFERIOR SURFACE OF THE CEREBELLUM.

The Nodule and Flocculus.—The nodule is a distinct prominence, forming the anterior extremity of the inferior worm. It projects into the roof of the fourth ventricle, and can only be distinctly seen after the cerebellum has been separated from the medulla and pons. On each side of the nodule is a thin layer of white substance, named the *inferior medullary velum*. It is semilunar in form, its convex border being continuous with the white substance of the cerebellum; it extends on either side as far as the flocculus, which it connects with the nodule. The flocculus is a prominent, irregular lobule, situated just in front of the biventral lobe, between it and the middle peduncle of the cerebellum. It is subdivided into a few small laminæ, and is connected to the inferior medullary velum by its central white core.

The Uvula and Amygdalæ.—The uvula occupies a considerable portion of the inferior worm; it is separated on either side from the amygdala by a deep groove, the *sulcus valleculæ*, at the bottom of which it is connected to the amygdala by a commissure of gray matter, indented on its surface, and called the *furrowed band*. It is marked on its surface by three or four transverse fissures. The amygdalæ, or tonsils, are rounded masses, situated in the lateral hemispheres. Each lies in a deep fossa between the uvula and the biventral lobe; this fossa is known by the name of the *bird's nest* (*nidus avis*).

The Pyramid and Biventral Lobes.—The pyramid is a conical projection, forming the largest prominence of the lower worm. It is separated from the hemispheres by the sulcus valleculæ, across which it is connected to the biventral lobe by an indistinct band of gray matter, analogous to the furrowed band already described. The biventral lobe is triangular in shape, with the apex pointing inward and backward to become joined by the connecting band to the pyramid. The external border is separated from the slender lobe by the post-pyramidal fissure. The base is directed forward, and is on a line with the anterior border of the amygdala, and is separated from the flocculus by the post-nodular fissure.

The Tuber Valvulæ or Tuber Posticum, and Posterior Inferior Lobes.—The tuber valvulæ is the posterior division of the inferior worm. It is of small size, and laterally spreads out into the large posterior inferior lobes of the hemispheres. These lobes, which, as stated above, comprise at least two-thirds of the inferior surface of the hemisphere, are divided into two by the post-gracile fissure. The anterior lobe is named the *slender lobe*, and the posterior, the *inferior semilunar lobe*. Both these lobes show a tendency to subdivision into two; that of the slender lobe is well marked, and its subdivisions are sometimes described as distinct lobes and named the *anterior* and *posterior slender lobes*, the fissure between them being termed the *intra-gracile fissure*.

INTERNAL STRUCTURE OF THE CEREBELLUM.

The cerebellum consists of white and gray matter.

The White Matter.—If a sagittal section (Fig. 366) is made through either hemisphere of the cerebellum, the interior will be found to consist of a central stem of white matter, which contains in its interior a gray mass, the *corpus dentatum*. From the surface of this central stem a series of plates of medullary matter are detached, which, covered with gray matter, form the laminæ. In consequence of the main branches from the central stem dividing and subdividing, the section presents a characteristic appearance, which is named the *arbor vitæ*. If a vertical section is made in the median plane of the cerebellum it will be found that the central stem divides into two main branches, which, from their direction, may be named respectively the vertical and the horizontal branch. The *vertical* branch passes upward to the culmen, where it subdivides freely, some of its ramifications passing forward and upward to the central lobe. The *horizontal* branch passes backward to the folium cacuminis, considerably diminished in size in consequence of having given off large secondary branches: one, from its upper surface, ascends to the clivus; the others descend, and enter the lobes in the inferior vermiform process, the tuber valvulæ, the pyramid, the uvula, and the nodule. It is not necessary to describe in detail the various divisions of the white matter, as they correspond to the lobes on the surface.

The white matter of the cerebellum includes two varieties of nerve matter: (1) the *peduncular fibres*, which are directly continuous with those of the peduncles of the cerebellum; (2) the fibres proper (*fibræ propriæ*) of the cerebellum itself.

The Peduncles of the Cerebellum.—From the anterior part of each hemisphere arise three large processes or peduncles—superior, middle, and inferior—by which the cerebellum is connected with the rest of the encephalon.

The **superior peduncles** form the upper lateral boundaries of the floor of the fourth ventricle. As they extend forward and upward they converge on the dorsal aspect of the ventricle, and thus assist to roof it in. They may be traced as far as the corpora quadrigemina, under which they pass. They enter the upper and mesial part of the medullary substance of the hemispheres, beneath the ala lobuli centralis and the frænulum, and pass to a great extent into the interior of the corpus dentatum, though some of their fibres wind round it and reach the gray cortical matter, especially of the inferior surface.

The fibres of the superior peduncles mainly emerge from the hilum of the corpus dentatum; others come from the cortex and probably also from the smaller nuclei in the central white substance. The majority of the fibres decussate with those of the opposite peduncle below the corpora quadrigemina, and pass to the red nucleus of the tegmentum, from which a relay is prolonged through the optic thalamus to the cerebral cortex. Fibres also connect the spinal cord with the cerebellum through its superior peduncles; these are chiefly derived from the antero-lateral ascending cerebellar tract of Gowers.

The Valve of Vieussens or Superior Medullary Velum.—Stretched across from one superior peduncle to the other is a thin, transparent lamina of white matter, the *valve of Vieussens*; on to the dorsal surface of its lower half the folia of the lingula are prolonged. It forms with the superior peduncles the roof of the upper part of the fourth ventricle, and is continuous with the central white stem of the cerebellum. It is narrow above, where it passes beneath the corpora quadrigemina, and broader below, at its connection with the white substance of the superior worm of the cerebellum. A slight elevated ridge descends upon the upper part of the valve from between the lower corpora quadrigemina, and on either side of this may be seen the fourth nerve.

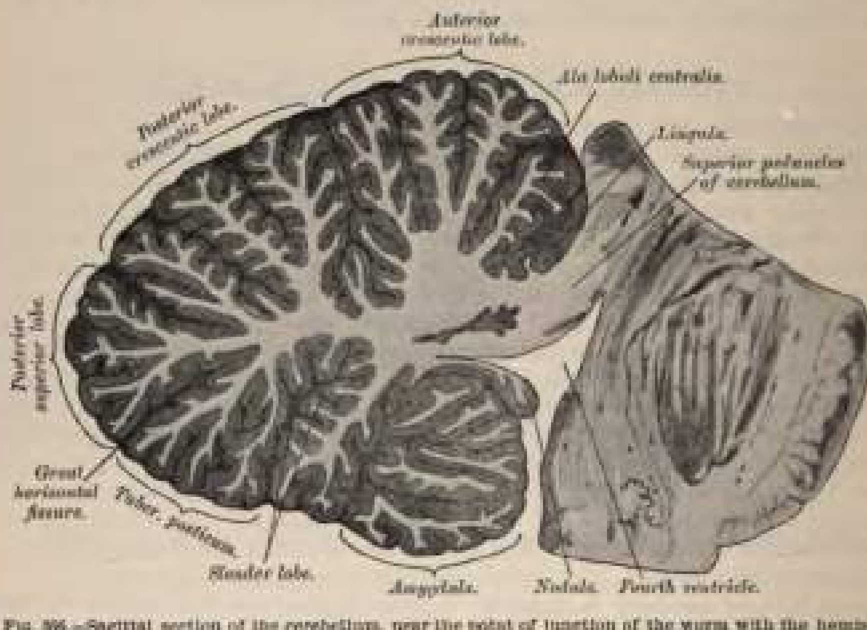

FIG. 396.—Sagittal section of the cerebellum, near the point of junction of the worm with the hemisphere. (Schäfer.)

The **middle peduncles** are the largest of the three pairs. They consist of a mass of curved fibres, which, as already described, comprises most of the transverse fibres of the pons. They enter the cerebellum between the margins of the great horizontal fissure at the anterior notch, and the fibres spread out in all directions: some passing to the upper part, and some to the lower part of the hemisphere, while others pass to its middle region. Of the fibres contained in the middle peduncles many are commissural between the two hemispheres of the cerebellum; others apparently end in the gray matter; others have been described as giving fibres to the posterior longitudinal bundle, and through it to the nuclei of the third, fourth, and six nerves. Cajal describes still another set, which have their origin in the gray reticular formation of the pons, and which pass partly into the peduncle of the same side and partly into that of the opposite side.

The **inferior peduncles** connect the cerebellum with the medulla oblongata. As the restiform bodies of the latter, they will be described in the sequel. They pass upward and outward, forming part of the lateral wall of the fourth ventricle, and enter the cerebellum beneath the middle peduncle; passing upward they end in the gray cortex of the upper surface of the hemisphere, some being prolonged into the white matter of the superior vermiform process. The following are the chief sets of fibres in the inferior peduncles: (1) from the direct cerebellar tract of the spinal cord; (2) from the gracile and cuneate nuclei (crossed and uncrossed fibres); (3) from the opposite olivary body of the medulla; (4) fibres to the nuclei of the fifth, eighth, ninth, and tenth nerves; (5) descending cerebellar fibres which pass down the restiform body and antero-lateral column of the cord to terminate around the cells in the anterior horn of the cord.

The **fibræ propriæ of the cerebellum** are of two kinds: (1) *commissural fibres*, which cross the middle line to connect the opposite halves of the cerebellum, some at the anterior part, and others at the posterior part of the vermiform process; (2) *arcuate* or *association fibres*, which connect adjacent laminæ with each other.

The **gray matter** of the cerebellum is found in two situations: (1) on the surface, forming the cortex; (2) as independent masses in the interior.

1. The **gray matter of the cortex** presents a characteristic foliated appearance, due to the series of laminæ which are given off from the central white matter; these in their turn give off secondary laminæ, which are covered with gray matter. This

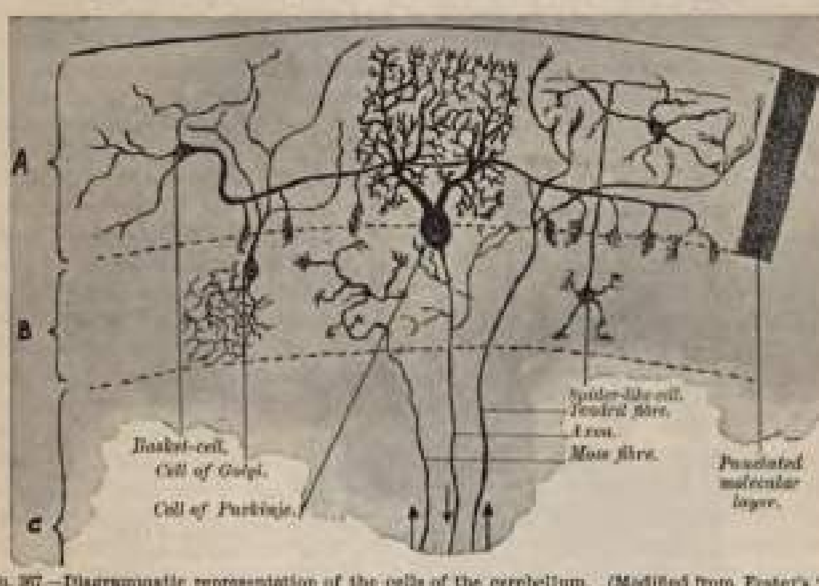

FIG. 367.—Diagrammatic representation of the cells of the cerebellum. (Modified from Foster's "Physiology.") A, molecular layer; B, nuclear layer; C, white matter.

arrangement gives to the cut surface of the organ a foliated appearance (Fig. 366). Externally, the cortex is covered by pia mater; internally, is the medullary centre, consisting mainly of nerve-fibres.

Microscopic Appearance of the Cortex.—The cortex presents a remarkable structure, consisting of two distinct layers, viz., an external gray molecular layer, and an internal, rust-colored, granular layer. Between the two layers is an incomplete stratum of the characteristic cells of the cerebellum, the *corpuscles of Purkinje*.

The *external gray* or *molecular layer* (Figs. 367, 368) consists of fibres and cells. The nerve-fibres are delicate fibrillæ, and are derived from the following sources: (*a*) the dendrites and axon collaterals of Purkinje's cells; (*b*) fibres from cells in the granular layer; (*c*) fibres from the central white substance of the cerebellum; (*d*) fibres derived from cells in the molecular layer itself. In addition to these are other fibres, which have a vertical direction. These are the processes of large glia-cells, situated in the granular layer. They pass outward to the periphery of the gray matter, where they expand into little conical enlargements, which form a sort of limiting membrane beneath the pia mater, analogous to the membrana limitans interna in the retina, formed by the fibres of Müller.

The *cells* of the molecular layer are small, and are arranged in two strata, an outer and an inner. They all possess branching axis-cylinder processes; those of the inner layer run for some distance horizontally, *i. e.*, parallel with the surface of the folia, giving off at intervals collaterals, which pass in a vertical direction toward the cell-bodies of Purkinje's corpuscles, around which they become enlarged, and ramify like a basket. Hence these cells of the inner layer are named *basket-cells.*

The *corpuscles of Purkinje* (Fig. 368) are flask-shaped cells, situated at the junction of the molecular and granular layers, their bases resting against the latter.

FIG. 368.—Vertical section through the gray matter of the human cerebellum. Magnified about 100 diameters. (Klein and Noble Smith.)

From the bottom of the flask the axis-cylinder process arises; this passes through the granular layer, and, becoming medullated, is continued as a nerve-fibre in the medullary substance beneath. This axon gives off fine collaterals as it passes through the granular layer, some of which run back into the molecular layer. From the neck of the flask numerous dendrites are given off, which branch in an antler-like manner in the molecular layer and terminate in free extremities.

The *internal rust-colored* or *granular layer* (Fig. 368) is characterized by containing numerous small nerve-cells or granules of a reddish-brown color, together with many nerve-fibrils. Most of the cells are nearly spherical and provided with short dendrites, which spread out in a spider-like manner in the granular layer. Their axons pass outward into the molecular layer, and, bifurcating at right angles, run horizontally for some distance. In the outer part of the granular layer are also to be observed some larger cells, of the type termed *Golgi cells* (Fig. 367). Their axons undergo frequent division as soon as they leave the nerve-cells, and pass into the granular layer, while their dendrites ramify chiefly in the molecular layer.

Finally, in the gray matter of the cerebellar cortex fibres are to be seen which come from the white centre and penetrate the cortex. The cell origin of these fibres is unknown, though it is believed that it is probably in the gray matter of the spinal cord. Some of these fibres end in the granular layer, by dividing into numerous branches, on which are to be seen peculiar moss-like appendages; hence they have been termed by Ramón y Cajal the "moss fibres"; they form an arborescence around the cells of the granular layer. Other fibres derived from the medullary centre can be traced into the molecular layer, where their branches cling around the dendrites of Purkinje's cells, and hence they have been named the *clinging* or *tendril fibres*.

2. The **independent centres of gray matter in the cerebellum** are four in number on each side: one is of large size, and is known as the corpus dentatum; the other three, much smaller, are situated near the middle of the cerebellum, and are known as the nucleus emboliformis, nucleus globceus, and nucleus fastigii.

The *corpus dentatum* or *ganglion of the cerebellum* is situated a little to the inner side of the centre of the stem of the white matter of the hemisphere. It consists of an irregularly folded lamina of a grayish-yellow color, containing white fibres, and presenting on its antero-internal aspect an opening, the hilum, from which most of the fibres of the superior cerebellar peduncle emerge.

The *nucleus emboliformis* is a mass of gray matter placed immediately to the inner side of the corpus dentatum, and partly covering its hilum. The *nucleus globosus* is an elongated mass of gray matter, directed antero-posteriorly, and placed to the inner side of the preceding. The *nucleus fastigii* is somewhat larger than the other two, and is situated close to the middle line at the anterior end of the superior vermiform process, and immediately over the roof of the fourth ventricle, from which it is separated by a thin layer of white matter. It is known as the *roof nucleus of Stilling*.

Weight of the Cerebellum.—Its average weight in the male is about 5 oz., 4 drs. It attains its maximum weight between the twenty-fifth and fortieth years, its increase in weight after the fourteenth year being relatively greater in the female than in the male. The proportion between the cerebellum and cerebrum is, in the male, as 1 to 8½, and in the female as 1 to 8. In the infant the cerebellum is proportionately much smaller than in the adult, the relation between it and the cerebrum being, according to Chaussier, between 1 to 13, and 1 to 26; by Cruveilhier the proportion was found to be 1 to 20.

V. The Medulla Oblongata (Fig. 370).

The **medulla oblongata** or **metencephalon**, known also as the **spinal bulb**, is the lowest division of the encephalon, and is continuous with the spinal cord. It is developed from the fifth cerebral vesicle, the cavity of which forms the lower half of the fourth ventricle. It extends from the lower margin of the pons Varolii to a plane passing transversely just below the decussation of the pyramids, at which level the spinal cord commences. This plane corresponds to the lower margin of the foramen magnum. The upper limit of the medulla is marked off from the pons Varolii on its ventral aspect by the abrupt lower margin of the latter.

The medulla oblongata is directed from above obliquely downward and backward; its ventral surface rests on the basilar groove of the occipital bone, while its dorsal surface is received into the fossa between the hemispheres of the cerebellum, and forms the lower part of the floor of the fourth ventricle. It is pyramidal in shape, its broad extremity directed upward, its lower end being narrow at its point of connection with the cord. It measures an inch in length, three-quarters of an inch in breadth at its widest part, and half an inch in thickness. Its surface is marked, in the median line, in front and behind, by an *anterior* and a *posterior median fissure*, which are continuous with similar fissures on the anterior and posterior surfaces of the cord. The anterior fissure contains a fold of pia mater, and terminates just below the pons in a *cul-de-sac*, the *foramen cæcum* of Vicq d'Azyr. It is interrupted at its lower part by some bundles of fibres, which cross obliquely from one side to the other, forming the *decussation of the pyramids*. The posterior is a deep but narrow fissure, continued upward to about the middle of the medulla, where it expands into the fourth ventricle.

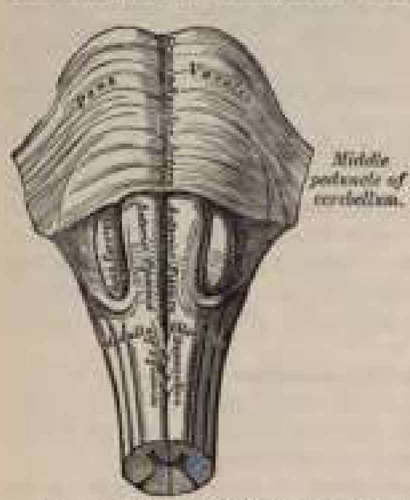

FIG. [illegible].—Medulla oblongata and pons Varolii. Anterior surface.

These two fissures divide the medulla into two symmetrical halves, each half presenting elongated eminences, which are continuous with the columns of the cord. By taking the lines along which some of the cranial nerves emerge from the medulla, as landmarks, the surface of this portion of the nervous system may be divided into three columns, in the same way as the spinal cord is divided into three columns by the lines corresponding to the points of exit of the anterior and posterior roots of the spinal nerves. The anterior column comprises that portion which is situated between the anterior median fissure and the fibres of origin of the hypoglossal nerve: this column is called the *pyramid*. The lateral column comprises that portion which is situated between the fibres of origin of the hypoglossal nerve and the fibres of origin of the glosso-pharyngeal, pneumogastric, and spinal accessory nerves. In the lower part of the medulla this column is single, and is called the *lateral tract;* but in the upper part an oval-shaped body comes forward between it and the pyramid, and pushes aside the lateral tract. This is called the *olivary body*. The posterior column comprises that portion which is situated between the fibres of the origin of the glosso-pharyngeal, pneumogastric, and spinal accessory nerves and the posterior median fissure. It is marked by slight furrows dividing it into smaller columns, and these in the lower part of the medulla are named, from without inward, the *funiculus of Rolando*, the *funiculus cuneatus*, and the *funiculus gracilis;* in the upper part of the medulla, the funiculus of Rolando and the funiculus cuneatus appear to become fused together, forming a single body, called the *restiform body* (Fig. 370).

The **pyramids** are two pyramidal bundles of white matter, placed one on either side of the anterior median fissure, and separated from the olivary body by a slight depression, from which the roots of the hypoglossal nerve emerge. At the lower border of the pons these bodies are somewhat constricted and are here crossed by a band of arched fibres, the *ponticulus* of Arnold: below this they become enlarged, and then taper as they descend to their lower extremity. The fibres of which these pyramids are composed may be arranged in two bundles: an outer, continuous below with the direct pyramidal tract of the anterior column of the same side of the spinal cord, and an inner, continuous with the crossed pyramidal tract of the lateral column of the opposite side of the cord. As will be subsequently mentioned, the direct pyramidal tract in the cord lies next to the anterior median fissure, but as the crossed pyramidal tract of the cord ascends to the medulla it decussates with its fellow of the opposite side across the anterior median fissure, and so displaces laterally the direct pyramidal tract, and ascends, after decussation, through the medulla to its inner or mesial side. This decussation is usually spoken of as the *decussation of the pyramids*, but it must be borne in mind that it is only a portion of the fibres of the pyramid which decussate: namely, those derived from the crossed pyramidal tract of the cord; the outermost fibres, derived from the anterior column of the cord, do not decussate. Each pyramid enters the substance of the pons in one bundle, and may be traced through it, after breaking up into several smaller fasciculi, into the corresponding crus cerebri.

The **lateral column**, in the lower part of the medulla, is of the same width as the lateral column of the cord, and appears on the surface to be a direct continuation of it. As a matter of fact it is only a part of the lateral column of the spinal cord which is continued upward into this column; for the crossed pyramidal tract passes into the pyramid of the opposite side, and the direct cerebellar tract of the lateral column of the cord passes into the restiform body. The rest of the lateral column of the cord, that is to say, the antero-lateral ground bundle and the antero-lateral cerebellar tract, can be traced upward into this area. In the upper part of the medulla, the lateral tract, on account of the interpolation of the olivary body, becomes almost concealed by this body.

Fig. 370.—Posterior surface of the medulla oblongata.

The **olivary body** is a prominent oval mass, situated on the outer side of the pyramid, from which it is separated by a slight groove, along which the fibres of the hypoglossal nerve emerge. It is separated externally from the restiform body by a longitudinal, narrow band of fibres, prolonged upward from the lateral tract, and by a groove, from which the glosso-pharyngeal, pneumogastric, and spinal accessory nerves arise. It is equal in breadth to the pyramid; it is broader above than below, and is about half an inch in length, being separated above from the pons Varolii by a slight depression, in which a band of arched fibres is sometimes to be seen. Numerous white fibres (*superficial arciform fibres*) are seen winding across the lower half of the pyramid and the olivary body to enter the restiform body.

The **funiculus of Rolando** is a longitudinal prominence on the outer side of the lateral tract. It begins at the lower end of the medulla by a tapering extremity, and has, apparently, no corresponding column in the cord. It gradually enlarges as it ascends, and forms, at a level with the lower border of the olivary body, a considerable prominence, known as the *tubercle of Rolando*. This is caused by the substantia gelatinosa of Rolando of the cord gradually finding its way to the surface, so as to form a prominence there. About half an inch below the pons the funiculus of Rolando appears to blend with the funiculus cuneatus. In front, it is separated from the lateral tract by a distinct groove, the continuation upward of the postero-lateral groove of the cord; behind, the separation from the funiculus cuneatus is much less distinct.

The **funiculus cuneatus** is the direct continuation upward of the postero-lateral column (tract of Burdach) of the cord. It is situated between the funiculus of Rolando and the funiculus gracilis. It enlarges as it ascends, and forms, opposite the lower extremity of the fourth ventricle, a slight eminence or enlargement, the *cuneate tubercle*, which is best marked in children. Above this point it disappears from the surface.

The **funiculus gracilis** is the direct continuation upward of the postero-median column of the cord (tract of Goll). It is a narrow white band, placed parallel to and along the side of the posterior median fissure. It is separated from the funiculus cuneatus by a slight groove, continuous with that on the surface of the cord, which marks off the postero-median column. At first the funiculi of the two sides lie in close contact on either side of the posterior median fissure. Opposite the apex of the fourth ventricle each presents an enlargement, the *clava*; they then diverge and form the lateral boundaries of the lower part of the fourth ventricle, and gradually tapering off become no longer traceable.

The Restiform Body.—The upper part of the posterior area of the medulla is occupied by the *restiform body*. It appears, at first sight, as if this body were the direct continuation upward of the funiculus cuneatus and the funiculus of Rolando, and it was formerly described as such. This, however, is not so, for the restiform body is largely formed by a set of fibres, the *external arcuate fibres*, which issue from the anterior median fissure and will presently be described. They pass laterally over the pyramid and olive, and assist in forming the restiform body. There is also a narrow strand of fibres, derived from the lateral column of the cord, the *direct cerebellar tract*, which joins the above-mentioned arcuate fibres. These two sets of fibres, reinforced by the *internal arcuate fibres* from the opposite side of the medulla, form the restiform body.

The restiform bodies are the largest prominences of the medulla, and are placed between the lateral tracts in front and the funiculus cuneatus behind, from both of which they are separated by slight grooves. As they ascend they diverge from each other, assist in forming the lower part of the lateral boundaries of the fourth ventricle, and then enter the corresponding hemisphere of the cerebellum, forming its inferior peduncles.

The **posterior surface of the medulla oblongata** forms part of the floor of the fourth ventricle. This portion is of a triangular form, bounded on each side by the diverging funiculi graciles and cuneati and restiform bodies. The divergence of these two funiculi and of the restiform bodies, together with the opening out of the posterior fissure and central canal of the spinal cord, displays in the floor of the ventricle the gray matter of the medulla, which is continuous below with the gray matter of the cord. In the middle line is seen a longitudinal furrow, which divides this part of the ventricle into right and left halves, and is continuous below with the central canal of the cord.

The **arciform** or **arcuate** fibres, which have been mentioned as forming part of the restiform body, are found in the upper half of the medulla, crossing its surface and also traversing its substance. They are divided for purposes of description into two sets—external and internal. The *external* or *superficial arciform fibres* have already been alluded to as crossing the pyramid and olivary body on each side. They emerge from the anterior median fissure, and if traced into it are found to enter the raphé and cross to the opposite side, after which their further course is a matter of some doubt. After emerging from the anterior median fissure they cross the pyramid and olivary body, often concealing from view the upper part of the cuneate and Rolandic funiculi, and enter the restiform body. As they cross the olivary body they are reinforced by some of the internal arciform fibres, which come to the surface on the inner side of, or through, this structure. The *internal arciform fibres* are described with the microscopic anatomy of the medulla.

It is advisable, at this stage, to take up the consideration of the cavity of the fourth ventricle, an acquaintance with which will render the description of the internal structure of the medulla oblongata more intelligible.

The Fourth Ventricle (Fig. 371).

The fourth ventricle is lozenge- or diamond-shaped; that is to say, it is composed of two triangles, with their bases in contact. The sides of the lower triangle are formed by the divergence of the funiculi graciles, funiculi cuneati, and restiform bodies of the medulla on either side. As these columns pass upward in the medulla they turn outward from the median line, and, diverging from each other, form the lateral boundaries of the lower half of the fourth ventricle. In like manner the sides of the upper triangle are formed by the convergence of the superior peduncles of the cerebellum. These peduncles are separated below by a somewhat wide interval, but as they pass upward and forward toward the corpora quadrigemina they gradually converge and ultimately come into contact with each other. This cavity is therefore bounded laterally by the superior peduncles of the cerebellum in its upper half, and by the funiculi graciles, the funiculi cuneati, and the restiform bodies in its lower half. It presents four angles. The upper angle reaches as high as the upper border of the pons, and corresponds with the lower opening of the aqueduct of Sylvius, by which this ventricle communicates with the third ventricle. The lower angle is on a level with the lower border of the olivary body, and is continuous with the central canal of the spinal cord. From the resemblance that it bears to the point of a writing pen it has been named the *calamus scriptorius*. Its lateral angles extend for some distance between the medulla and the cerebellum, each forming a pointed *lateral recess*.

The *roof* of the fourth ventricle is formed from above downward by the following structures: a part of the superior peduncles of the cerebellum, the superior medullary velum, the inferior medullary velum, the tela choroidea inferior, the obex, and the ligula.

The **superior peduncles of the cerebellum**, when they emerge from the medullary substance of its hemispheres, pass upward and forward, forming the lateral boundaries of the upper half of the fourth ventricle, but, converging as they approach the corpora quadrigemina, the mesial portions of the peduncles form a part of the roof of the cavity, in consequence of the ventricle extending to a slight extent underneath the peduncles.

The Superior Medullary Velum (Valve of Vieussens).—In the angular interval left between the two superior peduncles is a thin lamina of white matter, continuous with the white centre of the cerebellum, which bridges across from one peduncle to the other, and so completes the roof of the superior part of the ventricle. This is the *superior medullary velum*, or *valve of Vieussens*. Its dorsal surface is covered by the folia of the lingula, already described (page 686).

The **inferior medullary velum** is a thin layer of white substance, prolonged from the white centre of the medulla on either side of the nodule, which assists in forming a part of the roof of the fourth ventricle, stretching over it toward its lateral angles. It is continuous with the white substance of the cerebellum by its convex edge, while its thin concave margin is apparently free. In reality, however, it is continuous with the epithelium of the ventricle, which is prolonged downward from the velum to the edge of the ligula.

The **tela choroidea inferior** is a layer of pia mater, which covers in the lower part of the fourth ventricle below the inferior medullary velum. Superiorly it is reflected on to the under surface of the cerebellum, while inferiorly it is continued on to the restiform bodies and lower part of the medulla. This part of the roof of the ventricle contains no nervous matter, but consists merely of the ventricular epithelium covered by pia mater. The tela choroidea inferior, like the superior, really consists of two layers, which become more or less adherent, viz., that covering the under surface of the cerebellum and that covering the epithelium. It also possesses a pair of choroid plexuses, which project into the ventricular cavity invaginating before them the epithelial lining. Each plexus consists of a *vertical* portion which extends forward, near the middle line, from the foramen of Majendie, and of a *transverse* part, which passes outward into the lateral recess of the ventricle as far as the foramina of Key and Retzius. The two plexuses present the form of a T, the vertical limb of which is, however, double, ╥. The tela does not form a complete membrane, for in it there are three openings, one in the middle line at the inferior angle of the ventricle, just above the position of the opening of the central canal of the cord; this is the *foramen of Majendie:* the other two are at the extremities of the lateral recesses of the ventricle, and are named the *foramina of Key and Retzius* (see page 642). Through these foramina the ventricles of the brain communicate with the subarachnoid space.

The **obex** is a thin triangular lamina of gray matter, continuous below with the anterior gray commissure of the cord, which fills in the angle between the two diverging funiculi graciles for a short distance.

The **ligula** (*tæniæ*) are narrow bands of white matter, which project from the internal border of the funiculi graciles. They at first run upward and forward,

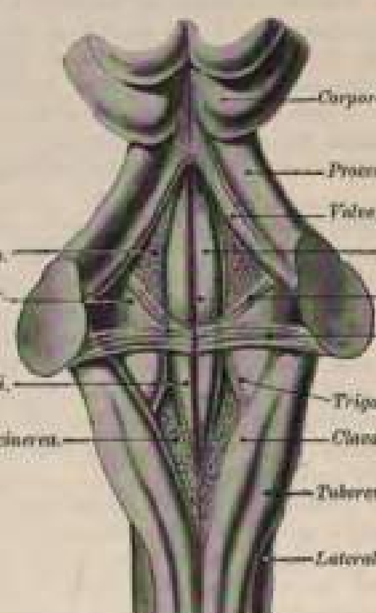

FIG. 371.—Floor of the fourth ventricle. Diagrammatic.

ana then turn outward over the restiform bodies, as far as the latera recesses of the ventricle. Their inner borders are continuous with the epithelial roof of the ventricle.

The **floor of the fourth ventricle** (Fig. 371) is rhomboidal in shape, and is traversed by a vertical median fissure, the *sulcus longitudinalis medianus*. At its widest part, opposite the level of the lateral recesses, it is marked by some transverse white lines, the *striæ medullaris* or *striæ acusticæ*. These consist of white fibres, which emerge from the longitudinal sulcus, and pass outward across the floor of the ventricle.

These striæ divide the floor of the ventricle into two triangles, inferior and superior. The *inferior triangle*, or lower half of the floor, presents above an angular groove, the *fovea inferior*, the apex of which is at the striæ, while the two limbs diverge below, and form the sides of a triangular, dark area, termed the *ala cinerea*, which becomes elevated into a prominence below (*eminentia cinerea*). This area corresponds with the nuclei of the vagus and glosso-pharyngeal nerves, and is therefore termed the *trigonum vagi*. A second triangular area lies between the inner limb of the fovea and the median sulcus; its base is directed upward, and limited by the striæ medullaris. It is termed the *trigonum hypoglossi*, because it corresponds in position to the tract of nerve-cells from which the hypoglossal nerve takes origin. A third triangular area to the outer side of the fovea inferior, is named the *trigonum acustici*. It lies between the groove forming the outer boundary of the fovea inferior and the lateral wall of the ventricle, and, like the trigonum hypoglossi, has its base directed upward. Here it is continuous with a prominence, the *tuberculum acusticum*, which extends into the anterior part of the floor of the ventricle.

The *superior triangle*, or upper half of the floor of the fourth ventricle, *i. e.*, the part above the striæ medullaris, presents in the middle line the continuation of the median longitudinal sulcus. On either side of this is a spindle-shaped longitudinal eminence, prominent in its centre, but less so above and below. This is the *eminentia teres*, and is produced by an underlying bundle of white fibres, the *funiculus teres*, formed, in part at all events, by the fibres of the facial nerve. Immediately above and to the outer side of the eminentia teres is an angular depression, the *fovea superior*; this is sometimes crossed by a whitish band of fibres, the *conductor sonorus*, which is connected below with the striæ medullaris. Above the fovea is a bluish depressed area, the *locus cæruleus*. Its color is due to some pigmented nerve-cells, showing through the white covering of the floor. These pigmented cells are named the *substantia ferruginosa*, and in them one of the roots of the fifth nerve terminates.

The **lining membrane** of the fourth ventricle is continuous above with that of the third, through the aqueduct of Sylvius, and below with that of the central canal of the spinal cord. The cavity of the ventricle communicates below with the subarachnoidean space by means of the foramen of Majendie and the foramina of Key and Retzius, already described.

Internal Structure of the Medulla Oblongata (Fig. 372).

If the cranial nerves emerging from the medulla are traced into its substance, it will be seen that they divide each half into three wedge-shaped areas, which are named the anterior, lateral, and posterior areas of the medulla, and each of which corresponds to one of the subdivisions already described on the surface of this portion of the encephalon.

The **anterior area** comprises that portion which is situated between the anterior median fissure and the fibres of origin of the hypoglossal nerve. On the surface of the medulla this area corresponds to the pyramid.

The **lateral area** is situated between the fibres of origin of the hypoglossal nerve on the one hand, and the fibres of the glosso-pharyngeal, pneumogastric, and spinal accessory nerves on the other. On the surface of the medulla, in its lower part, this area is single, and is called the *lateral tract*; but in the upper part an oval-shaped body, the *olivary body*, comes forward between it and the pyramid, pushing aside the lateral tract.

The **posterior area** comprises that portion which is situated between the fibres of origin of the glosso-pharyngeal, pneumogastric, and spinal accessory nerves, and the posterior median fissure. On the surface of the medulla this area is marked by slight furrows, splitting it up into smaller columns; those in the lower part of the medulla are named, from without inward, the funiculus of Rolando, the funiculus cuneatus, and the funiculus gracilis; in the upper part of the medulla they are replaced by the restiform body. Finally, the halves of the medulla are separated from each other by a median septum or raphé.

Each of these three areas is made up of gray and white matter, the former being derived for the most part from that of the cord. In like manner the white matter is partly made up of longitudinal fibres continuous with those of the cord, and partly of transverse fibres which intersect them.

In order to understand the internal structure of the medulla, it is necessary to describe the appearances as they are seen in the upper and lower portions of the medulla, since they differ considerably in these two parts.

The Lower Part of the Medulla.—The first change in the internal structure is caused by the passage of the fibres of the crossed pyramidal tract obliquely through the gray matter of the anterior horn. As stated above, the pyramid is composed of fibres derived from the direct pyramidal tract of the anterior column of the cord of the same side, and from the crossed pyramidal tract of the lateral column of the opposite half of the cord. Those fibres which are derived from the direct pyramidal tract and which in the cord lie close to the median fissure are in the medulla placed to the outer side of the pyramid, being pushed aside, as it were, by the interpolation of the fibres derived from the crossed pyramidal tract, which are much more numerous. The crossed pyramidal fibres ascend from the lateral column of the spinal cord, and, passing through the anterior gray cornu and across the middle line, form the inner part of the pyramid. In consequence of this passage of white fibres through its substance the anterior gray cornu is

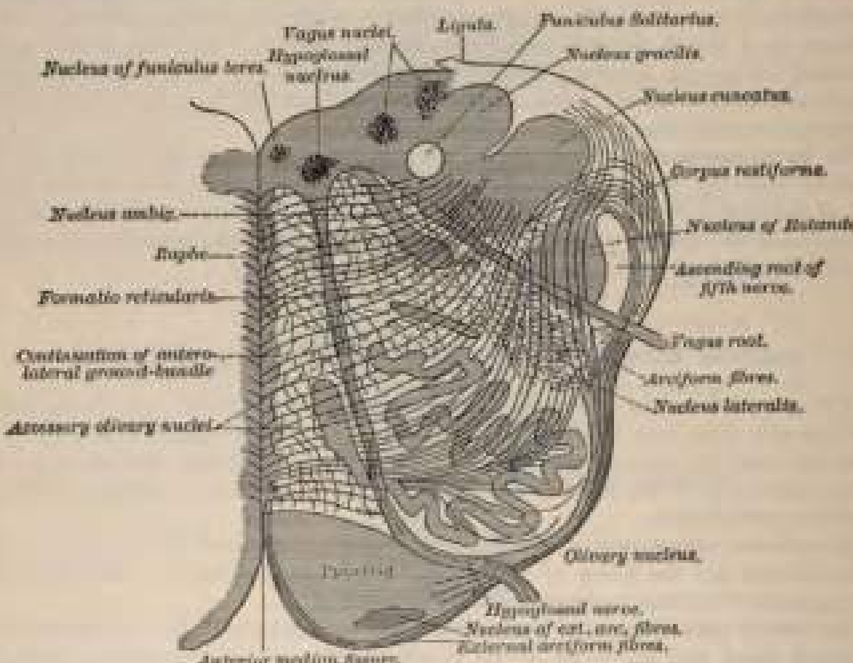

FIG. 372.—Section of the medulla oblongata at about the middle of the olivary body. (Schwalbe.)

broken up into a coarse network, while one portion of it, the caput cornu, is entirely separated from the rest; only the base of the cornu remains intact, close to the ventro-lateral aspect of the central canal. The caput cornu, thus separated, is displaced laterally, and comes to lie close to the caput cornu posterioris, which has also shifted its position. In consequence of this breaking up of the greater part of the anterior gray cornu by white fibres a coarse network is formed in the anterior and lateral areas of the medulla, which is named the *formatio reticularis*.

The posterior cornu also undergoes somewhat similar changes. It becomes subdivided by the passage through it of the sensory fibres of the columns of Goll and Burdach. These pass across to the opposite anterior area of the medulla, where they are seen to lie immediately on the dorsal aspect of the pyramids. In their passage through the posterior horns of gray matter the latter become subdivided, in a manner somewhat similar to what has been seen to occur in the anterior horns. This crossing of the sensory fibres is termed the *superior pyram-*

idal or *sensory decussation.* The caput cornu is displaced outward, so as almost to reach the surface, where it forms a projection, the *funiculus Rolando*, which enlarges above into a distinct prominence, the *tubercle of Rolando.* Above the level of the tubercle of Rolando the caput cornu is separated from the surface by a band of fibres, termed the *ascending root of the fifth nerve*, and by the external arcuate fibres. The neck of the cornu becomes broken up into a reticular formation by the decussation of the columns of Goll and Burdach, and by this means the caput is separated from the rest of the gray matter. The base of the cornu increases in size, and, as the central canal expands into the fourth ventricle, becomes pushed outward, and portions of it extend into the funiculi graciles and cuneati, and produce externally the eminences of the clava and cuneate tubercle. A third portion of the base becomes separated from the rest, and is placed outside the nucleus of the funiculus cuneatus. This is called the *accessory cuneate nucleus*, and is supposed to be a continuation upward of Clarke's vesicular column of the cord.

The Upper Part of the Medulla.—The upper part of the medulla comprises the portion which enters into the formation of the floor of the fourth ventricle, where, in fact, the upper end of the central canal has opened out into this cavity. In this region the formatio reticularis is confined chiefly to the anterior and lateral areas. In the ventral portion of the posterior area there is only a small amount of reticular formation, but in addition to this there are individual masses of cells scattered among the longitudinal fibres.

The **formatio reticularis** is situated in the medulla, behind the pyramid and olivary body, extending laterally as far as the restiform bodies, and dorsally to within a short distance of the floor of the fourth ventricle. It presents a peculiar reticulated appearance, from which it derives its name, and which is due to the intersection of bundles of fibres running at right angles to each other, some being longitudinal, others transverse. The formatio reticularis presents a different appearance in the anterior area from what it does in the lateral area. In the former there is almost an entire absence of nerve-cells in the reticulated network, and hence it is known as the *formatio reticularis alba;* whereas, in the lateral area, the nerve-cells are numerous, and, as a consequence, this part is known as the *formatio reticularis grisea.* In the substance of the formatio reticularis is a small nucleus of gray matter. It is situated near the dorsal aspect of the hilum of the olivary nucleus, and has been named the *inferior central nucleus.* The fibres of the formatio reticularis are longitudinal and transverse. In the anterior area the longitudinal fibres may be arranged in two well-defined sets: (1) one set lies immediately behind the pyramid, and is named the *fillet* or *lemniscus.* The fibres of the fillet are chiefly derived from the cells of the gracile and cuneate nuclei, and may therefore be regarded as relay fibres of the columns of Goll and Burdach of the spinal cord, which terminate in synapses around the cells of the gracile and cuneate nuclei. They are prolonged inward and forward across the middle line forming the superior pyramidal or sensory decussation (decussation of the fillet); (2) the other set is continued from the antero-lateral ground bundle of the cord, and a portion of these fibres forms the *posterior longitudinal bundle* already referred to (page 695). Both these sets of fibres are continued upward into the pons and mid-brain. The longitudinal fibres of the reticular formation in the lateral area are not arranged in distinct bundles. They are derived from the lateral column of the cord, after the crossed pyramidal tract has passed over to the opposite side. The longitudinal fibres of the posterior area are merely indeterminate fibres of the formatio reticularis, with the exception of two distinct bundles, which may be regarded as ascending roots of the fifth and vago-glosso-pharyngeal nerves; the latter is termed the *funiculus solitarius.*

The *transverse* fibres of the reticular formation are the arched or arcuate fibres. The *external arciform fibres* have already been described. The *internal arciform fibres* are more numerous than the superficial set; they traverse nearly the whole area of the upper half of the medulla, except the pyramid. They pass from the raphé; some become superficial and join the external arciform fibres, while others remain deep and pass to the olivary body, the restiform body, and to the nuclei of the funiculus cuneatus and funiculus gracilis.

Independent Nuclei.—In the upper part of the medulla are several independent nuclei of gray matter, which may be divided into two sets: (1) those which are traceable from the gray matter of the spinal cord; and (2) those which are not represented in the cord. The former are the hypoglossal nucleus, the nucleus of the funiculus teres, and those of the auditory, glosso-pharyngeal, vagus, and spinal accessory nerves. The latter are the nucleus of the olivary body and the accessory olivary nuclei. In addition to these, small collections of gray matter are to be found in the median septum or raphé.

The Hypoglossal Nucleus.—The base of the anterior horn, which in the lower part of the medulla was situated on the ventro-lateral aspect of the central canal, now approaches the floor of the ventricle, where it lies close to the median sulcus under the funiculus teres. In it is a column of large nerve-cells, from which the roots of the hypoglossal nerve are derived. It is accordingly designated the *hypoglossal nucleus.*

The Auditory Nuclei.—Toward the upper part of the medulla, a considerable tract of gray matter may be found lying immediately beneath that portion of the floor of the fourth ventricle which is known as the trigonum acustici. This is the *dorsal* or *inner auditory nucleus*, and it lies just external to the vago-glosso-pharyngeal nucleus. In addition to this, there is a small collection of nerve-cells on the ventral surface of the restiform body, between the two roots of the auditory nerve, which is known as the *accessory* or *ventral auditory nucleus.* On the outer side of the restiform body is a mass of cells associated with the cochlear root of the auditory nerve. This mass is termed the *lateral acoustic tubercle* or *ganglion radicis cochlearis.*

Nuclei of the Glosso-pharyngeal and Vagus Nerves.—These are two in number, *principal* and *accessory*. The *principal* nucleus of the two nerves lies beneath that portion of the floor of the fourth ventricle, which is known as the ala cinerea and fovea inferior. They form an oblong mass of gray matter, above the nucleus of the spinal accessory and lateral to the hypoglossal nucleus. The *accessory* nuclei are situated in the reticular formation of the posterior area, some distance from the floor of the fourth ventricle. They consist of a pear-shaped mass of cells, which is connected with the rest of the gray matter by a sort of stalk or peduncle, and was formerly known as the *nucleus ambiguus.*

Nucleus of the Spinal Accessory Nerve.—This nucleus consists of a group of cells, which is situated partly in the lower part of the medulla at the base of the posterior horn and close to the central canal. It extends upward, lying beneath the lower part of the floor of the fourth ventricle and on the outer side of the hypoglossal nucleus.

The Nucleus of the Olivary Body.—When the olivary body is cut across, it is seen to be covered externally by white fibres, and internally to consist of a gray layer. This gray layer is the *nucleus of the olivary body*, or, as it is sometimes called, the *corpus dentatum of the olive.* It is composed of a thin, wavy lamina, which is arranged in the form of a hollow capsule, open at its upper and inner part, and presenting a zigzag or dentated outline. Microscopically examined, the olivary nucleus is seen to consist of small rounded yellowish nerve-cells embedded in a matrix of neuroglia and fine nerve-fibres. White fibres, which can be traced from the raphé, and are probably derived from the opposite olive, enter the interior of the capsule by the aperture at its upper or inner part, constituting the olivary peduncle.

The fibres of the olivary peduncle as they enter the body diverge, and some are lost in the gray matter of the olivary nucleus; others pass through it, and of these some turn backward to join the restiform body, and pass to the cerebellum as internal arcuate fibres; while others pierce the white matter of the olivary body and, reaching the surface, are continued to the restiform body as external arcuate fibres. The fibres of the olivary peduncle connect the olivary nucleus with the cerebral hemisphere of the same side. The nucleus is also connected to the anterior horn of the same side of the cord; and with the opposite cerebellar hemisphere through the internal arcuate fibres. Removal of one cerebellar hemisphere is followed by atrophy of the opposite olivary nucleus.

Accessory Olivary Nuclei.—Two small isolated masses of gray matter are to be found, one on the mesial and the other on the dorsal aspect of the corpus dentatum. These are the *mesial* and *lateral accessory olivary nuclei*. They are connected with the restiform body by some of the internal arcuate fibres. The fibres of the hypoglossal nerve, as they traverse the bulb, pass between the mesial accessory nucleus and the chief olivary nucleus.

The Raphe.—The raphé is situated in the middle line of the medulla, above the decussation of the pyramids. It consists of nerve-fibres intermingled with nerve-cells. The fibres have different directions, which can only be seen in suitable microscopic sections, thus: 1. Some are antero-posterior; these in front are continuous with the superficial arciform fibres. 2. Some are longitudinal; these are derived from the arciform fibres, which on entering the raphé change their direction and become longitudinal. 3. Some are oblique; these are continuous with the deep arciform fibres which pass from the raphé.

The nerve-cells of the raphé are multipolar; some are connected with the antero-posterior fibres, others with the superficial arcuate fibres.

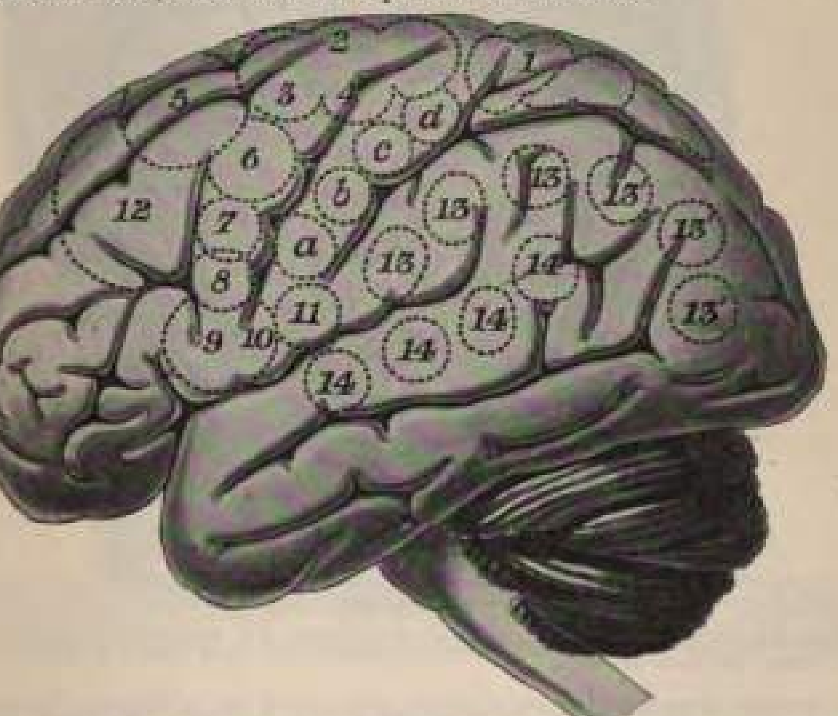

Fig. [illegible].—Side view of the brain of man, showing the localization of various functions. (After Ferrier.) 1. Centre for movements of opposite leg and foot. 2, 3, 4. Centres for complex movements of the arms and legs, as in swimming. 5. Extension forward of the arm and hand. 6. Supination of the hand and flexion of the forearm. 7, 8. Elevators and depressors of the angle of the mouth. 9, 10. Movements of the lips and tongue. 11. Retraction of the angle of the mouth. 12. Movements of the eyes. 13, 13'. Vision. 14. Hearing. a, b, c, d. Movements of the wrists and fingers.

Weight of the Encephalon.—The average weight of the brain in the adult male is 49½ oz., or a little more than 3 lbs. avoirdupois; that of the female 44 oz.; the average difference between the two being from 5 to 6 oz. The prevailing weight of the brain in the male ranges between 46 oz. and 53 oz., and in the female between 41 oz. and 47 oz. In the male the maximum weight out of 278 cases was 65 oz., and the minimum weight 34 oz. The maximum weight of the adult female brain, out of 191 cases, was 56 oz., and the minimum weight 31 oz. According to Luschka, the average weight of a man's brain is 1424 grammes (about 45 oz.), of a woman's 1272 grammes (about 41 oz.), and, according to Krause, 1570 grammes (about 48½ oz.) for the male, and 1350 (about 43 oz.) for the female. It appears that the weight of the brain increases rapidly up to the seventh year, more slowly to between sixteen and twenty, and still more slowly to between thirty and forty, when it reaches its maximum. Beyond this period, as age advances and the mental faculties decline, the brain diminishes slowly in weight, about an ounce for each subsequent decennial period. These results apply alike to both sexes.

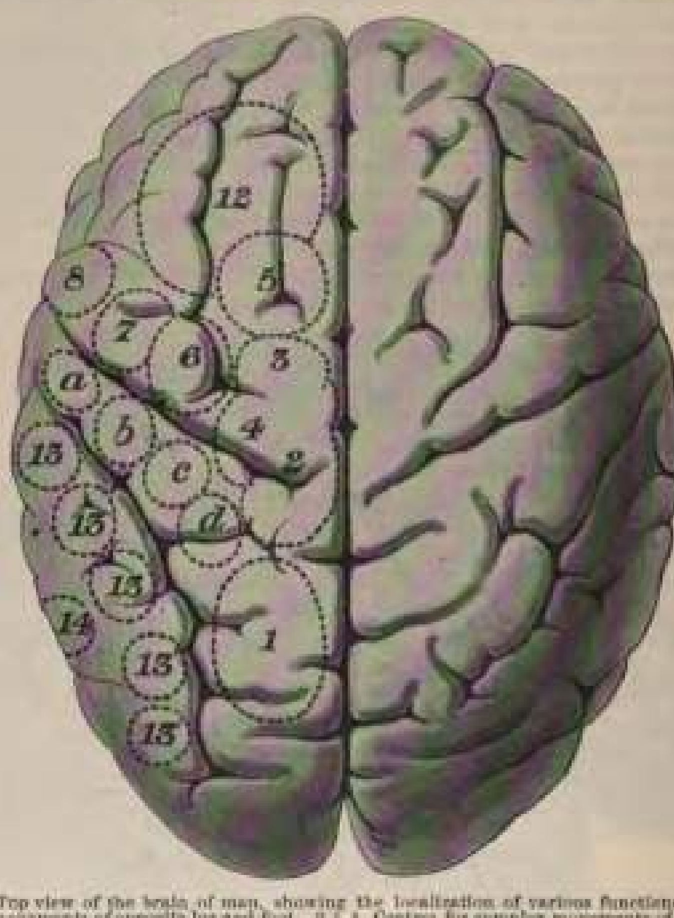

FIG. 374.—Top view of the brain of man, showing the localization of various functions. (After Ferrier.) 1. Centre for movements of opposite leg and foot. 2, 3, 4. Centres for complex movements of the arms and legs, as in swimming. 5. Extension forward of the arm and hand. 6. Supination of the hand and flexion of the forearm. 7, 8. Elevators and depressors of the angle of the mouth. 9, 10. Movements of the lips and tongue. 11. Retraction of the angle of the mouth. 12. Movements of the eyes. 13, 13'. Vision. 14. Hearing. a, b, c, d. Movements of the wrists and fingers.

The size of the brain was formerly said to bear a general relation to the intellectual capacity of the individual. Cuvier's brain weighed rather more than 64 oz., that of the late Dr. Abercrombie 63 oz., and that of Dupuytren 62½ oz. On the other hand, the brain of an idiot seldom weighs more than 23 oz. But these facts are by no means conclusive, and it is well known that these weights have been equalled by the brains of persons who never displayed any remarkable intellect. Dr. Haldeman of Cincinnati has recorded the case of a mulatto, aged forty-five, whose brain weighed 68¾ oz.; he had been a slave, and was never regarded as particularly intelligent; he was illiterate, but is said to have been reserved, meditative, and economical. Dr. Ensor, district medical officer at Port Elizabeth, reports that the brain of Carey, the Irish informer, weighed 61 oz. M. Nikiforoff has published an article on the subject of the weight of brains in the *Novosti.* According to him, the weight of the brain has no influence whatever on the mental faculties. It ought to be remembered that the significance of the weight of the brain should depend upon the proportion it bears to the dimensions of the whole body and to the age of the individual. It is equally important to know what was the cause of death, for long illness or old age exhausts the brain. To define the real degree of development of the brain it is therefore necessary to have a knowledge of the condition of the whole body, and, as this is usually lacking, the mere record of weight possesses little significance.

The human brain is heavier than that of all the lower animals, excepting the elephant and whale. The brain of the former weighs from eight to ten pounds; and that of a whale, in a specimen seventy-five feet long, weighed rather more than five pounds.

FIG. 375.—Drawing to illustrate cranio-cerebral topography. (Taken from a cast in the Museum of the Royal College of Surgeons of England, prepared by Professor Cunningham.)

Cerebral Localization and Topography.—Physiological and pathological research have now gone far to prove that the surface of the brain may be mapped out into series of definite areas, each one of which is intimately connected with some well-defined function. And this is especially true with regard to the convolutions on either side of the fissure of Rolando, which are believed by most physiologists of the present day to be concerned in motion, those grouped around the fissure being associated with movements of the extremities of the opposite side of the body, and those around the lower end of the fissure being related to movements of the mouth and tongue.

This is not the place, nor can space be given, to describe these localities. But the two accompanying cuts from Ferrier (Figs. 373, 374) have been introduced, and will serve to indicate the position of the more important areas.

The relation of the principal fissures and convolutions of the cerebrum to the outer surface of the scalp has been the subject of much investigation, and many systems have been devised by which one may localize these parts from an examination of the external surface of the head.

These plans can only be regarded as approximately correct for several reasons: in the first place, because the relations of the convolutions and sulci to the surface are found to be very variable in different individuals; secondly, because the surface area of the scalp is greater than the surface area of the brain, so that lines drawn on the one cannot correspond exactly to sulci or convolutions on the other; and thirdly, because the sulci and convolutions in two individuals are never precisely alike. Nevertheless, the principal fissures and convolutions can be mapped out with sufficient accuracy for all practical purposes, so that any particular convolution can be generally exposed by removing with the trephine a certain portion of the skull's area.

The various landmarks on the outside of the skull, which can be easily felt, and which serve as indications of the position of the parts beneath, have been already referred to (see page 222), and the relation of the fissures and convolutions to these landmarks is as follows:

Longitudinal Fissure.—This corresponds to a line drawn from the glabella at the root of the nose to the external occipital protuberance.

The Fissure of Sylvius.—The position of the fissure of Sylvius and its horizontal limb is marked by a line starting from a point one inch and a quarter horizontally behind the external angular process of the frontal bone to a point three-quarters of an inch below the most prominent point of the parietal eminence. The first three-quarters of an inch will represent the main fissure, the remainder the horizontal limb. The bifurcation of the fissure is, therefore, two inches behind and about a quarter of an inch above the level of the external angular process. The ascending limb of the fissure passes upward from this point parallel to, and immediately behind, the coronal suture.

Fissure of Rolando.—To find the upper end of the fissure of Rolando, a measurement should be taken from the glabella to the external occipital protuberance. The position of the top of the sulcus will be, measuring from in front, 55.6 per cent. of the whole distance from the glabella to the external occipital protuberance. Professor Thane adopts a somewhat simpler method. He divides the distance from the glabella to the external occipital protuberance over the top of the head into two equal parts, and, having thus defined the middle point of the vertex, he takes half an inch behind it as the top of the sulcus. This is not quite so accurate as the former method, but it is sufficiently so for all practical purposes, and on account of its simplicity is very generally adopted. From this point the fissure runs downward and forward for 3½

Fig. 376.—Relations of the principal fissures and convolutions of the cerebrum to the outer surface of the scalp. (Reid.)

inches, its axis making an angle of 67° with the middle line. Cunningham states that this angle more nearly averages 71.5°. In order to mark this groove, two strips of metal may be employed—one, the shorter, being fixed to the middle of the other at the angle mentioned. If the longer strip is now placed along the sagittal suture so that the junction of the two strips is over the point corresponding to the top of the furrow, the shorter, oblique strip will indicate the direction and 3½ inches will mark the length of the furrow. Dr. Wilson has devised an instrument, called a cyrtometer, which combines the scale of measurements for localizing the fissure with data for representing its length and direction.[1] Professor Thane gives the lower end of the furrow as "close to the posterior limb, and about half an inch behind the bifurcation of the fissure of Sylvius." So that, according to this anatomist, a line drawn from a point half an inch behind the mid-point between the glabella and external occipital protuberance to this spot would mark out the fissure of Rolando. Dr. Reid adopts a different method (Fig. 376). He first indicates on the surface the longitudinal fissure and the horizontal limb of the fissure of Sylvius (as above). He then draws two perpendicular lines from his "base-line" (that is, a line from the lowest part of the infra-orbital margin through the middle of the external auditory meatus to the back of the head) to the top of the cranium, one (D E, Fig. 376) from the depression in front of the external auditory meatus, and the other (F G, Fig. 376) from the posterior border of the mastoid process at its root. He has thus described on the surface of the head a four-sided figure (F D G E, Fig. 376), and a diagonal line from the posterior superior angle to the anterior perpendicular line where it is crossed by the fissure of Sylvius will represent the furrow.

The *parieto-occipital fissure* on the upper surface of the cerebrum runs outward at right angles to the great longitudinal fissure for about an inch, from a point one-fifth of an inch in front of the lambda (posterior fontanelle). Reid states that if the horizontal limb of the fissure of Sylvius be continued onward to the sagittal suture, the last inch of this line will indicate the position of the sulcus.

The *precentral sulcus* begins four-fifths of an inch in front of the middle of the fissure of Rolando, and extends nearly, but not quite, to the horizontal limb of the fissure of Sylvius.

The *superior frontal fissure* runs backward from the supra-orbital notch, parallel with the line of the longitudinal fissure to two-fifths of an inch in front of the line indicating the position of the fissure of Rolando.

The *inferior frontal fissure* follows the course of the superior temporal ridge on the frontal bone.

The *intraparietal fissure* begins on a level with the junction of the middle and lower third of the fissure of Rolando, on a line carried across the head from the back of the root of one auricle to that of the other. After passing upward it curves backward, lying parallel to the longitudinal fissure, midway between it and the parietal eminence; it then curves downward to end midway between the posterior fontanelle and the parietal eminence.

THE SPINAL CORD AND ITS MEMBRANES.

Dissection.—To dissect the cord and its membranes it will be necessary to lay open the whole length of the spinal canal. For this purpose the muscles must be separated from the vertebral grooves, so as to expose the spinous processes and laminæ of the vertebræ; and the latter must be sawn through on each side, close to the roots of the transverse processes, from the third or fourth cervical vertebra above to the sacrum below. The vertebral arches having been displaced by means of a chisel and the separate fragments removed, the dura mater will be exposed, covered by a plexus of veins and a quantity of loose areolar tissue, often infiltrated with serous fluid. The arches of the upper vertebræ are best divided by means of a strong pair of cutting bone-forceps.

MEMBRANES OF THE CORD.

The membranes which envelop the spinal cord are three in number. The most external is the *dura mater*, a strong fibrous membrane which forms a loose sheath around the cord. The most internal is the *pia mater*, a cellulo-vascular membrane which closely invests the entire surface of the cord. Between the two is the *arachnoid membrane*, a non-vascular membrane which envelops the cord and is connected to the pia mater by slender filaments of connective tissue.

The **Dura Mater** of the cord represents only the meningeal or supporting layer of the cranial dura mater. The endocranial or endosteal layer ceases at the foramen magnum posteriorly, but reaches as low as the third cervical vertebra in front; below these levels its place is taken by the periosteum. It forms a loose sheath which surrounds the cord, and is separated from the bony walls of the spinal canal by a quantity of loose areolar tissue and a plexus of veins. The situation of the veins between the dura mater of the cord and the periosteum of the vertebræ corresponds therefore to that of the cranial sinuses between the endocranial and supporting layers. It is attached to the circumference of the foramen magnum, and to the axis and third cervical vertebra; it is also fixed to the posterior common ligament, especially near the lower end of the spinal canal, by fibrous slips; it extends below as far as the second or third piece of the sacrum; here it becomes

[1] *Lancet*, 1888, vol. i., p. 408.

impervious, and, ensheathing the filum terminale, descends to the back of the coccyx, where it blends with the periosteum. The dura mater is much larger than is necessary for its contents, and its size is greater in the cervical and lumbar regions than in the dorsal. Its inner surface is smooth. On each side may be seen the double openings which transmit the two roots of the corresponding spinal nerve, the fibrous layer of the dura mater being continued in the form of a tubular prolongation on them as they pass through these apertures. These prolongations of the dura mater are short in the upper part of the spine, but become gradually longer below, forming a number of tubes of fibrous membrane, which enclose the sacral nerves, and are contained in the spinal canal.

The chief peculiarities of the dura mater of the cord, as compared with that investing the brain, are the following:

The dura mater of the cord is not adherent to the bones of the spinal canal, which have an independent periosteum.

It does not send partitions into the fissures of the cord, as in the brain.

Its fibrous laminæ do not separate to form venous sinuses, as in the brain.

Structure.—The dura mater consists of white fibrous and elastic tissue arranged in bands or lamellæ, which, for the most part, are parallel with one another and have a longitudinal arrangement. Its internal surface is covered by a layer of endothelial cells which gives this surface its smooth appearance. It is sparingly supplied with vessels, and some few nerves have been traced into it.

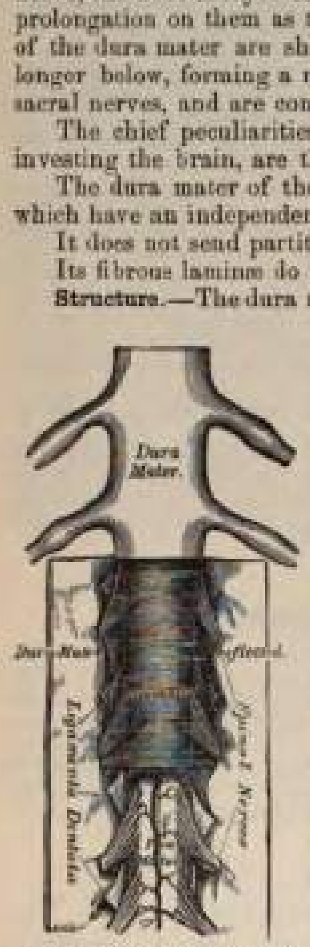

Fig. 377.—The spinal cord and its membranes.

The **Arachnoid** is exposed by slitting up the dura mater and reflecting that membrane to either side (Fig. 377). It is a thin, delicate, tubular membrane which invests the surface of the cord, and is connected to the pia mater by slender filaments of connective tissue. Above, it is continuous with the cerebral arachnoid, on each side it is continued on the various nerves, so as to form a sheath for them as they pass outward to the intervertebral foramina. The outer surface of the arachnoid is in contact with the inner surface of the dura mater, and the two are, here and there, joined together by isolated connective-tissue trabeculæ, especially on the posterior surface of the cord. For the most part, however, the membranes are not connected together, and the interval between them is named the *subdural space.* The inner surface of the arachnoid is separated from the pia mater by a considerable interval, which is called the *subarachnoidean space.* The space is the largest at the lower part of the spinal canal, and encloses the mass of nerves which form the cauda equina. Superiorly it is continuous with the cranial subarachnoid space, and communicates with the general ventricular cavity of the brain by means of an opening in the pia mater, in the roof of the fourth ventricle (*foramen of Majendie* and *foramina of Key and Retzius*). It contains an abundant serous secretion, the *cerebro-spinal fluid.* This secretion is sufficient in amount to expand the arachnoid membrane, so as to fill up completely the whole of the space included in the dura mater. The subarachnoidean space is occupied by trabeculæ of delicate connective tissue, connecting the pia mater on the one hand with the arachnoid membrane on the other. This is named *subarachnoid tissue.* In addition to this it is partially subdivided by a longitudinal membranous partition, the *septum posticum,* which serves to connect the arachnoid with the pia mater, opposite the posterior median fissure of the spinal cord, a partition which is incomplete and cribriform in structure, consisting of bundles of white fibrous tissue interlacing with each other. This space is to be regarded as, in reality, a great lymph space, from which the lymph carried to it by the perivascular lymphatics is conveyed back into the circulation.

Structure.—The arachnoid is a delicate membrane made up of closely arranged interlacing bundles of connective tissue in several layers.

The **Pia Mater** of the cord is exposed on the removal of the arachnoid (Fig. 377). It covers the entire surface of the cord, to which it is very intimately adherent, forming its neurilemma, and sending a process downward into its anterior fissure. It also forms a sheath for each of the filaments of the spinal nerves, and invests the nerves themselves. A longitudinal fibrous band extends along the middle line on its anterior surface, called by Haller the *linea splendens;* and a somewhat similar band, the *ligamentum denticulatum*, is situated on each side. At the point where the cord terminates the pia mater becomes contracted, and is continued down as a long, slender filament (*filum terminale*), which descends through the centre of the mass of nerves forming the cauda equina. It perforates the dura about the level of the second or third lumbar vertebræ, receiving a sheath from it, and extends downward as far as the base of the coccyx, where it blends with the periosteum. It assists in maintaining the cord in its position during the movements of the trunk, and is from this circumstance called the *central ligament* of the spinal cord. It contains a little gray nervous substance, which may be traced for some distance into its upper part, and is accompanied by a small artery and vein. At the upper part of the cord the pia mater presents a grayish, mottled tint, which is owing to yellow or brown pigment-cells scattered among the elastic fibres.

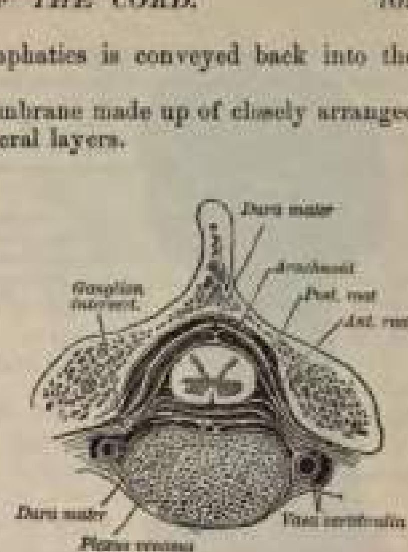

FIG. 378.—Transverse section of the spinal cord and its membranes. (Gegenbaur.)

Structure.—The pia mater of the cord is less vascular in structure, but thicker and denser, than the pia mater of the brain, with which it is continuous. It consists of two layers: an outer composed of bundles of connective-tissue fibres, arranged for the most part longitudinally; and an inner, consisting of stiff bundles of the same tissue, which present peculiar angular bends, and is covered on both surfaces by a layer of endothelium. Between the two layers are a number of cleftlike lymphatic spaces which communicate with the subarachnoid cavity, and a number of blood-vessels which are enclosed in a perivascular sheath, derived from the inner layer of the pia mater, into which the lymphatic spaces open. It is also supplied with nerves, which are derived from the sympathetic.

The **Ligamentum Denticulatum** (Fig. 377) is a narrow fibrous band, situated on each side of the spinal cord, throughout its entire length, and separating the anterior from the posterior roots of the spinal nerves. It has received its name from the serrated appearance which it presents. Its inner border is continuous with the pia mater at the side of the cord. Its outer border presents a series of triangular, dentated serrations, the points of which are fixed at intervals to the dura mater. These serrations are twenty-one in number on each side, the first being attached to the dura mater, opposite the margin of the foramen magnum between the vertebral artery and the hypoglossal nerve, and the last near the lower end of the cord. Its use is to support the cord in the fluid by which it is surrounded.

Surgical Anatomy.—Evidence of great value in the diagnosis of meningitis may be obtained by puncturing the theca of the cord and withdrawing some of the cerebrospinal fluid, and the operation is regarded by some as curative, under the supposition that the draining away of the cerebrospinal fluid relieves the patient by diminishing the intracranial pressure. The operation is performed by inserting a trocar, of the smallest size, between the laminæ of the third and fourth or the fourth and fifth lumbar vertebræ through the ligamenta subflava. The spinal cord even of a child at birth does not reach below the third lumbar vertebra, and therefore the canal may be punctured between the third and fourth vertebra without any risk of injuring its contents. The point of puncture is indicated by laying the child on its side and dropping a perpendicular line from the highest point of the crest of the ilium; this will cross the upper border of the spine of the fourth lumbar vertebra, and will indicate the level at which the trocar should be inserted a little to one side of the median line.

Fig. 379.—Posterior view of the spinal cord in situ.

THE SPINAL CORD (Fig. 379).

The **Spinal Cord** (*medulla spinalis*) is the cylindrical, elongated part of the cerebro-spinal axis which is contained in the vertebral canal. Its length is usually about seventeen or eighteen inches, and its weight, when divested of its membranes and nerves, about one ounce and a half, its proportion to the encephalon being about 1 to 33. It does not nearly fill the canal in which it is contained, its investing membranes being separated from the surrounding walls by areolar tissue and a plexus of veins. It occupies, in the adult, the upper two-thirds of the vertebral canal, extending from the upper border of the atlas to the lower border of the body of the first lumbar vertebra, where it terminates in a slender filament of gray substance, which

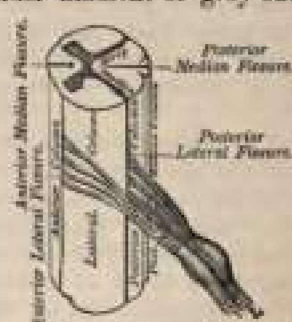

Fig. 380.—Spinal cord. Side view. Plan of the fissures and columns.

is continued for some distance into the *filum terminale*. In the fœtus, before the third month, it extends to the bottom of the sacral canal, but after this period it gradually recedes from below, as the growth of the bones composing the canal is more rapid in proportion than that of the cord, so that in the child at birth the cord extends as far as the third lumbar vertebra. Its position varies also according to the degree of curvature of the spinal column, being raised somewhat in flexion of the spine. On examining its surface it presents a difference in its diameter in different parts, being marked by two enlargements, an upper or cervical, and a lower or lumbar. The cervical enlargement extends from about the third cervical to the first or second dorsal vertebra; its greatest diameter is in the transverse direction (13 mm.), and it corresponds with the origin of the nerves which supply the upper extremities. The lumbar enlargement is situated opposite the last two or three dorsal vertebræ, and corresponds with the origin of the nerves which supply the lower extremities. Below the lumbar enlargement the cord gradually tapers to form a cone, the *conus medullaris*, the apex of which is continuous with the filum terminale. In form, the spinal cord is a cylinder, flattened before and behind.

Fissures.—It presents on its anterior surface, along the middle line, a longitudinal fissure, the *anterior median fissure*, and on its posterior surface another fissure, which also extends along the entire length of the cord, the *posterior median fissure*. These fissures penetrate through the greater part of the thickness of the cord, and incompletely divide the cord into symmetrical halves, united in the middle line by a transverse band of nervous substance, the *commissure*.

The **Anterior Median Fissure** is wider, but of less depth, than the posterior, extending into the cord for about one-third of its thickness, and is deepest at the lower part of the cord. It contains a prolongation from the pia mater, and its floor is formed by the *anterior white commissure*, which is perforated by numerous blood-vessels passing to the centre of the cord.

The **Posterior Median Fissure** is not an actual fissure, as the space between the lateral halves of the posterior part of the cord is crossed by connective tissue and numerous blood-vessels, so that no actual hiatus exists, and there is consequently no prolongation of the pia mater into it. It extends into the cord to about one-half its depth, and its floor is formed by the *posterior gray commissure*.

FIG. 391.—Transverse sections of the cord.

FIG. 392.—From a transverse section through the spinal cord of a calf. Magnified about 180 diameters, showing part of the central canal and the tissue immediately around it, viz., the central grey matter. (Klein and Noble Smith.) The canal is lined with epithelium, composed of ciliated, more or less conical, cells; in most instances a filamentous process passes from the cell into the tissue underneath. This tissue contains, in a hyaline matrix, a network of fibrils; most of these run horizontally; others have a longitudinal course, and appear therefore here cut transversely—*i. e.*, as small dots. The nuclei correspond to the cells of the neuroglia, the cell-substance not being shown. Both the nuclei of the neuroglia-cells and those of the epithelium contain three or more large disc-shaped particles.

Lateral Fissures.—On each side of the posterior median fissure, along the line of attachment of the posterior roots of the nerves, a delicate fissure may be seen, leading down to the gray matter which approaches the surface in this situation; this is called the *postero-lateral fissure* of the spinal cord. On the posterior surface of the spinal cord, between the posterior median fissure and the postero-lateral fissure on each side, is a slight longitudinal furrow (*posterior intermediate furrow*), marking off two slender tracts, the *postero-median and postero-lateral columns*. These are most distinct in the cervical region, but are stated by Foville to exist throughout the whole length of the cord. On each side of the anterior median fissure the anterior roots of the spinal nerves emerge from the cord, not in one vertical line, but by separate bundles which occupy an area of some width. This is called, by some anatomists, the *antero-lateral fissure* of the cord, although no actual fissure exists in this situation.

Columns of the Cord.—Each half of the spinal cord is thus divided into four columns: an anterior column, a lateral column, a posterior column, and a postero-median column. This division, however, is very imperfect, since the limit between the so-called anterior and lateral columns cannot be defined on account of the bundles of the anterior roots being spread over a considerable area. It is therefore customary to divide each half of the spinal cord into two columns, separated by the postero-lateral groove: (1) a small *posterior column*, which is bounded internally by the posterior median fissure, and externally by the postero-lateral fissure, and (2) a large *antero-lateral column*, which comprises the rest of the cord. The posterior column is further divided, at all events at its upper part, by the posterior intermediate septum, into a postero-median column and a postero-lateral column.

Structure of the Cord.—If a transverse section of the spinal cord be made, it will be seen to consist of white and gray nervous substance. The white matter is situated externally, and constitutes the greater part. The gray substance occupies the centre, and is so arranged as to present on the surface of the section two crescentic masses, placed one in each lateral half of the cord, united together by a transverse band of gray matter, the *gray commissure*. Each crescentic mass has an anterior (ventral) and a posterior (dorsal) horn. The posterior horn is long and narrow, and approaches the surface of the postero-lateral fissure, near which it presents a slight enlargement, the *caput cornu:* from this it tapers to form the *apex cornu*, which at the surface of the cord becomes continuous with some of the fibres of the posterior roots of the spinal nerves. The anterior horn is short and thick, and does not quite reach the surface, but extends toward the point of attachment of the anterior roots of the nerves. Its margin presents a dentate or stellate appearance. Owing to the projections toward the surface of the anterior and posterior horns of the gray matter, each half of the cord is divided, more or less completely, into three columns, anterior, middle, and posterior, the anterior and middle being joined to form the antero-lateral column, as the anterior horn does not quite reach the surface.

The **commissure of the spinal cord** is composed of white and gray matter, and is therefore divided into the white and gray commissures. The *white commissure* is situated at the bottom of the anterior median fissure, and is formed of medullated nerve-fibres, which pass between the gray matter of the anterior horn and the anterior white column of the one side into similar parts on the other. The fibres are oblique in direction; many which enter at the posterior part of the commissure on the one side leave it at the anterior part of the commissure on the other, and *vice versâ*, a decussation taking place in the middle line.

The *gray commissure*, which connects the two crescentic masses of gray matter, is separated from the bottom of the anterior median fissure by the anterior white commissure. It consists of transverse medullated nerve-fibres, with a considerable quantity of neuroglia between them. The fibres when they reach the lateral crescents diverge: some pass backward to the posterior roots; others spread out, at various angles, into the crescent.

Running through the gray commissure of the whole length of the cord is a minute canal, which is barely visible to the naked eye in the human cord, but is proportionately larger in some of the lower vertebrata. It is called the *central canal;* it opens above into the fourth ventricle, and terminates below in a somewhat dilated extremity. It is surrounded by an area of neuroglia, which, in the recent state, has a gelatinous appearance, and in which there are no nerve-fibres. This is sometimes called the *substantia gelatinosa centralis*. When hardened in alcohol or chromic salts it has a finely reticulated appearance. The canal is lined in the fœtus by columnar ciliated epithelium, but in the adult the cilia have disappeared, and the canal is filled with their remains.

The mode of arrangement of the gray matter, and its amount in proportion to the white, vary in different parts of the cord. Thus, the posterior horns are long and narrow in the cervical region; short and narrower in the dorsal; short, but wider, in the lumbar region. In the cervical region the crescentic portions are small, and the white matter more abundant than in any other region of the cord. In the dorsal region the gray matter is least developed, the white matter being also small in quantity. In the lumbar region the gray matter is more abundant than in any other region of the cord. Toward the lower end of the cord the white matter gradually ceases. The crescentic portions of the gray matter soon blend into a single mass, which forms the only constituent of the extreme point of the cord.

Minute Anatomy of the Cord.—The cord consists of an outer part, composed of medullated nerve-fibres, which is the *white substance;* and of a central part, the *gray matter,* both supported in a peculiar kind of tissue, called *neuroglia.*

The **neuroglia** consists of a homogeneous transparent matrix, of a network of very delicate fibrillæ, and of small stellate or branched cells, the *neuroglia-cells.*

In addition to forming a ground substance, in which the nerve-fibres, nerve-cells, and blood-vessels are imbedded, a considerable accumulation of neuroglia takes place in three situations—(1) on the surface of the cord, beneath the pia mater; (2) around the central canal, the *substantia gelatinosa centralis;* and (3) as a cap over the extremity of the posterior horn, forming the *substantia cinerea gelatinosa.*

The **white substance of the cord** consists of medullated nerve-fibres, mostly disposed longitudinally, with blood-vessels and neuroglia. When stained with carmine it presents a very striking appearance on transverse section. It is seen to be studded all over with minute dots, surrounded by a white area (Fig. 387). This is due to the longitudinal medullated fibres seen on section. The dot is the axis-cylinder, the white area the substance of Schwann. Externally, the neuroglia forms a sheath closely investing the outer surface of the cord immediately beneath the pia mater; from it numerous septa pass inward and separate the respective bundles of fibres and extend between the individual nerve-fibres, acting as a supporting medium, in which they are imbedded.

There are, however, also oblique and transverse fibres in the white substance. These principally consist of (1) the fibres of the white commissure; (2) horizontal or oblique fibres passing from the roots of the nerves into the gray matter; and (3) fibres leaving the gray matter and pursuing a longer or shorter horizontal course.

Conducting Tracts.—It is impossible to trace the course of the nerve-fibres in their passage through the cord; but the investigation of pathological lesions has shown that the white matter of the cord consists of certain columns or tracts of fibres; for it has been found that certain lesions are strictly limited to certain well-determined parts of the cord without involving neighboring regions. That these parts or fasciculi correspond to so many distinct anatomical systems, each endowed with special functions, seems abundantly proved by the researches of Flechsig and others on the development of the spinal cord during the later periods of utero-gestation and in the newly born infant. By these researches several tracts can be traced along the greater part of the cord and into or from the encephalon. Thus (1) in the antero-lateral column of the cord, on either side of the anterior median fissure, a portion of the column may be divided off as the *direct pyramidal tract* (*fasciculus of Türck*). This tract

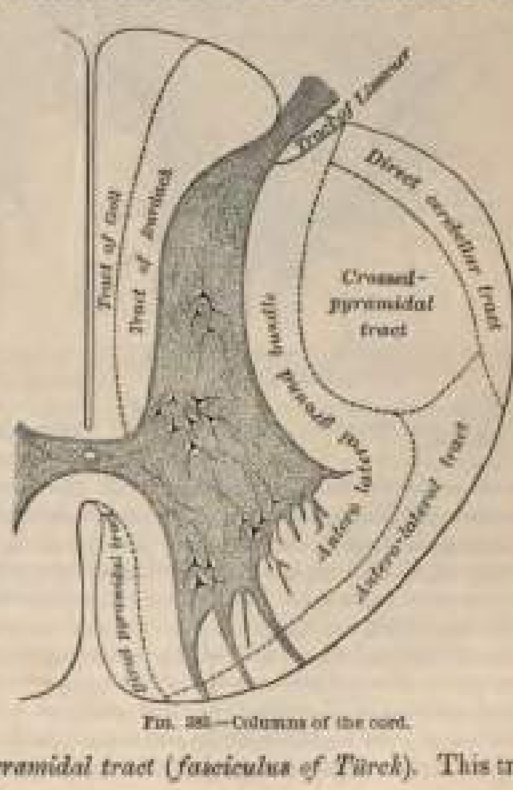

FIG. 388.—Columns of the cord.

is only found in the upper part of the cord; it gradually diminishes as it is traced downward, and disappears about the middle of the dorsal region. It consists of centrifugal or descending fibres which can be traced downward from the pyramid of the medulla of the same side, and are derived from the motor area of the cerebral cortex. The fibres of this tract decussate in their course down the cord, passing across the middle line through the anterior white commissure; this explains the gradual diminution and eventual disappearance of the tract. (2) In the hinder part of the antero-lateral column is a somewhat triangular area, larger than the preceding, which is named the *crossed pyramidal tract.* This also consists of descending fibres, which are derived from the pyramid of the medulla of the opposite side, and which have crossed in the decussation of the pyramids. The fibres are derived from the motor area of the cerebral cortex of the opposite side. Thus it will be seen that all the fibres from the motor area, which descend through the internal capsule, the crus cerebri, and the pons Varolii to the pyramidal body of the medulla, decussate; some at the upper part of the cord, and these descend through it as the crossed pyramidal tract; and others, which descend as the direct pyramidal tract and cross through the anterior commissure of the cord to reach the crossed pyramidal tract of the opposite side. Although this is the usual method of describing the crossing of the direct pyramidal tract in the cord, it seems probable that its fibres cross in the anterior commissure and pass directly to the anterior horn of gray matter, to end by forming synapses around its cells. (3) The *antero-lateral ascending tract* (Gower's tract) is an extensive crescent-shaped strand which skirts the circumference of the anterior three-quarters of the antero-lateral column of the cord. Behind, where it is thickest, it lies in the angle formed by the direct cerebellar and crossed pyramidal tracts, becoming narrower as it passes forward toward the direct pyramidal tract. It consists of centripetal or ascending fibres, which arise from cells situated at the base of the posterior horn and which cross to the opposite side of the cord in the anterior gray commissure. They can be traced upward through the medulla and pons to the cerebellum, reaching the latter through its superior peduncles. If the spinal cord is divided in the cervical region, some scattered fibres in this column degenerate in a downward direction. This would seem to prove therefore that it contains some descending fibres, which are believed to be derived from the same side of the cerebellum. (4) The *direct cerebellar tract* is situated at the circumference of the cord behind the preceding and external to the crossed pyramidal tract, occupying a narrow area which extends backward as far as the postero-lateral fissure or nearly so. It commences at the level of the upper lumbar region, and increases in size as it ascends and passes through the restiform body of the medulla to the cerebellum. Its fibres are derived from the cells of the posterior vesicular column of Clarke in the gray matter of the cord. (5) Close to the point where the posterior roots enter the cord, in the antero-lateral column, is a small collection of fibres, which is known as the *tract of Lissauer;* it is formed by some of the fibres of the posterior roots which run upward in the tract for a short distance, and then enter the posterior horn of the gray matter. (6) The rest of the antero-lateral column of the spinal cord is occupied by the *antero-lateral ground bundle.* It surrounds the anterior cornu and separates the antero-lateral tract and the crossed pyramidal tract from the gray matter of the cord. It consists of (*a*) longitudinal

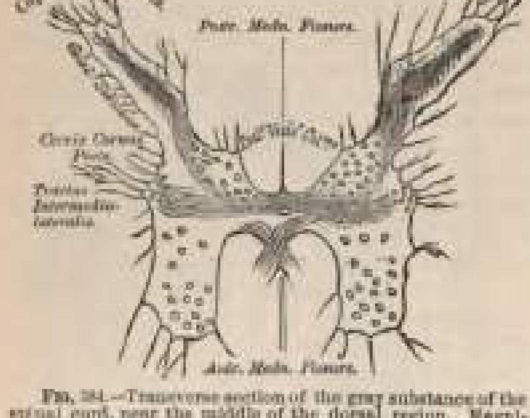

FIG. 384.—Transverse section of the gray substance of the spinal cord, near the middle of the dorsal region. Magnified 15 diameters.

commissural fibres, which unite the groups of cells in the gray matter with one another; (*b*) of fibres which pass across the anterior commissure from the gray matter of the opposite side; and (*c*) horizontal fibres belonging to the anterior roots of the nerves, which pass through it before leaving the cord.

In the posterior column of the cord there are two tracts. They are marked off from each other by the posterior intermediate furrow on the surface of the cord. The part which has been described previously as the posterior median column pretty nearly corresponds to the one tract, the *tract of Goll*, and the remainder of the posterior column corresponds to the other, the *tract of Burdach*. (7) The *tract of Goll* increases as it ascends, and consists of long, but small, fibres derived from the posterior roots of the spinal nerves, which ascend to the medulla oblongata, where they end in the nucleus gracilis. (8) The *tract of Burdach* consists of shorter, but larger, fibres than the preceding; they are, however, derived from the same source, the posterior roots; some ascend only for a short distance in the tract and then enter the gray matter and come into close relationship with the cells of the posterior vesicular column of Clarke; others incline toward the mesial plane, and, entering Goll's column, can be traced as far as the medulla. In the cervical

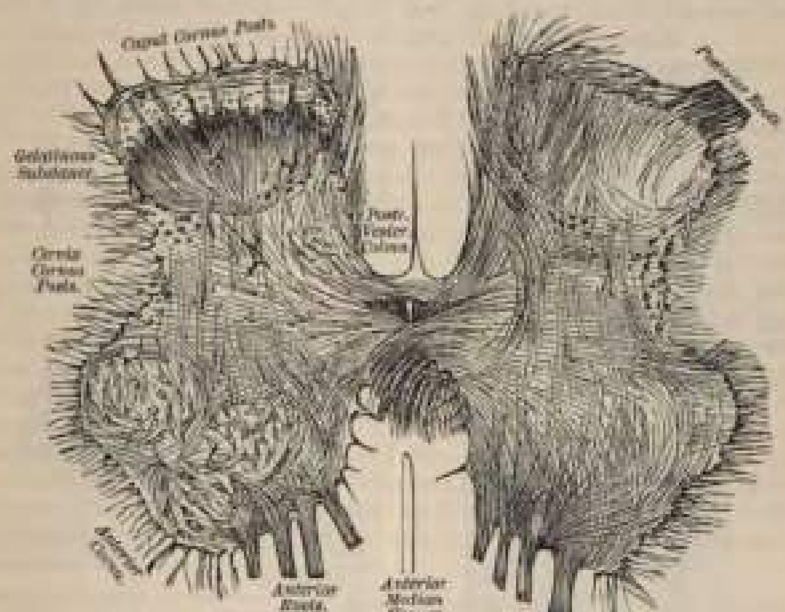

FIG. [illegible].—Transverse section of the gray substance of the spinal cord through the middle of the lumbar enlargement. On the left side of the figure groups of large cells are seen; on the right side, the course of the fibres is shown without the cells. Magnified 13 diameters.

and upper dorsal regions there is contained in the substance of Burdach's column a small strand of fibres, called the *descending comma tract*. It presents, on transverse section, the appearance of a comma, the blunt extremity of which is directed forward. The fibres forming it probably represent in part descending portions of the dorsal nerve-roots, together with descending commissural fibres within the cord itself. A small strand of similar descending fibres is seen, in the lower part of the cord, lying in the inner part of Goll's column.

The **gray substance of the cord** occupies its central part in the shape of two crescentic horns, joined together by the gray commissure. Each of these crescents has an anterior or ventral and a posterior or dorsal cornu.

The *posterior horn* consists of a slightly narrowed portion, at its base, where it is connected with the rest of the gray substance—this is the *cervix cornu*; from this it gradually expands into the main part of the horn, the *caput cornu*; around its extremity is a lamina or layer of gelatinous material, which covers the head like a cap, and from this it tapers almost to a point, which approaches the surface of the cord at the postero-lateral groove.

The gelatinous substance is a peculiar accumulation of neuroglia (Klein) similar to that found around the central canal (page 713), and has been named by Rolando the *substantia cinerea gelatinosa*. It probably takes its origin from the columnar cells which line the posterior part of the embryonic spinal canal.

The *anterior horn of the gray substance* in the cervical and lumbar swellings, where it gives origin to the motor nerves of the extremities, is much larger than in any other region, and contains several distinct groups of large and variously shaped cells.

In addition to this, a *lateral horn* is found projecting outward from the lateral region of the gray matter on a level with the gray commissure in the upper part of the dorsal region of the cord; in the cervical and lumbar regions this lateral horn blends with the anterior horn, which thus becomes broad and expanded. From the concavity of the crescent, between the anterior and posterior horns, processes of gray matter extend into the white substance, where they divide and anastomose to form a network, termed the *formatio reticularis*.

FIG. 386.—Longitudinal section of the white and gray substance of the spinal cord, through the middle of the lumbar enlargement. Magnified 14 diameters.

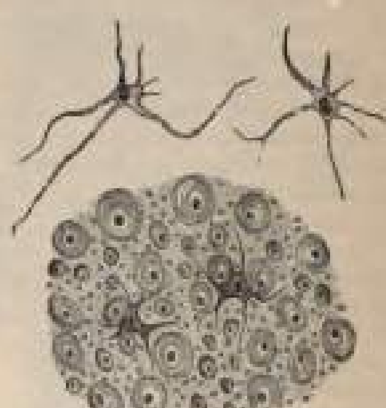

FIG. 387.—Transverse section through the white matter of the spinal cord of a calf. Magnified about 300 diameters. (Klein and Noble Smith.)

In the upper part are shown two isolated flattened nucleated cells of the neuroglia, under a somewhat higher power than the rest. In the bulk of the figure the nerve-fibres are seen in transverse section. They are of different sizes, and possess a laminated medullary sheath surrounding the axis-cylinder, which was deeply stained in the preparation, and is here represented by a black dot. The nerve-fibres are embedded in the neuroglia. Among the neuroglia are also seen two branched connective-tissue cells—neuroglia-cells.

The gray commissure contains the central canal, and is situated behind the white commissure, which separates it from the bottom of the anterior median fissure.

The **gray substance of the cord** consists of—(1) nerve-fibres of variable but smaller average diameter than those of the white columns; (2) nerve-cells of various shapes and sizes, with from two to eight processes; (3) blood-vessels and connective tissue.

The *nerve-fibres* of the gray matter of the posterior horn are for the most part composed of a dense interlacement of minute fibrils, intermingled with nerves of a larger size. This interlacement is formed partly by the axons and dendrites of the cells of the gray matter, and partly by fibres which enter the gray matter and which come from various sources.

The *nerve-cells* of the gray matter are collected into groups as seen on transverse section, but they really form columns of cells placed longitudinally; or else they are found scattered throughout the whole of the gray matter.

In the anterior horn the cells consist of two chief groups: one mesial, the more constant, near the anterior column; the other lateral, near the lateral column. A second lateral group is present in the cervical and lumbar enlargements. At the base of the posterior horn on its inner side, adjoining the gray commissure, is a group of nerve-cells, called *Clarke's posterior vesicular column*, which extends from the eighth cervical to the second lumbar nerve.

At the junction of the anterior and posterior cornu, in the outer portion of the gray matter, is a third group of cells, the *lateral cell column*; this is best seen in the dorsal region. In certain regions of the cord these cells extend in among the fibres of the white matter of the lateral column, and give rise to the lateral horn. In addition to these groups a few large scattered cells are found in the posterior horn and in the substantia gelatinosa of Rolando.

Origin of the Spinal Nerves.—The roots of the spinal nerves are attached to the surface of the cord, opposite the horns of gray matter.

The *posterior nerve-root* enters the cord in two bundles, *mesial* and *lateral*. The mesial strand consists of coarse fibres which enter the outer part of the column of Burdach. The lateral strand is sometimes divided into a middle and an external bundle. The former contains large fibres, and passes through the gelatinous substance of Rolando into the posterior horn. The external bundle consists of fine fibres which assume a longitudinal direction in Lissauer's tract. All the posterior root-fibres divide into ascending and descending branches on entering the cord, and these in their turn give off collaterals. The fibres and their collaterals terminate by forming arborescences, some around the cells in the posterior horn, and others around the cells of Clarke's column, while the long ascending branches pass up in the columns of Goll and Burdach, and end by arborizing around the cells in the gracile and cuneate nuclei. Some of the fibres, however, pass to the gray matter of the opposite horn, and others to the anterior horn of the same side of the cord.

Anterior Nerve-roots.—The majority of the fibres of the anterior nerve-roots are the continuations outward of the axons of the large or small multipolar cells in the anterior horn of gray matter. Some, however, appear to pass across in the anterior white commissure to the cells in the anterior horn of the opposite side, while others extend backward to the posterior horn and outward to the lateral column of the same side.

The Nerve-tracts.

The anatomy of the various parts of the central nervous system having been described, a short account will now be given of the course taken by its more important nerve-tracts, and of the direction in which impulses pass along them. Before doing so, however, it is necessary to refer to the methods employed in elucidating this complex subject. All nerve fibres may be regarded as outgrowths from nerve-cells, and it is found that if a nerve-fibre be cut, the portion of it which is severed from the cell undergoes degeneration and becomes atrophied. Until recent years it was believed that the cell itself showed no change under such circumstances. This, however, is not the case, for if a nerve, the sciatic for instance, be divided in an animal, and after an interval of some weeks the animal be injected with methylene-blue and killed, it will be seen, on examining sections of the lumbar region of the spinal cord, that the cells are stained imperfectly or not at all, owing to a diminution, or, it may be, an entire disappearance of the chromatin, a substance which, in a normal cell, shows marked affinity for staining reagents. Further, the body of the cell is swollen, the nucleus displaced toward the periphery, and the part of the axon still attached to the altered cell is diminished in size and somewhat atrophied. Under favorable conditions the cell is capable of reassuming its normal appearance, and the axon may commence to grow. This method of injecting methylene-blue is of great value in determining the origin of nerve-fibres from their cells. Again, stimulation of certain localized areas of the brain or of the tracts arising from them is followed by the contraction of the muscles of the body. These cortical centres of the motor tracts are situated in the convolutions adjacent to the fissure of Rolando. When the stimulus is applied to one part the muscles of the hind limb contract, while other portions control the movements of the fore limb, etc. Destruction of these parts entails loss of function, paralysis of muscles, and degeneration of the tracts below the seat of injury. During life injury and disease may give rise to symptoms resembling either the effects of stimulation or those of destruction; and after death the tracts, or the centres of the tracts, are seen to be degenerated or otherwise altered. Further, by observing the development of the nervous system during the growth of the embryo, the fact is disclosed that all axis-cylinders do not acquire a medullary sheath at one and the same time. Speaking generally, it may be said that afferent fibres become medullated before efferent, and that in the case of the latter myelination occurs earlier in the brain than in the cord. By watching the effects of these different processes the functions of a considerable part of the brain and of the nerves leading from or to it have been determined.

The Motor, Efferent, or Descending Tract.

The constituent fibres of this tract are the axis-cylinder processes of cells situated in the cortex of the convolutions around the fissure of Rolando. At first they are somewhat widely diffused, but as they descend through the corona radiata they gradually approach each other and pass between the lenticular nucleus and optic thalamus in the genu and anterior two-thirds of the posterior limb of the internal capsule. Proceeding downward they next occupy the middle of the pes or crusta of the crus cerebri, and enter the pons Varolii, where the transverse fibres of this body not only conceal them, but divide them up into irregular bundles. Eventually they reach the medulla, and here the motor tracts form the anterior pyramids which lie one on each side of the median fissure. The transit of the fibres from the medulla is effected by two paths. The fibres nearest to the anterior median fissure cross the middle line, forming the *decussation of the pyramids*, and descend in the opposite side of the cord as the indirect or crossed pyramidal tract. Throughout the length of the spinal cord fibres from this column pass into the gray matter, to terminate by ramifying around the cells of the anterior horn. The more laterally placed portion of the motor tract does not decussate in the medulla, but descends as the direct or uncrossed pyramidal tract; these fibres, however, end in the anterior gray horn of the opposite side of the spinal cord by passing across in the

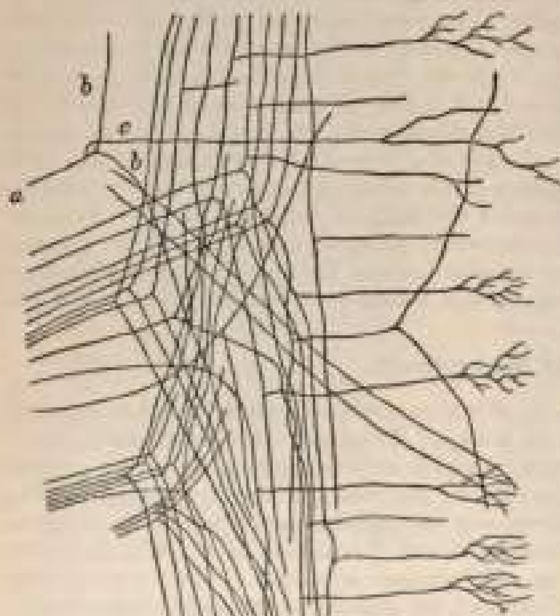

FIG. 388.—Dorsal roots entering cord and dividing into ascending and descending branches. (Van Gehuchten.) a, stem-fibre; b, b, ascending and descending limbs of bifurcation; c, collateral arising from stem-fibre.

anterior white commissure. Further, it must be remembered that many fibres which descend in and constitute part of the motor tract decussate before reaching the medulla, and terminate by forming synapses with the nuclei of the cranial nerves situated near the aqueduct of Sylvius, in the pons or in the medulla itself. There is considerable variation in the extent to which decussation takes place in the medulla, the commonest condition being that in which about three-fourths of the fibres decussate in the medulla and the remainder in the cord.

Other Descending Tracts.

1. From the cortex of the frontal lobe, anterior to the Rolandic area, fibres arise which descend through the anterior limb of the internal capsule and enter the crusta, where they lie to the inner side of the pyramidal tract; finally they enter, and end in, the pons.

2. Descending fibres also take origin in the temporo-occipital cortex and pass through the posterior limb of the internal capsule behind the fibres from the Rolandic area. They pass through the crusta, where they lie to the outer side of the same tract, and end in the pons.

3. A small tract arises from the cells of the caudate nucleus and descends to end in the substantia nigra or pons. In the crus cerebri it lies immediately above the motor tract, which is on its ventral aspect.

The Sensory, Afferent, Ascending Tract.

The course taken by those fibres of the posterior nerve-roots which ascend has been arrived at by dividing the nerve-roots between their ganglia and their entrance into the spinal cord and subsequently examining the degenerated areas. It has been found that the fibres pursue an oblique course, being situated at first in the outer part of Burdach's column; higher up they occupy the middle of this column, being displaced inward by the accession of other entering fibres, while still higher they enter and are continued upward in the column of Goll. The upper cervical fibres do not reach the column of Goll, but are entirely confined to that of Burdach. The degeneration method proves that the localization of these fibres is very precise: the sacral nerves lying to the inner side of Goll's column and near its periphery; the lumbar nerves to their outer side; the dorsal nerves still more laterally: while the cervical nerves are confined to the outer part of Burdach's column.

On reaching the medulla these ascending fibres end by arborizing around the cells in the gracile and cuneate nuclei, and the further upward course of the tract is effected by the axis-cylinder processes of these cells. These new fibres decussate in the medulla, dorsal to the crossing of the motor tract, in what is termed the *superior pyramidal decussation*, the *sensory decussation*, or *decussation of the fillet*; terms which are synonymous. Having crossed the middle line they ascend through the pons and tegmentum of the crus cerebri, and, reaching the ventral surface of the optic thalamus, the majority end either in the subthalamic region or in the optic thalamus, but a small proportion is continued directly into the brain cortex. From the gray matter of the optic thalamus the fibres of the third link in the chain arise. They pass through the internal capsule and end in the cerebral cortex: those which go to the fronto-parietal cortex being situated in the extreme front part of the anterior limb of the internal capsule, while in the hinder extremity of the posterior limb other fibres pass to their distribution in the temporal and occipital cortex.

Other Ascending Tracts.

The direct cerebellar tract begins about the level of the second lumbar vertebra, and is the continuation upward of the axis-cylinders of Clarke's column. At the upper end of the cord it passes into the restiform body and through this reaches the cerebellum. This tract seems to lose some of its fibres in the cord, since the area of its degeneration resulting from a section of the lower part of the cord diminishes from below upward; only some of its fibres therefore pass directly to the cerebellum. On the other hand, the tract is reinforced by an accession of fibres from the cord itself, so that its transverse area is greater above than below.

The antero-lateral ascending tract of Gower arises in the cord, probably as the axis-cylinders of cells situated in the posterior horn. Passing across the middle line through the anterior gray commissure the fibres ascend in the antero-lateral column of the cord, and ultimately reach the cerebellum through its superior peduncles.[1]

THE CRANIAL NERVES.

The cranial nerves arise from some part of the cerebrospinal centre, and are transmitted through foramina in the base of the cranium. They have been named numerically, according to the order in which they pass through the dura mater lining the base of the skull. Other names are also given to them, derived from the parts to which they are distributed or from their functions. Taken in their order, from before backward, they are as follows:

1st. Olfactory.	7th. Facial (Portio dura).
2d. Optic.	8th. Auditory (Portio mollis).
3d. Motor oculi.	9th. Glosso-pharyngeal.
4th. Trochlear (Pathetic).	10th. Pneumogastric (or Vagus).
5th. Trifacial (Trigeminus).	11th. Spinal accessory.
6th. Abducent.	12th. Hypoglossal.

All the cranial nerves are connected to some part of the surface of the brain. This is termed their *superficial* or *apparent origin*. But their fibres may, in all cases, be traced deeply into the substance of the brain to some special centre of gray matter, termed a *nucleus*. This is called their *deep* or *real origin*. The nerves, after emerging from the brain at their apparent origin, pass through foramina or tubular prolongations in the dura mater, leave the skull through foramina in its base, and pass to their final distribution.

The First Nerve (Fig. 350, page 654).

The **First cranial** or the **Olfactory nerves** (*nn. olfactorii*), the special nerves of the sense of smell, are about twenty in number. They are given off from the under surface of the olfactory bulb, an oval mass of a grayish color, which rests on the cribriform plate of the ethmoid bone, and forms the anterior expanded extremity of a slender process of brain-substance, named the *olfactory tract*. The olfactory tract and bulb have already been described (page 654).

Each nerve is surrounded by a tubular prolongation from the dura mater and pia mater, the former being lost on the periosteum lining the nose, the latter in the neurilemma of the nerve. The nerves, as they enter the nares, are divisible into two groups: an inner group, larger than those on the outer wall, spread out over the upper third of the septum; and an outer set, which is distributed over the superior turbinated bone, and the surface of the ethmoid in front of it. As the filaments descend, they unite in a plexiform network, and are believed by most observers to terminate by becoming continuous with the deep extremities of the olfactory cells.

The olfactory differs in structure from other nerves in being composed exclusively of non-medullated fibres. They are deficient in the white substance of Schwann, and consist of axis-cylinders, with a distinct nucleated sheath, in which there are, however, fewer nuclei than in ordinary non-medullated fibres. The olfactory centre in the cortex is not definitely known. It is generally ass-

[1] Testut describes the ascending column of Gower as joining with the fillet, and through it being carried to the cerebral cortex.

ciated with the temporal lobe, where it probably includes the gyrus hippocampi, uncus, and hippocampus major. It is further described as comprising the part of the callosal convolution which lies below the genu and rostrum of the corpus callosum, and also the posterior part of the orbital surface of the frontal lobe.

Surgical Anatomy.—In severe injuries to the head the olfactory bulb may become separated from the olfactory nerves, thus producing loss of the sense of smelling (*anosmia*), and with this a considerable loss in the sense of taste, as much of the perfection of the sense of taste is due to the sapid substances being also odorous and simultaneously exciting the sense of smell.

The Second Nerve (Fig. 389).

The **Second** or **Optic nerve** (*n. opticus*), the special nerve of the sense of sight, is distributed exclusively to the eyeball. The nerves of opposite sides are connected together at the commissure, and from the back of the commissure they may be traced to the brain, under the name of the *optic tracts.*

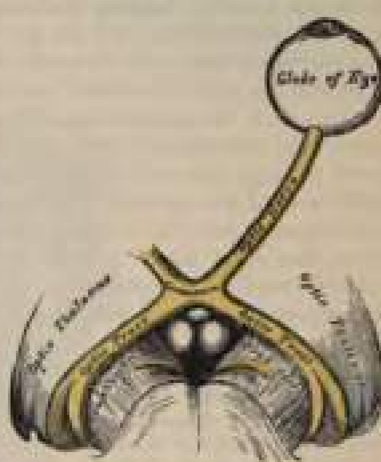

Fig. 389.—The left optic nerve and optic tracts.

The *optic tract*, at its connection with the brain, is divided into two bands, external and internal. The *external* band is the larger; it arises from the external geniculate body and from the under part of the pulvinar of the optic thalamus, and is partly continuous with the brachium of the anterior or upper quadrigeminal body. The *internal* band curves round the crusta, and passes beneath the internal geniculate body, with which it is connected, and then appears to lose itself in the brachium of the posterior or inferior quadrigeminal body. The fibres by which it is connected to the internal geniculate body are merely commissural, forming part of Gudden's commissure. From this origin the tract winds obliquely across the under surface of the crus cerebri, in the form of a flattened band, and is attached to the crus by its anterior margin. It then assumes a cylindrical form, and, as it passes forward, is connected with the tuber cinereum and lamina cinerea. It finally joins with the tract of the opposite side to form the *optic commissure.*

The *commissure* or *chiasma*, somewhat quadrilateral in form, rests upon the olivary eminence and on the anterior part of the diaphragma sellæ, being bounded, above, by the lamina cinerea; behind by the tuber cinereum; on either side by the anterior perforated space. Within the commissure, the optic nerves of the two sides undergo a partial decussation. The fibres which form the inner margin of each tract and posterior part of the commissure have no connection with the optic nerves. They simply pass across the commissure from one hemisphere of the brain to the other, and connect the internal geniculate bodies of the two sides. They are known as the *commissure of Gudden.* The remainder and principal part of the commissure consists of two sets of fibres, crossed and uncrossed. The *crossed*, which are the more numerous, occupy the central part of the chiasma, and pass from the optic tract of one side to the optic nerve of the other, decussating in the commissure with similar fibres of the opposite tract. The uncrossed fibres occupy the outer part of the chiasma, and pass from the tract of one side to the nerve of the same side.[1]

Fig. 390.—Course of the fibres in the optic commissure.

[1] A specimen of congenital absence of the optic commissure is to be found in the Museum of the Westminster Hospital. See also Henle, *Nervenlehre*, p. 393, ed. 2.

The great majority of the fibres of the optic nerve consist of the afferent axons of nerve-cells in the retina. Some few, however, are efferent fibres, and grow out from the brain. The afferent fibres end in arborizations around the cells in the external geniculate body, pulvinar, and upper quadrigeminal body, which are sometimes termed the *lower visual centres*. From these nuclei other fibres are prolonged to the *cortical visual centre*, which, according to most observers, is situated in the cuneus, and probably also in the lingual lobule of the occipital lobe.

It should be stated that some fibres are detached from the optic tract, and pass through the crus cerebri to the nucleus of the third nerve. These fibres are small, and may be regarded as afferent branches for the sphincter pupillæ and ciliary muscles. Other fibres pass to the cerebellum through its superior peduncles, while others, again, are lost in the pons.

The *optic nerves* arise from the fore part of the commissure, and, diverging from one another, become rounded in form and firm in texture, and are enclosed in a sheath derived from the pia mater and arachnoid. As each nerve passes through the corresponding optic foramen it receives a sheath from the dura mater; and as it enters the orbit this sheath subdivides into two layers, one of which becomes continuous with the periosteum of the orbit; the other forms the proper sheath of the nerve and surrounds it as far as the sclerotic. The nerve passes forward and outward through the cavity of the orbit, pierces the sclerotic and choroid coats at the back part of the eyeball, about one-eighth of an inch to the nasal side of its centre, and expands into the retina. A small artery, the *arteria centralis retinæ*, perforates the optic nerve a little behind the globe, and runs along its interior in a tubular canal of fibrous tissue. It supplies the inner surface of the retina, and is accompanied by corresponding veins.

Surgical Anatomy.—The optic nerve is peculiarly liable to become the seat of neuritis or undergo atrophy in affections of the central nervous system, and, as a rule, the pathological relationship between the two affections is exceedingly difficult to trace. There are, however, certain points in connection with the anatomy of this nerve which tend to throw light upon the frequent association of these affections with intracranial disease: (1) From its mode of development and from its structure the optic nerve must be regarded as a prolongation of the brain-substance, rather than as an ordinary cerebrospinal nerve. (2) As it passes from the brain it receives sheaths from the three cerebral membranes—a perineural sheath from the pia mater, an intermediate sheath from the arachnoid, and an outer sheath from the dura mater, which is also connected with the periosteum as it passes through the optic foramen. These sheaths are separated from each other by spaces which communicate with the subdural and subarachnoid spaces respectively. The innermost or perineural sheath sends a process around the arteria centralis retinæ into the interior of the nerve, and enters intimately into its structure. Thus inflammatory affections of the meninges or of the brain may readily extend themselves along these spaces or along the interstitial connective tissue in the nerve.

The course of the fibres in the optic commissure has an important pathological bearing, and has been the subject of much controversy. Microscopic examination, experiments, and pathology all seem to point to the fact that there is a partial decussation of the fibres, each tract supplying the corresponding half of each eye, so that the right tract supplies the right half of each eye, and the left tract the left half of each eye. At the same time, Charcot believes—and his view has met with general acceptation—that the fibres which do not decussate at the optic commissure have already decussated in the corpora quadrigemina, so that lesion of the cerebral centre of one side causes complete blindness of the opposite eye, because both sets of decussating fibres are destroyed. Whereas should one tract—say the right—be destroyed by disease, there will be blindness of the right half of both retinæ.

An antero-posterior section through the commissure would divide the decussating fibres, and would therefore produce blindness of the inner half of each eye; while a section at the margin of the side of the optic commissure would produce blindness of the external half of the retina of the same side.

The optic nerve may also be affected in injuries or diseases involving the orbit, in fractures of the anterior fossa of the base of the skull, in tumors of the orbit itself, or those invading this cavity from neighboring parts.

The Third Nerve (Figs. 391, 392, 393).

The **Third** or **Motor oculi nerve** (*n. oculo-motorius*) supplies all the muscles of the orbit except the Superior oblique and External rectus; it also supplies, through its connection with the ciliary ganglion, the Sphincter muscle of the iris and the Ciliary muscle. It is rather a large nerve, of rounded form and firm texture.

Its aparent origin is from the inner surface of the crus cerebri, immediately in front of the pons Varolii. The *deep origin* may be traced through the substantia nigra and tegmentum of the crus to a nucleus situated on either side of the median line beneath the floor of the aqueduct of Sylvius. The nucleus of the third nerve also receives fibres from the sixth nerve of the opposite side. These will be referred to again in the description of the latter nerve. The nucleus of the third nerve, considered from a physiological standpoint, can be subdivided into several smaller groups of cells, each group controlling a particular muscle. The nerves to the different muscles appear to take their origin from before backward, as follows: Inferior oblique, Inferior rectus, Superior rectus and Levator palpebræ, Internal rectus; while from the anterior end of the nucleus the fibres for accommodation and for the Sphincter pupillæ take their origin.

FIG. 391.—Nerves of the orbit. Seen from above.

On emerging from the brain, the nerve is invested with a sheath of pia mater, and enclosed in a prolongation from the arachnoid. It passes between the superior cerebellar and posterior cerebral arteries, and then pierces the dura mater in front of and external to the posterior clinoid process, passing between the two processes from the free and attached borders of the tentorium, which are prolonged forward to be connected with the anterior and posterior clinoid processes of the sphenoid bone. It passes along the outer wall of the cavernous sinus, above the other orbital nerves, receiving in its course one or two filaments from the cavernous plexus of the sympathetic, and a communicating branch from the first division of the fifth. It then divides into two branches, which enter the orbit through the sphenoidal fissure, between the two heads of the External rectus muscle. On passing through the fissure, the nerve is placed below the fourth and the frontal and lachrymal branches of the ophthalmic nerve, and has passing between its two divisions the nasal nerve.

The *superior division*, the smaller, passes inward over the optic nerve, and supplies the Superior rectus and Levator palpebræ.

The *inferior division*, the larger, divides into three branches. One passes beneath the optic nerve to the Internal rectus; another, to the Inferior rectus; and the third, the longest of the three, passes forward between the Inferior and External recti to the Inferior oblique. From this latter a short, thick branch is given off to the lower part of the lenticular ganglion, which forms its inferior root. It also gives off one or two filaments to the Inferior rectus. All these branches enter the muscles on their ocular surface, except that to the Inferior oblique, which enters its posterior border.

Surgical Anatomy.—Paralysis of the third nerve may be the result of many causes: as cerebral disease; conditions causing pressure on the cavernous sinus; periostitis of the bones entering into the formation of the sphenoidal fissure. It results, when complete, in (1) ptosis, or drooping of the upper eyelid, in consequence of the Levator palpebræ being paralyzed; (2) external strabismus, on account of the unopposed action of the External rectus muscle, which is not supplied by the third nerve, and is not therefore paralyzed; (3) dilatation of the pupil, because the sphincter fibres of the iris are paralyzed; (4) loss of power of accommodation, as the sphincter pupillæ, the ciliary muscle, and the Internal rectus are paralyzed; (5) slight prominence of the eyeball, owing to most of its muscles being relaxed. Occasionally paralysis may affect only a part of the nerve; that is to say, there may be, for example, a dilated and fixed pupil, with ptosis, but no other signs. Irritation of the nerve causes spasm of one or other of the muscles supplied by it; thus, there may be internal strabismus from spasm of the Internal rectus; accommodation for near objects only from spasm of the ciliary muscle, or myosis, contraction of the pupil, from irritation of the sphincter of the pupil.

The Fourth Nerve (Fig. 391).

The **Fourth** or **Trochlear nerve** (*n. trochlearis*), the smallest of the cranial nerves, supplies the Superior oblique muscle.

Its *apparent origin*, at the base of the brain, is on the outer side of the crus cerebri, just in front of the pons Varolii, but the fibres can be traced backward

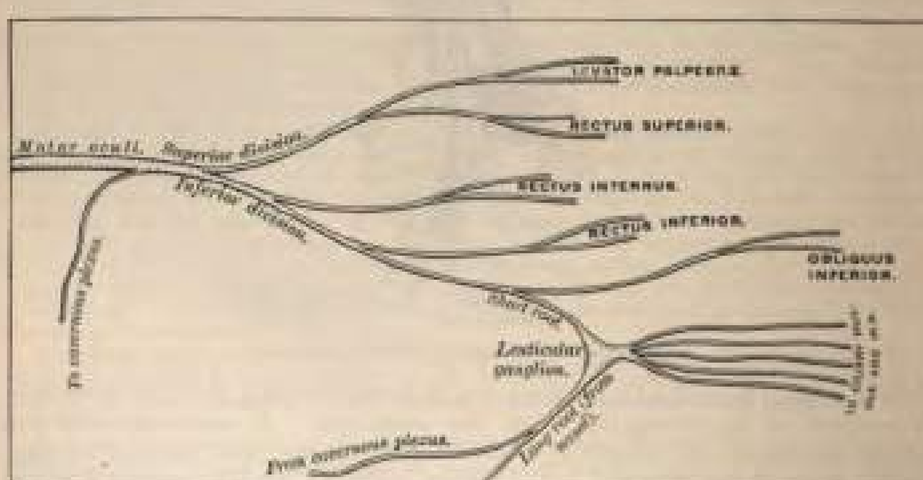

FIG. 392.—Plan of the motor oculi nerve. (After Flower.)

behind the corpora quadrigemina to the valve of Vieussens, on the upper surface of which the two nerves decussate. Its *deep origin* may be traced to a nucleus in the floor of the aqueduct of Sylvius immediately below that of the third nerve, with which it is continuous.

Emerging from the upper end of the valve of Vieussens, the nerve is directed outward across the superior peduncle of the cerebellum, and then winds forward round the outer side of the crus cerebri, immediately above the pons Varolii, pierces the dura mater in the free border of the tentorium cerebelli, just behind, and external to, the posterior clinoid process, and passes forward in the outer wall of the cavernous sinus, between the third nerve and the ophthalmic division of the fifth. It crosses the third nerve and enters the orbit through the sphenoidal fissure. It now becomes the highest of all the nerves, lying at the inner extremity of the fissure internal to the frontal nerve. In the orbit it passes inward, above the origin of the Levator palpebræ, and finally enters the orbital surface of the Superior oblique muscle. In the outer wall of the cavernous sinus this nerve is not infrequently blended with the ophthalmic division of the fifth.

Branches of Communication.—In the outer wall of the cavernous sinus it receives some filaments from the cavernous plexus of the sympathetic. In the sphenoidal fissure it occasionally gives off a branch to assist in the formation of the lachrymal nerve.

Branches of Distribution.—It gives off a recurrent branch, which passes backward between the layers of the tentorium, dividing into two or three filaments which may be traced as far back as the wall of the lateral sinus.

Surgical Anatomy.—The fourth nerve when paralyzed causes loss of function in the Superior oblique, so that the patient is unable to turn his eye downward and outward. Should the patient attempt to do this, the eye on the affected side is twisted inward, producing diplopia or double vision. Accordingly, it is said that the first symptom of this disease which presents itself is giddiness when going down hill or in descending stairs, owing to the double vision induced by the patient looking at his steps while descending.

The Fifth Nerve.

The **Fifth** or **Trifacial Nerve** (*n. trigeminus*) is the largest cranial nerve. It resembles a spinal nerve (1) in arising by two roots; (2) in having a ganglion developed on its posterior root; and (3) in its function, since it is a compound nerve. It is the great sensory nerve of the head and face and the motor nerve of the muscles of mastication. Its upper two divisions are entirely sensory; the third division is partly sensory and partly motor. It arises by two roots: of these the anterior is the smaller, and is the motor root; the posterior, the larger and sensory. Its *superficial origin* is from the side of the pons Varolii, nearer to the upper than the lower border. The smaller root consists of three or four bundles; the larger root consists of numerous bundles of fibres, varying in number from seventy to a hundred. The two roots are separated from one another by a few of the transverse fibres of the pons. The *deep origin* of the larger or sensory root is chiefly from a long tract in the medulla, the *lower sensory nucleus*, which is continuous below with the substantia gelatinosa of Rolando. The fibres from this nucleus form the so-called *ascending root of the fifth*; they pass upward through the pons and join with fibres from the locus cœruleus or *upper sensory nucleus*, which is situated to the outer side of the nucleus, from which the lower part of the motor root takes origin. The *deep origin* of the smaller or motor root is derived partly from a nucleus embedded in the gray matter of the upper part of the floor of the fourth ventricle and partly from a collection of nerve-cells situated at the side of the aqueduct of Sylvius, from which the fibres pass downward under the name of the *descending root of the fifth*. The real origin of the sensory root is from the Gasserian ganglion, which corresponds with the ganglion on a spinal nerve (see Development of Spinal Nerves in section on Embryology).

The two roots of the nerve pass forward below the tentorium cerebelli as it bridges over the notch on the inner part of the superior border of the petrous portion of the temporal bone: they then run between the bone and the dura mater to the apex of the petrous portion of the temporal bone, where the fibres of the sensory root form a large semilunar ganglion (*Gasserian*), while the motor root passes beneath the ganglion without having any connection with it, and joins outside the cranium with one of the trunks derived from it.

The **Gasserian** or **semilunar ganglion**[1] is lodged in an osteo-fibrous space, the *cavum Meckelii*, near the apex of the petrous portion of the temporal bone. It is of somewhat crescentic form, with its convexity turned forward. Its upper surface is intimately adherent to the dura mater. Besides the small or motor root, the large superficial petrosal nerve lies underneath the ganglion.

Branches of Communication.—This ganglion receives, on its *inner side*, filaments from the carotid plexus of the sympathetic. *Branches of Distribution.*—It gives off minute branches to the tentorium cerebelli and the dura mater in the middle fossa of the cranium. From its *anterior border*, which is directed forward and outward, three large branches proceed—the *ophthalmic*, *superior maxillary*, and *inferior maxillary*. The ophthalmic and superior maxillary consist exclusively of fibres derived from the larger root and ganglion, and are solely nerves of common sensation. The third division, or inferior maxillary, is joined outside the cranium by the motor root. This, therefore, strictly speaking, is the only portion of the fifth nerve which can be said to resemble a spinal nerve.

Ophthalmic Nerve (Figs. 391, 393, 394).

The **Ophthalmic** (*n. ophthalmicus*), or first division of the fifth, is a sensory nerve. It supplies the eyeball, the lachrymal gland, the mucous lining of the eye and nasal fossæ, and the integument of the eyebrow, forehead, and nose. It is the smallest of the three divisions of the fifth, arising from the upper part of the Gasserian ganglion. It is a short, flattened band, about an inch in length, which passes forward along the outer wall of the cavernous sinus, below the other nerves, and just before entering the orbit, through the sphenoidal fissure, divides into three branches—*lachrymal*, *frontal*, and *nasal*.

Branches of Communication.—The ophthalmic nerve is joined by filaments from the cavernous plexus of the sympathetic, communicates with the third and sixth nerves, and is not infrequently joined with the fourth.

Branches of Distribution.—It gives off recurrent filaments which pass between the layers of the tentorium, and then divides into

Lachrymal. Frontal. Nasal.

The **lachrymal** is the smallest of the three branches of the ophthalmic. It sometimes receives a filament from the fourth nerve, but this is possibly derived from the branch of communication which passes from the ophthalmic to the fourth. It passes forward in a separate tube of dura mater, and enters the orbit through the narrowest part of the sphenoidal fissure. In the orbit it runs along the upper border of the External rectus muscle, with the lachrymal artery, and communicates with the temporo-malar branch of the superior maxillary. It enters the lachrymal gland and gives off several filaments, which supply the gland and the conjunctiva. Finally, it pierces the superior palpebral ligament, and terminates in the integument of the upper eyelid, joining with filaments of the facial nerve. The lachrymal nerve is occasionally absent, when its place is taken by the temporal branch of the superior maxillary. Sometimes the latter branch is absent, and a continuation of the lachrymal is substituted for it.

The **frontal** is the largest division of the ophthalmic, and may be regarded, both from its size and direction, as the continuation of the nerve. It enters the orbit above the muscles, through the sphenoidal fissure, and runs forward along the middle line, between the Levator palpebræ and the periosteum. Midway between

[1] A Viennese anatomist, Raimund Balthasar Hirsch (1765), was the first who recognized the ganglionic nature of the swelling on the sensory root of the fifth nerve, and called it, in honor of his otherwise unknown teacher, Jon. Laur. Gasser, the "Ganglion Gasseri." Julius Casserius, whose name is given to the musculo-cutaneous nerve of the arm, was professor at Padua, 1545-1605. (See Hyrtl, *Lehrbuch der Anatomie*, p. 895 and p. 55.)

the apex and the base of the orbit it divides into two branches, supratrochlear and supra-orbital.

The *supratrochlear branch*, the smaller of the two, passes inward, above the pulley of the superior oblique muscle, and gives off a descending filament, which joins with the infratrochlear branch of the nasal nerve. It then escapes from the orbit between the pulley of the Superior oblique and the supra-orbital foramen, curves up on to the forehead close to the bone, ascends beneath the Corrugator supercilii and Occipito-frontalis muscles, and, dividing into branches which pierce these muscles, it supplies the integument of the lower part of the forehead on either side of the middle line and sends filaments to the conjunctiva and skin of the upper lid.

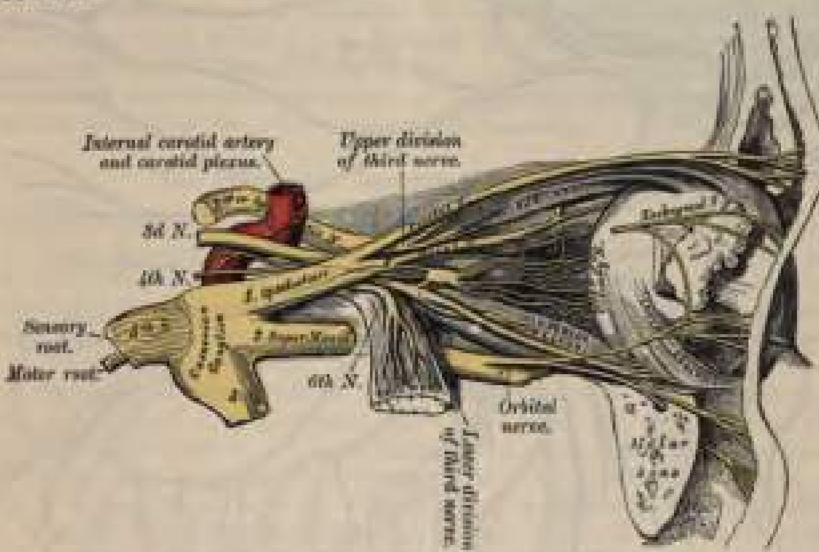

FIG. [illegible].—Nerves of the orbit and ophthalmic ganglion. Side view.

The *supra-orbital branch* passes forward through the supra-orbital foramen, and gives off, in this situation, palpebral filaments to the upper eyelid. It then ascends upon the forehead, and terminates in cutaneous and pericranial branches. The *cutaneous branches*, two in number, an inner and an outer, supply the integument of the cranium as far back as the occiput. They are at first situated beneath the Occipito-frontalis, the inner branch perforating the frontal portion of the muscle, the outer branch its tendinous aponeurosis. The *pericranial branches* are distributed to the pericranium over the frontal and parietal bones.

The **Nasal nerve** is intermediate in size between the frontal and lachrymal, and more deeply placed than the other branches of the ophthalmic. It enters the orbit between the two heads of the External rectus, and passes obliquely inward across the optic nerve, beneath the Superior rectus and Superior oblique muscles, to the inner wall of the orbit, where it passes through the anterior ethmoidal foramen, and, entering the cavity of the cranium, traverses a shallow groove on the front of the cribriform plate of the ethmoid bone, and passes down, through the slit by the side of the crista galli, into the nose, where it divides into two branches, an internal and an external. The *internal branch* supplies the mucous membrane near the fore part of the septum of the nose. The *external branch* descends in a groove on the inner surface of the nasal bone, and supplies a few filaments to the mucous membrane covering the fore part of the outer wall of the nares as far as the inferior spongy bone; it then leaves the cavity of the nose, between the lower border of the nasal bone and the upper lateral cartilage of the nose, and, passing down beneath the Compressor nasi, supplies the integument of the ala and the tip of the nose, joining with the facial nerve.

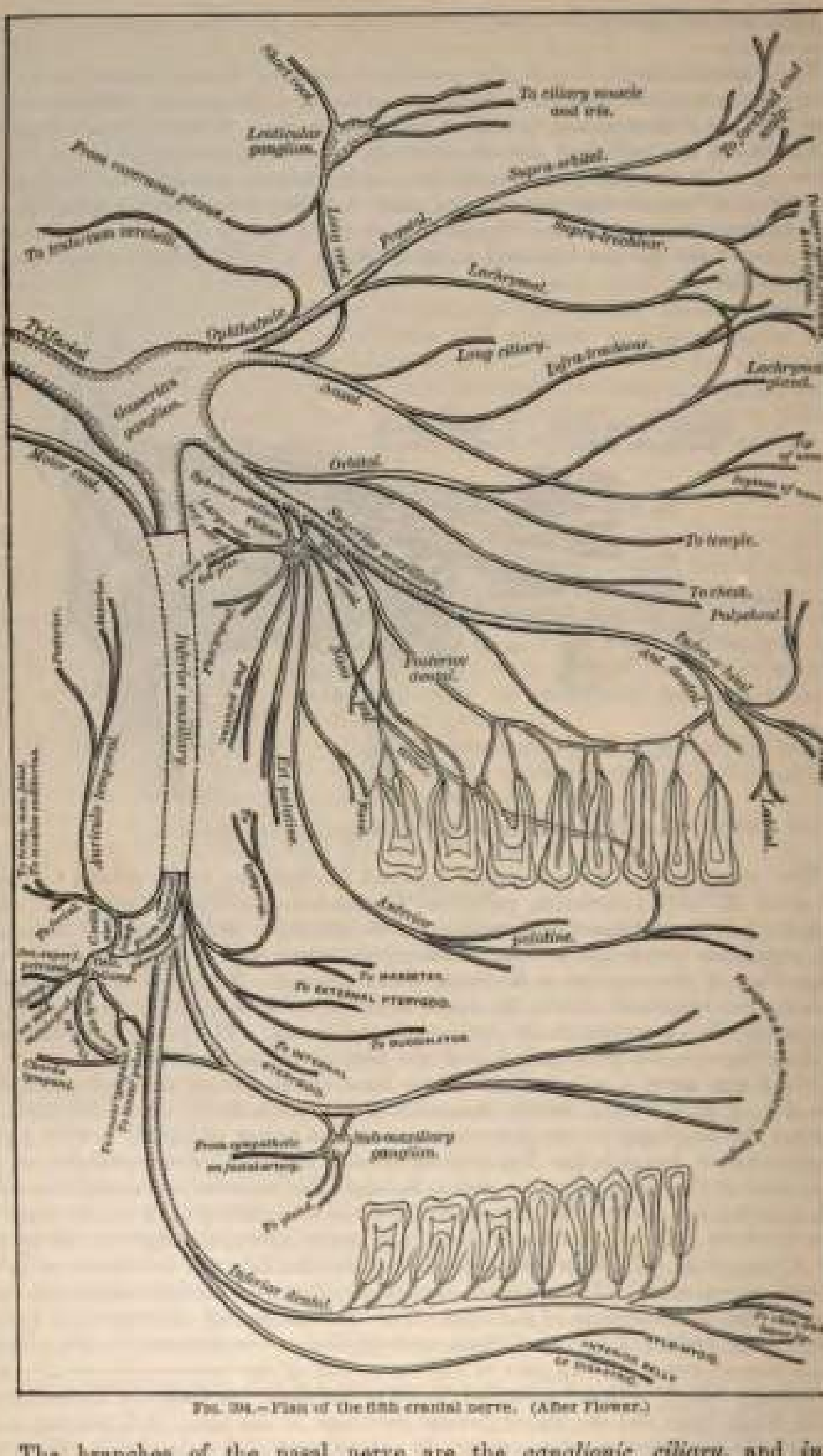

FIG. 394.—Plan of the fifth cranial nerve. (After Flower.)

The branches of the nasal nerve are the *ganglionic*, *ciliary*, and *infr*
trochlear.

The *ganglionic* is a slender branch, about half an inch in length, which usually arises from the nasal, between the two heads of the External rectus. It passes forward on the outer side of the optic nerve, and enters the postero-superior angle of the ciliary ganglion, forming its superior or long root. It is sometimes joined by a filament from the cavernous plexus of the sympathetic or from the superior division of the third nerve.

The *long ciliary nerves*, two or three in number, are given off from the nasal as it crosses the optic nerve. They join the short ciliary nerves from the ciliary ganglion, pierce the posterior part of the sclerotic, and, running forward between it and the choroid, are distributed to the ciliary muscles, iris, and cornea.

The *infratrochlear branch* is given off just before the nasal nerve passes through the anterior ethmoidal foramen. It runs forward along the upper border of the Internal rectus, and is joined, beneath the pulley of the Superior oblique, by a filament from the supratrochlear nerve. It then passes to the inner angle of the eye, and supplies the integument of the eyelids and side of the nose, the conjunctiva, lachrymal sac, and caruncula lachrymalis.

The Ophthalmic Ganglion (Figs. 391, 394).

Connected with the three divisions of the fifth nerve are four small ganglia. With the first division is connected the *ophthalmic ganglion;* with the second division, the *spheno-palatine* or *Meckel's ganglion;* and with the third, the *otic* and *submaxillary ganglia*. All the four receive sensory filaments from the fifth, and motor and sympathetic filaments from various sources; these filaments are called the *roots of the ganglia*.

The **Ophthalmic, Lenticular,** or **Ciliary Ganglion** is a small, quadrangular, flattened ganglion, of a reddish-gray color, and about the size of a pin's head, situated at the back part of the orbit between the optic nerve and the External rectus muscle, lying generally on the outer side of the ophthalmic artery. It is enclosed in a quantity of loose fat, which makes its dissection somewhat difficult.

Its *branches of communication*, or *roots*, are three, all of which enter its posterior border. One, the long or sensory root, is derived from the nasal branch of the ophthalmic and joins its superior angle. The second, the short or motor root, is a short, thick nerve, occasionally divided into two parts, which is derived from the branch of the third nerve to the Inferior oblique muscle, and is connected with the inferior angle of the ganglion. The third, the sympathetic root, is a slender filament from the cavernous plexus of the sympathetic. This is frequently blended with the long root, though it sometimes passes to the ganglion separately. According to Tiedemann, this ganglion receives a filament of communication from the spheno-palatine ganglion.

Its *branches of distribution* are the short ciliary nerves. These are delicate filaments, from six to ten in number, which arise from the fore part of the ganglion in two bundles, connected with its superior and inferior angles; the lower bundle is the larger. They run forward with the ciliary arteries in a wavy course, one set above and the other below the optic nerve, and are accompanied by the long ciliary nerves from the nasal. They pierce the sclerotic at the back part of the globe, pass forward in delicate grooves on its inner surface, and are distributed to the Ciliary muscle, iris, and cornea. Tiedemann has described one small branch as penetrating the optic nerve with the arteria centralis retinæ.

The Superior Maxillary Nerve (Fig. 395).

The **Superior Maxillary** (*n. maxillaris*), or second division of the fifth, is a sensory nerve. It is intermediate, both in position and size, between the ophthalmic and inferior maxillary. It commences at the middle of the Gasserian ganglion as a flattened plexiform band, and, passing horizontally forward, it leaves the skull through the foramen rotundum, where it becomes more cylindrical in form and firmer in texture. It then crosses the spheno-maxillary fossa, enters the orbit through the spheno-maxillary fissure, traverses the infra-orbital canal in the floor of the orbit, and appears upon the face at the infra-orbital foramen.[1] At its termination the nerve lies beneath the Levator labii superioris muscle, and divides into a leash of branches, which spread out upon the side of the nose, the lower eyelid, and upper lip, joining with filaments of the facial nerve.

Branches of Distribution.—The branches of this nerve may be divided into four groups: 1. Those given off in the cranium. 2. Those given off in the spheno-maxillary fossa. 3. Those in the infra-orbital canal. 4. Those on the face.

In the cranium . . .	Meningeal.
Spheno-maxillary fossa	Orbital or temporo-malar. Spheno-palatine. Posterior superior dental.
Infra-orbital canal .	Middle superior dental. Anterior superior dental.
On the face . . .	Palpebral. Nasal. Labial.

The **meningeal branch** is given off directly after its origin from the Gasserian ganglion; it accompanies the middle meningeal artery and supplies the dura mater.

The **orbital** or **temporo-malar branch** arises in the spheno-maxillary fossa, enters the orbit by the spheno-maxillary fissure, and divides at the back of that cavity into two branches, temporal and malar.

The *temporal branch* runs in a groove along the outer wall of the orbit (in the malar bone), receives a branch of communication from the lachrymal, and, passing through a foramen in the malar bone, enters the temporal fossa. It ascends between the bone and substance of the Temporal muscle, pierces this muscle and the temporal fascia about an inch above the zygoma, and is distributed to the integument covering the temple and side of the forehead, communicating with the facial and auriculo-temporal branch of the inferior maxillary nerve. As it pierces the temporal fascia it gives off a slender twig, which runs between the two layers of the fascia to the outer angle of the orbit.

The *malar branch* passes along the external inferior angle of the orbit, emerges upon the face through a foramen in the malar bone, and, perforating the Orbicularis palpebrarum muscle, supplies the skin on the prominence of the cheek, and is named *subcutaneus malæ*. It joins with the facial and the palpebral branches of the superior maxillary.

The **spheno-palatine branches,** two in number, descend to the spheno-palatine ganglion.

The **posterior superior dental branches** arise from the trunk of the nerve just as it is about to enter the infra-orbital canal; they are generally two in number, but sometimes arise by a single trunk, and immediately divide and pass downward on the tuberosity of the superior maxillary bone. They give off several twigs to the gums and neighboring parts of the mucous membrane of the cheek (*superior gingival branches*). They then enter the posterior dental canals on the zygomatic surface of the superior maxillary bone, and, passing from behind forward in the substance of the bone, communicate with the middle dental nerve, and give off branches to the lining membrane of the antrum and three twigs to each of the molar teeth. These twigs enter the foramina at the apices of the fangs and supply the pulp.

The **middle superior dental branch** is given off from the superior maxillary nerve in the back part of the infra-orbital canal, and runs downward and forward in a special canal in the outer wall of the antrum to supply the two bicuspid teeth. It communicates with the posterior and anterior dental branches. At its point of

[1] After it enters the infra-orbital canal, the nerve is frequently called the *infra-orbital*.

communication with the posterior branch is a slight thickening which has received the name of the *ganglion of Valentin;* and at its point of communication with the anterior branch is a second enlargement, which is called the *ganglion of Bochdalek.* Neither of these is probably a true ganglion.

The **anterior superior dental branch**, of large size, is given off from the superior maxillary nerve just before its exit from the infra-orbital foramen; it enters a special canal in the anterior wall of the antrum, and divides into a series of branches which supply the incisor and canine teeth. It communicates with the middle dental nerve, and gives off a *nasal branch*, which passes through a minute canal into the nasal fossa, and supplies the mucous membrane of the fore part of the inferior meatus and the floor of this cavity, communicating with the nasal branches from Meckel's ganglion.

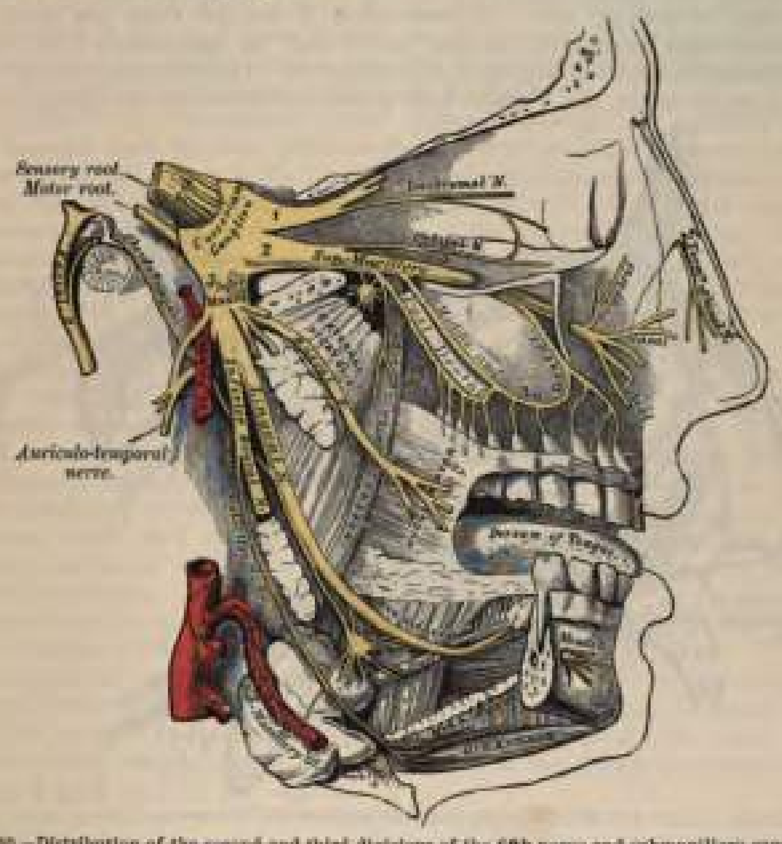

FIG. [illegible].—Distribution of the second and third divisions of the fifth nerve and submaxillary ganglion.

The **palpebral branches** pass upward beneath the Orbicularis palpebrarum. They supply the integument and conjunctiva of the lower eyelid with sensation, joining at the outer angle of the orbit with the facial nerve and malar branch of the orbital.

The **nasal branches** pass inward; they supply the integument of the side of the nose and join with the nasal branch of the ophthalmic.

The **labial branches**, the largest and most numerous, descend beneath the Levator labii superioris, and are distributed to the integument of the upper lip, the mucous membrane of the mouth, and labial glands.

All these branches are joined, immediately beneath the orbit, by filaments from the facial nerve, forming an intricate plexus, the *infra-orbital.*

The Spheno-palatine Ganglion (Fig. 396).

The **spheno-palatine ganglion** (*Meckel's*), the largest of the cranial ganglia, is deeply placed in the spheno-maxillary fossa, close to the spheno-palatine foramen. It is triangular or heart-shaped, of a reddish-gray color, and is situated just below the superior maxillary nerve as it crosses the fossa.

Its Branches of Communication.—Like the other ganglia of the fifth nerve, it possesses a motor, a sensory, and a sympathetic root. Its *sensory root* is derived from the superior maxillary nerve through its two spheno-palatine branches. These branches of the nerve, given off in the spheno-maxillary fossa, descend to the ganglion. Their fibres, for the most part, pass in front of the ganglion, as they proceed to their destination, in the palate and nasal fossa, and are not incorporated in the ganglionic mass; some few of the fibres, however, enter the ganglion, constituting its sensory root. Its *motor root* is derived from the facial nerve through the large superficial petrosal nerve, and its *sympathetic root* from the carotid plexus, through the large deep petrosal nerve. These two nerves join together to form a single nerve, the *Vidian*, before their entrance into the ganglion.

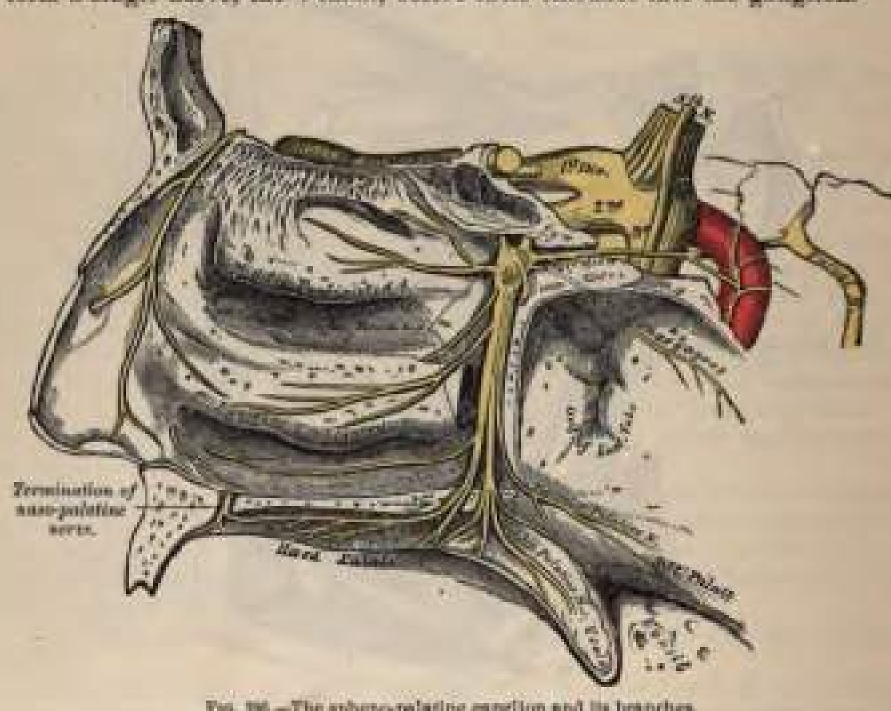

FIG. 396.—The spheno-palatine ganglion and its branches.

The *large superficial petrosal branch* (*nervus petrosus superficialis major*) is given off from the geniculate ganglion of the facial nerve in the aqueductus Fallopii; it passes through the hiatus Fallopii; enters the cranial cavity, and runs forward contained in a groove on the anterior surface of the petrous portion of the temporal bone, lying beneath the dura mater. It then enters the cartilaginous substance which fills in the foramen lacerum medium basis cranii, and, joining with the large deep petrosal branch, forms the Vidian nerve.

The *large deep petrosal branch* (*nervus petrosus profundus*) is given off from the carotid plexus, and runs through the carotid canal on the outer side of the internal carotid artery. It then enters the cartilaginous substance which fills in the foramen lacerum medium, and joins with the large superficial petrosal nerve to form the Vidian.

The *Vidian nerve*, formed in the cartilaginous substance which fills in the middle lacerated foramen by the junction of the two preceding nerves, passes forward, through the Vidian canal, with the artery of the same name, and is joined by a small ascending branch, the *sphenoidal branch*, from the otic ganglion. Finally, it enters the spheno-maxillary fossa, and joins the posterior angle of Meckel's ganglion.

Its *branches of distribution* are divisible into four groups: *ascending*, which pass to the orbit; *descending*, to the palate; *internal*, to the nose; and *posterior branches*, to the pharynx and nasal fossæ.

The *ascending branches* are two or three delicate filaments, which enter the orbit by the spheno-maxillary fissure, and supply the periosteum. According to Luschka, some filaments pass through foramina in the suture between the os planum of the ethmoid and frontal bones to supply the mucous membrane of the posterior ethmoidal and sphenoidal sinuses.

The *descending or palatine branches* are distributed to the roof of the mouth, the soft palate, tonsil, and lining membrane of the nose. They are almost a direct continuation of the spheno-palatine branches of the superior maxillary nerve, and are three in number—anterior, middle, and posterior.

The *anterior* or *large palatine nerve* descends through the posterior palatine canal, emerges upon the hard palate at the posterior palatine foramen, and passes forward through a groove in the hard palate nearly as far as the incisor teeth. It supplies the gums, the mucous membrane and glands of the hard palate, and communicates in front with the termination of the naso-palatine nerve. While in the posterior palatine canal it gives off *inferior nasal branches*, which enter the nose through openings in the palate bone, and ramify over the inferior turbinated bone and middle and inferior meatuses; and at its exit from the canal a palatine branch is distributed to both surfaces of the soft palate.

The *middle* or *external palatine nerve* descends through one of the accessory palatine canals, distributing branches to the uvula, tonsil, and soft palate. It is occasionally wanting.

The *posterior* or *small palatine nerve* descends with a minute artery through the small posterior palatine canal, emerging by a separate opening behind the posterior palatine foramen. It supplies the Levator palati and Azygos uvulæ muscles,[1] the soft palate, tonsil, and uvula. The middle and posterior palatine join with the tonsillar branches of the glosso-pharyngeal to form the plexus around the tonsil (*circulus tonsillaris*).

The *internal branches* are distributed to the septum and outer wall of the nasal fossæ. They are the superior nasal (anterior) and the naso-palatine.

The *superior nasal branches* (*anterior*), four or five in number, enter the back part of the nasal fossa by the spheno-palatine foramen. They supply the mucous membrane covering the superior and middle spongy bones, and that lining the posterior ethmoidal cells, a few being prolonged to the upper and back part of the septum.

The *naso-palatine nerve* (*Cotunnius*) also enters the nasal fossa through the spheno-palatine foramen, and passes inward across the roof of the nose, below the orifice of the sphenoidal sinus, to reach the septum; it then runs obliquely downward and forward along the lower part of the septum, to the anterior palatine foramen, lying between the periosteum and mucous membrane. It descends to the roof of the mouth through the anterior palatine canal. The two nerves are here contained in separate and distinct canals, situated in the intermaxillary suture, and termed the foramina of Scarpa, the left nerve being usually anterior to the right one. In the mouth they become united, supply the mucous membrane behind the incisor teeth, and join with the anterior palatine nerve. The naso-palatine nerve furnishes a few small filaments to the mucous membrane of the septum.

The *posterior branches* are the pharyngeal (pterygo-palatine) and the upper posterior nasal branches.

The *pharyngeal nerve* (*pterygo-palatine*) is a small branch arising from the

[1] It is probable that this is not the true motor supply to these muscles, but that they are supplied by the spinal accessory through the pharyngeal plexus.

back part of the ganglion, being generally blended with the Vidian nerve. It passes through the pterygo-palatine canal with the pterygo-palatine artery, and is distributed to the mucous membrane of the upper part of the pharynx, behind the Eustachian tube.

The *upper posterior nasal branches* are a few twigs given off from the posterior part of the ganglion, which run backward in the sheath of the Vidian nerve to the mucous membrane at the back part of the roof, septum, and superior meatus of the nose and that covering the end of the Eustachian tube.

The Inferior Maxillary Nerve (Fig. 395).

The **Inferior Maxillary Nerve** (*n. mandibularis*) distributes branches to the teeth and gums of the lower jaw, the integument of the temple and external ear, the lower part of the face and lower lip, and the muscles of mastication; it also supplies the tongue with a large branch. It is the largest of the three divisions of the fifth, and is made up of two roots: a large or sensory root proceeding from the inferior angle of the Gasserian ganglion; and a small or motor root, which passes beneath the ganglion, and unites with the sensory root just after its exit from the skull through the foramen ovale. Immediately beneath the base of the skull this nerve divides into two trunks, anterior and posterior. Previous to its division the primary trunk gives off from its inner side a recurrent (meningeal) branch and the nerve to the Internal pterygoid muscle.

The **recurrent branch** is given off directly after its exit from the foramen ovale. It passes backward into the skull through the foramen spinosum with the middle meningeal artery. It divides into two branches, anterior and posterior, which accompany the main divisions of the artery and supply the dura mater. The posterior branch also supplies the mucous lining of the mastoid cells. The anterior branch communicates with the meningeal branch of the superior maxillary nerve.

The **Internal Pterygoid Nerve,** given off from the inferior maxillary previous to its division, is intimately connected at its origin with the otic ganglion. It is a long and slender branch, which passes inward to enter the deep surface of the Internal pterygoid muscle.

The *anterior* and smaller division, which receives nearly the whole of the motor root, divides into branches which supply the muscles of mastication. They are the masseteric, deep temporal, buccal, and external pterygoid.

The **masseteric branch** passes outward, above the External pterygoid muscle, in front of the temporo-mandibular articulation and behind the tendon of the temporal muscle; it crosses the sigmoid notch with the masseteric artery, to the deep surface of the Masseter muscle, in which it ramifies nearly as far as its anterior border. It occasionally gives a branch to the Temporal muscle, and a filament to the articulation of the jaw.

The **deep temporal branches,** two in number, anterior and posterior, supply the deep surface of the Temporal muscle. The *posterior branch*, of small size, is placed at the back of the temporal fossa. It is sometimes joined with the masseteric branch. The *anterior branch* is frequently given off from the buccal nerve; it is reflected upward, at the pterygoid ridge of the sphenoid, to the front of the temporal fossa. Sometimes there are three deep temporal branches; the third branch (*middle deep temporal*) passes outward above the External pterygoid muscle, and runs upward on the bone to enter the deep surface of the Temporal muscle.

The **buccal branch** passes forward between the two heads of the External pterygoid, and downward beneath the inner surface of the coronoid process of the lower jaw, or through the fibres of the Temporal muscle, to reach the surface of the Buccinator, upon which it divides into a superior and an inferior branch. It gives a branch to the External pterygoid during its passage through that muscle, and a few ascending filaments to the Temporal muscle, one of which occasionally joins with the anterior branch of the deep temporal nerve. The *upper branch* supplies the integument and upper part of the Buccinator muscle, joining with the facial nerve round the facial vein. The *lower branch* passes forward to the angle of the mouth: it supplies the integument and Buccinator muscle, as well as the mucous membrane lining the inner surface of that muscle, and joins the facial nerve.[1]

The **External Pterygoid Nerve** is most frequently derived from the buccal, but it may be given off separately from the anterior trunk of the nerve. It enters the muscle on its inner surface.

The *posterior* and larger division of the inferior maxillary nerve is for the most part sensory, but receives a few filaments from the motor root. It divides into three branches: auriculo-temporal, lingual (gustatory), and inferior dental.

The **auriculo-temporal nerve** generally arises by two roots, between which the middle meningeal artery passes. It runs backward beneath the External pterygoid muscle to the inner side of the neck of the lower jaw. It then turns upward with the temporal artery, between the external ear and condyle of the jaw, under cover of the parotid gland, and, escaping from beneath this structure, ascends over the zygoma and divides into two temporal branches.

The *branches of communication* are with the facial and with the otic ganglion. The branches of communication with the facial, usually two in number, pass forward from behind the neck of the condyle of the jaw, to join this nerve at the posterior border of the Masseter muscle. They form one of the principal branches of communication between the facial and the fifth nerve. The filaments of communication with the otic ganglion are derived from the commencement of the auriculo-temporal nerve.

The *branches of distribution* are—

Anterior auricular.	Articular.
Branches to the meatus auditorius.	Parotid.
Superficial temporal.	

The *anterior auricular branches* are usually two in number. They supply the front of the upper part of the pinna, being distributed principally to the skin covering the front of the helix and tragus.

Branches to the meatus auditorius, two in number, enter the canal between the bony and cartilaginous portion of the meatus. They supply the skin lining the meatus; the upper one sending a filament to the membrana tympani.

A *branch to the temporo-mandibular articulation* is usually derived from the auriculo-temporal nerve.

The *parotid branches* supply the parotid gland.

The *superficial temporal* accompanies the temporal artery to the vertex of the skull, and supplies the integument of the temporal region, communicating with the facial nerve, and the temporal branch of the temporo-malar, from the superior maxillary.

The **lingual nerve (gustatory)** supplies the papillæ and mucous membrane of the anterior two-thirds of the tongue. It is deeply placed throughout the whole of its course. It lies at first beneath the External pterygoid muscle, together with the inferior dental nerve, being placed to the inner side of this nerve, and is occasionally joined to it by a branch which may cross the internal maxillary artery. The chorda tympani also joins it at an acute angle in this situation. The nerve then passes between the Internal pterygoid muscle and the inner side of the ramus of the jaw, and crosses obliquely to the side of the tongue over the Superior constrictor and Stylo-glossus muscles, and then between the Hyo-glossus muscle and deep part of the submaxillary gland; the nerve finally runs across Wharton's duct, and along the side of the tongue to its apex, lying immediately beneath the mucous membrane.

The *branches of communication* are with the facial through the chorda tympani, the inferior dental and hypoglossal nerves, and the submaxillary ganglion.

[1] There seems to be no reason to doubt that the branch supplying the Buccinator muscle is entirely a nerve of ordinary sensation, and that the true motor supply of this muscle is from the facial.

The branches to the submaxillary ganglion are two or three in number; those connected with the hypoglossal nerve form a plexus at the anterior margin of the Hyo-glossus muscle.

The *branches of distribution* supply the mucous membrane of the mouth, the gums, the sublingual gland, the filiform and fungiform papillæ and mucous membrane of the tongue; the terminal filaments communicate, at the tip of the tongue, with the hypoglossal nerve.

The **Inferior Dental** is the largest of the three branches of the inferior maxillary nerve. It passes downward with the inferior dental artery, at first beneath the External pterygoid muscle, and then between the internal lateral ligament and the ramus of the jaw to the dental foramen. It then passes forward in the dental canal of the inferior maxillary bone, lying beneath the teeth, as far as the mental foramen, where it divides into two terminal branches, incisor and mental.

The branches of the inferior dental are, the mylo-hyoid, dental, incisive, and mental.

The *mylo-hyoid* is derived from the inferior dental just as that nerve is about to enter the dental foramen. It descends in a groove on the inner surface of the ramus of the jaw, in which it is retained by a process of fibrous membrane. It reaches the under surface of the Mylo-hyoid muscle, and supplies it and the anterior belly of the Digastric.

The *dental branches* supply the molar and bicuspid teeth. They correspond in number to the fangs of those teeth: each nerve entering the orifice at the point of the fang and supplying the pulp of the tooth.

The *incisive branch* is continued onward within the bone to the middle line, and supplies the canine and incisor teeth.

The *mental branch* emerges from the bone at the mental foramen, and divides beneath the Depressor anguli oris into two or three branches; one descends to supply the skin of the chin, and another (sometimes two) ascends to supply the skin and mucous membrane of the lower lip. These branches communicate freely with the facial nerve.

Two small ganglia are connected with the inferior maxillary nerve—the otic with the trunk of the nerve, and the submaxillary with its lingual branch.

Otic Ganglion (Fig. 397).

The **Otic Ganglion** (*Arnold's*) is a small, oval-shaped, flattened ganglion of a reddish-gray color, situated immediately below the foramen ovale, on the inner surface of the inferior maxillary nerve, and round the origin of the internal pterygoid nerve. It is in relation, *externally*, with the trunk of the inferior maxillary nerve, at the point where the motor root joins the sensory portion; *internally*, with the cartilaginous part of the Eustachian tube, and the origin of the Tensor palati muscle; *behind* it is the middle meningeal artery.

Branches of Communication.—This ganglion is connected with the internal pterygoid branch of the inferior maxillary nerve by two or three short, delicate filaments. From this it may obtain a motor root, and possibly also a sensory root, as these filaments from the nerve to the Internal pterygoid may contain sensory fibres. It communicates with the glosso-pharyngeal and facial nerves through the small superficial petrosal nerve continued from the tympanic plexus, and through this communication it probably receives its sensory root from the glosso-pharyngeal and its motor root from the facial; its communication with the sympathetic is effected by a filament from the plexus surrounding the middle meningeal artery. The ganglion also communicates with the auriculo-temporal nerve. This is probably a branch from the glosso-pharyngeal which passes to the ganglion, and through it and the auriculo-temporal nerve to the parotid gland. A slender filament (*sphenoidal*) ascends from it to the Vidian nerve.

Its *branches of distribution* are a filament to the Tensor tympani and one to the Tensor palati. The former passes backward on the outer side of the Eustachian tube; the latter arises from the ganglion, near the origin of the internal pterygoid nerve, and passes forward. The fibres of these nerves are, however, mainly derived

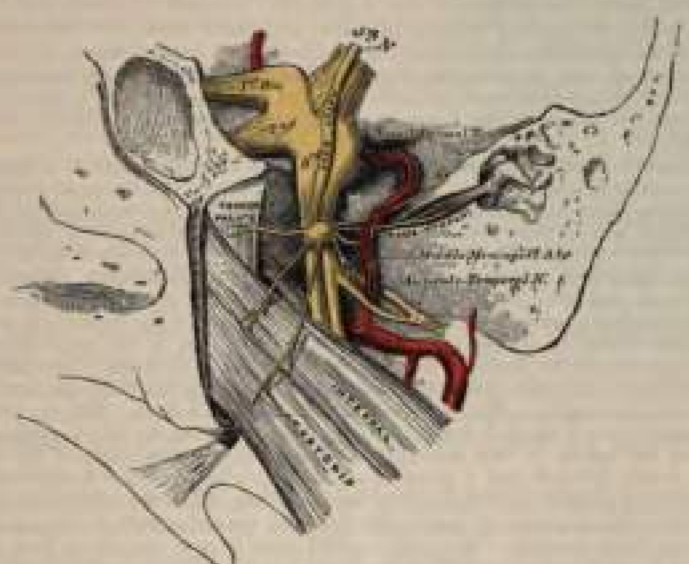

Fig. 397.—The otic ganglion and its branches.

from the nerve to the Internal pterygoid muscle. It also gives off a small communicating branch to the chorda tympani.

The Submaxillary Ganglion (Fig. 395).

The **submaxillary ganglion** is of small size, fusiform in shape, and situated above the deep portion of the submaxillary gland, near the posterior border of the Mylo-hyoid muscle, being connected by filaments with the lower border of the lingual (gustatory) nerve.

Branches of Communication.—This ganglion is connected with the lingual (gustatory) nerve by a few filaments which join it separately at its fore and back part. It also receives a branch from the chorda tympani, by which it communicates with the facial, and communicates with the sympathetic by filaments from the sympathetic plexus around the facial artery.

Branches of Distribution.—These are five or six in number: they arise from the lower part of the ganglion, and supply the mucous membrane of the mouth and Wharton's duct, some being lost in the submaxillary gland. The branch of communication from the lingual to the fore part of the ganglion is by some regarded as a branch of distribution, by which filaments of the chorda tympani pass from the ganglion to the nerve, and by it are conveyed to the sublingual gland and the tongue.

Surface Marking.—It will be seen from the above description that the three terminal branches of the three divisions of the fifth nerve emerge from foramina in the bones of the skull and face on to the face: the terminal branch of the first division emerging through the supra-orbital foramen; that of the second through the infra-orbital foramen; and the third through the mental foramen. The supra-orbital foramen is situated at the junction of the internal and middle third of the supra-orbital arch. If a straight line is drawn from this point to the lower border of the inferior maxillary bone, so that it passes between the two bicuspid teeth of the lower jaw, it will pass over the infra-orbital and mental foramina, the former being situated about one centimetre (two-fifths of an inch) below the margin of the orbit, and the latter varying in position according to the age of the individual. In the adult it is midway between the upper and lower borders of the inferior maxillary bone; in the child it is nearer the lower border; and in the edentulous jaw of old age it is close to the upper margin.

Surgical Anatomy.—The fifth nerve may be affected in its entirety, or its sensory or motor root may be affected, or one of its primary main divisions. In injury to the sensory root there is anæsthesia of the half of the face on the side of the lesion, with the exception of the skin over the parotid gland; insensibility of the conjunctiva, followed by destructive inflammation of the cornea, partly from loss of trophic influence, and partly from the irritation produced by the presence of foreign bodies on it, which are not perceived by the patient, and therefore not expelled by the act of winking; dryness of the nose, loss to a considerable extent of the sense of taste, and diminished secretion of the lachrymal and salivary glands. In injury to the motor root there is impaired action of the lower jaw from paralysis of the muscles of mastication on the affected side.

The fifth nerve is often the seat of neuralgia, and each of the three divisions has been divided or a portion of the nerve excised for this affection. The supra-orbital nerve may be exposed by making an incision an inch and a half in length along the supra-orbital margin below the eyebrow, which is to be drawn upward, the centre of the incision corresponding to the supra-orbital notch. The skin and Orbicularis palpebrarum having been divided, the nerve can be easily found emerging from the notch and lying in some loose cellular tissue. It should be drawn up by a blunt hook and divided, or, what is better, a portion of it removed. The infra-orbital nerve has been divided at its exit by an incision on the cheek; or the floor of the orbit has been exposed, the infra-orbital canal opened up, and the anterior part of the nerve resected; or the whole nerve, together with Meckel's ganglion as far back as the foramen rotundum, has been removed. This latter operation, though undoubtedly a severe proceeding, appears to have been followed by the best results. The operation is performed as follows: The superior maxillary bone is first exposed by a T-shaped incision, one limb passing along the lower margin of the orbit, the other from the centre of this vertically down the cheek to the angle of the mouth. The nerve is then found, divided, and a piece of silk tied to it as a guide. A small trephine (one-half inch) is then applied to the bone below, but including, the infra-orbital foramen, and the antrum opened. The trephine is now applied to the posterior wall of the antrum, and the spheno-maxillary fossa exposed. The infra-orbital canal is now opened up from below by fine cutting-pliers or a chisel, and the nerve drawn down into the trephine hole, it being held on the stretch by means of the piece of silk: it is severed with fine curved scissors as near the foramen rotundum as possible, any branches coming off from the ganglion being also divided.[1] The mental branch of the inferior dental nerve has been divided at its exit from the foramen by an incision made through the mucous membrane where it is reflected from the alveolar process on to the lower lip; or a portion of the trunk of the inferior dental nerve has been resected by an incision on the cheek through the Masseter muscle, exposing the outer surface of the ramus of the jaw. A trephine was then applied over the position of the inferior dental foramen and the outer table removed, so as to expose the inferior dental canal. The nerve was dissected out of the portion of the canal exposed, and, having been divided after its exit from the mental foramen, it was by traction on the end exposed in the trephine hole, drawn out entire, and cut off as high up as possible.[2] The inferior dental nerve has also been divided by an incision within the mouth, the bony point guarding the inferior dental foramen forming the guide to the nerve. The buccal nerve may be divided by an incision through the mucous membrane of the mouth and the Buccinator just in front of the anterior border of the ramus of the lower jaw (Stimson).

The lingual (gustatory) nerve is occasionally divided with the view of relieving the pain in cancerous disease of the tongue. This may be done in that part of its course where it lies below and behind the last molar tooth. If a line is drawn from the middle of the crown of the last molar tooth to the angle of the jaw, it will cross the nerve, which lies about half an inch behind the tooth, parallel to the bulging alveolar ridge on the inner side of the body of the bone. If the knife is entered three-quarters of an inch behind and below the last molar tooth and carried down to the bone, the nerve will be divided. Hilton divided it opposite the second molar tooth, where it is covered only by the mucous membrane, and Lucas pulls the tongue forward and over to the opposite side, when the nerve can be seen standing out as a firm cord under the mucous membrane by the side of the tongue and can be easily seized with a sharp hook and divided or a portion excised. This is a simple enough operation on the cadaver, but when the disease is extensive and has extended to the floor of the mouth, as is generally the case when division of the nerve is required, the operation is not practicable.

The Sixth Nerve (Fig. 393).

The **Sixth** or **Abducent Nerve** supplies the External rectus muscle.

Its *superficial origin* is by several filaments from the constricted part of the pyramid, close to the pons, or from the lower border of the pons itself, in the groove between this body and the medulla. Its *deep origin* is from the upper part of the floor of the fourth ventricle, close to the median line, beneath the eminentia teres.

From the nucleus of the sixth nerve fibres pass through the posterior longi-

[1] Carnochan, *Amer. Journ. Med. Science*, 1858, p. 136.

[2] Mears, *Trans. Amer. Surg. Assoc.*, vol. ii. p. 469.

tudinal bundle to the oculo-motor nucleus of the opposite side and into the third nerve, along which they are carried to the Internal rectus muscle. The External rectus of one eye and the Internal rectus of the other may therefore be said to receive their nerves from the same nucleus—a factor of great importance in connection with the conjugate movements of the eyeball, and one that may explain certain paralytic phenomena of the Recti muscles, which are often associated with lesions in the pons.

The nerve pierces the dura mater on the basilar surface of the sphenoid bone, runs through a notch immediately below the posterior clinoid process, and enters the cavernous sinus. It passes forward through the sinus, lying on the outer side of the internal carotid artery. It enters the orbit through the sphenoidal fissure, and lies above the ophthalmic vein, from which it is separated by a lamina of dura mater. It then passes between the two heads of the External rectus, and is distributed to that muscle on its ocular surface.

Branches of Communication.—It is joined by several filaments from the carotid and cavernous plexus, and by one from the ophthalmic nerve.

The above-mentioned nerve, as well as the third, fourth, and the ophthalmic division of the fifth, as they pass to the orbit, bear a certain relation to each other in the cavernous sinus, at the sphenoidal fissure, and in the cavity of the orbit, which will now be described.

In the *cavernous sinus* (Fig. 327) the third, fourth, and ophthalmic division of the fifth are placed on the outer wall of the sinus, in their numerical order both from above downward and from within outward. The sixth nerve lies at the outer side of the internal carotid artery. As these nerves pass forward to the sphenoidal fissure, the third and fifth nerves become divided into branches, and the sixth approaches the rest, so that their relative position becomes considerably changed.

In the *sphenoidal fissure* (Fig. 398) the fourth and the frontal and lachrymal divisions of the ophthalmic lie upon the same plane, the former being most

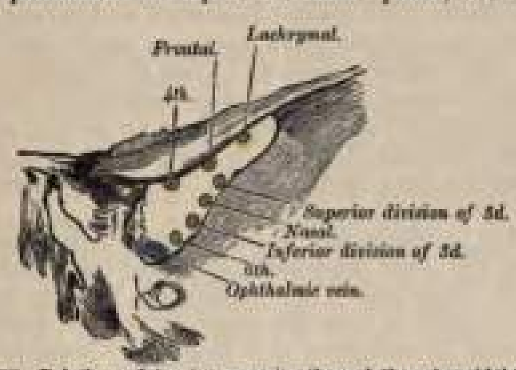

Fig. 398.—Relations of structures passing through the sphenoidal fissure.

internal, the latter external, and they enter the cavity of the orbit above the muscles. The remaining nerves enter the orbit between the two heads of the External rectus. The superior division of the third is the highest of these; beneath this lies the nasal branch of the ophthalmic; then the inferior division of the third; and the sixth lowest of all.

In the *orbit* the fourth and the frontal and lachrymal divisions of the ophthalmic lie on the same plane immediately beneath the periosteum, the fourth nerve being internal and resting on the Superior oblique, the frontal resting on the Levator palpebræ, and the lachrymal on the External rectus. Next in order comes the superior division of the third nerve, lying immediately beneath the Superior rectus, and then the nasal branch of the ophthalmic, crossing the optic nerve from the outer to the inner side of the orbit. Beneath these is found the optic nerve, surrounded in front by the ciliary nerves, and having the lenticular ganglion on its outer side, between it and the External rectus. Below the optic is the inferior division of the third and the sixth, which lies on the outer side of the orbit.

Surgical Anatomy.—The sixth nerve is more frequently involved in fractures of the base of the skull than any other of the cranial nerves. The result of paralysis of this nerve is internal or convergent squint. When injured so that its function is destroyed, there is, in addition to the paralysis of the External rectus muscle, often a certain amount of contraction of the pupil, because some of the sympathetic fibres to the radiating muscle of the iris pass along with this nerve.

The Seventh Nerve (Figs. 399, 400, 401).

The **Seventh** or **Facial Nerve** (*portio dura*) is the motor nerve of all the muscles of expression in the face, and of the Platysma and Buccinator; the muscles of the External ear; the posterior belly of the Digastric, and the Stylo-hyoid. Its chorda tympani branch is the nerve of taste for the anterior two-thirds of the tongue and the vaso-dilator nerve of the submaxillary and sublingual glands; its tympanic branch supplies the Stapedius.

Its *superficial origin* is from the upper end of the medulla oblongata, in the groove between the olivary and restiform bodies. Its *deep origin* is from a nucleus situated in the reticular formation of the lower part of the pons, a little external and ventral to the nucleus of the sixth nerve. From this origin the fibres pursue a curved course in the substance of the pons. They first pass backward and inward, and then turn upward and forward forming the funiculus teres, which produces an eminence (eminentia teres) on the floor of the fourth ventricle, and finally bend sharply downward and outward round the upper end of the nucleus of origin of the sixth nerve, to reach their superficial origin between the olivary and restiform bodies. From the nucleus of the third nerve some fibres arise which descend in the posterior longitudinal bundle and join the facial just before it leaves the pons; these fibres are said to supply the anterior belly of the Occipito-frontalis, Orbicularis palpebrarum, and the Corrugator supercilii, as these muscles have been observed to escape paralysis in lesions of the nucleus of the facial nerve.

FIG. 399.—The course and connections of the facial nerve in the temporal bone.

The auditory nerve (*portio mollis*) lies to its outer side; and between the two is a small fasciculus, the *pars intermedia* of Wrisberg, which arises from the medulla and joins the facial nerve in the internal auditory meatus. The deep origin of the pars intermedia is from the upper end of the nucleus of the glosso-pharyngeal nerve, and at its emergence it is frequently connected with both nerves.

The pars intermedia may be regarded as the *sensory* root of the facial nerve, analogous to the sensory root of the fifth, and its real nucleus of origin would then consist of the geniculate ganglion.

The facial nerve, firmer, rounder, and smaller than the auditory, passes forward and outward upon the middle peduncle of the cerebellum, and enters the internal auditory meatus with the auditory nerve. Within the meatus the facial nerve lies in a groove along the upper and anterior part of the auditory nerve, and the pars intermedia is placed between the two, and joins the inner angle of the geniculate ganglion. Occasionally a few of its fibres pass into the auditory nerve. Beyond the ganglion its fibres are generally regarded as forming the chorda tympani.

At the bottom of the meatus, the facial nerve enters the aqueductus Fallopii, and follows the course of that canal through the petrous portion of the temporal bone, from its commencement at the internal meatus, to its termination at the stylo-mastoid foramen. It is at first directed outward between the cochlea and vestibule toward the inner wall of the tympanum; it then bends suddenly backward and arches downward behind the tympanum to the stylo-mastoid foramen.

At the point where it changes its direction, it presents a reddish gangliform swelling (*intumescentia gangliformis*, or *geniculate ganglion*). On emerging from the stylo-mastoid foramen it runs forward in the substance of the parotid gland, crosses the external carotid artery, and divides behind the ramus of the lower jaw into two primary branches, *temporo-facial* and *cervico-facial*, from which numerous offsets are distributed over the side of the head, face, and upper part of the neck, supplying the superficial muscles in these regions. As the primary branches and their offsets diverge from each other, they present somewhat the appearance of a bird's claw; hence the name of *pes anserinus* is given to the divisions of the facial nerve in and near the parotid gland.

The communications of the facial nerve may be thus arranged:

In the internal auditory meatus .	With the auditory nerve.
From the geniculate ganglion .	With Meckel's ganglion by the large superficial petrosal nerve. With the otic ganglion by the small superficial petrosal nerve. With the sympathetic on the middle meningeal by the external superficial petrosal nerve.
In the Fallopian aqueduct . .	With the auricular branch of the pneumogastric.
At its exit from the stylo-mastoid foramen	With the glosso-pharyngeal. With the pneumogastric. With the auricularis magnus. With the auriculo-temporal.
Behind the ear	With the small occipital.
On the face	With the three divisions of the fifth.
In the neck	With the superficial cervical.

In the internal auditory meatus some minute filaments pass between the facial and auditory nerves.

Opposite the hiatus Fallopii, the gangliform enlargement on the facial nerve communicates with Meckel's ganglion by means of the large superficial petrosal nerve, which forms its motor root; with the otic ganglion, by the small superficial petrosal nerve; and with the sympathetic filaments accompanying the middle meningeal artery, by the external petrosal (Bidder). From the gangliform enlargement, according to Arnold, a twig is sent back to the auditory nerve. Just before the facial nerve emerges from the stylo-mastoid foramen it generally receives a twig of communication from the auricular branch of the pneumogastric.

After its exit from the stylo-mastoid foramen, it sends a twig to the glosso-pharyngeal, another to the pneumogastric nerve, and communicates with the great auricular branch of the cervical plexus, with the auriculo-temporal branch of the inferior maxillary nerve in the parotid gland, with the small occipital behind the ear, on the face with the terminal branches of the three divisions of the fifth, and in the neck with the transverse cervical.

Branches of Distribution.

Within the aquæductus Fallopii .	Tympanic, to the Stapedius muscle. Chorda tympani.	
At its exit from the stylo-mastoid foramen	Posterior Auricular. Digastric. Stylo-hyoid.	
On the face	Temporo-facial	Temporal. Malar. Infra-orbital.
	Cervico-facial	Buccal. Supramaxillary. Inframaxillary.

The **tympanic branch** arises from the nerve opposite the pyramid; it passes through a small canal in the pyramid and supplies the Stapedius muscle.

The **chorda tympani** is given off from the facial as it passes vertically downward at the back of the tympanum, about a quarter of an inch before its exit from the stylo-mastoid foramen. It passes from below upward and forward in a

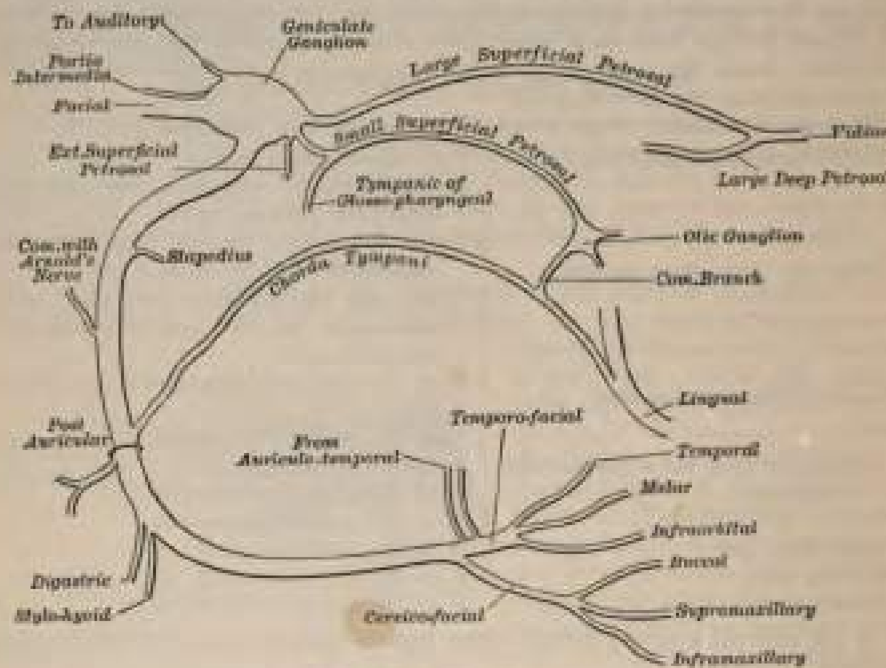

FIG. 406.—Plan of the facial nerve.

distinct canal, and enters the cavity of the tympanum through an aperture (*iter chordæ posterius*) on its posterior wall between the opening of the mastoid cells and the attachment of the membrana tympani, and becomes invested with mucous membrane. It passes forward through the cavity of the tympanum, between the fibrous and mucous layers of the membrana tympani, and over the handle of the malleus, emerging from that cavity through a foramen at the inner end of the Glaserian fissure, which is called the *iter chordæ anterius*, or *canal of Huguier*. It then descends between the two Pterygoid muscles, meets the lingual nerve at an acute angle, and accompanies it to the submaxillary gland; part of it then joins the submaxillary ganglion; the rest is continued onward through the muscular substance of the tongue to the mucous membrane covering its anterior two-thirds. A few of its fibres probably pass through the submaxillary ganglion to the sublingual gland. Before joining the lingual nerve it receives a small communicating branch from the otic ganglion. As already stated, the chorda tympani nerve is by many regarded as the continuation of the pars intermedia of Wrisberg.

The **Posterior auricular nerve** arises close to the stylo-mastoid foramen, and passes upward in front of the mastoid process, where it is joined by a filament from the auricular branch of the pneumogastric, and communicates with the mastoid branch of the great auricular and with the small occipital. As it ascends between the meatus and mastoid process it divides into two branches. The *auricular branch* supplies the Retrahens auriculum and the small muscles on the cranial surface of the pinna. The *occipital branch*, the larger, passes backward along the superior curved line of the occipital bone, and supplies the occipital portion of the Occipito-frontalis.

The **digastric branch** usually arises by a common trunk with the Stylo-hyoid branch: it divides into several filaments, which supply the posterior belly of the Digastric; one of these perforates that muscle to join the glosso-pharyngeal nerve.

The **stylo-hyoid** is a long, slender branch, which passes inward, entering the Stylo-hyoid muscle about its middle.

The **Temporo-facial**, the larger of the two terminal branches, passes upward and forward through the parotid glands, crosses the external carotid artery and temporo-maxillary vein, and passes over the neck of the condyle of the jaw, being connected in this situation with the auriculo-temporal branch of the inferior maxillary nerve, and divides into branches which are distributed over the temple and upper part of the face; these are divided into three sets—temporal, malar, and infra-orbital.

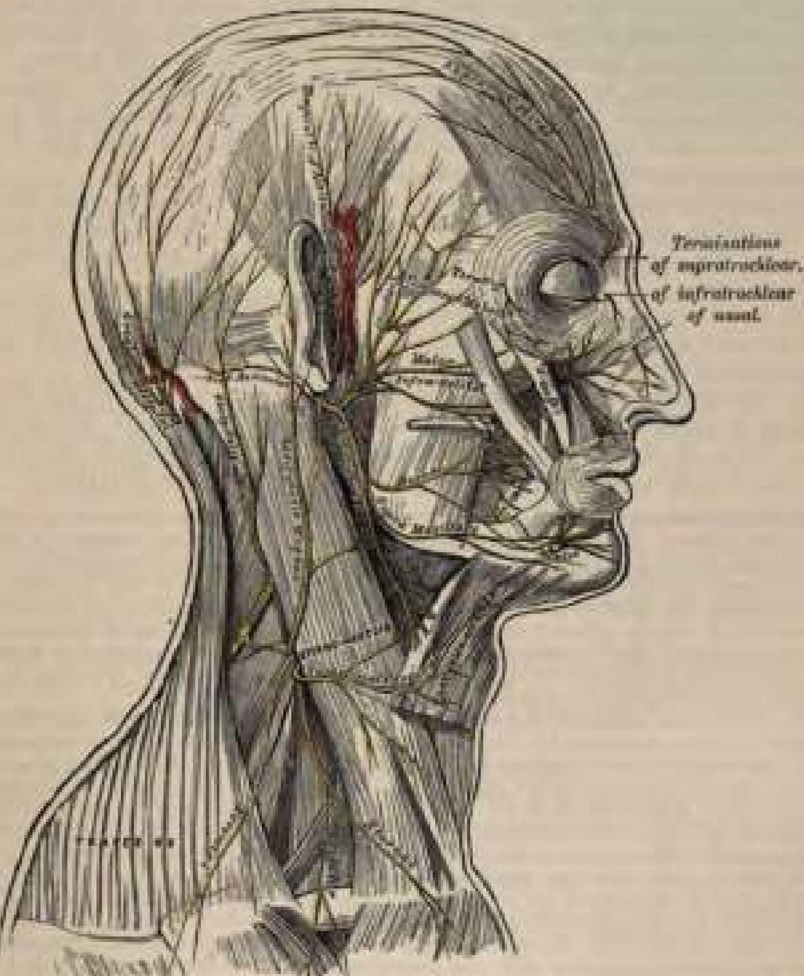

FIG. 391.—The nerves of the scalp, face, and side of the neck.

The *temporal branches* cross the zygoma to the temporal region, supplying the Attrahens and Attollens auriculam muscles, and join with the temporal branch of the temporo-malar, a branch of the superior maxillary, and with the auriculo-temporal branch of the inferior maxillary. The more anterior branches supply the frontal portion of the Occipito-frontalis, the Orbicularis palpebrarum, and Corrugator supercilii muscles, joining with the supra-orbital and lachrymal branches of the ophthalmic.

The *malar branches* pass across the malar bone to the outer angle of the orbit, where they supply the Orbicularis palpebrarum muscle, joining with filaments from the lachrymal nerve; others supply the lower eyelid, joining with filaments of the malar branch (*subcutaneus malæ*) of the superior maxillary nerve.

The *infra-orbital*, of larger size than the rest, pass horizontally forward to be distributed between the lower margin of the orbit and the mouth. The *superficial branches* run beneath the skin and above the superficial muscles of the face, which they supply: some branches are distributed to the Pyramidalis nasi, joining at the inner angle of the orbit with the infratrochlear and nasal branches of the ophthalmic. The *deep branches* pass beneath the Zygomatici and the Levator labii superioris, supplying them and the Levator anguli oris, and form a plexus (*infra-orbital*) by joining with the infra-orbital branch of the superior maxillary nerve and the buccal branches of the cervico-facial. This branch also supplies the Levator labii superioris alæque nasi and the small muscles of the nose.

The **Cervico-facial division of the facial nerve** passes obliquely downward and forward through the parotid gland, crossing the external carotid artery. In this situation it is joined by branches from the great auricular nerve. Opposite the angle of the lower jaw it divides into branches which are distributed on the lower half of the face and upper part of the neck. These may be divided into three sets —buccal, supramaxillary, and inframaxillary.

The *buccal branches* cross the Masseter muscle. They supply the Buccinator and Orbicularis oris, and join with the infra-orbital branches of the temporo-facial division of the nerve, and with filaments of the buccal branch of the inferior maxillary nerve.

The *supramaxillary* or *mandibular branches* pass forward beneath the Platysma and Depressor anguli oris, supplying the muscles of the lower lip and chin, and communicating with the mental branch of the inferior dental nerve.

The *inframaxillary* or *cervical branches* run forward beneath the Platysma, and form a series of arches across the side of the neck over the suprahyoid region. One of these branches descends vertically to join with the superficial cervical nerve from the cervical plexus; others supply the Platysma.

Surgical Anatomy.—The facial nerve is more frequently paralyzed than any of the other of the cranial nerves. The paralysis may depend either upon (1) central causes—*i. e.* blood-clots or intracranial tumors pressing on the nerve before its entrance into the internal auditory meatus. It is also one of the nerves involved in "bulbar paralysis." Or (2) it may be paralyzed in its passage through the petrous bone by damage due to middle-ear disease or by fractures of the base. Or (3) it may be affected at or after its exit from the stylo-mastoid foramen. This is commonly known as "Bell's paralysis." It may be due to exposure to cold or to injury of the nerve, either from accidental wounds of the face or during some surgical operation, as removal of parotid tumors, opening of abscesses, or operations on the lower jaw.

When the cause is central, the sixth nerve is usually paralyzed as well, and there is also hemiplegia on the opposite side. In these cases the electrical reactions are the same as in health; whereas, when the paralysis is in the course of the nerve, the reaction is usually lost. When the nerve is paralyzed in the petrous bone, in addition to the paralysis of the muscles of expression, there is loss of taste in the anterior part of the tongue, and the patient is unable to recognize the difference between bitters and sweets, acids and salines, from involvement of the chorda tympani. The mouth is dry, because the salivary glands are not secreting; and the sense of hearing is affected from paralysis of the Stapedius. When the cause of the paralysis is from fracture of the base of the skull, the auditory nerve and the petrosal nerves, which are connected with the intumescentia gangliformis, are also involved. When the injury to the nerve is after its exit from the stylo-mastoid foramen, all the muscles of expression, except the Levator palpebræ, together with the posterior belly of the Digastric and Stylo-hyoid, are paralyzed. There is smoothness of the forehead, and the patient is unable to frown; the eyelids cannot be closed, and the lower lid droops, so that the punctum is no longer in contact with the globe, and the tears run down the cheek; there is smoothness of the cheek and loss of the naso-labial furrow; the nostril cannot be dilated; the mouth is drawn to the sound side, and there is inability to whistle; food collects between the cheek and gum from paralysis of the Buccinator.

The facial nerve is at fault in cases of so-called "histrionic spasm," which consists in an almost constant and uncontrollable twitching of the muscles of the face. This twitching is sometimes so severe as to cause great discomfort and annoyance to the patient and to interfere with sleep, and for its relief the facial nerve has been stretched. The operation is performed by making an incision behind the ear from the root of the mastoid process to the angle of the jaw. The parotid is turned forward, and the dissection carried along the anterior border of the

Sterno-mastoid muscle and mastoid process until the upper border of the posterior belly of the Digastric is found. The nerve is parallel to this on about a level of the middle of the mastoid process. When found, the nerve must be stretched by passing a blunt hook beneath it and pulling it forward and outward. Too great force must not be used, for fear of permanent injury to the nerve.

Eighth Nerve.

The **Eighth** or **Auditory Nerve** (*portio mollis*) is the special nerve of the sense of hearing, being distributed exclusively to the internal ear.

Origin of the Eighth Nerve.—The eighth nerve consists of two sets of fibres, which, although differing in their central connections, are both concerned in the transmission of afferent impulses from the internal ear to the medulla and pons, and from there, by means of new fibres which arise from collections of gray matter in these structures, to the cerebrum and cerebellum. One set of fibres forms the vestibular root of the nerve, and arises from the cells in the ganglion of Scarpa; the other set constitutes the cochlear root, and takes origin from the cells in the ganglion spirale or ganglion of Corti. At its connection with the brain the eighth nerve occupies the groove between the pons and medulla, where it is situated between the restiform body, which is behind, and the seventh nerve, which is in front.

Vestibular or Ventral Root.—The fibres of this root enter the medulla to the inner side of those of the cochlear root, and pass between the restiform body, which is to their outer side, and the inferior root of the fifth, which lies to their inner side. They then divide into an ascending and a descending set. The fibres of the latter end by arborizing round the cells of the internal nucleus, which is situated in the *trigonum acustici* in the floor of the fourth ventricle. The ascending fibres either end in the same manner or in the *external nucleus*, which is situated to the outer side of the trigonum acustici and farther from the ventricular floor. It is described as consisting of two parts, an inner, the *nucleus of Deiters*, and an outer, the *nucleus of Bechterew*. Some of the axons of the cells of the external nucleus, and possibly also of the internal nucleus, are continued upward through the restiform body to the roof nuclei of the opposite side of the cerebellum, to which also are prolonged other fibres of the vestibular root without undergoing a relay in the nuclei of the medulla. A second set of fibres from the internal and external nuclei end partly in the tegmentum, while the remainder ascend in the posterior longitudinal bundle to arborize around the nuclei of the oculo-motor nerve.

Cochlear or Dorsal Root.—This part of the nerve is placed externally to the vestibular root. Its fibres end in two nuclei, one of which, the *accessory nucleus*, lies immediately in front of the restiform body; the other, the *tuberculum acusticum*, somewhat to its outer side.

The striæ acusticæ or medullary striæ are the axons of the cells of the tuberculum acusticum. They pass backward and inward over the restiform body, and across the floor of the fourth ventricle toward the middle line. Here they dip into the substance of the pons, to end around the cells of the *superior olive* of the same or opposite side. There are, however, other fibres, and these are both direct and crossed, which do not arborize around the tegmental nuclei, but pass into the lateral fillet. The cells of the accessory nucleus give origin to fibres which pass transversely in the pons and constitute the trapezium. The description given as to the mode of ending of the striæ acusticæ is applicable to that of the trapezoid fibres, viz., around the cells of the superior olive or of the *trapezoid nucleus* (which lies ventral to the olive) of the same or opposite side, while others, crossed or uncrossed, pass directly into the lateral fillet.

If the farther connections of the cochlear nerve of one side, say the left, are considered, it is found that they lie to the outer side of the main sensory tract, the fillet, and are therefore termed the *lateral fillet*. The fibres comprising the left lateral fillet arise in the superior olive or trapezoid nucleus of the same or opposite side, while others are the uninterrupted fibres already alluded to, and these are either crossed or uncrossed, the former being the axons of the cells of the right accessory nucleus or of the cells of the right tuberculum acusticum, while the latter are derived from the same cells of the left side. In the upper part of the fillet there is a collection of nerve-cells, the *nucleus of the fillet*, around the cells of which some of the fibres arborize, and from the cells of which axons originate to continue upward the tract of the lateral fillet. The ultimate ending of the left lateral fillet is partly in the quadrigeminal bodies of the same or opposite side, while the remainder of the fibres ascend in the posterior limb of the internal capsule to reach the first and perhaps the second left temporal convolution.

The auditory nerve contains a few afferent fibres which arise in the quadrigeminal bodies, the nucleus of the lateral fillet, trapezoid nucleus, and superior olive.

The auditory nerve after leaving the medulla passes forward across the posterior border of the middle peduncle of the cerebellum, in company with the facial nerve, from which it is partially separated by a small artery (auditory). It then enters the internal auditory meatus with the facial nerve. At the bottom of the meatus it receives one or two filaments from the facial nerve, and then divides into its two branches, *cochlear* and *vestibular*. The auditory nerve is soft in texture (hence the name, *portio mollis*), and is destitute of neurilemma. The distribution of the auditory nerve in the internal ear will be found described along with the anatomy of that organ in a subsequent page.

Surgical Anatomy.—The auditory nerve is frequently injured, together with the facial nerve, in fractures of the middle fossa of the base of the skull implicating the internal auditory meatus. The nerve may be either torn across, producing permanent deafness, or it may be bruised or pressed upon by extravasated blood or inflammatory exudation, when the deafness will in all probability be temporary. The nerve may also be injured by violent blows on the head without fracture, and deafness may arise from loud explosions from dynamite, etc., probably from some lesion of this nerve, which is more liable to be injured than the other cranial nerves on account of its structure. The test that the nerve is destroyed and that the deafness is not due to some lesion of the auditory apparatus is obtained by placing a vibrating tuning-fork on the head. The vibrations will be heard in cases where the auditory apparatus is at fault, but not in cases of destruction of the auditory nerve.

The Ninth Pair (Figs. 402, 403, 404).

The **Ninth** or **Glosso-pharyngeal Nerve** is distributed, as its name implies, to the tongue and pharynx, being the nerve of ordinary sensation to the mucous membrane of the pharynx, fauces, and tonsil; and the nerve of taste to all parts of the tongue to which it is distributed.

Its *superficial origin* is by three or four filaments, closely connected together, from the upper part of the medulla oblongata, in the groove between the olivary and restiform body.

Its *deep origin* may be traced through the fasciculi of the lateral tract, to three different sources: (1) some of the fibres may be traced to a nucleus of gray matter at the lower part of the floor of the fourth ventricle beneath the inferior fovea; (2) others may be traced downward into the *funiculus solitarius*, a rounded bundle of fibres in the lower part of the medulla, commencing immediately above the decussation of the pyramids (these fibres have not been distinctly traced to cells); (3) a third set of fibres take origin from the cells of the *nucleus ambiguus*. This nucleus is situated some distance from the floor of the fourth ventricle and lies slightly internal to the inferior fovea. It gives origin to the motor branches of the glosso-pharyngeal and vagus, and to the bulbar part of the spinal accessory. The real origin of the sensory fibres of the glosso-pharyngeal must be looked for in the jugular and petrosal ganglia which are developed from the neural crest.

FIG. 402.—Origin, ganglia, and communications of the ninth, tenth, and eleventh cranial nerves.

From its superficial origin it passes outward across the flocculus, and leaves the

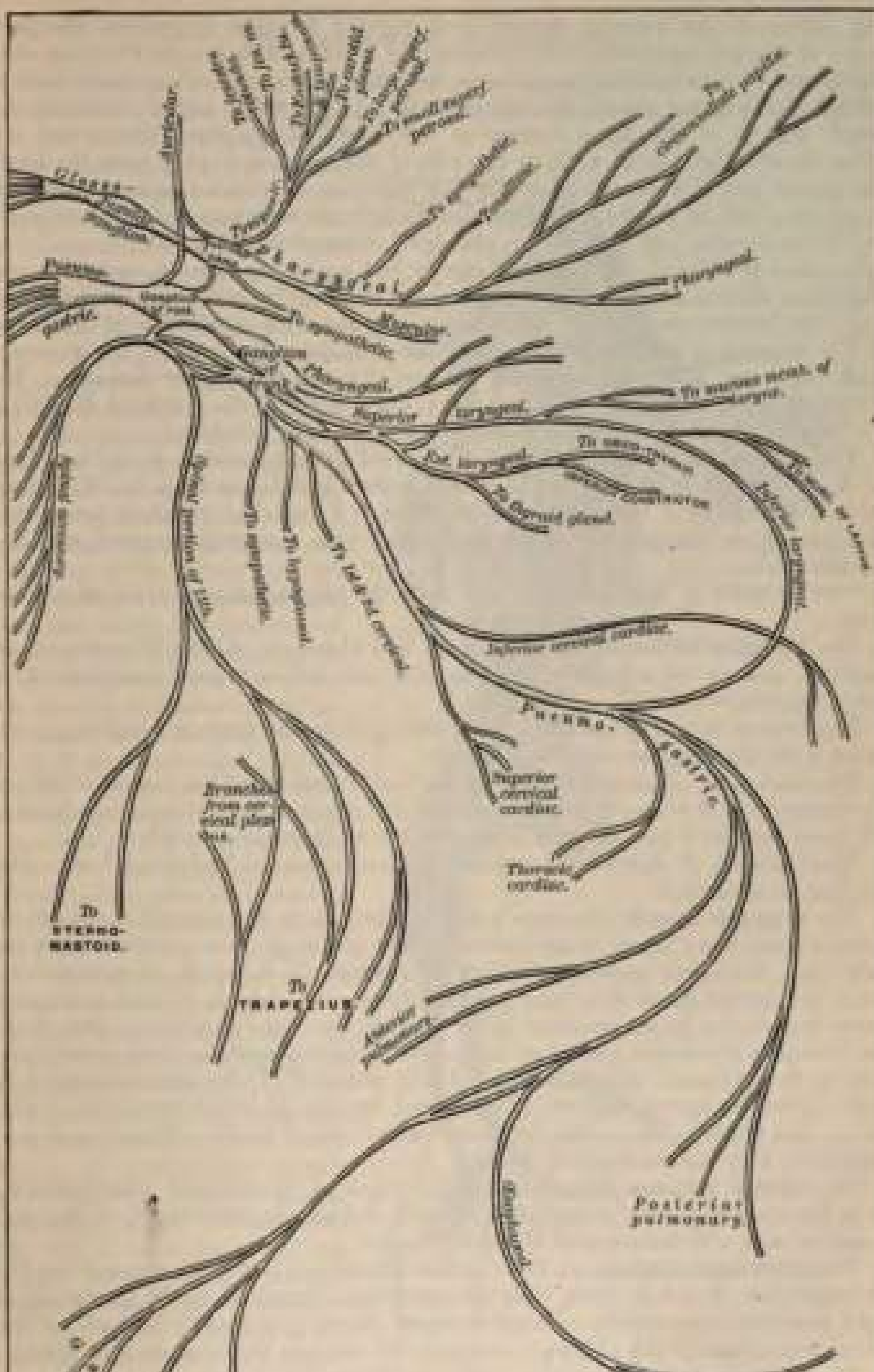

FIG. 402.—Plan of the glosso-pharyngeal, pneumogastric, and spinal accessory nerves. (After Flower.)

skull at the central part of the jugular foramen, in a separate sheath of the dura mater, external to and in front of the pneumogastric and spinal accessory nerves

(Fig. 329). In its passage through the jugular foramen it grooves the lower border of the petrous portion of the temporal bone, and at its exit from the skull passes forward between the jugular vein and internal carotid artery, and descends in front of the latter vessel, and beneath the styloid process and the muscles connected with it, to the lower border of the Stylo-pharyngeus. The nerve now curves inward, forming an arch on the side of the neck, and lying upon the Stylo-pharyngeus and Middle constrictor of the pharynx. It then passes beneath the Hyoglossus, and is finally distributed to the mucous membrane of the fauces and base of the tongue, and the mucous glands of the mouth and tonsil.

In passing through the jugular foramen the nerve presents, in succession, two gangliform enlargements. The superior, the smaller, is called the *jugular ganglion;* the inferior and larger, the *petrous ganglion*, or the *ganglion of Andersch.*

The **superior** or **jugular ganglion** is situated in the upper part of the groove in which the nerve is lodged during its passage through the jugular foramen. It is of very small size, and involves only the lower part of the trunk of the nerve. It is usually regarded as a segmentation from the lower ganglion.

The **inferior**, or **petrous, ganglion** is situated in a depression in the lower border of the petrous portion of the temporal bone; it is larger than the former and involves the whole of the fibres of the nerve. From this ganglion arise those filaments which connect the glosso-pharyngeal with the pneumogastric and sympathetic nerves.

The *branches of communication* are with the pneumogastric, sympathetic, and facial.

The branches to the pneumogastric are two filaments, arising from the petrous ganglion, one to its auricular branch, and one to the upper ganglion of the pneumogastric.

The branch to the sympathetic, also arising from the petrous ganglion, is connected with the superior cervical ganglion.

The branch of communication with the facial perforates the posterior belly of the Digastric. It arises from the trunk of the nerve below the petrous ganglion, and joins the facial just after its exit from the stylo-mastoid foramen.

The *branches of distribution* are the tympanic, carotid, pharyngeal, muscular, tonsillar, and lingual.

The **tympanic branch** (*Jacobson's nerve*) arises from the petrous ganglion, and enters a small bony canal in the lower surface of the petrous portion of the temporal bone, the lower opening of which is situated on the bony ridge which separates the carotid canal from the jugular fossa. It ascends to the tympanum, enters that cavity by an aperture in its floor close to the inner wall, and divides into branches which are contained in grooves upon the surface of the promontory, forming the tympanic plexus. This plexus gives off (1) the greater part of the small superficial petrosal nerve; (2) a branch to join the great superficial petrosal nerve; and (3) branches to the tympanic cavity, all of which will be described in connection with the anatomy of the ear.

The **carotid branches** descend along the trunk of the internal carotid artery as far as its commencement, communicating with the pharyngeal branch of the pneumogastric and with branches of the sympathetic.

The **pharyngeal branches** are three or four filaments which unite opposite the Middle constrictor of the pharynx with the pharyngeal branches of the pneumogastric and sympathetic nerves to form the pharyngeal plexus, branches from which perforate the muscular coat of the pharynx to supply the muscles and mucous membrane.

The **muscular branch** is distributed to the Stylo-pharyngeus.

The **tonsillar branches** supply the tonsil, forming a plexus (*circulus tonsillaris*) around this body, from which branches are distributed to the soft palate and fauces, where they communicate with the palatine nerves.

The **lingual branches** are two in number: one supplies the circumvallate papillæ and the mucous membrane covering the surface of the base of the tongue; the other perforates its substance, and supplies the mucous membrane and follicular glands of the posterior half of the tongue and communicates with the lingual nerve.

The Tenth Pair (Figs. 403, 404).

The **Tenth or Pneumogastric Nerve** (*nervus vagus or par vagum*) has a more extensive distribution than any of the other cranial nerves, passing through the neck and thorax to the upper part of the abdomen. It is composed of both motor and sensory fibres. It supplies the organs of voice and respiration with motor and sensory fibres, and the pharynx, œsophagus, stomach, and heart with motor fibres. Its *superficial origin* is by eight or ten filaments from the groove between the olivary and the restiform body below the glosso-pharyngeal; its *deep origin* may be traced through the fasciculi of the medulla to terminate in a nucleus of gray matter, the *nucleus vagi*, at the lower part of the floor of the fourth ventricle beneath the ala cinerea below and continuous with the nucleus of origin of the glosso-pharyngeal. In addition to this a few fibres pass into the funiculus solitarius, and others into the nucleus ambiguus or accessory vagal nucleus. The real origin of the sensory fibres of the vagus is to be found in the cells of the ganglia on the nerve, viz., the ganglion of the root and the ganglion of the trunk. The filaments become united and form a flat cord, which passes outward beneath the flocculus to the jugular foramen, through which it emerges from the cranium. In passing through this opening the pneumogastric accompanies the spinal accessory, being contained in the same sheath of dura mater with it, a membranous septum separating them from the glosso-pharyngeal, which lies in front (Fig. 329). The nerve in this situation presents a well-marked ganglionic enlargement, which is called the *jugular ganglion*, or the *ganglion of the root of the pneumogastric*: to it the accessory part of the spinal accessory nerve is connected by one or two filaments. After the exit of the nerve from the jugular foramen the nerve is joined by the accessory portion of the spinal accessory, and enlarges into a second gangliform swelling, called the *ganglion inferius*, or the *ganglion of the trunk of*

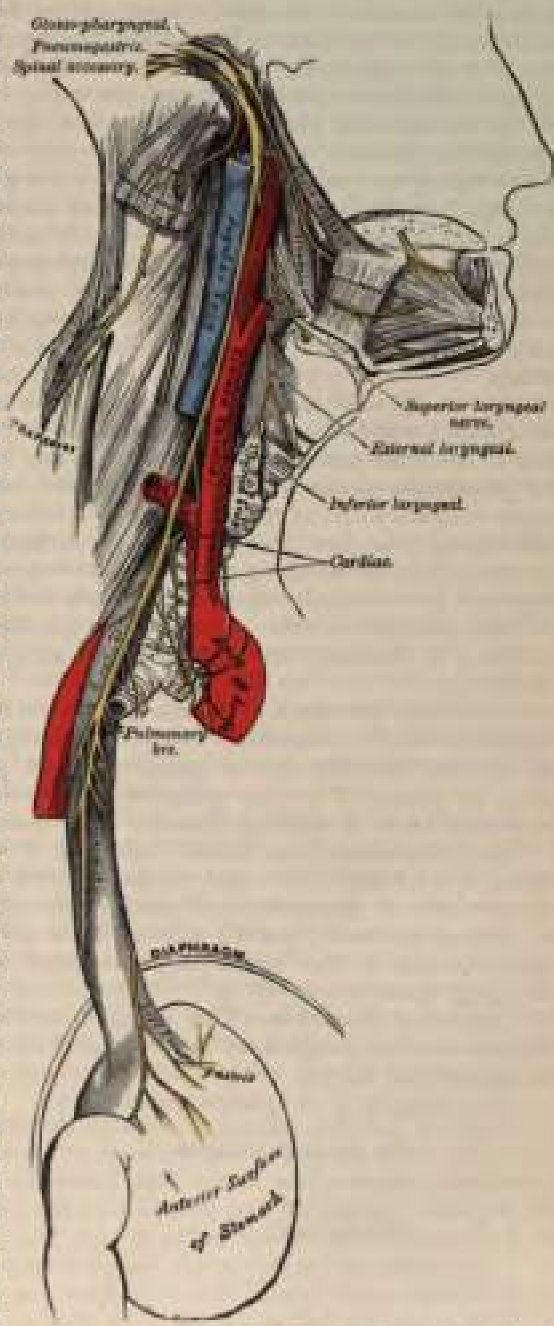

FIG. 404.—Course and distribution of the ninth, tenth, and eleventh nerves.

the nerve, through which the fibres of the spinal accessory pass unchanged, being principally distributed to the pharyngeal and superior laryngeal branches of the vagus; but some of the filaments from it are continued into the trunk of the vagus below the ganglion, to be distributed with the recurrent laryngeal nerve, and probably also with the cardiac nerves. The nerve passes vertically down the neck within the sheath of the carotid vessels lying between the internal carotid artery and internal jugular vein as far as the thyroid cartilage, and then between the same vein and the common carotid to the root of the neck. Here the course of the nerve becomes different on the two sides of the body.

On the *right side* the nerve passes across the subclavian artery between it and the right innominate vein, and descends by the side of the trachea to the back part of the root of the lung, where it spreads out in a plexiform network (*posterior pulmonary*), from the lower part of which two cords descend upon the œsophagus, on which they divide, forming, with branches from the opposite nerve, the œsophageal plexus (*plexus gulæ*); below, these branches are collected into a single cord, which runs along the back part of the œsophagus, enters the abdomen, and is distributed to the posterior surface of the stomach, joining the left side of the solar plexus, and sending filaments to the splenic plexus and a considerable branch to the cœliac plexus.

On the *left side* the pneumogastric nerve enters the chest between the left carotid and subclavian arteries, behind the left innominate vein. It crosses the arch of the aorta and descends behind the root of the left lung, forming the *posterior pulmonary plexus*, and along the anterior surface of the œsophagus, where it unites with the nerve of the right side in forming the plexus gulæ, to the stomach, distributing branches over its anterior surface, some extending over the great *cul-de-sac*, and others along the lesser curvature. Filaments from these branches enter the gastro-hepatic omentum and join the hepatic plexus.

The *ganglion of the root* is of a grayish color, circular in form, about two lines in diameter, and resembles the ganglion on the large root of the fifth nerve.

Connecting Branches.—To this ganglion the accessory portion of the spinal accessory nerve is connected by several delicate filaments; it also has a communicating twig with the petrous ganglion of the glosso-pharyngeal, with the facial nerve by means of its (the ganglion's) auricular branch, and with sympathetic by means of an ascending filament from the superior cervical ganglion.

The *ganglion of the trunk* (inferior) is a plexiform cord, cylindrical in form, of a reddish color, and about an inch in length; it involves the whole of the fibres of the nerve, and passing through it is the accessory portion of the spinal accessory nerve, which blends with the pneumogastric below the ganglion, and is then principally continued into its pharyngeal and superior laryngeal branches.

Connecting Branches.—This ganglion is connected with the hypoglossal, the superior cervical ganglion of the sympathetic, and the loop between the first and second cervical nerves.

The *branches of the pneumogastric* are—

In the jugular fossa . . .	Meningeal. Auricular.
In the neck	Pharyngeal. Superior laryngeal. Recurrent laryngeal. Cervical cardiac.
In the thorax	Thoracic cardiac. Anterior pulmonary. Posterior pulmonary. Œsophageal.
In the abdomen	Gastric.

The **meningeal branch** is a recurrent filament given off from the ganglion of the root in the jugular foramen. It passes backward, and is distributed to the dura mater covering the posterior fossa of the base of the skull.

The **auricular branch** (*Arnold's*) arises from the ganglion of the root, and is joined soon after its origin by a filament from the petrous ganglion of the glosso-pharyngeal; it passes outward behind the jugular vein, and enters a small canal on the outer wall of the jugular fossa. Traversing the substance of the temporal bone, it crosses the aqueductus Fallopii about two lines above its termination at the stylo-mastoid foramen; here it gives off an ascending branch, which joins the facial; the continuation of the nerve reaches the surface by passing through the auricular fissure between the mastoid process and the external auditory meatus, and divides into two branches, one of which communicates with the posterior auricular nerve, while the other supplies the integument at the back part of the pinna and the posterior part of the external auditory meatus.

The **pharyngeal branch**, the principal motor nerve of the pharynx, arises from the upper part of the inferior ganglion of the pneumogastric. It consists principally of filaments from the accessory portion of the spinal accessory; it passes across the internal carotid artery to the upper border of the Middle constrictor, where it divides into numerous filaments which join with those from the glosso-pharyngeal, superior laryngeal (its external branch), and sympathetic, to form the pharyngeal plexus, from which branches are distributed to the muscles and mucous membrane of the pharynx and the muscles of the soft palate. From the pharyngeal plexus a minute filament is given off, which descends and joins the hypoglossal nerve as it winds round the occipital artery.

The **superior laryngeal** is the nerve of sensation to the larynx. It is larger than the preceding, and arises from the middle of the inferior ganglion of the pneumogastric. It consists principally of filaments from the accessory portion of the spinal accessory. In its course it receives a branch from the superior cervical ganglion of the sympathetic. It descends by the side of the pharynx behind the internal carotid, where it divides into two branches, the external and internal laryngeal.

The *external laryngeal branch*, the smaller, descends by the side of the larynx, beneath the Sterno-thyroid, to supply the Crico-thyroid muscle. It gives branches to the pharyngeal plexus and the Inferior constrictor, and communicates with the superior cardiac nerve, behind the common carotid.

The *internal laryngeal branch* descends to the opening in the thyro-hyoid membrane, through which it passes with the superior laryngeal artery, and is distributed to the mucous membrane of the larynx. A small branch communicates with the recurrent laryngeal nerve. The branches to the mucous membrane are distributed, some in front to the epiglottis, the base of the tongue, and the epiglottidean glands; while others pass backward, in the aryteno-epiglottidean fold, to supply the mucous membrane surrounding the superior orifice of the larynx, as well as the membrane which lines the cavity of the larynx as low down as the vocal cord. The filament which joins with the recurrent laryngeal descends beneath the mucous membrane on the inner surface of the thyroid cartilage, where the two nerves become united.

The **inferior** or **recurrent laryngeal**, so called from its reflected course, is the motor nerve of the larynx. It arises on the right side, in front of the subclavian artery; winds from before backward round that vessel, and ascends obliquely to the side of the trachea, behind the common carotid and behind or in front of the inferior thyroid artery. On the left side it arises in front of the arch of the aorta, and winds from before backward round the aorta at the point where the remains of the ductus arteriosus are connected with it, and then ascends to the side of the trachea. The nerves on both sides ascend in the groove between the trachea and œsophagus, and, passing under the lower border of the Inferior constrictor muscle, enter the larynx behind the articulation of the inferior cornu of the thyroid cartilage with the cricoid, being distributed to all the muscles of the larynx except the Crico-thyroid. It communicates with the superior laryngeal nerve and gives off a few filaments to the mucous membrane of the lower part of the larynx.

The recurrent laryngeal, as it winds round the subclavian artery and aorta, gives off several cardiac filaments, which unite with the cardiac branches from the pneumogastric and sympathetic. As it ascends in the neck it gives off œsophageal branches, more numerous on the left than on the right side, which supply the mucous membrane and muscular coat of the œsophagus; tracheal branches to the mucous membrane and muscular fibres of the trachea: and some pharyngeal filaments to the inferior constrictor of the pharynx.

The **cervical cardiac branches**, two or three in number, arise from the pneumogastric, at the upper and lower part of the neck.

The *superior branches* are small, and communicate with the cardiac branches of the sympathetic. They can be traced to the great or deep cardiac plexus.

The *inferior branches*, one on each side, arise at the lower part of the neck, just above the first rib. On the right side this branch passes in front or by the side of the arteria innominata, and communicates with one of the cardiac nerves proceeding to the great or deep cardiac plexus. On the left side it passes in front of the arch of the aorta and joins the superficial cardiac plexus.

The **thoracic cardiac branches**, on the right side, arise from the trunk of the pneumogastric as it lies by the side of the trachea, and from its recurrent laryngeal branch, but on the left side from the recurrent nerve only; passing inward, they terminate in the deep cardiac plexus.

The **anterior pulmonary branches**, two or three in number, and of small size, are distributed on the anterior aspect of the root of the lungs. They join with filaments from the sympathetic, and form the *anterior pulmonary plexus.*

The **posterior pulmonary branches**, more numerous and larger than the anterior, are distributed on the posterior aspect of the root of the lung: they are joined by filaments from the third and fourth (sometimes also first and second) thoracic ganglia of the sympathetic, and form the *posterior pulmonary plexus*. Branches from both plexuses accompany the ramification of the air-tubes through the substance of the lungs.

The **œsophageal branches** are given off from the pneumogastric both above and below the pulmonary branches. The lower are more numerous and larger than the upper. They form, together with branches from the opposite nerve, the *œsophageal plexus* or *plexus gulæ*. From this plexus branches are distributed to the back of the pericardium.

The **gastric branches** are the terminal filaments of the pneumogastric nerve. The nerve on the right side is distributed to the posterior surface of the stomach, and joins the left side of the cœliac plexus and the splenic plexus. The nerve on the left side is distributed over the anterior surface of the stomach, some filaments passing across the great *cul-de-sac*, and others along the lesser curvature. They unite with branches of the right nerve and with the sympathetic, some filaments passing through the lesser omentum to the hepatic plexus.

Surgical Anatomy.—The laryngeal nerves are of considerable importance in considering some of the morbid conditions of the larynx. When the peripheral terminations of the superior laryngeal nerve are irritated by some foreign body passing over them, reflex spasm of the glottis is the result. When the trunk of this same nerve is pressed upon by, for instance, a goitre or an aneurism of the upper part of the carotid, we have a peculiar dry, brassy cough. When the nerve is paralyzed, we have anæsthesia of the mucous membrane of the larynx, so that foreign bodies can readily enter the cavity, and, in consequence of its supplying the crico-thyroid muscle, the vocal cords cannot be made tense, and the voice is deep and hoarse. Paralysis of the superior laryngeal nerves may be the result of bulbar paralysis, may be a sequel to diphtheria, when both nerves are usually involved, or it may, though less commonly, be caused by the pressure of tumors or aneurisms, when the paralysis is generally unilateral. Irritation of the inferior laryngeal nerves produces spasm of the muscles of the larynx. When both these recurrent nerves are paralyzed, the vocal cords are motionless, in the so-called "cadaveric position"—that is to say, in the position in which they are found in ordinary tranquil respiration—neither closed as in phonation, nor open as in deep inspiratory efforts. When one recurrent nerve is paralyzed, the cord of the same side is motionless, while the opposite one crosses the middle line to accommodate itself to the affected one; hence phonation is present, but the voice is altered and weak in timbre. The recurrent laryngeal nerves may be paralyzed in bulbar paralysis or after diphtheria, when it usually affects both sides; or they may be affected by the pressure of aneurisms of the aorta, innominate or subclavian arteries; by mediastinal tumors; by bronchocele; or by cancer of the upper part of the œsophagus, when the paralysis is often unilateral.

The Eleventh Pair (*Figs.* 403, 404).

The **Eleventh** or **Spinal Accessory Nerve** consists of two parts: one, the accessory part to the vagus, and the other the spinal portion.

The **bulbar** or **accessory part** is the smaller of the two. Its *superficial origin* is by four or five delicate filaments from the side of the medulla, below the roots of the vagus. Its *deep origin* may be traced to a nucleus of gray matter at the back of the medulla, dorso-lateral to the hypoglossal nucleus, and extending as far down as the intermedio-lateral tract of the spinal cord. It passes outward to the jugular foramen, where it interchanges fibres with the spinal portion or becomes united to it for a short distance; it is also connected, in the foramen, with the upper ganglion of the vagus by one or two filaments. It then passes through the foramen, and becoming again separated from the spinal portion it is continued over the surface of the ganglion of the trunk of the vagus, being adherent to its surface, and is distributed principally to the pharyngeal and superior laryngeal branches of the pneumogastric. Through the pharyngeal branch it probably supplies the muscles of the soft palate (see page 331). Some few filaments from it are continued into the trunk of the vagus below the ganglion, to be distributed with the recurrent laryngeal nerve, and probably also with the cardiac nerves.

The **spinal portion** is firm in texture. Its *superficial origin* is by several filaments from the lateral tract of the cord, as low down as the sixth cervical nerve. Its *deep origin* may be traced to the intermedio-lateral tract of the gray matter of the cord. This portion of the nerve ascends between the ligamentum denticulatum and the posterior roots of the spinal nerves, enters the skull through the foramen magnum, and is then directed outward to the jugular foramen, through which it passes, lying in the same sheath as the pneumogastric, but separated from it by a fold of the arachnoid. In the jugular foramen it receives one or two filaments from the accessory portion. At its exit from the jugular foramen it passes backward, either in front of or behind the internal jugular vein, and descends obliquely behind the Digastric and Stylo-hyoid muscles to the upper part of the Sterno-mastoid. It pierces that muscle, and passes obliquely across the posterior triangle, to terminate in the deep surface of the Trapezius. This nerve gives several branches to the Sterno-mastoid during its passage through it, and joins in its substance with branches from the second cervical, which supply the muscle. In the posterior triangle it joins with the second and third cervical nerves, while beneath the Trapezius it forms a sort of plexus with the third and fourth cervical nerves, and from this plexus fibres are distributed to the muscle.

Surgical Anatomy.—In cases of spasmodic torticollis in which all palliative treatment has failed, division or excision of a portion of the spinal accessory nerve has been resorted to. This may be done either along the anterior or posterior border of the Sterno-mastoid muscle. The former operation is performed by making an incision from the apex of the mastoid process, three inches in length, along the anterior border of the Sterno-mastoid muscle. The anterior border of the muscle is defined and pulled backward, so as to stretch the nerve, which is then to be sought for beneath the Digastric muscle, about two inches below the apex of the mastoid process. The other operation consists in making an incision along the posterior border of the muscle, so that the centre of the incision corresponds to the middle of this border of the muscle. The superficial structures having been divided and the border of the muscle defined, the nerve is to be sought for as it emerges from the muscle to cross the occipital triangle. When found, it is to be traced upward through the muscle, and a portion of it excised above the point where it gives off its branches to the Sterno-mastoid. In this operation one of the descending branches of the superficial cervical plexus is liable to be mistaken for the nerve.

The Twelfth Pair (Figs. 405, 406).

The **Twelfth** or **Hypoglossal Nerve** is the motor nerve of the tongue.

Its *superficial origin* is by several filaments, from ten to fifteen in number, from the groove between the pyramidal and olivary bodies of the medulla, in a continuous line with the anterior roots of the spinal nerves. Its *deep origin* can be traced to a nucleus of gray matter (*trigonum hypoglossi*) on the floor of the fourth ventricle.

The filaments of this nerve are collected into two bundles, which perforate the dura mater separately, opposite the anterior condyloid foramen, and unite together after their passage through it. In those cases in which the anterior condyloid foramen in the occipital bone is double, these two portions of the nerve are separated by the small piece of bone which divides the foramen. The nerve descends almost vertically to a point corresponding with the angle of the jaw. It is at first deeply seated beneath the internal carotid artery and internal jugular vein, and intimately connected with the pneumogastric nerve; it then passes forward

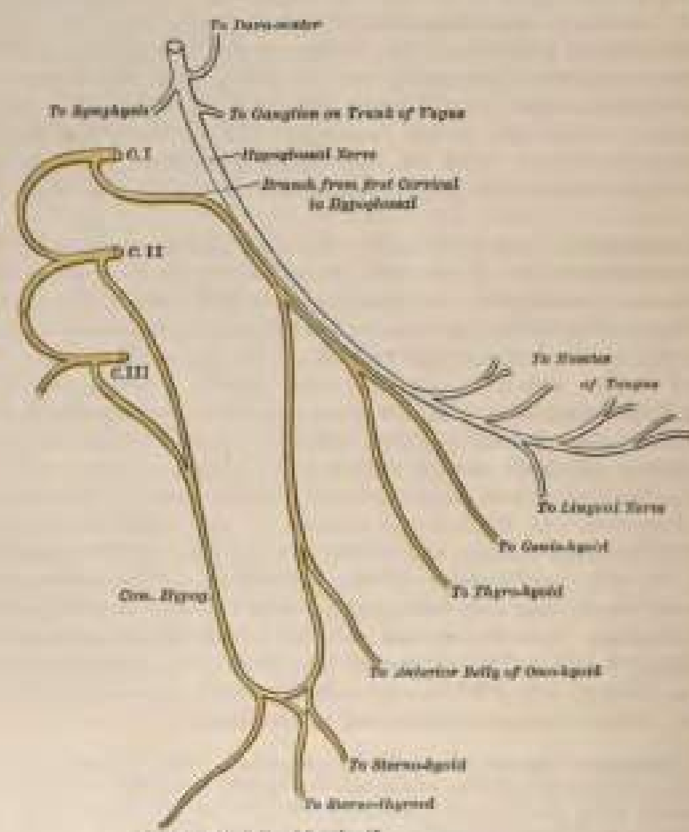

Fig. 406.—Plan of the hypoglossal nerve.

between the vein and artery, and lower down in the neck becomes superficial below the Digastric muscle. The nerve then loops round the occipital artery, and crosses the external carotid and its lingual branch below the tendon of the Digastric muscle. It passes beneath the tendon of the Digastric, the Stylo-hyoid, and the Mylo-hyoid muscles, lying between the last-named muscle and the Hyo-glossus, and communicates at the anterior border of the Hyo-glossus with the lingual (gustatory) nerve; it is then continued forward in the fibres of the Genio-hyo-glossus muscle as far as the tip of the tongue, distributing branches to its muscular substance.

The *branches of communication* are—with the

Pneumogastric.	First and Second Cervical Nerves.
Sympathetic.	Lingual (gustatory).

The first mentioned takes place close to the exit of the nerve from the skull, numerous filaments passing between the hypoglossal and lower ganglion of the pneumogastric through the mass of connective tissue which here unites the two nerves. It also communicates with the pharyngeal plexus by a minute filament as it winds round the occipital artery.

The communication with the sympathetic takes place opposite the atlas by branches derived from the superior cervical ganglion, and in the same situation the nerve is joined by filaments derived from the loop connecting the first two cervical nerves.

The communication with the lingual (gustatory) takes place near the anterior border of the Hyo-glossus muscle by numerous filaments which ascend upon it.

The *branches of distribution* are—the

Meningeal.	Thyro-hyoid.
Descendens hypoglossi.	Muscular.

Meningeal Branches.—As the hypoglossal nerve passes through the anterior

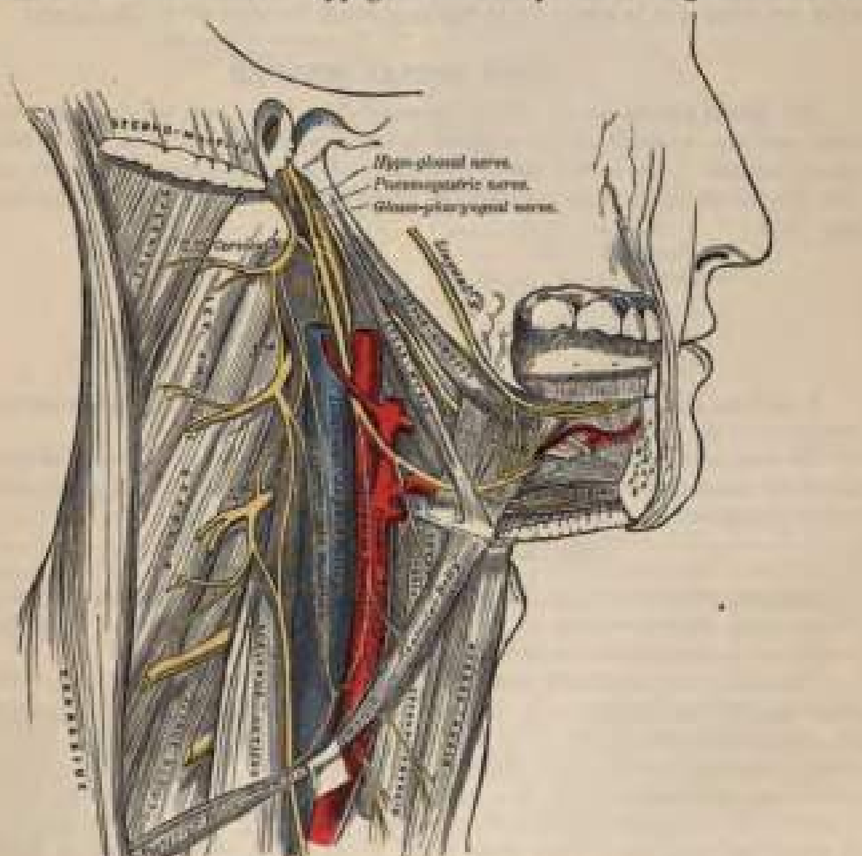

Fig. 486.—Hypoglossal nerve, cervical plexus, and their branches.

condyloid foramen it gives off, according to Luschka, several filaments to the dura mater in the posterior fossa of the base of the skull; these filaments are probably derived from a branch which passes from the first cervical nerve to the hypoglossal nerve.

The **descendens hypoglossi** is a long slender branch, which quits the hypoglossal where it turns round the occipital artery. It consists mainly of fibres which pass to the hypoglossal from the first and second cervical nerves in the above-mentioned communication. It descends in front of or within the sheath of the carotid vessels, giving off a branch to the anterior belly of the Omo-hyoid, and then joins the communicating branches from the second and third cervical nerves, just below the middle of the neck, to form a loop, the *ansa hypoglossi*. From the convexity of this loop branches pass to supply the Sterno-hyoid, Sterno-thyroid, and the posterior belly of the Omo-hyoid. According to Arnold, another filament descends in front of the vessels into the chest, and joins the cardiac and phrenic nerves.

The **thyro-hyoid** is a small branch arising from the hypoglossal near the posterior border of the Hyo-glossus; it passes obliquely across the great cornu of the hyoid bone and supplies the Thyro-hyoid muscle.

The **muscular branches** are distributed to the Stylo-glossus, Hyoglossus, Genio-hyoid, and Genio-hyo-glossus muscles. At the under surface of the tongue numerous slender branches pass upward into the substance of the organ to supply its intrinsic muscles.

Surgical Anatomy.—The hypoglossal nerve is an important guide in the operation of ligation of the lingual artery (see page 489). It runs forward on the Hyo-glossus just above the great cornu of the hyoid bone, and forms the upper boundary of the triangular space in which the artery is to be sought for by cutting through the fibres of the Hyo-glossus.

THE SPINAL NERVES.

The **spinal nerves** are so called because they take their origin from the spinal cord, and are transmitted through the intervertebral foramina on either side of the spinal column. There are thirty-one pairs of spinal nerves, which are arranged into the following groups, corresponding to the region of the spine through which they pass:

Cervical	8 pairs.
Dorsal	12 "
Lumbar	5 "
Sacral	5 "
Coccygeal	1 pair.

It will be observed that each group of nerves corresponds in number with the vertebræ in that region, except the cervical and coccygeal.

Each spinal nerve arises by two roots, an anterior or motor root and a posterior or sensory root, the latter being distinguished by a ganglion, termed the *spinal* ganglion.

The Roots of the Spinal Nerves.

The Anterior Roots.—The *superficial origin* is from the antero-lateral columns of the cord, corresponding to the situation of the anterior cornu of gray matter. Each root is composed of from four to eight filaments.

The *deep origin* can be traced through the antero-lateral column; the roots, after penetrating horizontally through the longitudinal fibres of this tract, enter the gray substance, where their fibrils diverge in several directions: some passing inward, are continued across the anterior commissure in front of the central canal, to become continuous with the axis-cylinder processes of the large cells of the anterior cornu of the opposite side; others terminate in the mesial group of cells of the anterior column of the same side; other fibrils pass outward, to become continuous with the axis-cylinder processes of the group of cells in the lateral part of the anterior column.

The Posterior Roots.—The *superficial origin* is from the postero-lateral fissure of the cord. The *real origin* of these fibres is from the nerve-cells in the posterior root ganglion, from which they can be traced into the cord in two main bundles, the course of which has already been studied (page 697).

The *anterior roots* are smaller than the posterior, devoid of ganglionic enlargement, and their component fibrils are collected into two bundles near the intervertebral foramina.

The *posterior roots* of the nerves are larger, but the individual filaments are finer and more delicate than those of the anterior. As their component fibrils pass outward toward the aperture in the dura mater, they coalesce into two bundles, receive a tubular sheath from that membrane, and enter the ganglion which is developed upon each root.

The posterior root of the first cervical nerve forms an exception to these characters. It is smaller than the anterior, has occasionally no ganglion developed upon it, and when the ganglion exists, it is often situated within the dura mater.

The Ganglia of the Spinal Nerves.

A **ganglion** is developed upon the posterior root of each of the spinal nerves. These ganglia are of an oval form and of a reddish color; they bear a proportion in size to the nerves upon which they are formed, and are placed in the intervertebral foramina, external to the point where the nerves perforate the dura

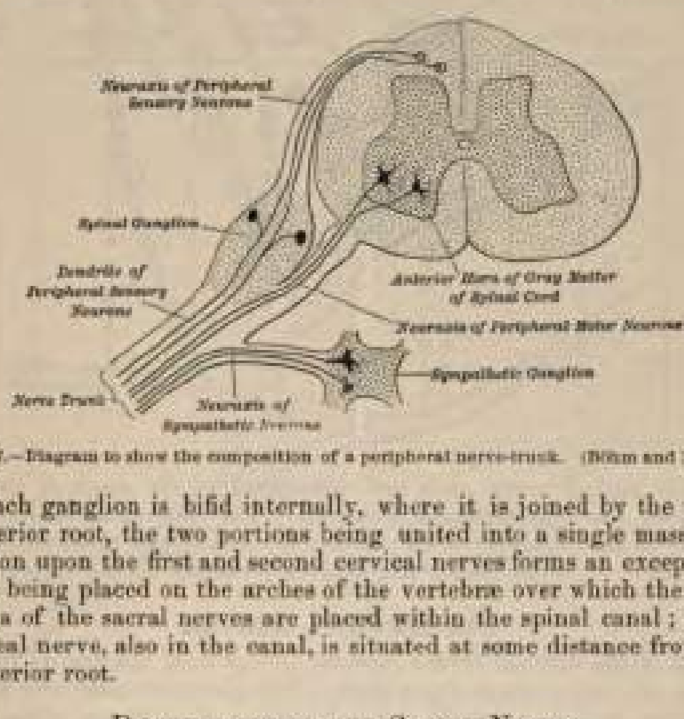

Fig. 407.—Diagram to show the composition of a peripheral nerve-trunk. (Böhm and Davidoff.)

mater. Each ganglion is bifid internally, where it is joined by the two bundles of the posterior root, the two portions being united into a single mass externally. The ganglion upon the first and second cervical nerves forms an exception to these characters, being placed on the arches of the vertebræ over which the nerves pass. The ganglia of the sacral nerves are placed within the spinal canal; and that on the coccygeal nerve, also in the canal, is situated at some distance from the origin of the posterior root.

Distribution of the Spinal Nerves.

Immediately beyond the ganglion the two roots coalesce, their fibres intermingle, and the trunk thus formed constitutes the *spinal nerve*; it passes out of the intervertebral foramen, and divides into a posterior division for the supply of the posterior part of the body, and an anterior division for the supply of the anterior part of the body, each containing fibres from both roots.

Before dividing, each spinal nerve gives off a small *recurrent* or *meningeal* branch, which is joined by a filament from the communicating branch of the sympathetic, which connects the ganglion with the anterior division. It passes inward through the intervertebral foramen and supplies the dura mater, sending branches to the bones and ligaments.

The **posterior divisions of the spinal nerves** are generally smaller than the anterior; they arise from the trunk resulting from the union of the roots, in the intervertebral foramina; and, passing backward, divide into internal and external branches, which are distributed to the muscles and integument behind the spine. The first cervical, the fourth and fifth sacral, and the coccygeal, do not divide into external and internal branches.

The **anterior divisions of the spinal nerves** supply the parts of the body in front of the spine, including the limbs. They are for the most part larger than the posterior divisions. Each division is connected by a slender filament with the sympathetic. In the dorsal region the anterior divisions of the spinal nerves are quite separate from each other, and are uniform in their distribution: but in the cervical, lumbar, and sacral regions they form intricate plexuses previous to their distribution.

Points of Emergence of the Spinal Nerves.

The roots of the spinal nerves from their origin in the cord run obliquely downward to their point of exit from the intervertebral foramina, the amount of obliquity varying in different regions of the spine, and being greater in the lower than the upper part. The level of their emergence from the cord is within certain

Level of Body of	No. of Nerve.	Level of tip of Spine of	Level of Body of	No. of Nerve.	Level of tip of Spine of
C. 1	C. 1	—	D. 8	9	7 d.
2 {	2	—	9	10	8 d.
	3	1 c.	10	11	9 d.
3	4	2 c.	—	12	10 d.
4	5	3 c.	11	L. 1	11 d.
5	6	4 c.		2	—
6	7	5 c.	12 {	3	} 12 d.
—	8	6 c.		4	
7	D. 1	7 c.		5	} —
D. 1	2	1 d.		S. 1	
2	3	—	L. 1 {	2	
3	4	2 d.		3	
4	5	3 d.		4	} 1 L.
5	6	4 d.	—	5	
6	7	5 d.	—	C. 1	
7	8	6 d.	L. 2	—	—

limits variable, and of course does not correspond to the point of emergence of the nerve from the intervertebral foramina. The preceding table, from Macalister, shows as accurately as can be shown the relation of these points of origin from the spinal cord to the bodies and spinous processes of the vertebræ.

THE CERVICAL NERVES.

The **roots of the cervical nerves** increase in size from the first to the fifth, and then remain the same size to the eighth. The posterior roots bear a proportion to the anterior as 3 to 1, which is much greater than in any other region, the individual filaments being also much larger than those of the anterior roots. The posterior root of the first cervical is an exception to this rule: it is smaller than the anterior root. In direction the roots of the cervical are less oblique than those of the other spinal nerves. The first cervical nerve is directed a little upward and outward; the second is horizontal; the others are directed obliquely downward and outward, the lowest being the most oblique, and consequently longer than the upper, the distance between their place of origin and their point of exit from the spinal canal never exceeding the depth of one vertebra.

The *trunk of the first cervical nerve* (*suboccipital*) leaves the spinal canal between the occipital bone and the posterior arch of the atlas; the second, between the posterior arch of the atlas and the lamina of the axis; and the eighth (the last), between the last cervical and first dorsal vertebræ.

Each nerve, at its exit from the intervertebral foramen, divides into a posterior and an anterior division. The anterior divisions of the four upper cervical nerves form the cervical plexus. The anterior divisions of the four lower cervical nerves, together with the first dorsal, form the brachial plexus.

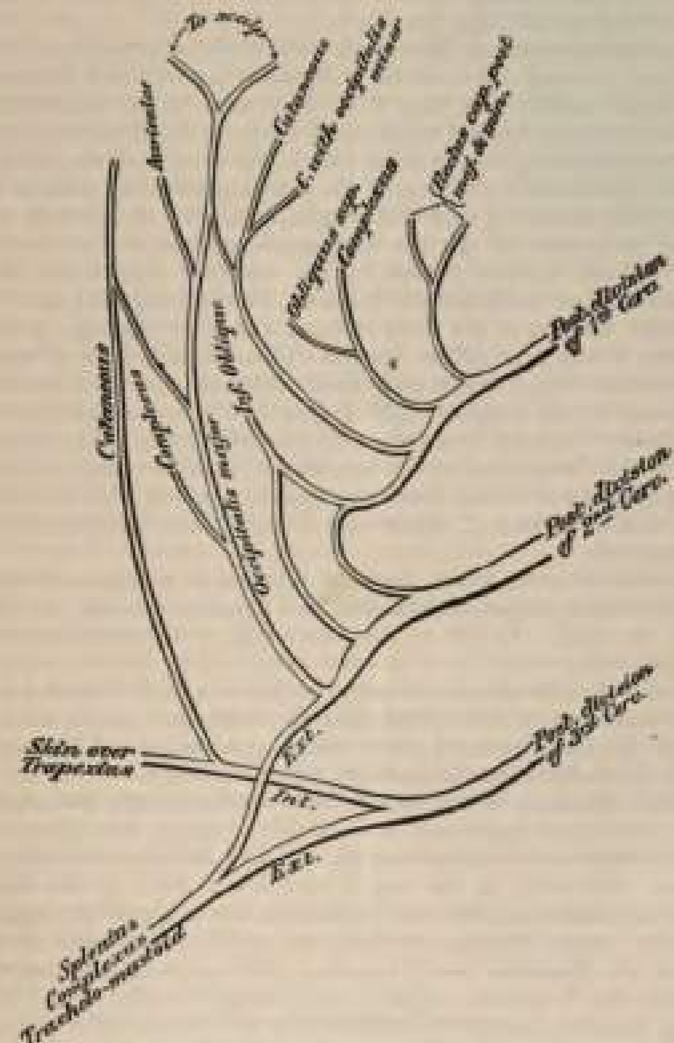

FIG. 408.—Posterior divisions of the upper cervical nerves.

Posterior Divisions of the Cervical Nerves (Fig. 408).

The **posterior division of the first cervical** (*suboccipital*) **nerve** differs from the posterior divisions of the other cervical nerves in not dividing into an internal and external branch. It is larger than the anterior division, and escapes from the spinal canal between the occipital bone and the posterior arch of the atlas, lying beneath the vertebral artery. It enters the suboccipital triangle formed by the Rectus capitis posticus major, the Obliquus superior, and Obliquus inferior, and supplies the Recti and Obliqui muscles, and the Complexus. From the branch which supplies the Inferior oblique a filament is given off which joins the second cervical nerve. This nerve also occasionally gives off a cutaneous filament, which accompanies the occipital artery and communicates with the occipitalis major and minor nerves.

The **posterior division of the second cervical nerve** is three or four times greater than the anterior division, and the largest of all the posterior cervical divisions. It emerges from the spinal canal between the posterior arch of the atlas and lamina of the axis, below the Inferior oblique. It supplies a twig to this muscle, and receives a communicating filament from the first cervical. It then divides into an internal and an external branch.

The *internal branch*, called, from its size and distribution, the *occipitalis major*, ascends obliquely inward between the Obliquus inferior and Complexus, and pierces the latter muscle and the Trapezius near their attachments to the cranium. It is now joined by a filament from the posterior division of the third cervical nerve, and, ascending on the back part of the head with the occipital artery, divides into two branches, which supply the integument of the scalp as far forward as the vertex, communicating with the occipitalis minor. It gives off an auricular branch to the back part of the ear and muscular branches to the Complexus. The *external branch* is often joined by the external branch of the posterior division of the third, and supplies the Splenius, Trachelo-mastoid, and Complexus.

The **posterior division of the third cervical** is smaller than the preceding, but larger than the fourth; it differs from the posterior divisions of the remaining cervical nerves in its supplying an additional filament, the third occipital nerve, to the integument of the occiput. The posterior division of the third nerve, like the others, divides into an internal and external branch. The *internal branch* passes between the Complexus and Semispinalis, and, piercing the Splenius and Trapezius, supplies the skin over the latter muscle; the *external branch* joins with that of the posterior division of the second to supply the Splenius, Trachelo-mastoid, and Complexus.

The *third occipital nerve* arises from the internal or cutaneous branch beneath the Trapezius; it then pierces that muscle, and supplies the skin on the lower and back part of the head. It lies to the inner side of the occipitalis major, with which it is connected.

The posterior division of the suboccipital nerve and the internal branches of the posterior divisions of the second and third cervical nerves are occasionally joined beneath the Complexus by communicating branches. This communication is described by Cruveilhier as the *posterior cervical plexus*.

The **posterior divisions of the fourth, fifth, sixth, seventh, and eighth cervical nerves** (Fig. 415) pass backward, and divide, behind the Intertransversales muscles, into internal and external branches. The *internal branches*, the larger, are distributed differently in the upper and lower part of the neck. Those derived from the fourth and fifth nerves pass between the Complexus and Semispinalis muscles, and, having reached the spinous processes, perforate the aponeurosis of the Splenius and Trapezius, and are continued outward to the integument over the Trapezius, whilst those derived from the three lowest cervical nerves are the smallest, and are placed beneath the Semispinalis colli, which they supply, and then pass into the Interspinales, Multifidus spinæ, and Complexus, and send twigs through this latter muscle to supply the integument near the spinous processes (Hirschfeld). The *external branches* supply the muscles at the side of the neck—viz. the Cervicalis ascendens, Transversalis colli, and Trachelo-mastoid.

Anterior Divisions of the Cervical Nerves.

The **anterior division of the first** or **suboccipital nerve** is of small size. It escapes from the spinal canal through a groove upon the posterior arch of the atlas. In this groove it lies beneath the vertebral artery, to the inner side of the Rectus capitis lateralis. As it crosses the foramen in the transverse process of the atlas it receives a filament from the sympathetic. It then descends in front of this process, to communicate with an ascending branch from the second cervical nerve.

Communicating filaments from the loop between this nerve and the second join the pneumogastric, the hypoglossal, and sympathetic and some branches are distributed to the Rectus lateralis and the two Anterior recti. The fibres which communicate with the hypoglossal simply pass through the latter nerve to become for the most part the descendens hypoglossi. According to Valentin, the anterior division of the suboccipital distributes filaments to the occipito-atlantal articulation and mastoid process of the temporal bone.

The **anterior division of the second cervical nerve** escapes from the spinal canal, between the posterior arch of the atlas and the lamina of the axis, and, passing forward on the outer side of the vertebral artery, divides in front of the Intertransverse muscle into an ascending branch, which joins the first cervical; and one or two descending branches, which join the third. It gives off the small occipital; a branch to assist in forming the great auricular; another to assist in forming the superficial cervical; one of the communicantes hypoglossi, and a filament to the Sterno-mastoid, which communicates in the substance of the muscle with the spinal accessory.

The **anterior division of the third cervical nerve** is double the size of the preceding. At its exit from the intervertebral foramen it passes downward and outward beneath the Sterno-mastoid, and divides into two branches. The ascending branch joins the anterior division of the second cervical; the descending branch passes down in front of the Scalenus anticus and communicates with the fourth. It gives off the larger part of the great auricular and superficial cervical nerves; one of the communicantes hypoglossi; a branch to the supraclavicular nerves; a filament to assist in forming the phrenic; and muscular branches to the Levator anguli scapulæ and Trapezius; this latter nerve communicates beneath the muscle with the spinal accessory. Sometimes the nerve to the Scalenus medius is derived from this source.

The **anterior division of the fourth cervical** is of the same size as the preceding. It receives a branch from the third, sends a communicating branch to the fifth cervical, and, passing downward and outward, divides into numerous filaments, which cross the posterior triangle of the neck, forming the supraclavicular nerves. It gives a branch to the phrenic nerve, while it is contained in the intertransverse space, and sometimes a branch to the Scalenus medius muscle. It also gives a branch to the Levator anguli scapulæ and to the Trapezius, which unites with the branch given off from the third nerve, and communicates beneath the muscle with the spinal accessory.

The **anterior divisions of the fifth, sixth, seventh,** and **eighth cervical nerves** are remarkable for their size. They are much larger than the preceding nerves, and are all of equal dimensions. They assist in the formation of the brachial plexus.

The Cervical Plexus.

The cervical plexus (Fig. 409) is formed by the anterior divisions of the four upper cervical nerves. It is situated opposite the four upper cervical vertebræ, resting upon the Levator anguli scapulæ and Scalenus medius muscles, and covered in by the Sterno-mastoid.

Its branches may be divided into two groups, *superficial* and *deep*, which may be thus arranged:

Superficial	Ascending		Occipitalis minor.
			Auricularis magnus.
			Superficialis colli.
	Descending	Supraclavicular	Suprasternal.
			Supraclavicular.
			Supra-acromial.

Deep . . .	Internal . . .		Communicating.
			Muscular.
			Communicantes hypoglossi.
			Phrenic.
	External . . .		Communicating.
			Muscular.

Superficial Branches of the Cervical Plexus.

The **Occipitalis minor** (Fig. 415) arises from the second cervical nerve, sometimes also from the third; it curves round the posterior border of the Sterno-mastoid, and ascends, running parallel to the posterior border of the muscle, to the back part of the side of the head. Near the cranium it perforates the deep fascia, and is continued upward along the side of the head behind the ear, supplying the integument, and communicating with the occipitalis major, the auricularis magnus, and with the posterior auricular branch of the facial.

This nerve gives off an *auricular branch*, which supplies the integument of the upper and back part of the auricle, communicating with the mastoid branch of the auricularis magnus. This branch is occasionally derived from the great occipital nerve. The occipitalis minor varies in size; it is occasionally double.

The **Auricularis Magnus** is the largest of the ascending branches. It arises from the second and third cervical nerves, winds round the posterior border of the Sterno-mastoid, and, after perforating the deep fascia, ascends upon that muscle beneath the Platysma to the parotid gland, where it divides into facial, auricular, and mastoid branches.

The *facial branches* pass across the parotid, and are distributed to the integument of the face over the parotid gland; others penetrate the substance of the gland and communicate with the facial nerve.

The *auricular branches* ascend to supply the integument of the back of the pinna, except at its upper part, communicating with the auricular branches of the facial and pneumogastric nerves. A filament pierces the pinna to reach its outer surface, where it is distributed to the lobule and lower part of the concha.

The *mastoid branch* communicates with the occipitalis minor and the posterior auricular branch of the facial, and is distributed to the integument behind the ear.

The **Superficialis Colli** arises from the second and third cervical nerves, turns round the posterior border of the Sterno-mastoid about its middle, and, passing obliquely forward beneath the external jugular vein to the anterior border of the muscle, perforates the deep cervical fascia, and divides beneath the Platysma into two branches which are distributed to the antero-lateral parts of the neck.

The *ascending branch* gives a filament which accompanies the external jugular vein; it then passes upward to the submaxillary region, and divides into branches, some of which form a plexus with the cervical branches of the facial nerve beneath the Platysma; others pierce that muscle and are distributed to the integument of the upper half of the neck, at its fore part, as high as the chin.

The *descending branch* (occasionally represented by two or more filaments) pierces the Platysma, and is distributed to the integument of the side and front of the neck, as low as the sternum.

The **Descending** or **supraclavicular branches** arise from the third and fourth cervical nerves: emerging beneath the posterior border of the Sterno-mastoid, they descend in the posterior triangle of the neck beneath the Platysma and deep cervical fascia. Near the clavicle they perforate the fascia and Platysma to become cutaneous, and are arranged, according to their position, into three groups.

The *inner* or *suprasternal branches* cross obliquely over the external jugular vein and the clavicular and sternal attachments of the Sterno-mastoid, and supply the integument as far as the median line. They furnish one or two filaments to the sterno-clavicular joint.

The *middle* or *supraclavicular branches* cross the clavicle, and supply the integument over the Pectoral and Deltoid muscles, communicating with the cutaneous branches of the upper intercostal nerves.

The *external* or *supra-acromial branches* pass obliquely across the outer surface of the Trapezius and the acromion, and supply the integument of the upper and back part of the shoulder.

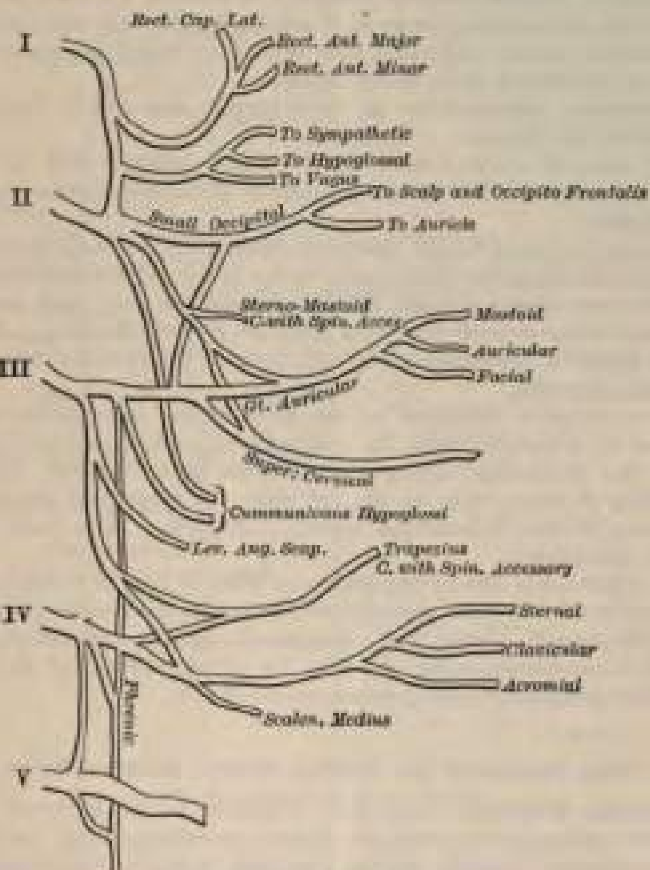

FIG. 409.—Plan of the cervical plexus.

Deep Branches of the Cervical Plexus. Internal Series.

The **communicating branches** consist of several filaments, which pass from the loop between the first and second cervical nerves in front of the atlas to the pneumogastric, hypoglossal, and sympathetic; of branches from all four cervical nerves to the superior cervical ganglion of the sympathetic, together with a branch from the fourth to the fifth cervical.

Muscular branches supply the Anterior recti and Rectus lateralis muscles; they proceed from the first cervical nerve, and from the loop formed between it and the second.

The **Communicans Hypoglossi** (Fig. 406) consists usually of two filaments, one being derived from the second, and the other from the third, cervical. These filaments pass downward on the outer side of the internal jugular vein, cross in front of the vein a little below the middle of the neck, and form a loop with the descendens hypoglossi in front of the sheath of the carotid vessels (see page 756). Occasionally, the junction of these nerves takes place within the sheath.

The **Phrenic Nerve** (*internal respiratory of Bell*) arises chiefly from the fourth cervical nerve, with a few filaments from the third and a communicating branch from the fifth. It descends to the root of the neck, running obliquely across the front of the Scalenus anticus, and beneath the Sterno-mastoid, the posterior belly of the Omo-hyoid, and the Transversalis colli and suprascapular vessels. It next passes over the first part of the subclavian artery, between it and the subclavian vein, and, as it enters the chest, crosses the internal mammary artery near its origin. Within the chest it descends nearly vertically in front of the root of the lung and by the side of the pericardium, between it and the mediastinal portion of the pleura, to the Diaphragm, where it divides into branches, which separately pierce that muscle and are distributed to its under surface.

The two phrenic nerves differ in their length, and also in their relations at the upper part of the thorax.

The *right nerve* is situated more deeply, and is shorter and more vertical in direction than the left; it lies on the outer side of the right vena innominata and superior vena cava.

The *left nerve* is rather longer than the right, from the inclination of the heart to the left side, and from the Diaphragm being lower on this than on the opposite side. It enters the thorax behind the left innominate vein, and crosses in front of the vagus and the arch of the aorta and the root of the lung. In the thorax each phrenic nerve is accompanied by a branch of the internal mammary artery, the comes nervi phrenici.

Each nerve supplies filaments to the pericardium and pleura, and near the chest is joined by a filament from the sympathetic, and, occasionally, by one from the union of the descendens hypoglossi with the spinal nerves: this filament is found, according to Swan, only on the left side. It frequently receives a filament from the nerve to the Subclavius muscle. Branches have been described as passing to the peritoneum.

From the *right nerve* one or two filaments pass to join in a small ganglion with phrenic branches of the solar plexus; and branches from this ganglion are distributed to the hepatic plexus, the suprarenal capsule, and inferior vena cava. From the *left nerve* filaments pass to join the phrenic plexus of the sympathetic, but without any ganglionic enlargement.

Deep Branches of the Cervical Plexus. External Series.

Communicating Branches.—The deep branches of the external series of the cervical plexus communicate with the spinal accessory nerve, in the substance of the Sterno-mastoid muscle, in the posterior triangle, and beneath the Trapezius.

Muscular branches are distributed to the Sterno-mastoid, Trapezius, Levator anguli scapulæ, and Scalenus medius.

The branch for the Sterno-mastoid is derived from the second cervical; the Trapezius and Levator anguli scapulæ receive branches from the third and fourth. The Scalenus medius is derived sometimes from the third, sometimes the fourth, and occasionally from both nerves.

The Brachial Plexus (Fig. 410).

The **Brachial Plexus** is formed by the union of the anterior divisions of the four lower cervical and the greater part of the first dorsal nerves, receiving usually a fasciculus from the fourth cervical nerve, and frequently one from the second dorsal nerve. It extends from the lower part of the side of the neck to the axilla. It is very broad, and presents little of a plexiform arrangement at its commencement. It is narrow opposite the clavicle, becomes broad and forms a more dense interlacement in the axilla, and divides opposite the coracoid process into numerous branches for the supply of the upper limb. The nerves which form the plexus are all similar in size, and their mode of communication is subject to considerable variation, so that no one plan can be given as applying to every case. The following appears, however, to be the most constant arrangement: the fifth and sixth cervical unite together soon after their exit from the intervertebral foramina to form a common trunk. The eighth cervical and first dorsal also unite to form one trunk. So that the nerves forming the plexus, as they lie on the Scalenus medius external to the outer border of the

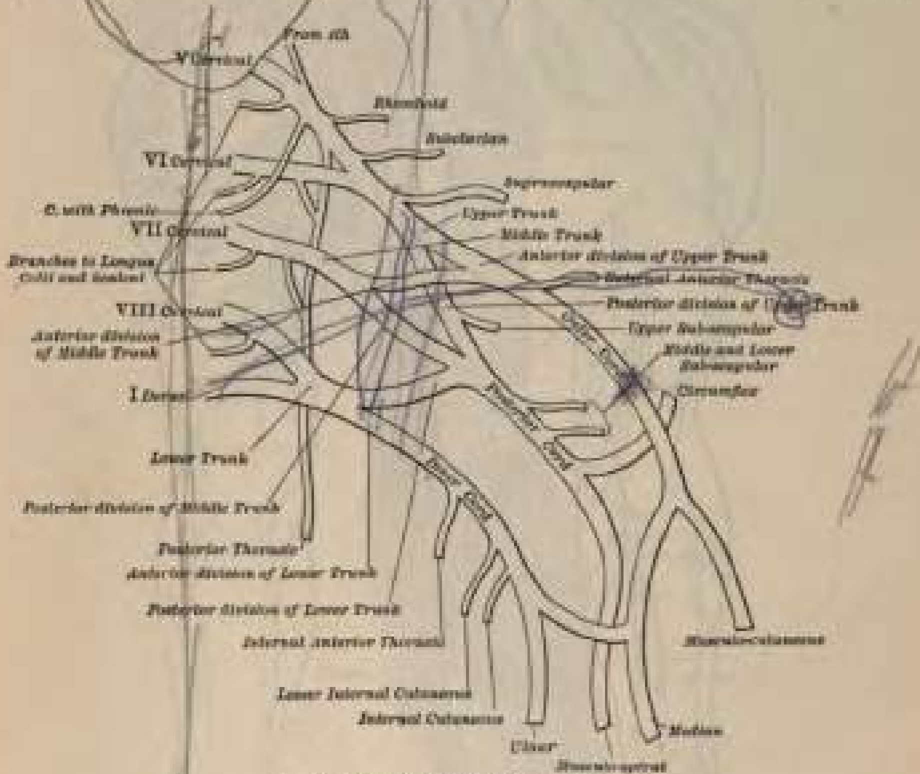

FIG. 410.—Plan of the brachial plexus.

Scalenus anticus, are blended into three trunks—an upper one, formed by the junction of the fifth and sixth cervical nerves; a middle one, consisting of the seventh cervical nerve; and a lower one, formed by the junction of the eighth cervical and first dorsal nerves. As they pass beneath the clavicle, each of these three trunks divides into two branches, an *anterior* and a *posterior*.[1] The anterior divisions of the upper and middle trunks then unite to form a common cord, which is situated on the outer side of the middle part of the axillary artery, and is called the *outer cord* of the brachial plexus. The anterior division of the lower trunk passes down on the inner side of the axillary artery in the middle of the axilla, and forms the *inner cord* of the brachial plexus. The posterior divisions of all three trunks unite to form the *posterior cord* of the brachial plexus, which is situated behind the second portion of the axillary artery. From this posterior cord are given off the two lower subscapular nerves, the upper subscapular nerve being given off from the posterior division of the upper trunk prior to its junction with the posterior division of the lower and middle trunks. The posterior cord divides into the circumflex and musculo-spiral nerves.

The brachial plexus communicates with the cervical plexus by a branch from the fourth to the fifth nerve, and with the phrenic nerve by a branch from the

[1] The posterior division of the lower trunk is very much smaller than the others, and is frequently derived entirely from the eighth cervical nerve.

nerve and gives off a few filaments to the mucous membrane of the lower part of the larynx.

The recurrent laryngeal, as it winds round the subclavian artery and aorta, gives off several cardiac filaments, which unite with the cardiac branches from the pneumogastric and sympathetic. As it ascends in the neck it gives off œsophageal branches, more numerous on the left than on the right side, which supply the mucous membrane and muscular coat of the œsophagus; tracheal branches to the mucous membrane and muscular fibres of the trachea: and some pharyngeal filaments to the Inferior constrictor of the pharynx.

The **cervical cardiac branches,** two or three in number, arise from the pneumogastric, at the upper and lower part of the neck.

The *superior branches* are small, and communicate with the cardiac branches of the sympathetic. They can be traced to the great or deep cardiac plexus.

The *inferior branches*, one on each side, arise at the lower part of the neck, just above the first rib. On the right side this branch passes in front or by the side of the arteria innominata, and communicates with one of the cardiac nerves proceeding to the great or deep cardiac plexus. On the left side it passes in front of the arch of the aorta and joins the superficial cardiac plexus.

The **thoracic cardiac branches,** on the right side, arise from the trunk of the pneumogastric as it lies by the side of the trachea, and from its recurrent laryngeal branch, but on the left side from the recurrent nerve only; passing inward, they terminate in the deep cardiac plexus.

The **anterior pulmonary branches,** two or three in number, and of small size, are distributed on the anterior aspect of the root of the lungs. They join with filaments from the sympathetic, and form the *anterior pulmonary plexus*.

The **posterior pulmonary branches,** more numerous and larger than the anterior, are distributed on the posterior aspect of the root of the lung: they are joined by filaments from the third and fourth (sometimes also first and second) thoracic ganglia of the sympathetic, and form the *posterior pulmonary plexus*. Branches from both plexuses accompany the ramification of the air-tubes through the substance of the lungs.

The **œsophageal branches** are given off from the pneumogastric both above and below the pulmonary branches. The lower are more numerous and larger than the upper. They form, together with branches from the opposite nerve, the *œsophageal plexus* or *plexus gulæ*. From this plexus branches are distributed to the back of the pericardium.

The **gastric branches** are the terminal filaments of the pneumogastric nerve. The nerve on the right side is distributed to the posterior surface of the stomach, and joins the left side of the cœliac plexus and the splenic plexus. The nerve on the left side is distributed over the anterior surface of the stomach, some filaments passing across the great *cul-de-sac*, and others along the lesser curvature. They unite with branches of the right nerve and with the sympathetic, some filaments passing through the lesser omentum to the hepatic plexus.

Surgical Anatomy.—The laryngeal nerves are of considerable importance in considering some of the morbid conditions of the larynx. When the peripheral terminations of the superior laryngeal nerve are irritated by some foreign body passing over them, reflex spasm of the glottis is the result. When the trunk of this same nerve is pressed upon by, for instance, a goitre or an aneurism of the upper part of the carotid, we have a peculiar dry, brassy cough. When the nerve is paralyzed, we have anæsthesia of the mucous membrane of the larynx, so that foreign bodies can readily enter the cavity, and, in consequence of its supplying the crico-thyroid muscle, the vocal cords cannot be made tense, and the voice is deep and hoarse. Paralysis of the superior laryngeal nerves may be the result of bulbar paralysis, may be a sequel to diphtheria, when both nerves are usually involved, or it may, though less commonly, be caused by the pressure of tumors or aneurisms, when the paralysis is generally unilateral. Irritation of the inferior laryngeal nerves produces spasm of the muscles of the larynx. When both these recurrent nerves are paralyzed, the vocal cords are motionless, in the so-called "cadaveric position"—that is to say, in the position in which they are found in ordinary tranquil respiration—neither closed as in phonation, nor open as in deep inspiratory efforts. When one recurrent nerve is paralyzed, the cord of the same side is motionless, while the opposite one crosses the middle line to accommodate itself to the affected one; hence phonation is present, but the voice

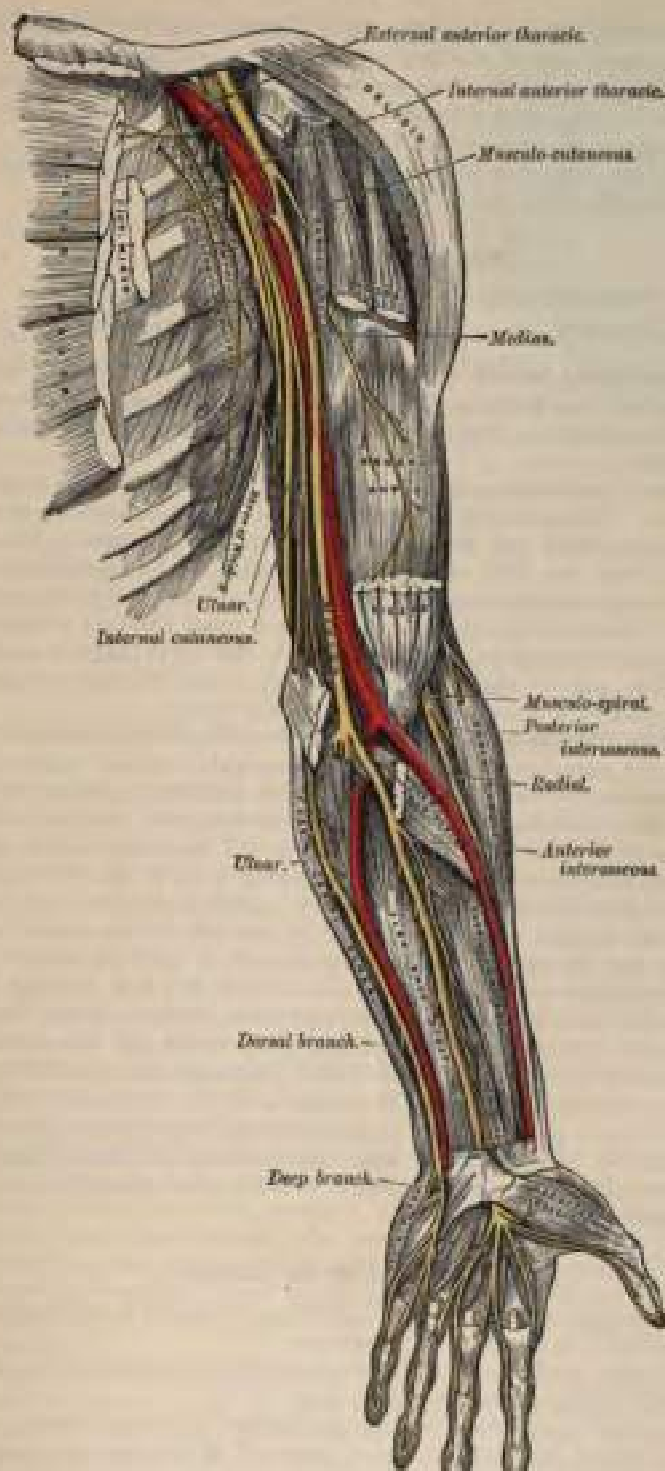

Fig. 453.—Nerves of the left upper extremity.

scaleni muscles, and then above and to the outer side of the subclavian artery: it next passes behind the clavicle and Subclavius muscle, lying upon the first serration of the Serratus magnus, and the Subscapularis muscles. *In the axilla*, it is placed on the outer side of the first portion of the axillary artery; it surrounds the artery in the second part of its course, one cord lying upon the outer side of that vessel, one on the inner side, and one behind it, and at the lower part of the axillary space gives off its terminal branches to the upper extremity.

Branches.—The branches of the brachial plexus are arranged in two groups—viz., those given off above the clavicle, and those below that bone.

Branches above the Clavicle.

Communicating.	Posterior thoracic.
Muscular.	Suprascapular.

The **communicating branch** with the phrenic is derived from the fifth cervical nerve or from the loop between the fifth and sixth; it joins the phrenic on the Anterior scalenus muscle. The communications with the sympathetic have already been referred to.

The **muscular branches** supply the Longus colli, Scaleni, Rhomboidei, and Subclavius muscles. Those for the Longus colli and Scaleni arise from the four lower cervical nerves at their exit from the intervertebral foramina. The Rhomboid branch arises from the fifth cervical, pierces the Scalenus medius, and passes beneath the Levator anguli scapulæ, which it occasionally supplies, to the Rhomboid muscles. The nerve to the Subclavius is a small filament which arises from the fifth cervical at its point of junction with the sixth nerve; it descends in front of the third part of the subclavian artery to the Subclavius muscle, and is usually connected by a filament with the phrenic nerve.

The **posterior thoracic nerve** (*long thoracic, external respiratory of Bell*) (Fig. 413) supplies the Serratus magnus, and is remarkable for the length of its course. It sometimes arises by two roots from the fifth and sixth cervical nerves immediately after their exit from the intervertebral foramina, but generally by three roots from the fifth, sixth, and seventh nerves. These unite in the substance of the Middle scalenus muscle, and, after emerging from it, the nerve passes down behind the brachial plexus and the axillary vessels, resting on the outer surface of the Serratus magnus. It extends along the side of the chest to the lower border of that muscle, supplying filaments to each of its digitations.

The **suprascapular nerve** (Fig. 414) arises from the cord formed by the fifth and sixth cervical nerves; passing obliquely outward beneath the Trapezius and the Omo-hyoid, it enters the supraspinous fossa below the transverse or suprascapular ligament, and, passing beneath the Supraspinatus muscle, curves round the external border of the spine of the scapula to the infraspinous fossa. In the supraspinous fossa it gives off two branches to the Supraspinatus muscle, and an articular filament to the shoulder-joint; and in the infraspinous fossa it gives off two branches to the Infraspinatus muscle, besides some filaments to the shoulder-joint and scapula.

Branches below the Clavicle.

The branches given off below the clavicle are derived from the three cords of the brachial plexus, in the following manner:

From the outer cord arise the external anterior thoracic nerve, the musculo-cutaneous, and the outer head of the median.

From the inner cord arise the internal anterior thoracic nerve, the internal cutaneous, the lesser internal cutaneous (nerve of Wrisberg), the ulnar, and inner head of the median.

From the posterior cord arise two of the three subscapular nerves, the third taking origin from the posterior division of the trunk formed by the fifth and sixth cervical nerves; the cord then divides into the musculo-spiral and circumflex nerves.

These may be arranged according to the parts they supply:

To the chest	Anterior thoracic.
To the shoulder	Subscapular. Circumflex.
To the arm, forearm, and hand .	Musculo-cutaneous. Internal cutaneous. Lesser internal cutaneous. Median. Ulnar. Musculo-spiral.

The fasciculi of which these nerves are composed may be traced through the plexus to the spinal nerves from which they originate. They are as follows:

External anterior thoracic	from	5th, 6th, and 7th cervical.
Internal anterior thoracic	"	8th cervical and 1st dorsal.
Subscapular	"	5th, 6th, 7th, and 8th cervical.
Circumflex	"	5th and 6th cervical.
Musculo-cutaneous	"	5th and 6th cervical.
Internal cutaneous	"	8th cervical and 1st dorsal.
Lesser internal cutaneous	"	1st dorsal.
Median	"	6th, 7th, and 8th cervical, and 1st dorsal.
Ulnar	"	8th cervical and 1st dorsal.
Musculo-spiral	"	6th, 7th, and 8th cervical, sometimes also from the 5th.

The **Anterior Thoracic Nerves** (Fig. 413), two in number, supply the Pectoral muscles.

The *external* or superficial nerve, the larger of the two, arises from the outer cord of the brachial plexus, through which its fibres may be traced to the fifth, sixth, and seventh cervical nerves. It passes inward, across the axillary artery and vein, pierces the costo-coracoid membrane, and is distributed to the under surface of the Pectoralis major. It sends down a communicating filament to join the internal nerve, which forms a loop round the inner side of the axillary artery.

The *internal* or deep nerve arises from the inner cord, and through it from the eighth cervical and first dorsal. It passes behind the first part of the axillary artery, then curves forward between the axillary artery and vein, and joins with the filament from the anterior nerve. It then passes to the under surface of the Pectoralis minor muscle, where it divides into a number of branches, which supply the muscle on its under surface. Some two or three branches pass through the muscle to supply the Pectoralis major.

The **Subscapular Nerves,** three in number, supply the Subscapularis, Teres major, and Latissimus dorsi muscles. The fasciculi of which they are composed may be traced to the fifth, sixth, seventh, and eighth cervical nerves.

The *upper subscapular nerve*, the smallest, enters the upper part of the Subscapularis muscle; this nerve is frequently represented by two branches.

The *lower subscapular nerve* enters the axillary border of the Subscapularis and terminates in the Teres major. The latter muscle is sometimes supplied by a separate branch.

The *middle* or *long subscapular*, the largest of the three, follows the course of the subscapular artery, along the posterior wall of the axilla to the Latissimus dorsi, through which it may be traced as far as its lower border.

The **Circumflex Nerve** (Fig. 414) supplies some of the muscles and the integument of the shoulder and the shoulder-joint. It arises from the posterior cord of the brachial plexus, in common with the musculo-spiral nerve, and its fibres may be traced through the posterior cord to the fifth and sixth cervical nerves. It is at first placed behind the axillary artery, between it and the Subscapularis muscle,

and passes downward and outward to the lower border of that muscle. It then winds backward in company with the posterior circumflex artery, through a quadrilateral space bounded above by the Teres minor, below by the Teres major, internally by the long head of the Triceps, and externally by the neck of the humerus, and divides into two branches.

The *upper branch* winds round the surgical neck of the humerus, beneath the Deltoid, with the posterior circumflex vessels, as far as the anterior border of that muscle, supplying it, and giving off cutaneous branches, which pierce the muscle and ramify in the integument covering its lower part.

The *lower branch*, at its origin, distributes filaments to the Teres minor and back part of the Deltoid muscles. Upon the filament to the former muscle an oval enlargement usually exists. The nerve then pierces the deep fascia, and supplies the integument over the lower two-thirds of the posterior surface of the Deltoid, as well as that covering the long head of the Triceps.

The circumflex nerve, before its division, gives off an articular filament, which enters the shoulder-joint below the Subscapularis.

The **Musculo-cutaneous Nerve** (Fig. 413) (*external cutaneous* or *perforans Casserii*)[1] supplies some of the muscles of the arm and the integument of the forearm. It arises from the outer cord of the brachial plexus, opposite the lower border of the Pectoralis minor, receiving filaments from the fifth, sixth, and seventh cervical nerves. It perforates the Coraco-brachialis muscle, passes obliquely between the Biceps and Brachialis anticus to the outer side of the arm, and, a little above the elbow, winds round the outer border of the tendon of the Biceps, and, perforating the deep fascia, becomes cutaneous. This nerve, in its course through the arm, supplies the Coraco-brachialis, Biceps, and the greater part of the Brachialis anticus muscles. The branch to the Coraco-brachialis is given off from the nerve close to its origin, and in some instances, especially in early life, as a separate filament from the outer cord of the plexus. The branches to the Biceps and Brachialis anticus are given off after the nerve has pierced the Coraco-brachialis. The nerve also sends a small branch to the bone, which enters the nutrient foramen with the accompanying artery, and a filament, from the branch supplying the Brachialis anticus, to the elbow-joint.

The cutaneous portion of the nerve passes behind the median cephalic vein, and divides, opposite the elbow-joint, into an anterior and a posterior branch.

The *anterior branch* descends along the radial border of the forearm to the wrist, and supplies the integument over the outer half of the anterior surface. At the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the back of the wrist, supplying the carpus. The nerve then passes downward to the ball of the thumb, where it terminates in cutaneous filaments. It communicates with a branch from the radial nerve and the palmar cutaneous branch of the median.

The *posterior branch* passes downward along the back part of the radial side of the forearm to the wrist. It supplies the integument of the lower third of the forearm, communicating with the radial nerve and the external cutaneous branch of the musculo-spiral.

The musculo-cutaneous nerve presents frequent irregularities. It may adhere for some distance to the median and then pass outward, beneath the Biceps, instead of through the Coraco-brachialis. Frequently some of the fibres of the median run for some distance in the musculo-cutaneous and then leave it to join their proper trunk. Less frequently the reverse is the case, and the median sends a branch to join the musculo-cutaneous. Instead of piercing the Coraco-brachialis, the nerve may pass under it or through the Biceps. Occasionally it gives a filament to the Pronator teres, and it has been seen to supply the back of the thumb when the radial nerve was absent.

The **Internal Cutaneous Nerve** (Fig. 413) is one of the smallest branches of the brachial plexus. It arises from the inner cord in common with the ulnar and

[1] See foot-note, page 726.

internal head of the median, and, at its commencement, is placed on the inner side of the axillary, and afterward of the brachial artery. It derives its fibres from the eighth cervical and first dorsal nerves. It passes down the inner side of the arm, pierces the deep fascia with the basilic vein, about the middle of the limb, and, becoming cutaneous, divides into two branches, anterior and posterior.

This nerve gives off, near the axilla, a cutaneous filament, which pierces the fascia and supplies the integument covering the Biceps muscle nearly as far as the elbow. This filament lies a little external to the common trunk, from which it arises.

The *anterior branch*, the larger of the two, passes usually in front of, but occasionally behind, the median basilic vein. It then descends on the anterior surface of the ulnar side of the forearm, distributing filaments to the integument as far as the wrist, and communicating with a cutaneous branch of the ulnar nerve.

The *posterior branch* passes obliquely downward on the inner side of the basilic vein, passes in front of, or over, the internal condyle of the humerus to the back of the forearm, and descends on the posterior surface of its ulnar side as far as the wrist, distributing filaments to the integument. It communicates, above the elbow, with the lesser internal cutaneous, and above the wrist with the dorsal cutaneous branch of the ulnar nerve (Swan).

The **Lesser Internal Cutaneous Nerve** (*nerve of Wrisberg*) (Fig. 413) is distributed to the integument on the inner side of the arm. It is the smallest of the branches of the brachial plexus, and, arising from the inner cord with the internal cutaneous and ulnar nerves, receives its fibres from the first dorsal nerve. It passes through the axillary space, at first lying behind, and then on the inner side of, the axillary vein, and communicates with the intercosto-humeral nerve. It descends along the inner side of the brachial artery to the middle of the arm, where it pierces the deep fascia, and is distributed to the integument of the back part of the lower third of the arm, extending as far as the elbow, where some filaments are lost in the integument in front of the inner condyle, and others over the olecranon. It communicates with the posterior branch of the internal cutaneous nerve.

In some cases the nerve of Wrisberg and intercosto-humeral are connected by two or three filaments which form a plexus at the back part of the axilla. In other cases the intercosto-humeral is of large size, and takes the place of the nerve of Wrisberg, receiving merely a filament of communication from the brachial plexus, which represents the latter nerve. In other cases this filament is wanting, the place of the nerve of Wrisberg being supplied entirely from the intercosto-humeral.

The **Median Nerve** (Fig. 413) has received its name from the course it takes along the middle of the arm and forearm to the hand, lying between the ulnar and the musculo-spiral and radial nerves. It arises by two roots, one from the outer, and one from the inner, cord of the brachial plexus; these embrace the lower part of the axillary artery, uniting either in front or on the outer side of that vessel. It receives filaments from the sixth, seventh, and eighth cervical and the first dorsal. As it descends through the arm, it lies at first on the outer side of the brachial artery, crosses that vessel in the middle of its course, usually in front, but occasionally behind it, and lies on its inner side to the bend of the elbow, where it is placed beneath the bicipital fascia, and is separated from the elbow-joint by the Brachialis anticus. *In the forearm* it passes between the two heads of the Pronator radii teres, and descends beneath the Flexor sublimis, lying on the Flexor profundus, to within two inches above the annular ligament, where it becomes more superficial, lying between the tendons of the Flexor sublimis and Flexor carpi radialis, beneath, and rather to the radial side of, the tendon of the Palmaris longus, covered by the integument and fascia. It then passes beneath the annular ligament into the hand. In its course through the forearm it is accompanied by a branch of the anterior interosseous artery.

Deep . . .	Internal . .	Communicating. Muscular. Communicantes hypoglossi. Phrenic.
	External . .	Communicating. Muscular.

Superficial Branches of the Cervical Plexus.

The **Occipitalis minor** (Fig. 415) arises from the second cervical nerve, sometimes also from the third; it curves round the posterior border of the Sterno-mastoid, and ascends, running parallel to the posterior border of the muscle, to the back part of the side of the head. Near the cranium it perforates the deep fascia, and is continued upward along the side of the head behind the ear, supplying the integument, and communicating with the occipitalis major, the auricularis magnus, and with the posterior auricular branch of the facial.

This nerve gives off an *auricular branch*, which supplies the integument of the upper and back part of the auricle, communicating with the mastoid branch of the auricularis magnus. This branch is occasionally derived from the great occipital nerve. The occipitalis minor varies in size; it is occasionally double.

The **Auricularis Magnus** is the largest of the ascending branches. It arises from the second and third cervical nerves, winds round the posterior border of the Sterno-mastoid, and, after perforating the deep fascia, ascends upon that muscle beneath the Platysma to the parotid gland, where it divides into facial, auricular, and mastoid branches.

The *facial branches* pass across the parotid, and are distributed to the integument of the face over the parotid gland; others penetrate the substance of the gland and communicate with the facial nerve.

The *auricular branches* ascend to supply the integument of the back of the pinna, except at its upper part, communicating with the auricular branches of the facial and pneumogastric nerves. A filament pierces the pinna to reach its outer surface, where it is distributed to the lobule and lower part of the concha.

The *mastoid branch* communicates with the occipitalis minor and the posterior auricular branch of the facial, and is distributed to the integument behind the ear.

The **Superficialis Colli** arises from the second and third cervical nerves, turns round the posterior border of the Sterno-mastoid about its middle, and, passing obliquely forward beneath the external jugular vein to the anterior border of the muscle, perforates the deep cervical fascia, and divides beneath the Platysma into two branches which are distributed to the antero-lateral parts of the neck.

The *ascending branch* gives a filament which accompanies the external jugular vein; it then passes upward to the submaxillary region, and divides into branches, some of which form a plexus with the cervical branches of the facial nerve beneath the Platysma; others pierce that muscle and are distributed to the integument of the upper half of the neck, at its fore part, as high as the chin.

The *descending branch* (occasionally represented by two or more filaments) pierces the Platysma, and is distributed to the integument of the side and front of the neck, as low as the sternum.

The **Descending** or **supraclavicular branches** arise from the third and fourth cervical nerves: emerging beneath the posterior border of the Sterno-mastoid, they descend in the posterior triangle of the neck beneath the Platysma and deep cervical fascia. Near the clavicle they perforate the fascia and Platysma to become cutaneous, and are arranged, according to their position, into three groups.

The *inner or suprasternal branches* cross obliquely over the external jugular vein and the clavicular and sternal attachments of the Sterno-mastoid, and supply the integument as far as the median line. They furnish one or two filaments to the sterno-clavicular joint.

The *middle* or *supraclavicular branches* cross the clavicle, and supply the integument over the Pectoral and Deltoid muscles, communicating with the cutaneous branches of the upper intercostal nerves.

The *external* or *supra-acromial branches* pass obliquely across the outer surface of the Trapezius and the acromion, and supply the integument of the upper and back part of the shoulder.

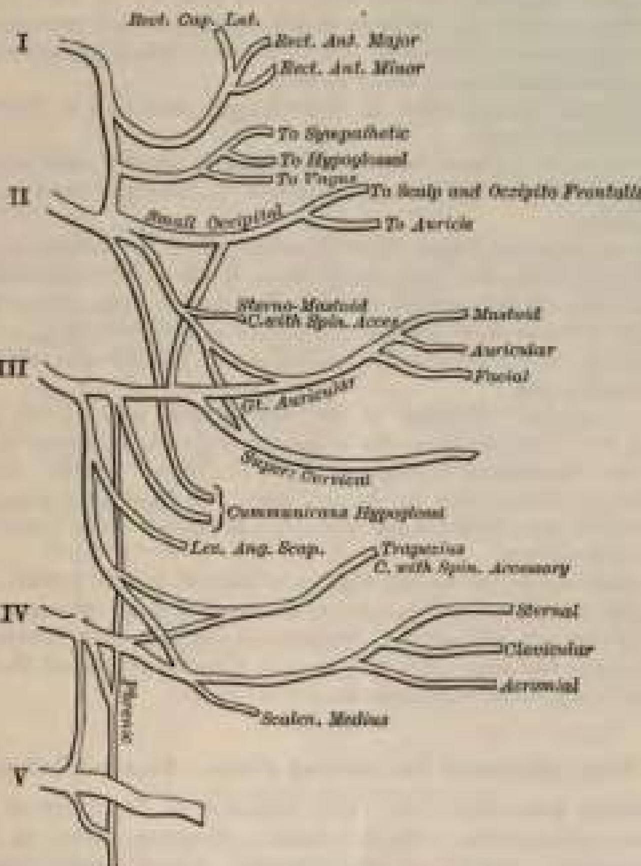

Fig. 409.—Plan of the cervical plexus.

Deep Branches of the Cervical Plexus. Internal Series.

The **communicating branches** consist of several filaments, which pass from the loop between the first and second cervical nerves in front of the atlas to the pneumogastric, hypoglossal, and sympathetic; of branches from all four cervical nerves to the superior cervical ganglion of the sympathetic, together with a branch from the fourth to the fifth cervical.

Muscular branches supply the Anterior recti and Rectus lateralis muscles; they proceed from the first cervical nerve, and from the loop formed between it and the second.

The **Communicans Hypoglossi** (Fig. 406) consists usually of two filaments, one being derived from the second, and the other from the third, cervical. These filaments pass downward on the outer side of the internal jugular vein, cross in front of the vein a little below the middle of the neck, and form a loop with the descendens hypoglossi in front of the sheath of the carotid vessels (see page 756). Occasionally, the junction of these nerves takes place within the sheath.

The **Phrenic Nerve** (*internal respiratory of Bell*) arises chiefly from the fourth cervical nerve, with a few filaments from the third and a communicating branch from the fifth. It descends to the root of the neck, running obliquely across the front of the Scalenus anticus, and beneath the Sterno-mastoid, the posterior belly of the Omo-hyoid, and the Transversalis colli and suprascapular vessels. It next passes over the first part of the subclavian artery, between it and the subclavian vein, and, as it enters the chest, crosses the internal mammary artery near its origin. Within the chest it descends nearly vertically in front of the root of the lung and by the side of the pericardium, between it and the mediastinal portion of the pleura, to the Diaphragm, where it divides into branches, which separately pierce that muscle and are distributed to its under surface.

The two phrenic nerves differ in their length, and also in their relations at the upper part of the thorax.

The *right nerve* is situated more deeply, and is shorter and more vertical in direction than the left; it lies on the outer side of the right vena innominata and superior vena cava.

The *left nerve* is rather longer than the right, from the inclination of the heart to the left side, and from the Diaphragm being lower on this than on the opposite side. It enters the thorax behind the left innominate vein, and crosses in front of the vagus and the arch of the aorta and the root of the lung. In the thorax each phrenic nerve is accompanied by a branch of the internal mammary artery, the comes nervi phrenici.

Each nerve supplies filaments to the pericardium and pleura, and near the chest is joined by a filament from the sympathetic, and, occasionally, by one from the union of the descendens hypoglossi with the spinal nerves: this filament is found, according to Swan, only on the left side. It frequently receives a filament from the nerve to the Subclavius muscle. Branches have been described as passing to the peritoneum.

From the *right nerve* one or two filaments pass to join in a small ganglion with phrenic branches of the solar plexus; and branches from this ganglion are distributed to the hepatic plexus, the suprarenal capsule, and inferior vena cava. From the *left nerve* filaments pass to join the phrenic plexus of the sympathetic, but without any ganglionic enlargement.

Deep Branches of the Cervical Plexus. External Series.

Communicating Branches.—The deep branches of the external series of the cervical plexus communicate with the spinal accessory nerve, in the substance of the Sterno-mastoid muscle, in the posterior triangle, and beneath the Trapezius.

Muscular branches are distributed to the Sterno-mastoid, Trapezius, Levator anguli scapulæ, and Scalenus medius.

The branch for the Sterno-mastoid is derived from the second cervical; the Trapezius and Levator anguli scapulæ receive branches from the third and fourth. The Scalenus medius is derived sometimes from the third, sometimes the fourth, and occasionally from both nerves.

The Brachial Plexus (Fig. 410).

The **Brachial Plexus** is formed by the union of the anterior divisions of the four lower cervical and the greater part of the first dorsal nerves, receiving usually a fasciculus from the fourth cervical nerve, and frequently one from the second dorsal nerve. It extends from the lower part of the side of the neck to the axilla. It is very broad, and presents little of a plexiform arrangement at its commencement. It is narrow opposite the clavicle, becomes broad and forms a more dense interlacement in the axilla, and divides opposite the coracoid process into numerous branches for the supply of the upper limb. The nerves which form the plexus are all similar in size, and their mode of communication is subject to considerable variation, so that no one plan can be given as applying to every case. The following appears, however, to be the most constant arrangement: the fifth and sixth cervical unite together soon after their exit from the intervertebral foramina to form a common trunk. The eighth cervical and first dorsal also unite to form one trunk. So that the nerves forming the plexus, as they lie on the Scalenus medius external to the outer border of the

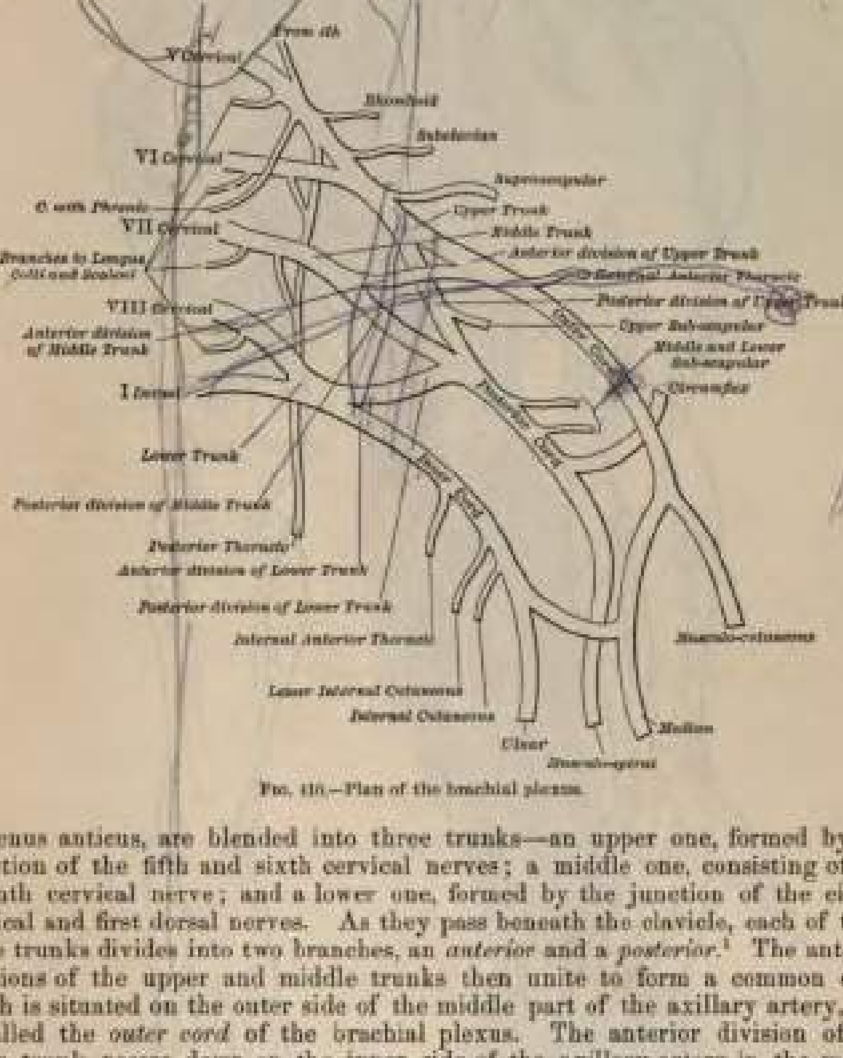

FIG. 416.—Plan of the brachial plexus.

Scalenus anticus, are blended into three trunks—an upper one, formed by the junction of the fifth and sixth cervical nerves; a middle one, consisting of the seventh cervical nerve; and a lower one, formed by the junction of the eighth cervical and first dorsal nerves. As they pass beneath the clavicle, each of these three trunks divides into two branches, an *anterior* and a *posterior*.[1] The anterior divisions of the upper and middle trunks then unite to form a common cord, which is situated on the outer side of the middle part of the axillary artery, and is called the *outer cord* of the brachial plexus. The anterior division of the lower trunk passes down on the inner side of the axillary artery in the middle of the axilla, and forms the *inner cord* of the brachial plexus. The posterior divisions of all three trunks unite to form the *posterior cord* of the brachial plexus, which is situated behind the second portion of the axillary artery. From this posterior cord are given off the two lower subscapular nerves, the upper subscapular nerve being given off from the posterior division of the upper trunk prior to its junction with the posterior division of the lower and middle trunks. The posterior cord divides into the circumflex and musculo-spiral nerves.

The brachial plexus communicates with the cervical plexus by a branch from the fourth to the fifth nerve, and with the phrenic nerve by a branch from the

[1] The posterior division of the lower trunk is very much smaller than the others, and is frequently derived entirely from the eighth cervical nerve.

Deep . . .	Internal . .	Communicating. Muscular. Communicantes hypoglossi. Phrenic.
	External . .	Communicating. Muscular.

Superficial Branches of the Cervical Plexus.

The **Occipitalis minor** (Fig. 415) arises from the second cervical nerve, sometimes also from the third; it curves round the posterior border of the Sterno-mastoid, and ascends, running parallel to the posterior border of the muscle, to the back part of the side of the head. Near the cranium it perforates the deep fascia, and is continued upward along the side of the head behind the ear, supplying the integument, and communicating with the occipitalis major, the auricularis magnus, and with the posterior auricular branch of the facial.

This nerve gives off an *auricular branch*, which supplies the integument of the upper and back part of the auricle, communicating with the mastoid branch of the auricularis magnus. This branch is occasionally derived from the great occipital nerve. The occipitalis minor varies in size; it is occasionally double.

The **Auricularis Magnus** is the largest of the ascending branches. It arises from the second and third cervical nerves, winds round the posterior border of the Sterno-mastoid, and, after perforating the deep fascia, ascends upon that muscle beneath the Platysma to the parotid gland, where it divides into facial, auricular, and mastoid branches.

The *facial branches* pass across the parotid, and are distributed to the integument of the face over the parotid gland; others penetrate the substance of the gland and communicate with the facial nerve.

The *auricular branches* ascend to supply the integument of the back of the pinna, except at its upper part, communicating with the auricular branches of the facial and pneumogastric nerves. A filament pierces the pinna to reach its outer surface, where it is distributed to the lobule and lower part of the concha.

The *mastoid branch* communicates with the occipitalis minor and the posterior auricular branch of the facial, and is distributed to the integument behind the ear.

The **Superficialis Colli** arises from the second and third cervical nerves, turns round the posterior border of the Sterno-mastoid about its middle, and, passing obliquely forward beneath the external jugular vein to the anterior border of the muscle, perforates the deep cervical fascia, and divides beneath the Platysma into two branches which are distributed to the antero-lateral parts of the neck.

The *ascending branch* gives a filament which accompanies the external jugular vein; it then passes upward to the submaxillary region, and divides into branches, some of which form a plexus with the cervical branches of the facial nerve beneath the Platysma; others pierce that muscle and are distributed to the integument of the upper half of the neck, at its fore part, as high as the chin.

The *descending branch* (occasionally represented by two or more filaments) pierces the Platysma, and is distributed to the integument of the side and front of the neck, as low as the sternum.

The **Descending** or **supraclavicular branches** arise from the third and fourth cervical nerves: emerging beneath the posterior border of the Sterno-mastoid, they descend in the posterior triangle of the neck beneath the Platysma and deep cervical fascia. Near the clavicle they perforate the fascia and Platysma to become cutaneous, and are arranged, according to their position, into three groups.

The *inner* or *suprasternal branches* cross obliquely over the external jugular vein and the clavicular and sternal attachments of the Sterno-mastoid, and supply the integument as far as the median line. They furnish one or two filaments to the sterno-clavicular joint.

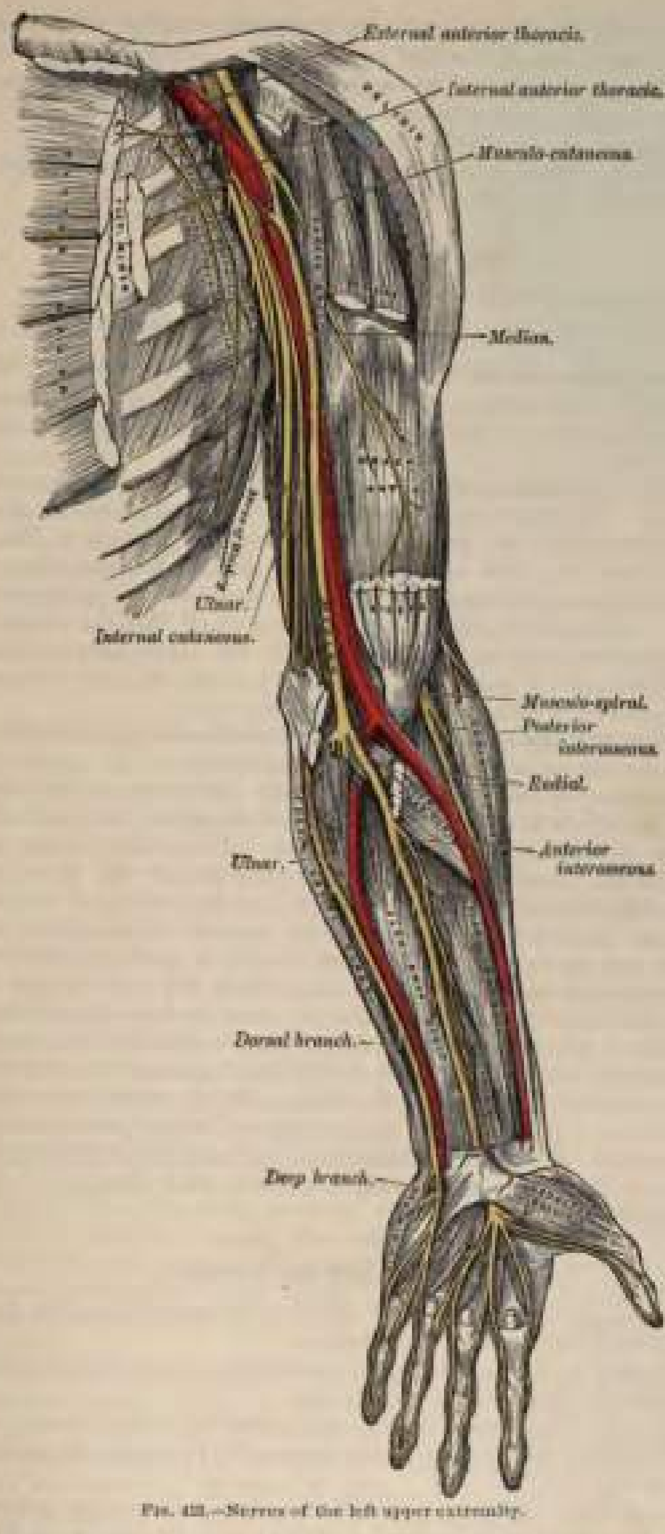

Fig. 423.—Nerves of the left upper extremity.

scaleni muscles, and then above and to the outer side of the subclavian artery: it next passes behind the clavicle and Subclavius muscle, lying upon the first serration of the Serratus magnus, and the Subscapularis muscles. *In the axilla*, it is placed on the outer side of the first portion of the axillary artery; it surrounds the artery in the second part of its course, one cord lying upon the outer side of that vessel, one on the inner side, and one behind it, and at the lower part of the axillary space gives off its terminal branches to the upper extremity.

Branches.—The branches of the brachial plexus are arranged in two groups—viz., those given off above the clavicle, and those below that bone.

Branches above the Clavicle.

Communicating.	Posterior thoracic.
Muscular.	Suprascapular.

The **communicating branch** with the phrenic is derived from the fifth cervical nerve or from the loop between the fifth and sixth; it joins the phrenic on the Anterior scalenus muscle. The communications with the sympathetic have already been referred to.

The **muscular branches** supply the Longus colli, Scaleni, Rhomboidei, and Subclavius muscles. Those for the Longus colli and Scaleni arise from the four lower cervical nerves at their exit from the intervertebral foramina. The Rhomboid branch arises from the fifth cervical, pierces the Scalenus medius, and passes beneath the Levator anguli scapulæ, which it occasionally supplies, to the Rhomboid muscles. The nerve to the Subclavius is a small filament which arises from the fifth cervical at its point of junction with the sixth nerve; it descends in front of the third part of the subclavian artery to the Subclavius muscle, and is usually connected by a filament with the phrenic nerve.

The **posterior thoracic nerve** (*long thoracic, external respiratory of Bell*) (Fig. 413) supplies the Serratus magnus, and is remarkable for the length of its course. It sometimes arises by two roots from the fifth and sixth cervical nerves immediately after their exit from the intervertebral foramina, but generally by three roots from the fifth, sixth, and seventh nerves. These unite in the substance of the Middle scalenus muscle, and, after emerging from it, the nerve passes down behind the brachial plexus and the axillary vessels, resting on the outer surface of the Serratus magnus. It extends along the side of the chest to the lower border of that muscle, supplying filaments to each of its digitations.

The **suprascapular nerve** (Fig. 414) arises from the cord formed by the fifth and sixth cervical nerves; passing obliquely outward beneath the Trapezius and the Omo-hyoid, it enters the supraspinous fossa below the transverse or suprascapular ligament, and, passing beneath the Supraspinatus muscle, curves round the external border of the spine of the scapula to the infraspinous fossa. In the supraspinous fossa it gives off two branches to the Supraspinatus muscle, and an articular filament to the shoulder-joint; and in the infraspinous fossa it gives off two branches to the Infraspinatus muscle, besides some filaments to the shoulder-joint and scapula.

Branches below the Clavicle.

The branches given off below the clavicle are derived from the three cords of the brachial plexus, in the following manner:

From the outer cord arise the external anterior thoracic nerve, the musculo-cutaneous, and the outer head of the median.

From the inner cord arise the internal anterior thoracic nerve, the internal cutaneous, the lesser internal cutaneous (nerve of Wrisberg), the ulnar, and inner head of the median.

From the posterior cord arise two of the three subscapular nerves, the third taking origin from the posterior division of the trunk formed by the fifth and sixth cervical nerves; the cord then divides into the musculo-spiral and circumflex nerves.

These may be arranged according to the parts they supply:

To the chest	Anterior thoracic.
To the shoulder	Subscapular. Circumflex.
To the arm, forearm, and hand .	Musculo-cutaneous. Internal cutaneous. Lesser internal cutaneous. Median. Ulnar. Musculo-spiral.

The fasciculi of which these nerves are composed may be traced through the plexus to the spinal nerves from which they originate. They are as follows:

External anterior thoracic	from	5th, 6th, and 7th cervical.
Internal anterior thoracic	"	8th cervical and 1st dorsal.
Subscapular	"	5th, 6th, 7th, and 8th cervical.
Circumflex	"	5th and 6th cervical.
Musculo-cutaneous	"	5th and 6th cervical.
Internal cutaneous	"	8th cervical and 1st dorsal.
Lesser internal cutaneous	"	1st dorsal.
Median	"	6th, 7th, and 8th cervical, and 1st dorsal.
Ulnar	"	8th cervical and 1st dorsal.
Musculo-spiral	"	6th, 7th, and 8th cervical, sometimes also from the 5th.

The **Anterior Thoracic Nerves** (Fig. 413), two in number, supply the Pectoral muscles.

The *external* or superficial nerve, the larger of the two, arises from the outer cord of the brachial plexus, through which its fibres may be traced to the fifth, sixth, and seventh cervical nerves. It passes inward, across the axillary artery and vein, pierces the costo-coracoid membrane, and is distributed to the under surface of the Pectoralis major. It sends down a communicating filament to join the internal nerve, which forms a loop round the inner side of the axillary artery.

The *internal* or deep nerve arises from the inner cord, and through it from the eighth cervical and first dorsal. It passes behind the first part of the axillary artery, then curves forward between the axillary artery and vein, and joins with the filament from the anterior nerve. It then passes to the under surface of the Pectoralis minor muscle, where it divides into a number of branches, which supply the muscle on its under surface. Some two or three branches pass through the muscle to supply the Pectoralis major.

The **Subscapular Nerves**, three in number, supply the Subscapularis, Teres major, and Latissimus dorsi muscles. The fasciculi of which they are composed may be traced to the fifth, sixth, seventh, and eighth cervical nerves.

The *upper subscapular nerve*, the smallest, enters the upper part of the Subscapularis muscle; this nerve is frequently represented by two branches.

The *lower subscapular nerve* enters the axillary border of the Subscapularis and terminates in the Teres major. The latter muscle is sometimes supplied by a separate branch.

The *middle* or *long subscapular*, the largest of the three, follows the course of the subscapular artery, along the posterior wall of the axilla to the Latissimus dorsi, through which it may be traced as far as its lower border.

The **Circumflex Nerve** (Fig. 414) supplies some of the muscles and the integument of the shoulder and the shoulder-joint. It arises from the posterior cord of the brachial plexus, in common with the musculo-spiral nerve, and its fibres may be traced through the posterior cord to the fifth and sixth cervical nerves. It is at first placed behind the axillary artery, between it and the Subscapularis muscle,

and passes downward and outward to the lower border of that muscle. It then winds backward in company with the posterior circumflex artery, through a quadrilateral space bounded above by the Teres minor, below by the Teres major, internally by the long head of the Triceps, and externally by the neck of the humerus, and divides into two branches.

The *upper branch* winds round the surgical neck of the humerus, beneath the Deltoid, with the posterior circumflex vessels, as far as the anterior border of that muscle, supplying it, and giving off cutaneous branches, which pierce the muscle and ramify in the integument covering its lower part.

The *lower branch*, at its origin, distributes filaments to the Teres minor and back part of the Deltoid muscles. Upon the filament to the former muscle an oval enlargement usually exists. The nerve then pierces the deep fascia, and supplies the integument over the lower two-thirds of the posterior surface of the Deltoid, as well as that covering the long head of the Triceps.

The circumflex nerve, before its division, gives off an articular filament, which enters the shoulder-joint below the Subscapularis.

The **Musculo-cutaneous Nerve** (Fig. 413) (*external cutaneous* or *perforans Casserii*)[1] supplies some of the muscles of the arm and the integument of the forearm. It arises from the outer cord of the brachial plexus, opposite the lower border of the Pectoralis minor, receiving filaments from the fifth, sixth, and seventh cervical nerves. It perforates the Coraco-brachialis muscle, passes obliquely between the Biceps and Brachialis anticus to the outer side of the arm, and, a little above the elbow, winds round the outer border of the tendon of the Biceps, and, perforating the deep fascia, becomes cutaneous. This nerve, in its course through the arm, supplies the Coraco-brachialis, Biceps, and the greater part of the Brachialis anticus muscles. The branch to the Coraco-brachialis is given off from the nerve close to its origin, and in some instances, especially in early life, as a separate filament from the outer cord of the plexus. The branches to the Biceps and Brachialis anticus are given off after the nerve has pierced the Coraco-brachialis. The nerve also sends a small branch to the bone, which enters the nutrient foramen with the accompanying artery, and a filament, from the branch supplying the Brachialis anticus, to the elbow-joint.

The cutaneous portion of the nerve passes behind the median cephalic vein, and divides, opposite the elbow-joint, into an anterior and a posterior branch.

The *anterior branch* descends along the radial border of the forearm to the wrist, and supplies the integument over the outer half of the anterior surface. At the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the back of the wrist, supplying the carpus. The nerve then passes downward to the ball of the thumb, where it terminates in cutaneous filaments. It communicates with a branch from the radial nerve and the palmar cutaneous branch of the median.

The *posterior branch* passes downward along the back part of the radial side of the forearm to the wrist. It supplies the integument of the lower third of the forearm, communicating with the radial nerve and the external cutaneous branch of the musculo-spiral.

The musculo-cutaneous nerve presents frequent irregularities. It may adhere for some distance to the median and then pass outward, beneath the Biceps, instead of through the Coraco-brachialis. Frequently some of the fibres of the median run for some distance in the musculo-cutaneous and then leave it to join their proper trunk. Less frequently the reverse is the case, and the median sends a branch to join the musculo-cutaneous. Instead of piercing the Coraco-brachialis, the nerve may pass under it or through the Biceps. Occasionally it gives a filament to the Pronator teres, and it has been seen to supply the back of the thumb when the radial nerve was absent.

The **Internal Cutaneous Nerve** (Fig. 413) is one of the smallest branches of the brachial plexus. It arises from the inner cord in common with the ulnar and

[1] See foot-note, page 726.

internal head of the median, and, at its commencement, is placed on the inner side of the axillary, and afterward of the brachial artery. It derives its fibres from the eighth cervical and first dorsal nerves. It passes down the inner side of the arm, pierces the deep fascia with the basilic vein, about the middle of the limb, and, becoming cutaneous, divides into two branches, anterior and posterior.

This nerve gives off, near the axilla, a cutaneous filament, which pierces the fascia and supplies the integument covering the Biceps muscle nearly as far as the elbow. This filament lies a little external to the common trunk, from which it arises.

The *anterior branch*, the larger of the two, passes usually in front of, but occasionally behind, the median basilic vein. It then descends on the anterior surface of the ulnar side of the forearm, distributing filaments to the integument as far as the wrist, and communicating with a cutaneous branch of the ulnar nerve.

The *posterior branch* passes obliquely downward on the inner side of the basilic vein, passes in front of, or over, the internal condyle of the humerus to the back of the forearm, and descends on the posterior surface of its ulnar side as far as the wrist, distributing filaments to the integument. It communicates, above the elbow, with the lesser internal cutaneous, and above the wrist with the dorsal cutaneous branch of the ulnar nerve (Swan).

The **Lesser Internal Cutaneous Nerve** (*nerve of Wrisberg*) (Fig. 413) is distributed to the integument on the inner side of the arm. It is the smallest of the branches of the brachial plexus, and, arising from the inner cord with the internal cutaneous and ulnar nerves, receives its fibres from the first dorsal nerve. It passes through the axillary space, at first lying behind, and then on the inner side of, the axillary vein, and communicates with the intercosto-humeral nerve. It descends along the inner side of the brachial artery to the middle of the arm, where it pierces the deep fascia, and is distributed to the integument of the back part of the lower third of the arm, extending as far as the elbow, where some filaments are lost in the integument in front of the inner condyle, and others over the olecranon. It communicates with the posterior branch of the internal cutaneous nerve.

In some cases the nerve of Wrisberg and intercosto-humeral are connected by two or three filaments which form a plexus at the back part of the axilla. In other cases the intercosto-humeral is of large size, and takes the place of the nerve of Wrisberg, receiving merely a filament of communication from the brachial plexus, which represents the latter nerve. In other cases this filament is wanting, the place of the nerve of Wrisberg being supplied entirely from the intercosto-humeral.

The **Median Nerve** (Fig. 413) has received its name from the course it takes along the middle of the arm and forearm to the hand, lying between the ulnar and the musculo-spiral and radial nerves. It arises by two roots, one from the outer, and one from the inner, cord of the brachial plexus; these embrace the lower part of the axillary artery, uniting either in front or on the outer side of that vessel. It receives filaments from the sixth, seventh, and eighth cervical and the first dorsal. As it descends through the arm, it lies at first on the outer side of the brachial artery, crosses that vessel in the middle of its course, usually in front, but occasionally behind it, and lies on its inner side to the bend of the elbow, where it is placed beneath the bicipital fascia, and is separated from the elbow-joint by the Brachialis anticus. *In the forearm* it passes between the two heads of the Pronator radii teres, and descends beneath the Flexor sublimis, lying on the Flexor profundus, to within two inches above the annular ligament, where it becomes more superficial, lying between the tendons of the Flexor sublimis and Flexor carpi radialis, beneath, and rather to the radial side of, the tendon of the Palmaris longus, covered by the integument and fascia. It then passes beneath the annular ligament into the hand. In its course through the forearm it is accompanied by a branch of the anterior interosseous artery.

and passes downward and outward to the lower border of that muscle. It then winds backward in company with the posterior circumflex artery, through a quadrilateral space bounded above by the Teres minor, below by the Teres major, internally by the long head of the Triceps, and externally by the neck of the humerus, and divides into two branches.

The *upper branch* winds round the surgical neck of the humerus, beneath the Deltoid, with the posterior circumflex vessels, as far as the anterior border of that muscle, supplying it, and giving off cutaneous branches, which pierce the muscle and ramify in the integument covering its lower part.

The *lower branch*, at its origin, distributes filaments to the Teres minor and back part of the Deltoid muscles. Upon the filament to the former muscle an oval enlargement usually exists. The nerve then pierces the deep fascia, and supplies the integument over the lower two-thirds of the posterior surface of the Deltoid, as well as that covering the long head of the Triceps.

The circumflex nerve, before its division, gives off an articular filament, which enters the shoulder-joint below the Subscapularis.

The **Musculo-cutaneous Nerve** (Fig. 413) (*external cutaneous* or *perforans Casserii*)[1] supplies some of the muscles of the arm and the integument of the forearm. It arises from the outer cord of the brachial plexus, opposite the lower border of the Pectoralis minor, receiving filaments from the fifth, sixth, and seventh cervical nerves. It perforates the Coraco-brachialis muscle, passes obliquely between the Biceps and Brachialis anticus to the outer side of the arm, and, a little above the elbow, winds round the outer border of the tendon of the Biceps, and, perforating the deep fascia, becomes cutaneous. This nerve, in its course through the arm, supplies the Coraco-brachialis, Biceps, and the greater part of the Brachialis anticus muscles. The branch to the Coraco-brachialis is given off from the nerve close to its origin, and in some instances, especially in early life, as a separate filament from the outer cord of the plexus. The branches to the Biceps and Brachialis anticus are given off after the nerve has pierced the Coraco-brachialis. The nerve also sends a small branch to the bone, which enters the nutrient foramen with the accompanying artery, and a filament, from the branch supplying the Brachialis anticus, to the elbow-joint.

The cutaneous portion of the nerve passes behind the median cephalic vein, and divides, opposite the elbow-joint, into an anterior and a posterior branch.

The *anterior branch* descends along the radial border of the forearm to the wrist, and supplies the integument over the outer half of the anterior surface. At the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the back of the wrist, supplying the carpus. The nerve then passes downward to the ball of the thumb, where it terminates in cutaneous filaments. It communicates with a branch from the radial nerve and the palmar cutaneous branch of the median.

The *posterior branch* passes downward along the back part of the radial side of the forearm to the wrist. It supplies the integument of the lower third of the forearm, communicating with the radial nerve and the external cutaneous branch of the musculo-spiral.

The musculo-cutaneous nerve presents frequent irregularities. It may adhere for some distance to the median and then pass outward, beneath the Biceps, instead of through the Coraco-brachialis. Frequently some of the fibres of the median run for some distance in the musculo-cutaneous and then leave it to join their proper trunk. Less frequently the reverse is the case, and the median sends a branch to join the musculo-cutaneous. Instead of piercing the Coraco-brachialis, the nerve may pass under it or through the Biceps. Occasionally it gives a filament to the Pronator teres, and it has been seen to supply the back of the thumb when the radial nerve was absent.

The **Internal Cutaneous Nerve** (Fig. 413) is one of the smallest branches of the brachial plexus. It arises from the inner cord in common with the ulnar and

[1] See foot-note, page 726.

internal head of the median, and, at its commencement, is placed on the inner side of the axillary, and afterward of the brachial artery. It derives its fibres from the eighth cervical and first dorsal nerves. It passes down the inner side of the arm, pierces the deep fascia with the basilic vein, about the middle of the limb, and, becoming cutaneous, divides into two branches, anterior and posterior.

This nerve gives off, near the axilla, a cutaneous filament, which pierces the fascia and supplies the integument covering the Biceps muscle nearly as far as the elbow. This filament lies a little external to the common trunk, from which it arises.

The *anterior branch*, the larger of the two, passes usually in front of, but occasionally behind, the median basilic vein. It then descends on the anterior surface of the ulnar side of the forearm, distributing filaments to the integument as far as the wrist, and communicating with a cutaneous branch of the ulnar nerve.

The *posterior branch* passes obliquely downward on the inner side of the basilic vein, passes in front of, or over, the internal condyle of the humerus to the back of the forearm, and descends on the posterior surface of its ulnar side as far as the wrist, distributing filaments to the integument. It communicates, above the elbow, with the lesser internal cutaneous, and above the wrist with the dorsal cutaneous branch of the ulnar nerve (Swan).

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In some cases the nerve of Wrisberg and intercosto-humeral are connected by two or three filaments which form a plexus at the back part of the axilla. In other cases the intercosto-humeral is of large size, and takes the place of the nerve of Wrisberg, receiving merely a filament of communication from the brachial plexus, which represents the latter nerve. In other cases this filament is wanting, the place of the nerve of Wrisberg being supplied entirely from the intercosto-humeral.

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and passes downward and outward to the lower border of that muscle. It then winds backward in company with the posterior circumflex artery, through a quadrilateral space bounded above by the Teres minor, below by the Teres major, internally by the long head of the Triceps, and externally by the neck of the humerus, and divides into two branches.

The *upper branch* winds round the surgical neck of the humerus, beneath the Deltoid, with the posterior circumflex vessels, as far as the anterior border of that muscle, supplying it, and giving off cutaneous branches, which pierce the muscle and ramify in the integument covering its lower part.

The *lower branch*, at its origin, distributes filaments to the Teres minor and back part of the Deltoid muscles. Upon the filament to the former muscle an oval enlargement usually exists. The nerve then pierces the deep fascia, and supplies the integument over the lower two-thirds of the posterior surface of the Deltoid, as well as that covering the long head of the Triceps.

The circumflex nerve, before its division, gives off an articular filament, which enters the shoulder-joint below the Subscapularis.

The **Musculo-cutaneous Nerve** (Fig. 413) (*external cutaneous* or *perforans Casserii*)[1] supplies some of the muscles of the arm and the integument of the forearm. It arises from the outer cord of the brachial plexus, opposite the lower border of the Pectoralis minor, receiving filaments from the fifth, sixth, and seventh cervical nerves. It perforates the Coraco-brachialis muscle, passes obliquely between the Biceps and Brachialis anticus to the outer side of the arm, and, a little above the elbow, winds round the outer border of the tendon of the Biceps, and, perforating the deep fascia, becomes cutaneous. This nerve, in its course through the arm, supplies the Coraco-brachialis, Biceps, and the greater part of the Brachialis anticus muscles. The branch to the Coraco-brachialis is given off from the nerve close to its origin, and in some instances, especially in early life, as a separate filament from the outer cord of the plexus. The branches to the Biceps and Brachialis anticus are given off after the nerve has pierced the Coraco-brachialis. The nerve also sends a small branch to the bone, which enters the nutrient foramen with the accompanying artery, and a filament, from the branch supplying the Brachialis anticus, to the elbow-joint.

The cutaneous portion of the nerve passes behind the median cephalic vein, and divides, opposite the elbow-joint, into an anterior and a posterior branch.

The *anterior branch* descends along the radial border of the forearm to the wrist, and supplies the integument over the outer half of the anterior surface. At the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the back of the wrist, supplying the carpus. The nerve then passes downward to the ball of the thumb, where it terminates in cutaneous filaments. It communicates with a branch from the radial nerve and the palmar cutaneous branch of the median.

The *posterior branch* passes downward along the back part of the radial side of the forearm to the wrist. It supplies the integument of the lower third of the forearm, communicating with the radial nerve and the external cutaneous branch of the musculo-spiral.

The musculo-cutaneous nerve presents frequent irregularities. It may adhere for some distance to the median and then pass outward, beneath the Biceps, instead of through the Coraco-brachialis. Frequently some of the fibres of the median run for some distance in the musculo-cutaneous and then leave it to join their proper trunk. Less frequently the reverse is the case, and the median sends a branch to join the musculo-cutaneous. Instead of piercing the Coraco-brachialis, the nerve may pass under it or through the Biceps. Occasionally it gives a filament to the Pronator teres, and it has been seen to supply the back of the thumb when the radial nerve was absent.

The **Internal Cutaneous Nerve** (Fig. 413) is one of the smallest branches of the brachial plexus. It arises from the inner cord in common with the ulnar and

[1] See foot-note, page 726.

internal head of the median, and, at its commencement, is placed on the inner side of the axillary, and afterward of the brachial artery. It derives its fibres from the eighth cervical and first dorsal nerves. It passes down the inner side of the arm, pierces the deep fascia with the basilic vein, about the middle of the limb, and, becoming cutaneous, divides into two branches, anterior and posterior.

This nerve gives off, near the axilla, a cutaneous filament, which pierces the fascia and supplies the integument covering the Biceps muscle nearly as far as the elbow. This filament lies a little external to the common trunk, from which it arises.

The *anterior branch*, the larger of the two, passes usually in front of, but occasionally behind, the median basilic vein. It then descends on the anterior surface of the ulnar side of the forearm, distributing filaments to the integument as far as the wrist, and communicating with a cutaneous branch of the ulnar nerve.

The *posterior branch* passes obliquely downward on the inner side of the basilic vein, passes in front of, or over, the internal condyle of the humerus to the back of the forearm, and descends on the posterior surface of its ulnar side as far as the wrist, distributing filaments to the integument. It communicates, above the elbow, with the lesser internal cutaneous, and above the wrist with the dorsal cutaneous branch of the ulnar nerve (Swan).

The **Lesser Internal Cutaneous Nerve** (*nerve of Wrisberg*) (Fig. 413) is distributed to the integument on the inner side of the arm. It is the smallest of the branches of the brachial plexus, and, arising from the inner cord with the internal cutaneous and ulnar nerves, receives its fibres from the first dorsal nerve. It passes through the axillary space, at first lying behind, and then on the inner side of, the axillary vein, and communicates with the intercosto-humeral nerve. It descends along the inner side of the brachial artery to the middle of the arm, where it pierces the deep fascia, and is distributed to the integument of the back part of the lower third of the arm, extending as far as the elbow, where some filaments are lost in the integument in front of the inner condyle, and others over the olecranon. It communicates with the posterior branch of the internal cutaneous nerve.

In some cases the nerve of Wrisberg and intercosto-humeral are connected by two or three filaments which form a plexus at the back part of the axilla. In other cases the intercosto-humeral is of large size, and takes the place of the nerve of Wrisberg, receiving merely a filament of communication from the brachial plexus, which represents the latter nerve. In other cases this filament is wanting, the place of the nerve of Wrisberg being supplied entirely from the intercosto-humeral.

The **Median Nerve** (Fig. 413) has received its name from the course it takes along the middle of the arm and forearm to the hand, lying between the ulnar and the musculo-spiral and radial nerves. It arises by two roots, one from the outer, and one from the inner, cord of the brachial plexus; these embrace the lower part of the axillary artery, uniting either in front or on the outer side of that vessel. It receives filaments from the sixth, seventh, and eighth cervical and the first dorsal. As it descends through the arm, it lies at first on the outer side of the brachial artery, crosses that vessel in the middle of its course, usually in front, but occasionally behind it, and lies on its inner side to the bend of the elbow, where it is placed beneath the bicipital fascia, and is separated from the elbow-joint by the Brachialis anticus. *In the forearm* it passes between the two heads of the Pronator radii teres, and descends beneath the Flexor sublimis, lying on the Flexor profundus, to within two inches above the annular ligament, where it becomes more superficial, lying between the tendons of the Flexor sublimis and Flexor carpi radialis, beneath, and rather to the radial side of, the tendon of the Palmaris longus, covered by the integument and fascia. It then passes beneath the annular ligament into the hand. In its course through the forearm it is accompanied by a branch of the anterior interosseous artery.

Branches.—With the exception of the nerve to the Pronator teres, which sometimes arises above the elbow-joint, the median nerve gives off no branches in the arm. *In the forearm* its branches are muscular, anterior interosseous, and palmar cutaneous, and, according to Rüdinger and Macalister, two articular twigs to the elbow-joint.

The *muscular branches* supply all the superficial muscles on the front of the forearm except the Flexor carpi ulnaris. These branches are derived from the nerve near the elbow.

The *anterior interosseous* supplies the deep muscles on the front of the forearm, except the inner half of the Flexor profundus digitorum. It accompanies the anterior interosseous artery along the interosseous membrane, in the interval between the Flexor longus pollicis and Flexor profundus digitorum muscles, both of which it supplies, and terminates below in the Pronator quadratus and wrist-joint.

The *palmar cutaneous branch* arises from the median nerve at the lower part of the forearm. It pierces the fascia above the annular ligament, and, descending over that ligament, divides into two branches; of which the *outer* supplies the skin over the ball of the thumb, and communicates with the anterior cutaneous branch of the musculo-cutaneous nerve; and the *inner* supplies the integument of the palm of the hand, communicating with the cutaneous branch of the ulnar.

In the palm of the hand the median nerve is covered by the integument and palmar fascia and crossed by the superficial palmar arch. It rests upon the tendons of the flexor muscles. In this situation it becomes enlarged, somewhat flattened, of a reddish color, and divides into two branches. Of these, the *external* supplies a muscular branch to some of the muscles of the thumb and digital branches to the thumb and index finger; the *internal* supplies digital branches to the contiguous sides of the index and middle and of the middle and ring fingers.

The *branch to the muscles of the thumb* is a short nerve which divides to supply the Abductor, Opponens, and the superficial head of the Flexor brevis pollicis muscles, the remaining muscles of this group being supplied by the ulnar nerve.

The *digital branches* are five in number. The *first* and *second* pass along the borders of the thumb, the external branch communicating with branches of the radial nerve. The *third* passes along the radial side of the index finger, and supplies the First lumbricalis muscle. The *fourth* subdivides to supply the adjacent sides of the index and middle fingers, and sends a branch to the Second lumbrical muscle. The *fifth* supplies the adjacent sides of the middle and ring fingers, and communicates with a branch from the ulnar nerve.

Each digital nerve, opposite the base of the first phalanx, gives off a dorsal branch, which joins the dorsal digital nerve from the radial and runs along the side of the dorsum of the finger, to end in the integument over the last phalanx. At the end of the finger the digital nerve divides into a palmar and a dorsal branch, the former of which supplies the extremity of the finger, and the latter ramifies round and beneath the nail. The digital nerves, as they run along the fingers, are placed superficial to the digital arteries.

The **Ulnar Nerve** (Fig. 413) is placed along the inner or ulnar side of the upper limb, and is distributed to the muscles and integument of the forearm and hand. It is smaller than the median, behind which it is placed, diverging from it in its course down the arm. It arises from the inner cord of the brachial plexus, in common with the inner head of the median and the internal cutaneous nerve, and derives its fibres from the eighth cervical and first dorsal nerves. At its commencement it lies to the inner side of the axillary artery, and holds the same relation with the brachial artery to the middle of the arm. From this point it runs obliquely across the internal head of the Triceps, pierces the internal intermuscular septum, and descends to the groove between the internal condyle and the olecranon, accompanied by the inferior profunda artery. *At the elbow* it rests upon the back of the inner condyle, and passes into the forearm between the two heads of the Flexor carpi ulnaris. *In the forearm* it descends in a perfectly straight course along its ulnar side, lying upon the Flexor profundus digitorum, its upper half being covered by the Flexor carpi ulnaris, its lower half lying on the outer side of the muscle, covered by the integument and fascia. The ulnar artery, in the upper third of its course, is separated from the ulnar nerve by a considerable interval, but in the rest of its extent the nerve lies to its inner side. *At the wrist* the ulnar nerve crosses the annular ligament on the outer side of the pisiform bone, to the inner side of and a little behind the ulnar artery, and immediately beyond this bone divides into two branches, superficial and deep palmar.

The branches of the ulnar nerve are—

In the forearm	Articular (elbow). Muscular. Cutaneous. Dorsal cutaneous. Articular (wrist).	In the hand	Superficial palmar. Deep palmar.

The *articular branches* distributed to the elbow-joint consist of several small filaments. They arise from the nerve as it lies in the groove between the inner condyle and olecranon.

The *muscular branches* are two in number—one supplying the Flexor carpi ulnaris; the other, the inner half of the Flexor profundus digitorum. They arise from the trunk of the nerve near the elbow.

The *cutaneous branch* arises from the ulnar nerve about the middle of the forearm, and divides into two branches.

One branch (frequently absent) pierces the deep fascia near the wrist, and is distributed to the integument, communicating with a branch of the internal cutaneous nerve.

The second branch (*palmar cutaneous*) lies on the ulnar artery, which it accompanies to the hand, some filaments entwining round the vessel; it ends in the integument of the palm, communicating with branches of the median nerve.

The *dorsal cutaneous branch* arises about two inches above the wrist; it passes backward beneath the Flexor carpi ulnaris, perforates the deep fascia, and, running along the ulnar side of the back of the wrist and hand, divides into branches; one of these supplies the inner side of the little finger; a second supplies the adjacent sides of the little and ring fingers; a third joins the branch of the radial nerve which supplies the adjoining sides of the middle and ring fingers, and assists in supplying them; a fourth is distributed to the metacarpal region of the hand, communicating with a branch of the radial nerve.

On the little finger the dorsal digital branches extend only as far as the base of the terminal phalanx, and on the ring finger as far as the base of the second phalanx; the more distal parts of these digits are supplied by dorsal branches derived from the palmar digital branches of the ulnar.

The *superficial palmar branch* supplies the Palmaris brevis and the integument on the inner side of the hand, and terminates in two digital branches, which are distributed, one to the ulnar side of the little finger, the other to the adjoining sides of the little and ring fingers, the latter communicating with a branch from the median. The digital branches are distributed to the fingers in the same manner as the digital branches of the median.

The *deep palmar branch*, accompanied by the deep branch of the ulnar artery, passes between the Abductor and Flexor brevis minimi digiti muscles; it then perforates the Opponens minimi digiti and follows the course of the deep palmar arch beneath the flexor tendons. At its origin it supplies the muscles of the little finger. As it crosses the deep part of the hand it sends two branches to each interosseous space, one for the Dorsal and one for the Palmar interosseous muscle, the branches to the Second and Third palmar interossei supplying filaments to the two inner Lumbrical muscles. At its termination between the thumb and index finger, it supplies the Adductores transversus et obliquus pollicis and the inner head of the Flexor brevis pollicis. It also sends articular filaments to the wrist-joint.

It will be remembered that the inner part of the Flexor profundus digitorum is supplied by the ulnar nerve; the two inner Lumbricales, which are connected with the tendons of this part of the muscle, are therefore supplied by the same nerve. The outer part of the Flexor profundus is supplied by the median nerve; the two outer Lumbricales, which are connected with the tendons of this part of the muscle, are therefore supplied by the same nerve. Brooks states that in twelve instances out of twenty-one he found that the third lumbrical received a twig from the median nerve, in addition to its branch from the ulnar.

FIG. 414.—The suprascapular, circumflex, and musculo-spiral nerves.

The **Musculo-spiral Nerve** (Fig. 414), the largest branch of the brachial plexus, supplies the muscles of the back part of the arm and forearm, and the integument of the same parts, as well as that of the back of the hand. It arises from the posterior cord of the brachial plexus, of which it may be regarded as the continuation. It receives filaments from the sixth, seventh, and eighth, and sometimes also from the fifth cervical nerves. At its commencement it is placed behind the axillary and upper part of the brachial arteries, passing down in front of the tendons of the Latissimus dorsi and Teres major. It winds round the humerus in the musculo-spiral groove with the superior profunda artery, passing from the inner to the outer side of the bone, between the internal and external heads of the Triceps muscle. It pierces the external intermuscular septum, and descends between the Brachialis anticus and Supinator longus to the front of the external condyle, where it divides into the radial and posterior interosseous nerves.

The branches of the musculo-spiral nerve are—

Muscular.
Cutaneous.
Radial.
Posterior interosseous.

The *muscular branches* are divided into internal, posterior, and external;

they supply the Triceps, Anconeus, Supinator longus, Extensor carpi radialis longior, and Brachialis anticus. These branches are derived from the nerve at the inner side, back part, and outer side of the arm.

The internal muscular branches supply the inner and middle heads of the Triceps muscle. That to the inner head of the Triceps is a long, slender filament which lies close to the ulnar nerve, as far as the lower third of the arm, and is therefore frequently spoken of as the *ulnar collateral*.

The posterior muscular branch, of large size, arises from the nerve in the groove between the Triceps and the humerus. It divides into branches which supply the outer and inner head of the Triceps and Anconeus muscles. The branch for the latter muscle is a long, slender filament which descends in the substance of the Triceps to the Anconeus.

The external muscular branches supply the Supinator longus, Extensor carpi radialis longior, and (usually) the outer part of the Brachialis anticus.

The *cutaneous branches* are three in number, one internal and two external.

The internal cutaneous branch arises in the axillary space with the inner muscular branch. It is of small size, and passes through the axilla to the inner side of the arm, supplying the integument on its posterior aspect nearly as far as the olecranon. In its course it crosses beneath the intercosto-humeral, with which it communicates.

The two external cutaneous branches perforate the outer head of the Triceps at its attachment to the humerus. The upper and smaller one passes to the front of the elbow, lying close to the cephalic vein, and supplies the integument of the lower half of the arm on its anterior aspect. The lower branch pierces the deep fascia below the insertion of the Deltoid, and passes down along the outer side of the arm and elbow, and then along the back part of the radial side of the forearm to the wrist, supplying the integument in its course, and joining, near its termination, with the posterior cutaneous branch of the musculo-cutaneous nerve.

The **radial nerve** passes along the front of the radial side of the forearm to the commencement of its lower third. It lies at first a little to the outer side of the radial artery, concealed beneath the Supinator longus. In the middle third of the forearm it lies beneath the same muscle, in close relation with the outer side of the artery. It quits the artery about three inches above the wrist, passes beneath the tendon of the Supinator longus, and, piercing the deep fascia at the outer border of the forearm, divides into two branches.

The external branch, the smaller of the two, supplies the integument of the radial side and ball of the thumb, joining with the anterior branch of the musculo-cutaneous nerve.

The internal branch communicates, above the wrist, with the posterior cutaneous branch from the musculo-cutaneous, and on the back of the hand forms an arch with the dorsal cutaneous branch of the ulnar nerve. It then divides into four digital nerves, which are distributed as follows: The first supplies the ulnar side of the thumb; the second, the radial side of the index finger; the third, the adjoining sides of the index and middle fingers; and the fourth, the adjacent borders of the middle and ring fingers.[1] The latter nerve communicates with a filament from the dorsal branch of the ulnar nerve.

The **Posterior Interosseous Nerve** winds to the back of the forearm round the outer side of the radius, passes between the two planes of fibres of the Supinator brevis, and is prolonged downward between the superficial and deep layer of muscles, to the middle of the forearm. Considerably diminished in size, it descends on the interosseous membrane, beneath the Extensor longus pollicis, to the back of the carpus, where it presents a gangliform enlargement from which filaments are distributed to the ligaments and articulations of the carpus. It supplies

[1] According to Hutchinson, the digital nerve to the thumb reaches only as high as the root of the nail; the one to the forefinger as high as the middle of the second phalanx, and the one to the middle and ring fingers not higher than the first phalangeal joint (*London Hosp. Gaz.*, vol. iii., p. 319).

all the muscles of the radial and posterior brachial regions, excepting the Anconeus, Supinator longus, and Extensor carpi radialis longior.

Surgical Anatomy.—The brachial plexus may be ruptured by traction on the limb, leading to complete paralysis. In these cases the lesion would appear to be rather a tearing away of the nerves from the spinal cord than a solution of continuity of the nerve-fibres themselves. In the axilla any of the nerves forming the brachial plexus may be injured in a wound of this part, the median being the one which is most frequently damaged from its exposed position, and the musculo-spiral, on account of its sheltered and deep position, being the least often wounded. The brachial plexus in the axilla is often damaged from the pressure of a crutch, producing the condition known as "crutch paralysis." In these cases the musculo-spiral appears most frequently to be the nerve which is chiefly implicated; the ulnar nerve being the one that appears to suffer next in frequency.

The *circumflex nerve* is of particular surgical interest. On account of its course round the surgical neck of the humerus, it is liable to be torn in fractures of this part of the bone, and in dislocations of the shoulder-joint, leading to paralysis of the deltoid, and, according to Erb, inflammation of the shoulder-joint is liable to be followed by a neuritis of this nerve from extension of the inflammation to it.

Mr. Hilton takes the circumflex nerve as an illustration of a law which he lays down, that "the same trunks of nerves whose branches supply the groups of muscles moving a joint furnish also a distribution of nerves to the skin over the insertions of the same muscles, and the interior of the joint receives its nerves from the same source." In this way he explains the fact that an inflamed joint becomes rigid, because the same nerves which supply the interior of the joint supply the muscles also which move that joint.

The *median nerve* is liable to injury in wounds of the forearm. When paralyzed, there is loss of flexion of the second phalanges of all the fingers and of the terminal phalanges of the index and middle fingers. Flexion of the terminal phalanges of the ring and middle fingers is effected by that portion of the Flexor profundus digitorum which is supplied by the ulnar nerve. There is power to flex the proximal phalanges through the Interossei. The thumb cannot be flexed or opposed, and is maintained in a position of extension and adduction. All power of pronation is lost. The wrist can be flexed, if the hand is first adducted, by the action of the Flexor carpi ulnaris. There is loss or impairment of sensation on the palmar surface of the thumb, index, middle, and outer half of the ring fingers, and on the dorsal surface of the same fingers over the last two phalanges; except in the thumb, where the loss of sensation would be limited to the back of the last phalanx. In order to expose the median nerve for the purpose of stretching an incision should be made along the radial side of the tendon of the Palmaris longus, which serves as a guide to the nerve.

The *ulnar nerve* is also liable to be injured in wounds of the forearm. When paralyzed, there is loss of power of flexion in the ring and little fingers; there is impaired power of ulnar flexion and adduction; there is inability to spread out the fingers from paralysis of the Interossei; and there is inability to adduct the thumb. Sensation is lost or impaired in the skin supplied by the nerve. In order to expose the nerve in the lower part of the forearm, an incision should be made along the outer border of the tendon of the Flexor carpi ulnaris, and the nerve will be found lying on the ulnar side of the ulnar artery.

The *musculo-spiral nerve* is probably more frequently injured than any other nerve of the upper extremity. In consequence of its close relationship to the humerus as it lies in the musculo-spiral groove, it is frequently torn or injured in fractures of this bone, or subsequently involved in the callus that may be thrown out around a fracture, and thus pressed upon and its functions interfered with. It is also liable to be contused against the bone by kicks or blows or to be divided by wounds of the arm. When paralyzed, the hand is flexed at the wrist and lies flaccid. This is known as "drop-wrist." The fingers are also flexed, and on an attempt being made to extend them the last two phalanges only will be extended through the action of the Interossei, the first phalanges remaining flexed. There is no power of extending the wrist. Supination is completely lost when the forearm is extended on the arm, but it is possible to a certain extent if the forearm is flexed so as to allow of the action of the Biceps. The power of extension of the forearm is lost on account of paralysis of the Triceps. The best position in which to expose the nerve for the purpose of stretching is to make an incision along the inner border of the Supinator longus, just above the level of the elbow-joint. The skin and superficial structures are to be divided and the deep fascia exposed. The white line in this structure indicating the border of the muscle is to be defined, and the deep fascia divided in this line. By now raising the Supinator longus the nerve will be found lying beneath it, on the Brachialis anticus.

THE DORSAL NERVES (Fig. 415).

The **Dorsal Nerves** are twelve in number on each side. The first appears between the first and second dorsal vertebræ, and the last between the last dorsal and first lumbar.

The *roots of the dorsal nerves* are of small size, and vary but slightly from the second to the last. Both roots are very slender, the posterior roots only slightly exceeding the anterior in thickness. They gradually increase in length from above downward, and in the lower part of the dorsal region pass down in contact with the spinal cord for a distance equal to the height of at least two vertebræ, before they emerge from the spinal canal. They then join in the intervertebral foramen, and at their exit divide into two primary divisions, a posterior (dorsal) and an anterior (intercostal).

The first, the second, and the last dorsal nerves are peculiar in some respects.

Posterior Divisions of the Dorsal Nerves.

The **posterior divisions of the dorsal nerves**, which are smaller than the anterior, pass backward between the transverse processes, and divide into internal and external branches.

The *internal branches of the six upper nerves* pass inward between the Semispinalis dorsi and Multifidus spinæ muscles, which they supply, and then, piercing the origins of the Rhomboidei and Trapezius muscles, become cutaneous by the side of the spinous processes and ramify in the integument. The internal branches of the six lower nerves are distributed to the Multifidus spinæ, without giving off any cutaneous filaments.

The *external branches* increase in size from above downward. They pass through the Longissimus dorsi to the cellular interval between it and the Iliocostalis, and supply those muscles, as well as their continuations upward to the head, and the Levatores costarum; the five or six lower nerves also give off cutaneous filaments, which pierce the Serratus posticus inferior and Latissimus dorsi in a line with the angles of the ribs, and then ramify in the integument.

The *cutaneous branches of the posterior primary divisions of the dorsal nerves* are twelve in number. The six upper cutaneous nerves are derived from the internal branches of the posterior divisions of the dorsal nerves. They pierce the origins of the Rhomboidei and Trapezius muscles, and become cutaneous by the side of the spinous processes, and then ramify in the integument. They are frequently furnished with gangliform enlargements. The six lower cutaneous nerves are derived from the external branches of the posterior divisions of the dorsal nerves. They pierce the Serratus posticus inferior and Latissimus dorsi in a line with the angles of the ribs, and then ramify in the integument.

Anterior Divisions of the Dorsal Nerves.

The **anterior divisions of the dorsal nerves** (*intercostal nerves*) are twelve in number on each side. They are, for the most part, distributed to the parietes of the thorax and abdomen, separately from each other, without being joined in a plexus; in which respect they differ from the other spinal nerves. Each nerve is connected with the adjoining ganglia of the sympathetic by one or two filaments. The intercostal nerves may be divided into two sets, from the difference they present in their distribution. The six upper, with the exception of the first and the intercosto-humeral branch of the second, are limited in their distribution to the parietes of the chest. The six lower supply the parietes of the chest and abdomen, the last one sending a cutaneous filament to the buttock.

The First Dorsal Nerve.—The anterior division of the first dorsal nerve divides into two branches: one, the larger, leaves the thorax in front of the neck of the first rib, and enters into the formation of the brachial plexus; the other and smaller branch runs along the first intercostal space, forming the *first intercostal nerve*, and terminates on the front of the chest by forming the first anterior cutaneous nerve of the thorax. Occasionally this anterior cutaneous branch is wanting. The first intercostal nerve, as a rule, gives off no lateral cutaneous branch, but sometimes a small branch is given off which communicates with the intercosto-humeral. It frequently receives a connecting twig from the second dorsal nerve, which passes upward over the neck of the second rib.

FIG. [illegible].—Superficial and deep distribution of the posterior divisions of the spinal nerves (after Hirschfeld and Leveillé). On the left side the cutaneous branches are represented lying on the superficial layer of muscles. On the right side the superficial muscles have been removed, the Splenius capitis and Complexus divided in the neck, and the Erector spinæ divided and partly removed in the back, so as to expose the posterior divisions of the spinal nerves near their origin. *a a.* Lesser occipital nerve from the cervical plexus. 1. External muscular branches of the first cervical nerve, and union by a loop with the second. 2, placed on the Rectus capitis posticus major muscle, marks the great occipital nerve, passing round the short muscles and piercing the Complexus: the external branch is seen to the outside. 3. External branch from the posterior division of the third nerve. 3'. Its internal branch, sometimes called the third occipital. 4' to 8'. The internal branches of the several corresponding nerves on the left side. The external branches of these nerves, proceeding to muscles, are displayed on the right side, *d* 1 to *d* 6, and thence to *d* 12. External muscular branches of the posterior divisions of the twelve dorsal nerves on the right side, *d* 1' to *d* 6'. The internal cutaneous branches of the six upper dorsal nerves on the left side, *d* 7' to *d* 12'. Cutaneous twigs from the external branches of the six lower dorsal nerves. *l l.* External branches from the posterior divisions of several lumbar nerves on the right side, piercing the muscles, the lower descending over the gluteal region. *l' l'.* The same, more superficially, on the left side. *s s.* The issue and union by loops of the posterior divisions of four sacral nerves on the right side. *s' s'.* Some of these distributed to the skin on the left side.

The Upper Dorsal Nerves.—The anterior divisions of the second, third, fourth, fifth, and sixth dorsal nerves and the small branch from the first dorsal are confined to the parietes of the thorax, and are named *upper* or *pectoral intercostal nerves.* They pass forward in the intercostal spaces with the intercostal vessels, being situated below them. At the back of the chest they lie between the pleura and the External intercostal muscle, but are soon placed between the two planes of Intercostal muscles as far as the middle of the rib. They then enter the substance of the Internal intercostal muscles, and, running amidst their fibres as far as the costal cartilages, they gain the inner surface of the muscles and lie between them and the pleura. Near the sternum, they cross in front of the internal mammary artery and Triangularis sterni muscle, pierce the Internal intercostal muscles, the anterior intercostal membrane, and Pectoralis major muscle, and supply the integument of the front of the chest and over the mammary gland, forming the anterior cutaneous nerves of the thorax; the branch from the second nerve is joined with the supraclavicular nerves of the cervical plexus.

Branches.—Numerous slender muscular filaments supply the Intercostals, the Infracostales, the Levatores costarum, Serratus posticus superior, and Triangularis sterni muscles. Some of these branches, at the front of the chest, cross the costal cartilages from one to another intercostal space.

Lateral Cutaneous Nerves.—These are derived from the intercostal nerves, midway between the vertebræ and sternum; they pierce the External intercostal and Serratus magnus muscles, and divide into two branches, anterior and posterior.

The *anterior branches* are reflected forward to the side and the fore part of the chest, supplying the integument of the chest and mamma; those of the fifth and sixth nerves supply the upper digitations of the External oblique.

The *posterior branches* are reflected backward to supply the integument over the scapula and over the Latissimus dorsi.

The lateral cutaneous branch of the second intercostal nerve is of large size, and does not divide, like the other nerves, into an anterior and posterior branch. It is named, from its origin and distribution, the *intercosto-humeral nerve* (Fig. 413). It pierces the External intercostal muscle, crosses the axilla to the inner side of the arm, and joins with a filament from the nerve of Wrisberg. It then pierces the fascia, and supplies the skin of the upper half of the inner and back part of the arm, communicating with the internal cutaneous branch of the musculo-spiral nerve. The size of this nerve is in inverse proportion to the size of the other cutaneous nerves, especially the nerve of Wrisberg. A second intercosto-humeral nerve is frequently given off from the third intercostal. It supplies filaments to the armpit and inner side of the arm.

The Lower Dorsal Nerves.—The anterior divisions of the seventh, eighth, ninth, tenth, and eleventh dorsal nerves are continued anteriorly from the intercostal spaces into the abdominal wall, and the twelfth dorsal is continued throughout its whole course in the abdominal wall, since it is placed below the last rib; hence these nerves are named *lower* or *abdominal intercostal nerves.* They have (with the exception of the last) the same arrangement as the upper ones as far as the anterior extremities of the intercostal spaces, where they pass behind the costal cartilages, and between the Internal oblique and Transversalis muscles, to the sheath of the Rectus, which they perforate. They supply the Rectus muscle, and terminate in branches which become subcutaneous near the linea alba. These branches are named the anterior cutaneous nerves of the abdomen. They are directed outward as far as the lateral cutaneous nerves, supplying the integument of the front of the belly. The lower intercostal nerves supply the Intercostals, Serratus posticus inferior, and Abdominal muscles, and, about the middle of their course, give off lateral cutaneous branches which pierce the External intercostal and External oblique muscles, in the same line as the lateral cutaneous nerves of the thorax, and divide into anterior and posterior branches, which are distributed to the integument of the abdomen and back; the anterior branches supply the digitations of the External oblique muscle and extend downward and forward nearly as far as the margin of the Rectus; the posterior branches pass backward to supply the skin over the Latissimus dorsi.

The **last dorsal** is larger than the other dorsal nerves. Its anterior division runs along the lower border of the last rib, and passes under the external arcuate ligament of the Diaphragm. It then runs in front of the Quadratus lumborum, perforates the Transversalis, and passes forward between it and the Internal oblique, to be distributed in the same manner as the lower intercostal nerves. It communicates with the ilio-hypogastric branch of the lumbar plexus, and is frequently connected with the first lumbar nerve by a slender branch, the *dorsi-lumbar nerve*, which descends in the substance of the Quadratus lumborum. It gives a branch to the Pyramidalis muscle.

The *lateral cutaneous branch of the last dorsal* is remarkable for its large size: it perforates the Internal and External oblique muscles, passes downward over the crest of the ilium in front of the iliac branch of the ilio-hypogastric (Fig. 422), and is distributed to the integument of the front part of the gluteal region, some of its filaments extending as low down as the trochanter major. It does not divide into an anterior and a posterior branch, like the other lateral cutaneous branches of the intercostal nerves.

Surgical Anatomy.—The lower seven intercostal nerves and the ilio-hypogastric from the first lumbar nerve supply the skin of the abdominal wall. They run downward and inward fairly equidistant from each other. The sixth and seventh supply the skin over the "pit of the stomach;" the eighth corresponds to about the position of the middle linea transversa; the tenth to the umbilicus; and the ilio-hypogastric supplies the skin over the pubes and external abdominal ring. There are several points of surgical importance about the distribution of these nerves, and it is important to remember their origin and course, for in many diseases affecting the nerve-trunks at or near the origin the pain is referred to their peripheral terminations. Thus in Pott's disease of the spine children will often be brought to the surgeon suffering from pain in the belly. This is due to the fact that the nerves are irritated at the seat of disease as they issue from the spinal canal. When the irritation is confined to a single pair of nerves, the sensation complained of is often a feeling of constriction, as if a cord were tied round the abdomen; and in these cases the situation of the sense of constriction may serve to localize the disease in the spinal column. In other cases, where the bone disease is more extensive and two or more nerves are involved, a more general diffused pain in the abdomen is complained of. A similar condition is sometimes present in affections of the cord itself, as in tabes dorsalis.

Again, it must be borne in mind that the same nerves which supply the skin of the abdomen supply also the planes of muscle which constitute the greater part of the abdominal wall. Hence it follows that any irritation applied to the peripheral terminations of the cutaneous branches in the skin of the abdomen is immediately followed by reflex contraction of the abdominal muscles. A good practical illustration of this may sometimes be seen in watching two surgeons examine the abdomen of the same patient. One, whose hand is cold, causes the muscles of the abdominal wall to at once contract and the belly to become rigid, and thus not nearly so suitable for examination; the other, who has taken the precaution to warm his hand, examines the abdomen without exciting any reflex contraction. The supply of both muscles and skin from the same source is of importance in protecting the abdominal viscera from injury. A blow on the abdomen, even of a severe character, will do no injury to the viscera if the muscles are in a condition of firm contraction; whereas in cases where the muscles have been taken unawares, and the blow has been struck while they were in a state of rest, an injury insufficient to produce any lesion of the abdominal wall has been attended with rupture of some of the abdominal contents. The importance, therefore, of immediate reflex contraction upon the receipt of an injury cannot be overestimated, and the intimate association of the cutaneous and muscular fibres in the same nerve produces a much more immediate response on the part of the muscles to any peripheral stimulation of the cutaneous filaments than would be the case if the two sets of fibres were derived from independent sources.

Again, the nerves supplying the abdominal muscles and skin derived from the lower intercostal nerves are intimately connected with the sympathetic supplying the abdominal viscera through the lower thoracic ganglia from which the splanchnic nerves are derived. In consequence of this, in laceration of the abdominal viscera and in acute peritonitis the muscles of the belly-wall become firmly contracted, and thus as far as possible preserve the abdominal contents in a condition of rest.

THE LUMBAR NERVES.

The **lumbar nerves** are five in number on each side. The first appears between the first and second lumbar vertebræ, and the last between the last lumbar and the base of the sacrum.

The **roots** of the **lumbar nerves** are the largest, and their filaments the most numerous, of all the spinal nerves, and they are closely aggregated together upon the lower end of the cord. The anterior roots are the smaller, but there is not the same disproportion between them and the posterior roots as in the cervical nerves. The roots of these nerves have a vertical direction, and are of considerable length, more especially the lower ones, since the spinal cord does not extend beyond the first lumbar vertebra. The roots become joined in the intervertebral foramina, and the nerves so formed divide at their exit into two divisions, posterior and anterior.

The Posterior Divisions of the Lumbar Nerves.

The **posterior divisions of the lumbar nerves** (Fig. 415) diminish in size from above downward; they pass backward between the transverse processes, and divide into internal and external branches.

The *internal branches*, the smaller, pass inward close to the articular processes of the vertebræ, and supply the Multifidus spinæ and Interspinales muscles.

The *external branches* supply the Erector spinæ and Intertransverse muscles. From the three upper branches cutaneous nerves are derived which pierce the aponeurosis of the Latissimus dorsi muscle and descend over the back part of the crest of the ilium, to be distributed to the integument of the gluteal region, some of the filaments passing as far as the trochanter major.

The Anterior Divisions of the Lumbar Nerves.

The **anterior divisions of the lumbar nerves** increase in size from above downward. At their origin they communicate with the lumbar ganglia of the sympathetic by long, slender filaments, which accompany the lumbar arteries round the sides of the bodies of the vertebræ, beneath the Psoas muscle. The nerves pass obliquely outward behind the Psoas magnus or between its fasciculi, distributing filaments to it and the Quadratus lumborum. The anterior divisions of the four upper nerves are connected together in this situation by anastomotic loops, and form the *lumbar plexus*. The anterior division of the fifth lumbar, joined with a branch from the fourth, descends across the base of the sacrum to join the anterior division of the first sacral nerve and assist in the formation of the sacral plexus. The cord resulting from the union of the fifth lumbar and the branch from the fourth is called the *lumbo-sacral cord.*

The Lumbar Plexus (Fig. 416).

The **lumbar plexus** is formed by the loops of communication between the anterior divisions of the four upper lumbar nerves. The plexus is narrow above, and often connected with the last dorsal by a slender branch, the *dorsi-lumbar nerve;* it is broad below, where it is joined to the sacral plexus by the lumbo-sacral cord. It is situated in the substance of the Psoas muscle near its posterior part, in front of the transverse process of the lumbar vertebræ.

The mode in which the plexus is arranged varies in different subjects. It differs from the brachial plexus in not forming an intricate interlacement, but the several nerves of distribution arise from one or more of the spinal nerves, somewhat in the following manner: The first lumbar nerve receives a branch from the last dorsal, and gives off a larger branch, which subdivides into the ilio-hypogastric and ilio-inguinal; a communicating branch which passes down to the second lumbar nerve; and a third branch which unites with a branch of the second lumbar to form the genito-crural nerve. The second, third, and fourth lumbar nerves divide into an anterior and a posterior division. The anterior division of the second divides into two branches, one of which joins with the above-mentioned branch of the first nerve to form the genito-crural; the other unites with the anterior division of the third nerve, and a part of the anterior division of the fourth nerve to form the obturator nerve. The remainder of the anterior division of the fourth nerve passes down to communicate with the fifth lumbar nerve. The posterior divisions of the second and third nerves divide into two branches, a smaller branch from each uniting to form the external cutaneous nerve, and a larger branch from each, which join with the whole of the posterior division of the fourth lumbar nerve to form the anterior crural. The accessory obturator, when it exists, is formed by the union of two small branches given off from the third and fourth nerves.

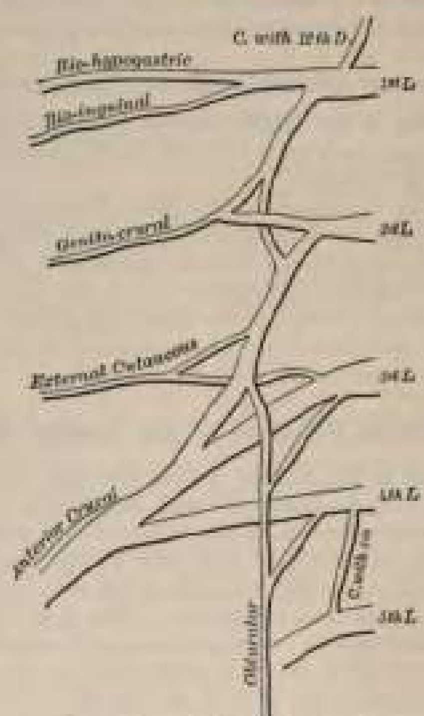


Fig. [illegible].—Plan of the lumbar plexus.

From this arrangement it follows that the ilio-hypogastric and ilio-inguinal are derived entirely from the first lumbar nerve; the genito-crural from the first and second nerves; the external cutaneous from the second and third; the anterior crural and obturator by fibres derived from the second, third, and fourth; and the accessory obturator, when it exists, from the third and fourth.

The branches of the lumbar plexus are—the

Ilio-hypogastric.	Anterior crural.
Ilio-inguinal.	Obturator.
Genito-crural.	Accessory obturator.
External cutaneous.	

The **Ilio-hypogastric Nerve** arises from the first lumbar nerve. It emerges from the outer border of the Psoas muscle at its upper part, and crosses obliquely in front of the Quadratus lumborum to the crest of the ilium. It then perforates the Transversalis muscle at its posterior part near the crest of the ilium, and divides between it and the Internal oblique into two branches, iliac and hypogastric.

The *iliac branch* pierces the Internal and External oblique muscles immediately above the crest of the ilium, and is distributed to the integument of the gluteal region, behind the lateral cutaneous branch of the last dorsal nerve (Fig. 422). The size of this nerve bears an inverse proportion to that of the cutaneous branch of the last dorsal nerve.

The *hypogastric branch* (Fig. 418) continues onward between the Internal oblique and Transversalis muscles. It then pierces the Internal oblique, and becomes cutaneous by perforating the aponeurosis of the External oblique, 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-hypogastric nerve communicates with the last dorsal and ilio-inguinal nerves.

The **Ilio-inguinal Nerve**, smaller than the preceding, arises with it from the first lumbar nerve. It emerges from the outer border of the Psoas just below the ilio-hypogastric, and, passing obliquely across the Quadratus lumborum and Iliacus muscles, perforates the Transversalis near the fore part of the crest of the ilium, and communicates with the ilio-hypogastric nerve between that muscle and the Internal oblique. The nerve then pierces the Internal oblique, distributing filaments to it; and, accompanying the spermatic cord through the external abdominal ring, is distributed to the integument of the upper and inner part of the thigh, and to the scrotum in the male and to the labium majus 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 from the ilio-hypogastric takes the place of the ilio-inguinal, or the latter nerve may be altogether absent.

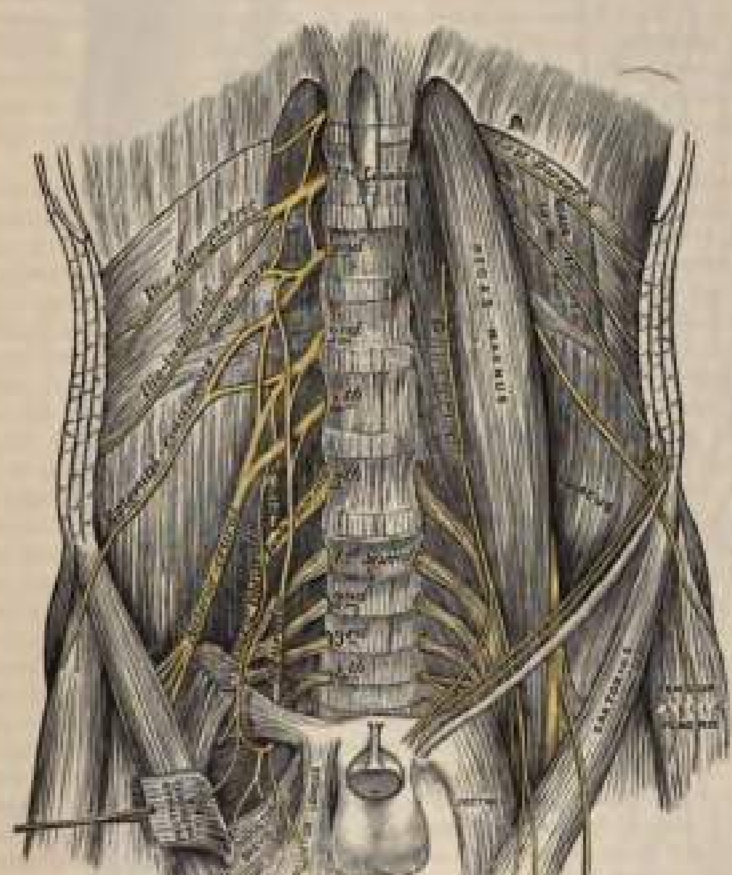


FIG. 417.—The lumbar plexus and its branches.

The **Genito-crural Nerve** arises from the first and second lumbar nerves. It passes obliquely through the substance of the Psoas, and emerges from its inner border at a level corresponding to the intervertebral substance between the third and fourth lumbar vertebræ; it then descends on the surface of the Psoas muscle, under cover of the peritoneum, and divides into a genital and a crural branch.

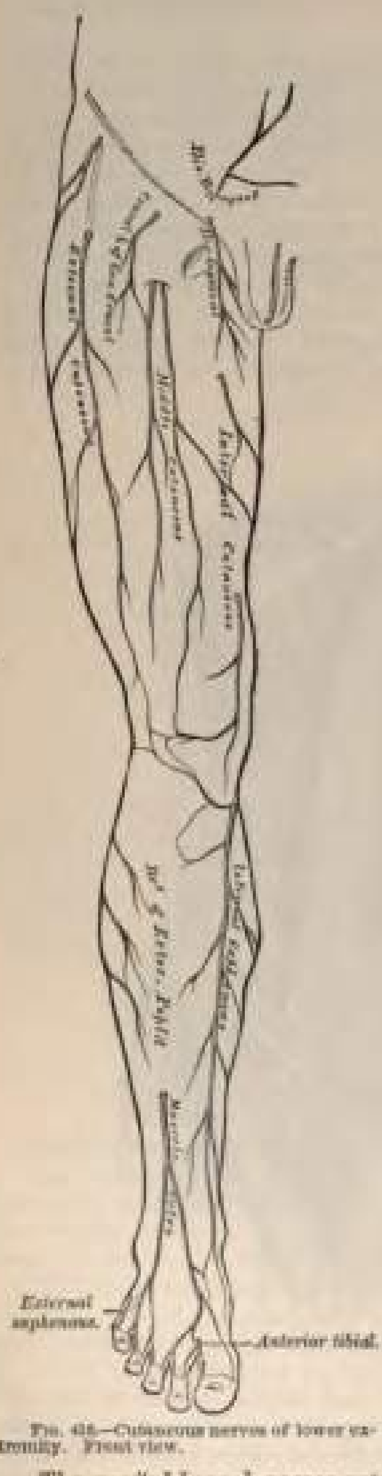


FIG. 418.—Cutaneous nerves of lower extremity. Front view.

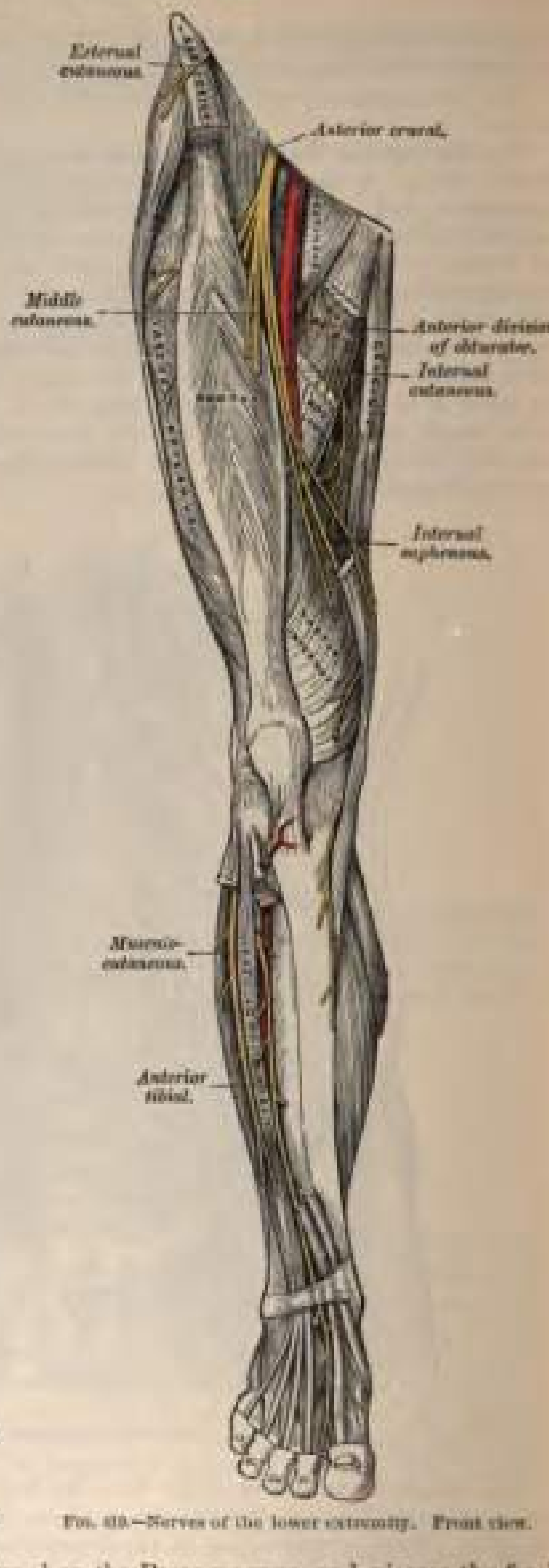


FIG. 419.—Nerves of the lower extremity. Front view.

The *genital branch* passes outward on the Psoas magnus, and pierces the fascia transversalis, or passes through the internal abdominal ring; it then descends along the back part of the spermatic cord to the scrotum, and supplies, in the male, the Cremaster muscle. In the female, it accompanies the round ligament, and is lost upon it.

The *crural branch* descends on the external iliac artery, sending a few filaments round it, and, passing beneath Poupart's ligament to the thigh, enters the sheath of the femoral vessels, 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.

A few filaments from this nerve may be traced on to the femoral artery; they are derived from the nerve as it passes beneath Poupart's ligament.

The **External Cutaneous Nerve** arises from the second and third lumbar nerves. It emerges from the outer border of the Psoas muscle about its middle, and crosses the Iliacus muscle obliquely, toward the anterior superior spine of the ilium. It then passes under Poupart's ligament and over the Sartorius muscle into the thigh, where it divides into two branches, anterior and posterior.

The *anterior branch* descends in an aponeurotic canal formed in the fascia lata, becomes superficial about four inches below Poupart's ligament, and divides into branches which are distributed to the integument along the anterior and outer part of the thigh, as far down as the knee. This nerve occasionally communicates with a branch of the long saphenous nerve in front of the knee-joint.

The *posterior branch* pierces the fascia lata, and subdivides into branches which pass backward across the outer and posterior surface of the thigh, supplying the integument from the crest of the ilium as far as the middle of the thigh.

The **Obturator Nerve** supplies the obturator externus and Adductor muscles of the thigh, the articulations of the hip and knee, and occasionally the integument of the thigh and leg. It arises by three branches—from the second, the third, and the fourth lumbar nerves. Of these, the branch from the third is the largest, while that from the second is often very small. It descends through the inner fibres of the Psoas muscle, and emerges from its inner border near the brim of the pelvis; it then runs along the lateral wall of the pelvis, above the obturator vessels, to the upper part of the obturator foramen, where it enters the thigh, and divides into an anterior and a posterior branch, separated by some of the fibres of the Obturator externus (Fig. 257), and lower down by the Adductor brevis muscle.

The *anterior branch* (Fig. 419) passes down in front of the Adductor brevis, being covered by the Pectineus and Adductor longus, and at the lower border of the latter muscle communicates with the internal cutaneous and internal saphenous nerves, forming a kind of plexus. It then descends upon the femoral artery, upon which it is finally distributed. The nerve, near the obturator foramen, gives off an articular branch to the hip-joint. Behind the Pectineus it distributes muscular branches to the Adductor longus and Gracilis, and usually to the Adductor brevis, and in rare cases to the Pectineus, and receives a communicating branch from the accessory obturator nerve.

Occasionally the communicating branch to the internal cutaneous and internal saphenous nerves is continued down, as a cutaneous branch, to the thigh and leg. When this is so, this *occasional cutaneous* branch emerges from beneath the lower border of the Adductor longus, descends along the posterior margin of the Sartorius to the inner side of the knee, where it pierces the deep fascia, communicates with the long saphenous nerve, and is distributed to the integument of the inner side of the leg as low down as its middle. When this communicating branch is small, its place is supplied by the internal cutaneous nerve.

The *posterior branch of the obturator nerve* pierces the Obturator externus, sending branches to supply it, and passes behind the Adductor brevis on the front of the Adductor magnus, where it divides into numerous muscular branches, which supply the Adductor magnus, and the Adductor brevis when the latter does not receive a branch from the anterior division of the nerve. One of the branches gives off a filament to the knee-joint.

The *articular branch for the knee-joint* is sometimes absent; it perforates the lower part of the Adductor magnus, and enters the popliteal space; it then descends upon the popliteal artery, as far as the back part of the knee-joint, where it perforates the posterior ligament, and is distributed to the synovial membrane. It gives filaments to the artery in its course.

The **Accessory Obturator Nerve** (Fig. 417) is not constantly present. It is of small size, and arises by separate filaments from the third and fourth lumbar nerves. It descends along the inner border of the Psoas muscle, crosses the ascending ramus of the os pubis, and passes under the outer border of the Pectineus muscle, where it divides into numerous branches. One of these supplies the Pectineus, penetrating its under surface; another is distributed to the hip-joint; while a third communicates with the anterior branch of the obturator nerve. When this nerve is absent the hip-joint receives two branches from the obturator nerve. Occasionally it is very small, and becomes lost in the capsule of the hip-joint.

The **Anterior Crural Nerve** (Figs. 417, 419) is the largest branch of the lumbar plexus. It supplies muscular branches to the Iliacus, Pectineus, and all the muscles on the front of the thigh, excepting the Tensor fasciæ femoris; cutaneous filaments to the front and inner side of the thigh, and to the leg and foot; and articular branches to the hip and knee. It arises from the second, third, and fourth lumbar nerves. It descends through the fibres of the Psoas muscle, emerging from it at the lower part of its outer border, and passes down between it and the Iliacus, and beneath Poupart's ligament, into the thigh, where it becomes somewhat flattened, and divides into an anterior and a posterior part. Under Poupart's ligament it is separated from the femoral artery by a portion of the Psoas muscle, and lies beneath the iliac fascia.

Within the abdomen the anterior crural nerve gives off from its outer side some small branches to the Iliacus, and a branch to the femoral artery which is distributed upon the upper part of that vessel. The origin of this branch varies; it occasionally arises higher than usual, or it may arise lower down in the thigh.

External to the pelvis the following branches are given off:

From the Anterior Division.	*From the Posterior Division.*
Middle cutaneous.	Long saphenous.
Internal cutaneous.	Muscular.
Muscular.	Articular.

The *middle cutaneous nerve* (Fig. 418) pierces the fascia lata (generally the Sartorius also) about three inches below Poupart's ligament, and divides into two branches, which descend in immediate proximity along the fore part of the thigh, to supply the integument as low as the front of the knee, where it communicates with the internal cutaneous and the patellar branch of the internal saphenous nerve, to form the patellar plexus. In the upper part of the thigh the outer division of the middle cutaneous communicates with the crural branch of the genito-crural nerve.

The *internal cutaneous nerve* passes obliquely across the upper part of the sheath of the femoral artery, and divides in front or at the inner side of that vessel into two branches, anterior and posterior or internal.

The *anterior branch* runs downward on the Sartorius, perforates the fascia lata at the lower third of the thigh, and divides into two branches, one of which supplies the integument as low down as the inner side of the knee; the other crosses to the outer side of the patella, communicating in its course with the nervus cutaneus patellæ, a branch of the internal saphenous nerve.

The *posterior* or *internal branch* descends along the inner border of the Sartorius muscle to the knee, where it pierces the fascia lata, communicates with the long saphenous nerve, and gives off several cutaneous branches. The nerve then passes down the inner side of the leg, to the integument of which it is distributed. This nerve, beneath the fascia lata, at the lower border of the Adductor longus, joins in a plexiform network by uniting with branches of the long saphenous and obturator nerves (Fig. 419). When the communicating branch from the obturator nerve is large and continued to the integument of the leg, the inner branch of the internal cutaneous is small and terminates at the plexus, occasionally giving off a few cutaneous filaments.

The internal cutaneous nerve, before dividing, gives off a few filaments, which pierce the fascia lata, to supply the integument of the inner side of the thigh, accompanying the long saphenous vein. One of these filaments passes through the saphenous opening; a second becomes subcutaneous about the middle of the thigh; and a third pierces the fascia at its lower third.

Muscular Branches of the Anterior Division.—The *nerve to the Pectineus* is often duplicated; it arises from the anterior crural immediately below Poupart's ligament, and passes inward behind the femoral sheath to enter the anterior surface of the muscle. The *nerve to the Sartorius* arises in common with the middle cutaneous.

The *long* or *internal saphenous nerve* is the largest of the cutaneous branches of the anterior crural. It approaches the femoral artery where this vessel passes beneath the Sartorius, and lies in front of it, beneath the aponeurotic covering of Hunter's canal, as far as the opening in the lower part of the Adductor magnus. It then quits the artery, and descends vertically along the inner side of the knee, beneath the Sartorius, pierces the fascia lata opposite the interval between the tendons of the Sartorius and Gracilis, and becomes subcutaneous. The nerve then passes along the inner side of the leg, accompanied by the internal saphenous vein, descends behind the internal border of the tibia, and, at the lower third of the leg divides into two branches: one continues its course along the margin of the tibia, terminating at the inner ankle; the other passes in front of the ankle, and is distributed to the integument along the inner side of the foot, as far as the great toe, communicating with the internal branch of the musculo-cutaneous nerve.

Branches.—The long saphenous nerve *about the middle of the thigh* gives off a communicating branch which joins the plexus formed by the obturator and internal cutaneous nerves.

At the inner side of the knee it gives off a large patellar branch (*nervus cutaneus patellæ*) which pierces the Sartorius and fascia lata, and is distributed to the integument in front of the patella. This nerve communicates above the knee with the anterior branch of the internal cutaneous and with the middle cutaneous; below the knee, with other branches of the long saphenous; and on the outer side of the joint, with branches of the external cutaneous nerve, forming a plexiform network, the *plexus patellæ*. The cutaneous nerve of the patella is occasionally small, and terminates by joining the internal cutaneous, which supplies its place in front of the knee.

Below the knee the branches of the long saphenous nerve are distributed to the integument of the front and inner side of the leg, communicating with the cutaneous branches from the internal cutaneous or from the obturator nerve.

The *muscular branches of the posterior division* supply the four parts of the Quadriceps extensor muscle.

The *branch to the Rectus muscle* enters its under surface high up, sending off a small filament to the hip-joint.

The *branch to the Vastus externus*, of large size, follows the course of the descending branch of the external circumflex artery to the lower part of the muscle. It gives off an articular filament to the knee-joint.

The *branch to the Vastus internus* is a long branch which runs down on the outer side of the femoral vessels in company with the internal saphenous nerve for its upper part. It enters the muscle about its middle, and gives off a filament which can usually be traced downward on the surface of the muscle to the knee-joint.

The *branch to the Crureus* enters the muscle on its anterior surface about the middle of the thigh, and sends a filament through the muscle to the Subcrureus and the knee-joint.

The *articular branch to the hip-joint* is derived from the nerve to the Rectus.

The *articular branches to the knee-joint* are three in number. One, a long, slender filament, is derived from the nerve to the Vastus externus; it penetrates the capsular ligament of the joint on its anterior aspect. Another is derived from the nerve to the Vastus internus. It can usually be traced downward on the surface of this muscle to near the joint; it then penetrates the muscular fibres, and accompanies the deep branch of the anastomotica magna artery, pierces the capsular ligament of the joint on its inner side, and supplies the synovial membrane. The third branch is derived from the nerve to the Crureus.

THE SACRAL AND COCCYGEAL NERVES.

The *sacral nerves* are five in number on each side. The four upper ones pass from the sacral canal through the sacral foramina; the fifth through the foramen between the sacrum and coccyx.

The *roots of the upper sacral nerves* are the largest of all the spinal nerves; while those of the lowest sacral and coccygeal nerve are the smallest. They are longer than those of any of the other spinal nerves, on account of the spinal cord not extending beyond the first lumbar vertebra. From their great length, and the appearance they present in connection with their attachment to the spinal cord, the roots of origin of these nerves are called collectively the *cauda equina*.

Each sacral and coccygeal nerve separates into two divisions, posterior and anterior.

The **posterior divisions of the sacral nerves** (Fig. 420) are small, diminish in

Fig. 420.—The posterior sacral nerves.

size from above downward, and emerge, except the last, from the sacral canal by the posterior sacral foramina.

The *three upper ones* are covered, at their exit from the sacral canal, by the Multifidus spinæ, and divide into internal and external branches.

The *internal branches* are small, and supply the Multifidus spinæ.

The *external branches* join with one another, and with the last lumbar and fourth sacral nerves, in the form of loops on the posterior surface of the sacrum. From these loops branches pass to the outer surface of the great sacro-sciatic ligament, where they form a second series of loops beneath the Gluteus maximus. Cutaneous branches from this second series of loops, usually two or three in number, pierce the Gluteus maximus along a line drawn from the posterior superior spine of the ilium to the tip of the coccyx. They supply the integument over the posterior part of the gluteal region.

The *posterior divisions of the two lower sacral nerves* are situated below the Multifidus spinæ. They are of small size, and do not divide into internal and external branches, but join with each other, and with the coccygeal nerve, so as to form loops on the back of the sacrum, filaments from which supply the Extensor coccygis and the integument over the coccyx.

The **coccygeal nerve** divides into its anterior and posterior divisions in the spinal canal. The *posterior division* is the smaller. It does not divide, but receives, as already mentioned, a communicating branch from the last sacral, and is lost in the integument over the back of the coccyx.

The anterior divisions of the sacral nerves diminish in size from above down-

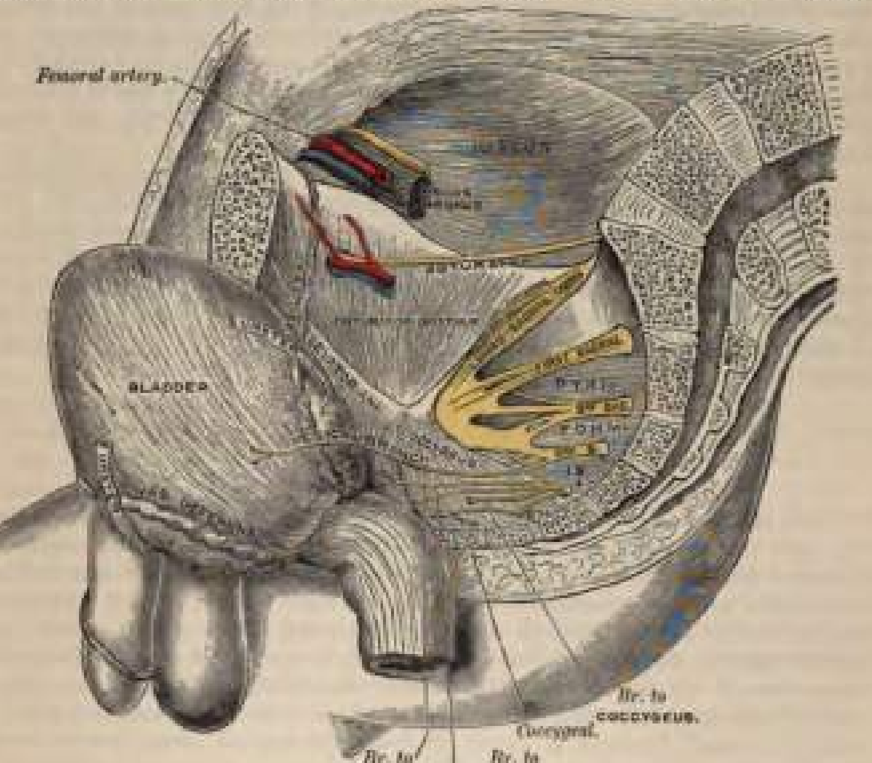


FIG. 421.—Side view of pelvis, showing sacral nerves.

ward. The four upper ones emerge from the anterior sacral foramina: the anterior division of the fifth, after emerging from the spinal canal through its terminal opening, curves forward between the sacrum and the coccyx. All the anterior sacral nerves communicate with the sacral ganglia of the sympathetic at their exit from the sacral foramina. The *first nerve*, of large size, unites with the *lumbo-sacral cord*, formed by the fifth lumbar, and a branch from the fourth lumbar. The *second*, equal in size to the preceding, and the *third*, about one-fourth the size of the second, unite with this trunk, and form, with a small fasciculus from the fourth, the *sacral plexus*, a visceral branch being given off from the third nerve to the bladder.

The **fourth anterior sacral nerve** sends a branch to join the sacral plexus. The remaining portion of the nerve divides into visceral and muscular branches, and a communicating filament descends to join the fifth sacral nerve. The *visceral branches* are distributed to the viscera of the pelvis, communicating with the sympathetic nerve. These branches ascend upon the rectum and bladder, and in the female upon the vagina, communicating with branches of the sympathetic from the pelvic plexus. The *muscular branches* are distributed to the Levator ani, Coccygeus, and Sphincter ani. The branch to the Sphincter ani pierces the Levator ani, so as to reach the ischio-rectal fossa, where it is found lying in front of the coccyx. Cutaneous filaments arise from the latter branch, which supply the integument between the anus and coccyx. Another cutaneous branch is frequently given off from this nerve, though sometimes from the pudic (Schwalbe). It perforates the great sacro-sciatic ligament, and, winding round the lower border of the Gluteus maximus, supplies the skin over the lower and inner part of this muscle.

The **fifth anterior sacral nerve**, after passing from the lower end of the sacral canal, curves forward through the fifth sacral foramen, formed between the lower part of the sacrum and the transverse process of the first piece of the coccyx. It pierces the Coccygeus muscle, and descends upon its anterior surface to near the tip of the coccyx, where it again perforates the muscle, to be distributed to the integument over the back part and side of the coccyx. This nerve communicates above with the fourth sacral and below with the coccygeal nerve, and supplies the Coccygeus muscle.

The **anterior division of the coccygeal nerve** is a delicate filament which escapes at the termination of the sacral canal; it passes downward behind the rudimentary transverse process of the first piece of the coccyx, and curves forward through the notch between the first and second pieces, piercing the Coccygeus muscle, and descending on its anterior surface to near the tip of the coccyx, where it again pierces the muscle, to be distributed to the integument over the back part and side of the coccyx. It is joined by a branch from the fifth anterior sacral as it descends on the surface of the Coccygeus muscle.

The Sacral Plexus (Fig. 421).

The **sacral plexus** is formed by the lumbo-sacral cord, the anterior divisions of the three upper sacral nerves, and part of that of the fourth. These nerves proceed in different directions: the upper ones obliquely downward and outward, the lower ones nearly horizontally, and they all unite into two cords: an *upper* and larger, which is formed by the lumbo-sacral cord with the first, second, and the greater part of the third sacral nerves; and a *lower* and smaller, formed by the remainder of the third, with a portion of the fourth sacral nerve. The upper cord is prolonged into the great sciatic nerve and the lower into the pudic. Frequently a small filament is given off from the second sacral nerve to join the lower cord.

The sacral plexus is triangular in form, its base corresponding with the exit of the nerves from the sacrum, its apex with the lower part of the great sacro-sciatic foramen. It rests upon the anterior surface of the Pyriformis, and is covered in front by the pelvic fascia, which separates it from the sciatic and pudic branches of the internal iliac artery and from the viscera of the pelvis.

The branches of the sacral plexus are:

Collateral branches: Muscular. Superior gluteal. Inferior gluteal. Small sciatic. Perforating cutaneous.
Terminal branches: Pudic. Great sciatic.

The **Muscular branches** supply the Pyriformis, Obturator internus, the two Gemelli, and the Quadratus femoris. The branch to the Pyriformis arises from the upper two sacral nerves before they enter the plexus; the branch to the Obturator internus arises at the junction of the lumbo-sacral and first sacral nerves: it passes out of the pelvis through the great sacro-sciatic foramen below the Pyriformis, crosses the spine of the ischium, and re-enters the pelvis through the lesser sacro-sciatic foramen to enter the inner surface of the Obturator internus; the branch to the Gemellus superior arises in common with the nerve to the Obturator internus: it enters the muscle at the upper part of its posterior surface; the small branch to the Gemellus inferior and Quadratus femoris also arises from the upper part of the plexus: it passes through the great sacro-sciatic foramen below the Pyriformis, and courses down beneath the great sciatic nerve, the Gemelli and tendon of the Obturator internus, and supplies the muscles on their deep or anterior surface. It gives off an articular branch to the hip-joint. A second articular branch is occasionally derived from the upper part of the sacral plexus.

The **Superior Gluteal Nerve** (Fig. 423) arises from the back part of the lumbo-sacral cord, with some filaments from the first sacral nerve; it passes from the pelvis through the great sacro-sciatic foramen above the Pyriformis muscle, accompanied by the gluteal vessels, and divides into a superior and an inferior branch.

The *superior branch* follows the line of origin of the Gluteus minimus, and supplies the Gluteus medius.

The *inferior branch* crosses obliquely between the Gluteus minimus and medius, distributing filaments to both these muscles, and terminates in the Tensor fasciæ femoris, extending nearly to its lower end.

The **Inferior Gluteal** arises from the lumbo-sacral cord and first and second sacral nerves, and is intimately connected with the small sciatic at its origin. It passes out of the pelvis through the great sciatic notch, beneath the Pyriformis muscle, and, dividing into a number of branches, enters the Gluteus maximus muscle on its under surface.

The **Small Sciatic Nerve** (Fig. 423) supplies the integument of the perineum and back part of the thigh and leg. It is usually formed by the union of two branches, which arise from the second and third nerves of the sacral plexus. It issues from the pelvis through the great sacro-sciatic foramen below the Pyriformis muscle, descends beneath the Gluteus maximus with the sciatic artery, and at the lower border of that muscle passes along the back part of the thigh, beneath the fascia lata and over the long head of the Biceps, to the lower part of the popliteal region, where it pierces the fascia and becomes cutaneous. It then accompanies the external saphenous vein to about the middle of the leg, its terminal filaments communicating with the external saphenous nerve.

The branches of the small sciatic nerve are all cutaneous, and are grouped as follows: gluteal, perineal, and femoral.

The *gluteal cutaneous branches* (*ascending*) consist of two or three filaments, which turn upward round the lower border of the Gluteus maximus to supply the integument covering the lower and outer part of that muscle.

The *perineal cutaneous branches* are distributed to the skin at the upper and inner side of the thigh, on its posterior aspect. One branch, longer than the rest, the *inferior pudendal*, curves forward below the tuber ischii, pierces the fascia lata, and passes forward beneath the superficial fascia of the perineum to be distributed to the integument of the scrotum in the male and the labium in the female, communicating with the superficial perineal and inferior hemorrhoidal nerves.

FIG. 4[illegible].—Cutaneous nerves of lower extremity. Posterior view.

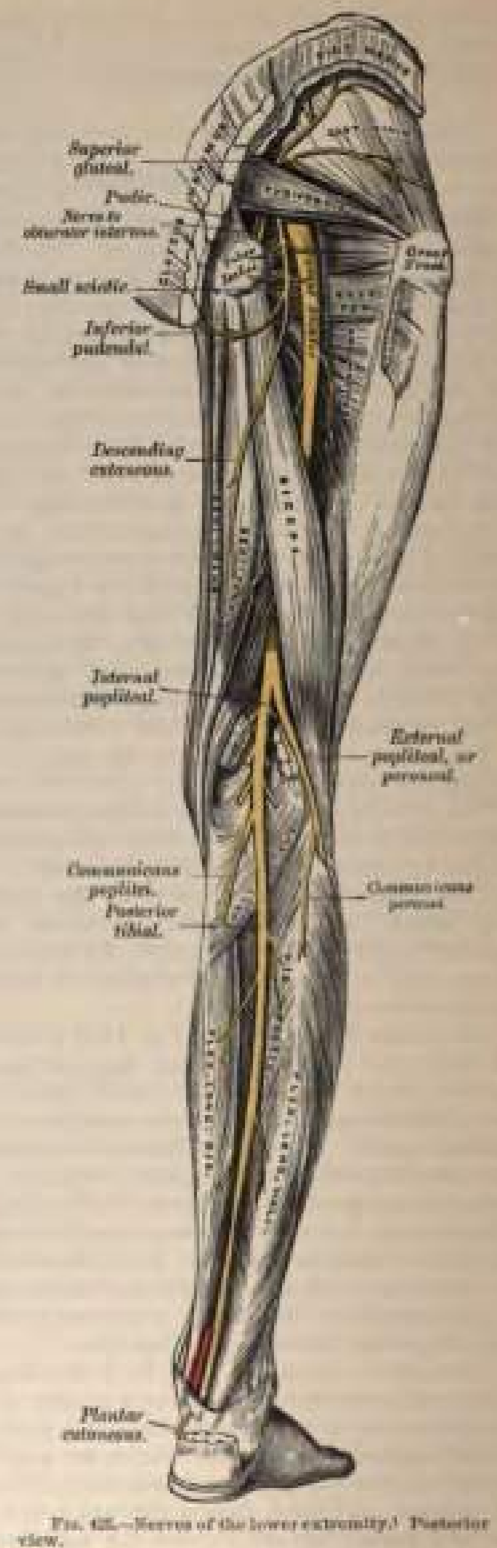


FIG. 4[illegible].—Nerves of the lower extremity.[1] Posterior view.

[1] N. B.—In this diagram the external saphenous and communicans peronei are not in their normal position. They have been displaced by the removal of the superficial muscles.

The *femoral cutaneous branches* (*descending*) are numerous filaments, derived from both sides of the nerves, which are distributed to the back, inner, and outer sides of the thigh, to the skin covering the popliteal space, and to the upper part of the leg.

The **Perforating Cutaneous Nerve** usually arises from the second and third sacral nerves, and is of small size. It is continued backward through the great sacro-sciatic ligament, and, winding round the lower border of the Gluteus maximus, supplies the integument covering the inner and lower part of that muscle.

The **Pudic Nerve** is the direct continuation of the lower cord of the sacral plexus, and derives its fibres from the third and fourth sacral nerves, and frequently from the second also. It leaves the pelvis through the great sacro-sciatic foramen, below the Pyriformis. It then crosses the spine of the ischium, and re-enters the pelvis through the lesser sacro-sciatic foramen. It accompanies the pudic vessels upward and forward along the outer wall of the ischio-rectal fossa, being contained in a sheath of the obturator fascia, termed *Alcock's canal*, and divides into two terminal branches, the perineal nerve and the dorsal nerve of the penis or clitoris. Before its division it gives off the inferior hemorrhoidal nerve.

The *inferior hemorrhoidal nerve* is occasionally derived separately from the sacral plexus. It passes across the ischio-rectal fossa, with its accompanying vessels, toward the lower end of the rectum, and is distributed to the Sphincter ani externus and to the integument round the anus. Branches of this nerve communicate with the inferior pudendal and superficial perineal nerves at the fore part of the perineum.

The *perineal nerve*, the inferior and larger of the two terminal branches of the pudic, is situated below the pudic artery. It accompanies the superficial perineal artery in the perineum, dividing into cutaneous and muscular branches.

The cutaneous branches (superficial perineal) are *two* in number, posterior and anterior. The *posterior* or *external branch* pierces the base of the triangular ligament of the urethra, and passes forward along the outer side of the urethral triangle in company with the superficial perineal artery; it is distributed to the skin of the scrotum. It communicates with the inferior hemorrhoidal, the inferior pudendal, and the other superficial perineal nerve. The *anterior* or *internal branch* also pierces the base of the triangular ligament, and passes forward nearer to the middle line, to be distributed to the inner and back part of the scrotum. Both these nerves supply the labia majora in the female.

The muscular branches are distributed to the Transversus perinæi, Accelerator urinæ, Erector penis, and Compressor urethræ. A distinct branch is given off from the nerve to the Accelerator urinæ, which pierces this muscle, and supplies the corpus spongiosum, ending in the mucous membrane of the urethra. This is the nerve to the bulb.

The *dorsal nerve of the penis* is the deepest division of the pudic nerve; it accompanies the pudic artery along the ramus of the ischium; it then runs forward along the inner margin of the ramus of the os pubis, between the superficial and deep layers of the triangular ligament. Piercing the superficial layer it gives a branch to the corpus cavernosum, and passes forward, in company with the dorsal artery of the penis, between the layers of the suspensory ligament, on to the dorsum of the penis, along which it is carried as far as the glans, to which it is distributed.

In the female the dorsal nerve is very small, and supplies the clitoris.

The **Great sciatic nerve** (Fig. 423) supplies nearly the whole of the integument of the leg, the muscles of the back of the thigh, and those of the leg and foot. It is the largest nervous cord in the body, measuring three-quarters of an inch in breadth, and is the continuation of the upper division of the sacral plexus. It passes out of the pelvis through the great sacro-sciatic foramen, below the Pyriformis muscle. It descends between the trochanter major and tuberosity of the ischium, along the back part of the thigh, to about its lower third, where it divides into two large branches, the *internal* and *external popliteal nerves*.

This division may take place at any point between the sacral plexus and the lower third of the thigh. When the division occurs at the plexus, the two nerves descend together side by side; or they may be separated, at their commencement, by the interposition of part or the whole of the Pyriformis muscle. As the nerve descends along the back of the thigh, it rests upon the posterior surface of the ischium, the nerve to the Quadratus femoris, and the External rotator muscles, in company with the small sciatic nerve and artery, being covered by the Gluteus maximus; lower down, it lies upon the Adductor magnus, and is covered by the long head of the Biceps.

The *branches* of the nerve, before its division, are articular and muscular.

The *articular branches* arise from the upper part of the nerve; they supply the hip-joint, perforating the posterior part of its fibrous capsule posteriorly. These branches are sometimes derived from the sacral plexus.

The *muscular branches* are distributed to the flexors of the leg: viz., the Biceps, Semitendinosus, and Semimembranosus, and a branch to the Adductor magnus. These branches are given off beneath the Biceps muscle.

The **Internal Popliteal Nerve,** the larger of the two terminal branches of the great sciatic, descends along the back part of the thigh, through the middle of the popliteal space, to the lower part of the Popliteus muscle, where it passes with the artery beneath the arch of the Soleus and becomes the posterior tibial. It is overlapped by the hamstring muscles above, and then becomes more superficial, and lies to the outer side of, and some distance from, the popliteal vessels; opposite the knee-joint it is in close relation with the vessels, and crosses to the inner side of the artery. Below, it is overlapped by the Gastrocnemius.

The *branches* of this nerve are—articular, muscular, and a cutaneous branch, the *communicans tibialis nerve*.

The *articular branches*, usually three in number, supply the knee-joint; two of these branches accompany the superior and inferior internal articular arteries, and a third, the azygos articular artery.

The *muscular branches*, four or five in number, arise from the nerve as it lies between the two heads of the Gastrocnemius muscle; they supply that muscle, the Plantaris, Soleus, and Popliteus. The filaments which supply the Popliteus turn round its lower border and are distributed to its deep surface.

The *communicans tibialis* descends between the two heads of the Gastrocnemius muscle, and about the middle of the back of the leg pierces the deep fascia, and joins a communicating branch (*communicans peronei*) from the external popliteal nerve to form the external or short saphenous (Fig. 422). The external saphenous nerve, formed by the communicating branches of the internal and external popliteal nerves, passes downward and outward near the outer margin of the tendo Achillis, lying close to the external saphenous vein, to the interval between the external malleolus and the os calcis. It winds round the outer malleolus, and is distributed to the integument along the outer side of the foot and little toe, communicating on the dorsum of the foot with the musculo-cutaneous nerve. In the leg its branches communicate with those of the small sciatic.

The **Posterior Tibial Nerve** (Fig. 423) commences at the lower border of the Popliteus muscle, and passes along the back part of the leg with the posterior tibial vessels to the interval between the inner malleolus and the heel, where it divides into the *external* and *internal plantar nerves*. It lies upon the deep muscles of the leg, and is covered in the upper part by the muscles of the calf, lower down by the skin and fascia. In the upper part of its course it lies to the inner side of the posterior tibial artery, but it soon crosses that vessel, and lies to its outer side as far as the ankle. In the lower third of the leg it is placed parallel with the inner margin of the tendo Achillis.

The *branches of the posterior tibial nerve* are muscular, calcaneo-plantar, and articular.

The *muscular branches* arise either separately or by a common trunk from the upper part of the nerve. They supply the Soleus, Tibialis posticus, Flexor longus digitorum, and Flexor longus hallucis muscles; the branch to the latter muscle accompanying the peroneal artery. The branch to the Soleus enters its deep surface, while the branch which this muscle receives from the internal popliteal enters its superficial aspect.

The *calcaneo-plantar (internal calcanean) branch* perforates the internal annular ligament, and supplies the integument of the heel and inner side of the sole of the foot.

The *articular branch* is given off just above the bifurcation of the nerve and supplies the ankle-joint.

The **Internal Plantar Nerve** (Fig. 424), the larger of the two terminal branches of the posterior tibial, accompanies the internal plantar artery along the inner side of the foot. From its origin at the inner ankle it passes beneath the Abductor hallucis, and then forward between this muscle and the Flexor brevis digitorum, divides opposite the bases of the metatarsal bones into four digital branches, and communicates with the external plantar nerve.

Branches.—In its course the internal plantar nerve gives off *cutaneous branches*, which pierce the plantar fascia and supply the integument of the sole of the foot; *muscular branches*, which supply the Abductor hallucis and Flexor brevis digitorum; *articular branches*, to the articulations of the tarsus and metatarsus; and *four digital branches*. The three outer branches pass between the divisions of the plantar fascia in the clefts between the toes: the first (innermost) branch becomes cutaneous farther back between the Adductor hallucis and Flexor brevis digitorum. They are distributed in the following manner: The *first* supplies the inner border of the great toe, and sends a filament to the Flexor brevis hallucis muscle; the *second* bifurcates, to supply the adjacent sides of the great and second toes, sending a filament to the First lumbrical muscle;[1] the *third digital branch* supplies the adjacent sides of the second and third toes; the *fourth* supplies the corresponding sides of the third and fourth toes, and receives a communicating branch from the external plantar nerve. Each digital nerve gives off cutaneous and articular filaments; and opposite the last phalanx sends a dorsal branch, which supplies the structures around the nail, the continuation of the nerve being distributed to the ball of the toe. It will be observed that the distribution of these branches is precisely similar to that of the median nerve in the hand.

FIG. 424.—The plantar nerves.

The **External Plantar Nerve**, the smaller of the two, completes the nervous supply to the structures of the sole of the foot, being distributed to the little toe and one-half of the fourth, as well as to most of the deep muscles, its distribution being similar to that of the ulnar in the hand. It passes obliquely forward with the external plantar artery to the outer side of the foot, lying between the Flexor brevis digitorum and Flexor accessorius, and in the interval between the former muscle and Abductor minimi digiti divides into a superficial and a deep branch. Before its division it supplies the Flexor accessorius and Abductor minimi digiti.

The *superficial branch* separates into two digital nerves: one, the smaller of the two, supplies the outer side of the little toe, the Flexor brevis minimi digiti,

[1] See foot-note, page 448.

and the two Interosseous muscles of the fourth metatarsal space; the other and larger digital branch supplies the adjoining sides of the fourth and fifth toes, and communicates with the internal plantar nerve.

The *deep or muscular branch* accompanies the external plantar artery into the deep part of the sole of the foot, beneath the tendons of the Flexor muscles and Adductor obliquus hallucis, and supplies all the Interossei (except those in the fourth metatarsal space), the three outer Lumbricales, the Adductor obliquus hallucis, and the Adductor transversus hallucis.

The **External Popliteal** or **Peroneal Nerve** (Fig. 423), about one-half the size of the internal popliteal, descends obliquely along the outer sides of the popliteal space to the head of the fibula, close to the inner margin of the Biceps muscle. It is easily felt beneath the skin behind the head of the fibula at the inner side of the tendon of the Biceps. It passes between the tendon of the Biceps and outer head of the Gastrocnemius muscle, winds round the neck of the fibula, between the Peroneus longus and the bone, and divides beneath the muscle into the anterior tibial and musculo-cutaneous nerves.

The *branches of the peroneal nerve*, previous to its division, are articular and cutaneous.

The *articular branches* are three in number; two of these accompany the superior and inferior external articular arteries to the outer side of the knee. The upper one occasionally arises from the great sciatic nerve before its bifurcation. The third (*recurrent*) articular nerve is given off at the point of division of the peroneal nerve; it ascends with the anterior recurrent tibial artery through the Tibialis anticus muscle to the front of the knee, which it supplies.

The *cutaneous branches*, two or three in number, supply the integument along the back part and outer side of the leg; one of these, larger than the rest, the *communicans peronei*, arises near the head of the fibula, crosses the external head of the Gastrocnemius to the middle of the leg, and joins with the communicans tibialis to form the external saphenous. This nerve occasionally exists as a separate branch, which is continued as far down as the heel.

The **Anterior Tibial Nerve** (Fig. 419) commences at the bifurcation of the peroneal nerve, between the fibula and upper part of the Peroneus longus, passes obliquely forward beneath the Extensor longus digitorum to the fore part of the interosseous membrane, and gets into relation with the anterior tibial artery above the middle of the leg; it then descends with the artery to the front of the ankle-joint, where it divides into an external and an internal branch. This nerve lies at first on the outer side of the anterior tibial artery, then in front of it, and again at its outer side at the ankle-joint.

The *branches of the anterior tibial nerve* in its course through the leg are the muscular branches to the Tibialis anticus, Extensor longus digitorum, Peroneus tertius, and Extensor proprius hallucis muscles, and an *articular branch* to the ankle-joint.

The *external* or *tarsal branch of the anterior tibial* passes outward across the tarsus, beneath the Extensor brevis digitorum, and, having become enlarged, like the posterior interosseous nerve at the wrist, supplies the Extensor brevis digitorum. From the enlargement three minute *interosseous branches* are given off which supply the tarsal joints and the metatarso-phalangeal joints of the second, third, and fourth toes. The first of these sends a filament to the second dorsal interosseous muscle.

The *internal branch*, the continuation of the nerve, accompanies the dorsalis pedis artery along the inner side of the dorsum of the foot, and at the first interosseous space divides into two branches, which supply the adjacent sides of the great and second toes, communicating with the internal branch of the musculo-cutaneous nerve. Before it divides it gives off an *interosseous branch* to the first space, which supplies the metatarso-phalangeal joint of the great toe and sends a filament to the First dorsal interosseous muscle.

The **Musculo-cutaneous Nerve** (Fig. 419) supplies the muscles on the fibular side of the leg and the integument of the dorsum of the foot. It passes forward between the Peronei muscles and the Extensor longus digitorum, pierces the deep fascia at the lower third of the leg on its front and outer side, and divides into two branches. This nerve in its course between the muscles gives off muscular branches to the Peroneus longus and brevis, and cutaneous filaments to the integument of the lower part of the leg.

The *internal branch of the musculo-cutaneous nerve* passes in front of the ankle-joint, and divides into two branches, one of which supplies the inner side of the great toe, the other, the adjacent sides of the second and third toes. It also supplies the integument of the inner ankle and inner side of the foot, communicating with the internal saphenous nerve, and joining with the anterior tibial nerve, between the great and second toes.

The *external branch*, the smaller, passes along the outer side of the dorsum of the foot, and divides into two branches, the inner being distributed to the contiguous sides of the third and fourth toes, the outer to the opposed sides of the fourth and fifth toes. It also supplies the integument of the outer ankle and outer side of the foot, communicating with the short saphenous nerve.

The branches of the musculo-cutaneous nerve supply all the toes excepting the outer side of the little toe, and the adjoining sides of the great and second toes, the former being supplied by the external saphenous, and the latter by the internal branch of the anterior tibial. It frequently happens, however, that some of the outer branches of the musculo-cutaneous are absent, their place being then taken by branches of the external saphenous nerve.

Surgical Anatomy.—The lumbar plexus passes through the Psoas muscle, and, therefore in psoas abscess any or all of its branches may be irritated, causing severe pain in the part to which the irritated nerves are distributed. The genito-crural nerve is the one which is most frequently implicated. This nerve is also of importance, as it is concerned in one of the principal reflexes employed in the investigation of diseases of the spine. If the skin over the inner side of the thigh just below Poupart's ligament, the part supplied by the crural branch of the genito-crural nerve, be gently tickled in a male child, the testicle will be noticed to be drawn upward through the action of the Cremaster muscle, supplied by the genital branch of the same nerve. The same result may sometimes be noticed in adults, and can almost always be produced by severe stimulation. This reflex, when present, shows that the portion of the cord from which the first and second lumbar nerves are derived is in a normal condition.

The anterior crural nerve is in danger of being injured in fractures of the true pelvis, since the fracture most commonly takes place through the ascending ramus of the os pubis, at or near the point where this nerve crosses the bone. It is also liable to be injured in fractures and dislocations of the femur, and is likely to be pressed upon, and its functions impaired, in some tumors growing in the pelvis. Moreover, on account of its superficial position, it is exposed to injury in wounds and stabs in the groin. When this nerve is paralyzed, the patient is unable to flex his hip completely, on account of the loss of motion in the Iliacus; or to extend the knee on the thigh, on account of paralysis of the Quadriceps extensor cruris; there are complete paralysis of the Sartorius and partial paralysis of the Pectineus. There is loss of sensation down the front and inner side of the thigh, except in that part supplied by the crural branch of the genito-crural, and by the ilio-inguinal. There is also loss of sensation down the inner side of the leg and foot as far as the ball of the great toe.

The obturator nerve is of special surgical interest. It is rarely paralyzed alone, but occasionally in association with the anterior crural. The principal interest attached to it is in connection with its supply to the knee; pain in the knee being symptomatic of many diseases in which the trunk of this nerve, or one of its branches, is irritated. Thus it is well known that in the earlier stages of hip-joint disease the patient does not complain of pain in that articulation, but on the inner side of the knee, or in the knee-joint itself, both these articulations being supplied by the obturator nerve, the final distribution of the nerve being to the knee-joint. Again, the same thing occurs in sacro-iliac disease; pain is complained of in the knee-joint or on its inner side. The obturator nerve is in close relationship with the sacro-iliac articulation, passing over it, and, according to some anatomists, distributing filaments to it. Again, in cancer of the sigmoid flexure, and even in cases where masses of hardened fæces are impacted in this portion of the gut, pain is complained of in the knee. The left obturator nerve lies beneath the sigmoid flexure, and is readily pressed upon and irritated when disease exists in this part of the intestine. Finally, pain in the knee forms an important diagnostic sign in obturator hernia. The hernial protrusion as it passes out through the opening in the obturator membrane presses upon the nerve and causes pain in the parts supplied by its peripheral filaments. When the obturator nerve is paralyzed, the patient is unable to press his knees together or to cross one leg over the other, on account of paralysis of the Adductor muscles.

Rotation outward of the thigh is impaired from paralysis of the Obturator externus. Sometimes there is loss of sensation in the upper half of the inner side of the thigh.

The great sciatic nerve is liable to be pressed upon by various forms of pelvic tumors, giving rise to pain along its trunk, to which the term sciatica is applied. Tumors growing from the pelvic viscera, or bones, aneurisms of some of the branches of the internal iliac artery, calculus in the bladder when of large size, accumulation of fæces in the rectum, may all cause pressure on the nerve inside the pelvis, and give rise to sciatica. Outside the pelvis exposure to cold, violent movements of the hip-joint, exostoses or other tumors growing from the margin of the sacro-sciatic foramen, may also give rise to the same condition. When paralyzed there is loss of motion in all the muscles below the knee, and loss of sensation in the same situation, except the upper half of the back of the leg, supplied by the small sciatic and the upper half of the inner side of the leg, when the communicating branch of the obturator is large (see page 785).

The sciatic nerve has been frequently cut down upon and stretched, or has been acupunctured for the relief of sciatica. The nerve has also been stretched in cases of locomotor ataxy, the anæsthesia of leprosy, etc. In order to define it on the surface, a point is taken at the junction of the middle and lower third of a line stretching from the posterior superior spine of the ilium to the outer part of the tuber ischii, and a line drawn from this to the middle of the upper part of the popliteal space. The line must be slightly curved with its convexity outward, and as it passes downward to the lower border of the Gluteus maximus is slightly nearer the tuber ischii than the great trochanter, as it crosses a line drawn between these two points. The operation of stretching the sciatic nerve is performed by making an incision over the course of the nerve about the centre of the thigh. The skin, superficial structures, and deep fascia having been divided, the interval between the inner and outer hamstrings is to be defined, and these muscles pulled inward and outward with retractors. The nerve will be found a little to the inner side of the Biceps. It is to be separated from the surrounding structures, hooked up with the finger, and stretched by steady and continuous traction for two or three minutes. The sciatic nerve may also be stretched by what is known as the "dry" plan. The patient is laid on his back, the foot is extended, the leg flexed on the thigh, and the thigh strongly flexed on the abdomen. While the thigh is maintained in this position the leg is forcibly extended to its full extent, and the foot as fully flexed on the leg.

The position of the external popliteal, close behind the tendon of the Biceps on the outer side of the ham, should be remembered in subcutaneous division of the tendon. After it is divided, a cord often rises up close beside it, which might be mistaken for a small undivided portion of the tendon, and the surgeon might be tempted to reintroduce his knife and divide it. This must never be done, as the cord is the external popliteal nerve, which becomes prominent as soon as the tendon is divided.

THE SYMPATHETIC NERVE.

The **Sympathetic Nervous System** consists of (1) a series of ganglia, connected together by intervening cords, extending from the base of the skull to the coccyx, one on each side of the middle line of the body, partly in front and partly on each side of the vertebral column; (2) of three great gangliated plexuses or aggregations of nerves and ganglia, situated in front of the spine in the thoracic, abdominal, and pelvic cavities respectively; (3) of smaller ganglia, situated in relation with the abdominal viscera; and (4) of numerous nerve-fibres. These latter are of two kinds: *communicating*, by which the ganglia communicate with each other and with the cerebro-spinal nerves; and *distributory*, supplying the internal viscera and the coats of the blood-vessels.

Each **gangliated cord** may be traced upward from the base of the skull into its cavity by an ascending branch, which passes through the carotid canal, forms a plexus on the internal carotid artery, and communicates with the ganglia on the first and second divisions of the fifth nerve. According to some anatomists, the two cords are joined, at their cephalic extremities, by these ascending branches communicating in a small ganglion (the *ganglion of Ribes*), situated upon the anterior communicating artery. The ganglia of these cords are distinguished as cervical, dorsal, lumbar, and sacral, and except in the neck they correspond pretty nearly in number to the vertebræ against which they lie. They may be thus arranged:

Cervical portion	. . 3	pairs of ganglia.
Dorsal "	. . 12	" "
Lumbar "	. . 4	" "
Sacral "	. . 4 or 5	" "

In the neck they are situated in front of the transverse processes of the vertebræ; in the dorsal region, in front of the heads of the ribs; in the lumbar region, on the sides of the bodies of the vertebræ; and in the sacral region, in front of the sacrum. As the two cords pass into the pelvis they converge and unite together in a single ganglion (*ganglion impar*) placed in front of the coccyx. Each ganglion may be regarded as a distinct centre, and, in addition to its branches of distribution, possesses also branches of communication which communicate with other ganglia and with the cerebro-spinal nerves.

The branches of communication between the ganglia are composed of gray and white nerve-fibres, the latter being continuous with those fibres of the spinal nerves which pass to the ganglia.

The branches of communication between the ganglia and the cerebro-spinal nerves also consist of white and gray nerve-fibres, which may be contained in separate filaments or united in a single branch; the former proceeding from the spinal nerve *to* the ganglion, the latter passing *from* the ganglion to the spinal nerve, so that a double interchange takes place between the two systems. While gray communicating fibres pass from all the sympathetic ganglia to all the spinal nerves, it would appear that the white communicating fibres from the spinal nerves to the sympathetic only exist in the dorsal and upper lumbar regions.

The **three great gangliated plexuses** are situated in front of the spine in the thoracic, abdominal, and pelvic regions, and are named, respectively, the *cardiac*, the *solar* or *epigastric*, and the *hypogastric plexus*. They consist of collections of nerves and ganglia, the nerves being derived from the gangliated cords and from the cerebro-spinal nerves. They distribute branches to the viscera.

Smaller ganglia are also found lying amidst the nerves, some of them of microscopic size, in certain viscera—as, for instance, in the heart, the stomach, and the uterus. They serve as additional centres for the origin of nerve-fibres.

The *branches of distribution* derived from the gangliated cords, from the prevertebral plexuses, and also from the smaller ganglia, are principally destined for the blood-vessels and thoracic and abdominal viscera, supplying the involuntary muscular fibre of the coats of the vessels and the hollow viscera, and the secreting cells, as well as the muscular coats of the vessels in the glandular viscera.

THE GANGLIATED CORD.

Cervical Portion of the Gangliated Cord.

The cervical portion of the gangliated cord consists of three ganglia on each side, which are distinguished, according to their position, as the superior, middle, and inferior cervical.

The **Superior Cervical Ganglion**, the largest of the three, is placed opposite the second and third cervical vertebræ. It is of a reddish-gray color, and usually fusiform in shape, sometimes broad and flattened, and occasionally constricted at intervals, so as to give rise to the opinion that it consists of the coalescence of several smaller ganglia; and it is usually believed that it is formed by the coalescence of the four ganglia corresponding to the four upper cervical nerves. It is in relation, in front, with the sheath of the internal carotid artery and internal jugular vein; behind, it lies on the Rectus capitis anticus major muscle.

Its branches may be divided into superior, inferior, external, internal, and anterior.

The *superior branch* appears to be a direct prolongation of the ganglion. It is soft in texture and of a reddish color. It ascends by the side of the internal carotid artery, and, entering the carotid canal in the temporal bone, divides into two branches, which lie, one on the outer, and the other on the inner, side of that vessel.

The *outer branch*, the larger of the two, distributes filaments to the internal carotid artery and forms the *carotid plexus*.

The *inner branch* also distributes filaments to the internal carotid, and, continuing onward, forms the *cavernous plexus*.

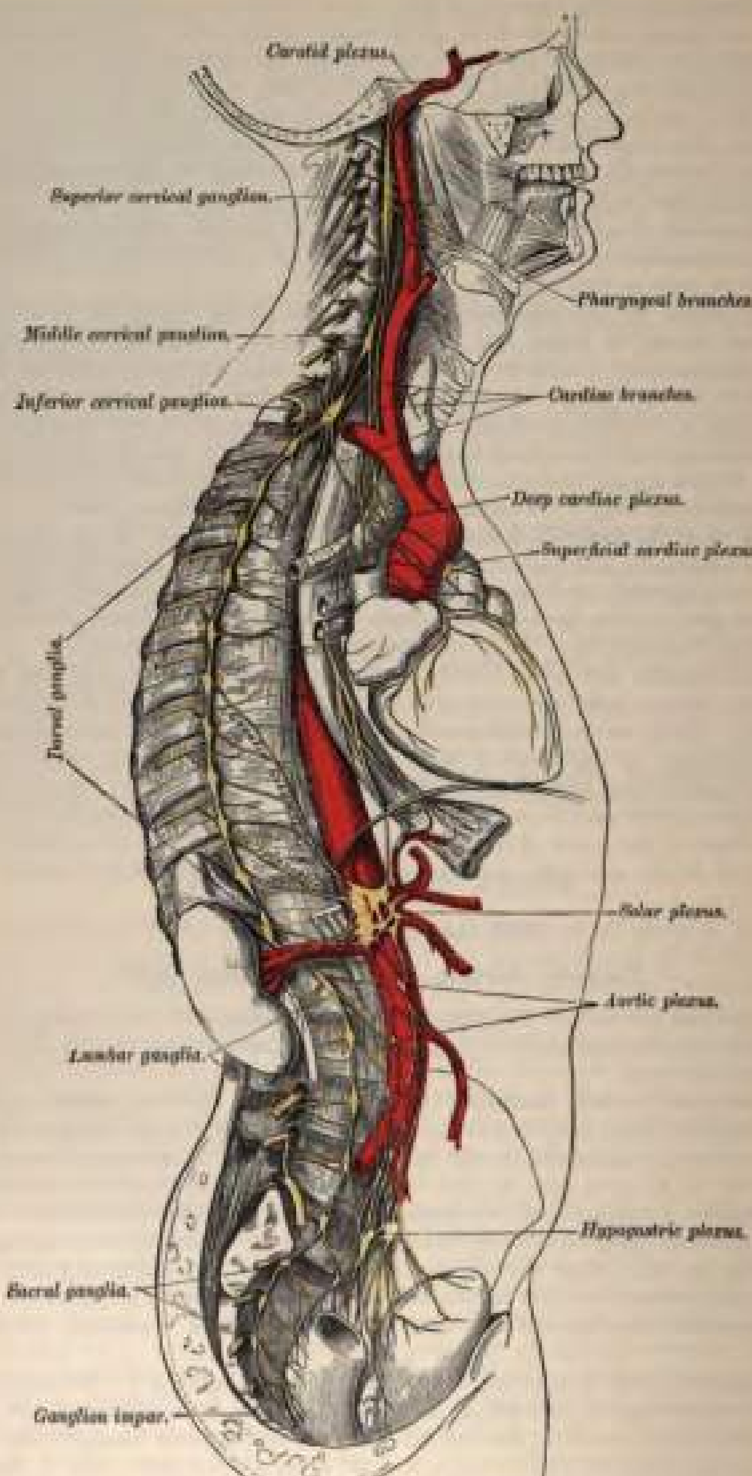


FIG. 425.—The sympathetic nerve.

The Carotid Plexus.

The carotid plexus is situated on the outer side of the internal carotid. Filaments from this plexus occasionally form a small gangliform swelling on the under surface of the artery, which is called the carotid ganglion. The carotid plexus communicates with the Gasserian ganglion, with the sixth nerve, and the spheno-palatine ganglion, and distributes filaments to the wall of the carotid artery and to the dura mater (Valentin), while in the carotid canal it communicates with Jacobson's nerve, the tympanic branch of the glosso-pharyngeal.

The *communicating branches with the sixth nerve* consist of one or two filaments which join that nerve as it lies upon the outer side of the internal carotid. Other filaments are also connected with the Gasserian ganglion. The communication with the spheno-palatine ganglion is effected by a branch, the *large deep petrosal*, which is given off from the plexus on the outer side of the artery, and which passes through the cartilage filling up the foramen lacerum medium, and joins the great superficial petrosal to form the Vidian nerve. The Vidian nerve then proceeds along the pterygoid or Vidian canal to the spheno-palatine ganglion. The communication with Jacobson's nerve is effected by two branches, one of which is called the *small deep petrosal nerve*, and the other the *carotico-tympanic*; the latter may consist of two or three delicate filaments.

The Cavernous Plexus.

The cavernous plexus is situated below and internal to that part of the internal carotid which is placed by the side of the sella Turcica in the cavernous sinus, and is formed chiefly by the internal division of the ascending branch from the superior cervical ganglion. It communicates with the third, the fourth, the ophthalmic division of the fifth, and the sixth nerves, and with the ophthalmic ganglion, and distributes filaments to the wall of the internal carotid. The branch of communication with the third nerve joins it at its point of division; the branch to the fourth nerve joins it as it lies on the outer wall of the cavernous sinus; other filaments are connected with the under surface of the trunk of the ophthalmic nerve; and a second filament of communication joins the sixth nerve.

The filament of connection with the ophthalmic ganglion arises from the anterior part of the cavernous plexus; it accompanies the nasal nerve or continues forward as a separate branch.

The terminal filaments from the carotid and cavernous plexuses are prolonged along the internal carotid, forming plexuses which entwine round the cerebral and ophthalmic arteries; along the former vessels they may be traced on to the pia mater; along the latter, into the orbit, where they accompany each of the subdivisions of the vessel, a separate plexus passing, with the arteria centralis retinæ, into the interior of the eyeball. The filaments prolonged on to the anterior communicating artery form a small ganglion, the *ganglion of Ribes*,[1] which serves, as mentioned above, to connect the sympathetic nerves of the right and left sides.

The **inferior** or **descending branch of the superior cervical ganglion** communicates with the middle cervical ganglion.

The **external branches** are numerous, and communicate with the cranial nerves and with the four upper spinal nerves. Sometimes the branch to the fourth spinal nerve may come from the cord connecting the upper and middle cervical ganglia. The branches of communication with the cranial nerves consist of delicate filaments, which pass from the superior cervical ganglion to the ganglion of the trunk of the pneumogastric and to the hypoglossal nerve. A separate filament from the cervical ganglion subdivides and joins the petrosal ganglion of the glosso-pharyngeal and the ganglion of the root of the pneumogastric in the jugular foramen.

The **internal branches** are three in number—the *pharyngeal*, *laryngeal*, and *superior cardiac nerve*. The *pharyngeal branches* pass inward to the side of the

[1] The existence of this ganglion is doubted by some observers.

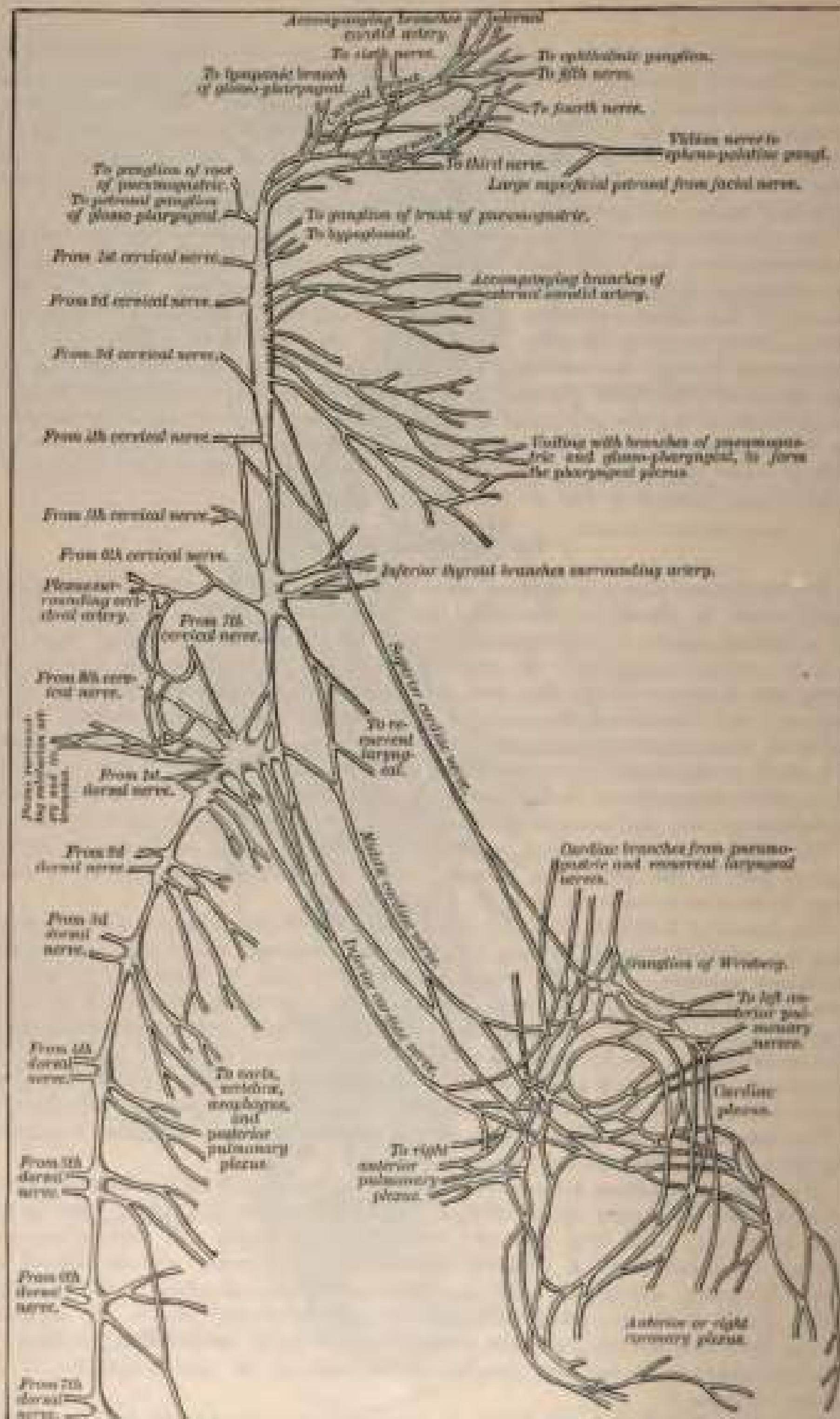


FIG. [illegible].—Plan of the cervical portion of the sympathetic. (After Flower.)

pharynx, where they join with branches from the glosso-pharyngeal, pneumogastric, and external laryngeal nerves to form the *pharyngeal plexus.* The *laryngeal branches* unite with the superior laryngeal nerve and its branches.

The *superior cardiac nerve* (*nervus superficialis cordis*) arises by two or more branches from the superior cervical ganglion, and occasionally receives a filament from the cord of communication between the first and second cervical ganglia. It runs down the neck behind the common carotid artery, lying upon the Longus colli muscle, and crosses in front of the inferior thyroid artery and recurrent laryngeal nerve.

The *right superior cardiac nerve*, at the root of the neck, passes either in front of or behind the subclavian artery, and along the arteria innominata, to the back part of the arch of the aorta, where it joins the deep cardiac plexus. This nerve, in its course, is connected with other branches of the sympathetic: about the middle of the neck it receives filaments from the external laryngeal nerve; lower down, one or two twigs from the pneumogastric; and as it enters the thorax it is joined by a filament from the recurrent laryngeal. Filaments from this nerve communicate with the thyroid branches from the middle cervical ganglion.

The *left superior cardiac nerve*, in the chest, runs by the side of the left common carotid artery and in front of the arch of the aorta to the superficial cardiac plexus, but occasionally it passes behind the aorta and terminates in the deep cardiac plexus.

The **anterior branches** ramify upon the external carotid artery and its branches, forming round each a delicate plexus, on the nerves composing which small ganglia are occasionally found. The plexuses accompanying some of these arteries have important communications with other nerves. That surrounding the external carotid is connected with the branch of the facial nerve to the Stylo-hyoid muscle; that surrounding the facial communicates with the submaxillary ganglion by one or two filaments; and that accompanying the middle meningeal artery sends offsets which pass to the otic ganglion and to the geniculate ganglion of the facial nerve (external petrosal).

The **Middle Cervical Ganglion** (*thyroid ganglion*) is the smallest of the three cervical ganglia, and is occasionally altogether wanting. It is placed opposite the sixth cervical vertebra, usually upon, or close to, the inferior thyroid artery; hence the name, "thyroid ganglion," assigned to it by Haller. It is probably formed by the coalescence of two ganglia corresponding to the fifth and sixth cervical nerves.

Its *superior branches* ascend to communicate with the superior cervical ganglion.

Its *inferior branches* descend to communicate with the inferior cervical ganglion.

Its *external branches* pass outward to join the fifth and sixth spinal nerves. These branches are not constantly found.

Its *internal branches* are the thyroid and the middle cardiac nerve.

The *thyroid branches* are small filaments which accompany the inferior thyroid artery to the thyroid gland; they communicate, on the artery, with the superior cardiac nerve, and, in the gland, with branches from the recurrent and external laryngeal nerves.

The *middle cardiac nerve* (*nervus cardiacus magnus*), the largest of the three cardiac nerves, arises from the middle cervical ganglion or from the cord between the middle and inferior ganglia. On the right side it descends behind the common carotid artery, and at the root of the neck passes either in front of or behind the subclavian artery; it then descends on the trachea, receives a few filaments from the recurrent laryngeal nerve, and joins the right side of the deep cardiac plexus. In the neck it communicates with the superior cardiac and recurrent laryngeal nerves. On the left side the middle cardiac nerve enters the chest between the left carotid and subclavian arteries, and joins the left side of the deep cardiac plexus.

The **Inferior Cervical Ganglion** is situated between the base of the transverse process of the last cervical vertebra and the neck of the first rib on the inner side of the superior intercostal artery. Its form is irregular; it is larger in size than the preceding, and frequently joined with the first thoracic ganglion. It is probably formed by the coalescence of two ganglia which correspond to the two last cervical nerves.

Its *superior branches* communicate with the middle cervical ganglion.

Its *inferior branches* descend, some in front of, others behind, the subclavian artery, to join the first thoracic ganglion.

Its *internal branch* is the inferior cardiac nerve.

The *inferior cardiac nerve* (*nervus cardiacus minor*) arises from the inferior cervical or first thoracic ganglion. It passes down behind the subclavian artery and along the front of the trachea to join the deep cardiac plexus. It communicates freely behind the subclavian artery with the recurrent laryngeal and middle cardiac nerves.

The *external branches* consist of several filaments, some of which communicate with the seventh and eighth spinal nerves; others accompany the vertebral artery along the vertebral canal, forming a plexus round the vessel, supplying it with filaments, which are continued up the vertebral and basilar to the cerebral arteries. The branches communicate with the cervical spinal nerves.

The Thoracic Portion of the Gangliated Cord.

The thoracic portion of the gangliated cord consists of a series of ganglia which usually correspond in number to that of the vertebræ, but, from the occasional coalescence of two, their number is uncertain. These ganglia are placed on each side of the spine, resting against the heads of the ribs and covered by the pleura costalis; the last two are, however, anterior to the rest, being placed on the side of the bodies of the eleventh and twelfth dorsal vertebræ. The ganglia are small in size and of a grayish color. The first, larger than the rest, is of an elongated form and frequently blended with the last cervical. They are connected together by cord-like prolongations from their substance.

The *external branches* from each ganglion, usually two in number, communicate with each of the dorsal spinal nerves.

The *internal branches from the five or six upper ganglia* are very small; they supply filaments to the thoracic aorta and its branches, besides small branches to the bodies of the vertebræ and their ligaments. Branches from the third and fourth, and sometimes also from the first and second ganglia, form part of the posterior pulmonary plexus.

The *internal branches from the six or seven lower ganglia* are large and white in color; they distribute filaments to the aorta, and unite to form the three splanchnic nerves. These are named the *great*, the *lesser*, and the *smallest* or *renal splanchnic*.

The *great splanchnic nerve* is of a white color, firm in texture, and bears a marked contrast to the ganglionic nerves. It is formed by branches from the thoracic ganglia between the fifth or sixth and the ninth or tenth, but the fibres in the higher roots may be traced upward in the sympathetic cord as far as the first or second thoracic ganglia. These roots unite to form a large round cord of considerable size. It descends obliquely inward in front of the bodies of the vertebræ along the posterior mediastinum, perforates the crus of the Diaphragm, and terminates in the semilunar ganglion of the solar plexus, distributing filaments to the renal and suprarenal plexus.

The *lesser splanchnic nerve* is formed by filaments from the tenth and eleventh ganglia, and from the cord between them. It pierces the Diaphragm with the preceding nerve, and joins the solar plexus. It communicates in the chest with the great splanchnic nerve, and occasionally sends filaments to the renal plexus.

The *smallest* or *renal splanchnic nerve* arises from the last ganglion, and, piercing the Diaphragm, terminates in the renal plexus and lower part of the solar plexus. It occasionally communicates with the preceding nerve.

A striking analogy appears to exist between the splanchnic and the cardiac nerves. The cardiac nerves are three in number; they arise from the three cervical ganglia, and are distributed to a large and important organ in the thoracic cavity. The splanchnic nerves, also three in number, are connected probably with all the dorsal ganglia, and are distributed to important organs in the abdominal cavity.

The Lumbar Portion of the Gangliated Cord.

The lumbar portion of the gangliated cord is situated in front of the vertebral column along the inner margin of the Psoas muscle. It consists usually of four ganglia, connected together by interganglionic cords. The ganglia are of small size, of a grayish color, shaped like a barleycorn, and placed much nearer the median line than the thoracic ganglia.

The *superior* and *inferior branches of the lumbar ganglia* serve as communicating branches between the chain of ganglia in this region. They are usually single and of a white color.

The *external branches* communicate with the lumbar spinal nerves. From the situation of the lumbar ganglia these branches are longer than in the other regions. They are usually two in number from each ganglion, but their connection with the spinal nerves is not so uniform as in other regions. They accompany the lumbar arteries around the sides of the bodies of the vertebræ, passing beneath the fibrous arches from which some of the fibres of the Psoas muscle arise.

Of the *internal branches*, some pass inward, in front of the aorta, and help to form the aortic plexus. Other branches descend in front of the common iliac arteries, and join over the promontory of the sacrum, helping to form the hypogastric plexus. Numerous delicate filaments are also distributed to the bodies of the vertebræ and the ligaments connecting them.

Pelvic Portion of the Gangliated Cord.

The pelvic portion of the gangliated cord is situated in front of the sacrum along the inner side of the anterior sacral foramina. It consists of four or five small ganglia on each side, connected together by interganglionic cords. Below, these cords converge and unite on the front of the coccyx by means of a small ganglion (the *coccygeal ganglion* or *ganglion impar*).

The *superior* and *inferior branches* are the cords of communication between the ganglia above and below.

The *external branches*, exceedingly short, communicate with the sacral nerves. They are two in number from each ganglion. The coccygeal nerve communicates either with the last sacral or coccygeal ganglion.

The *internal branches* communicate, on the front of the sacrum, with the corresponding branches from the opposite side; some, from the first two ganglia, pass to join the pelvic plexus, and others form a plexus which accompanies the middle sacral artery and sends filaments to the coccygeal gland.

THE GREAT PLEXUSES OF THE SYMPATHETIC.

The great plexuses of the sympathetic are the large aggregations of nerves and ganglia, above alluded to, situated in the thoracic, abdominal, and pelvic cavities respectively. From them are derived the branches which supply the viscera.

The Cardiac Plexus.

The cardiac plexus is situated at the base of the heart, and is divided into a *superficial part*, which lies in the concavity of the arch of the aorta, and a *deep* *part*, which lies between the trachea and aorta. The two plexuses are, however, closely connected.

The **great** or **deep cardiac plexus** (*plexus magnus profundus*, Scarpa) is situated in front of the trachea at its bifurcation, above the point of division of the pulmonary artery and behind the arch of the aorta. It is formed by the cardiac nerves derived from the cervical ganglia of the sympathetic and the cardiac branches of the recurrent laryngeal and pneumogastric. The only cardiac nerves which do not enter into the formation of this plexus are the left superior cardiac nerve and the inferior cervical cardiac branch from the left pneumogastric.

The branches from the *right side* of this plexus pass, some in front of, and others behind, the right pulmonary artery; the former, the more numerous, transmit a few filaments to the anterior pulmonary plexus, and are then continued onward to form part of the anterior coronary plexus; those behind the pulmonary artery distribute a few filaments to the right auricle, and are then continued onward to form part of the posterior coronary plexus.

The branches from the *left side* of the deep cardiac plexus distribute a few filaments to the superficial cardiac plexus, to the left auricle of the heart, and to the anterior pulmonary plexus, and then pass on to form the greater part of the posterior coronary plexus.

The **superficial (anterior) cardiac plexus** lies beneath the arch of the aorta, in front of the right pulmonary artery. It is formed by the left superior cardiac nerve, the left (and occasionally the right) inferior cervical cardiac branches of the pneumogastric, and filaments from the deep cardiac plexus. A small ganglion (*cardiac ganglion of Wrisberg*) is occasionally found connected with these nerves at their point of junction. This ganglion, when present, is situated immediately beneath the arch of the aorta, on the right side of the ductus arteriosus. The superficial cardiac plexus forms the chief part of the anterior coronary plexus, and several filaments pass along the pulmonary artery to the left anterior pulmonary plexus.

The **posterior** or **right coronary plexus** is chiefly formed by filaments prolonged from the left side of the deep cardiac plexus, and by a few from the right side. It surrounds the branches of the coronary artery at the back of the heart, and its filaments are distributed with those vessels to the muscular substance of the ventricles.

The **anterior** or **left coronary plexus** is formed chiefly from the superficial cardiac plexus, but receives filaments from the deep cardiac plexus. Passing forward between the aorta and pulmonary artery, it accompanies the left coronary artery on the anterior surface of the heart.

Valentin has described nervous filaments ramifying under the endocardium; and Remak has found, in several mammalia, numerous small ganglia on the cardiac nerves, both on the surface of the heart and in its muscular substance.

The Epigastric or Solar Plexus (Figs. 425, 427).

The **Epigastric** or **Solar plexus** supplies all the viscera in the abdominal cavity. It consists of a great network of nerves and ganglia, situated behind the stomach and in front of the aorta and crura of the Diaphragm. It surrounds the cœliac axis and root of the superior mesenteric artery, extending downward as low as the pancreas and outward to the suprarenal capsules. This plexus, and the ganglia connected with it, receive the great and small splanchnic nerves of both sides, and some filaments from the right pneumogastric. It distributes filaments which accompany, under the name of plexuses, all the branches from the front of the abdominal aorta.

Of the ganglia of which the solar plexus is partly composed the principal are the two **semilunar ganglia**, which are situated one on each side of the plexus, and are the largest ganglia in the body. They are large irregular gangliform masses formed by the aggregation of smaller ganglia, having interspaces between them.

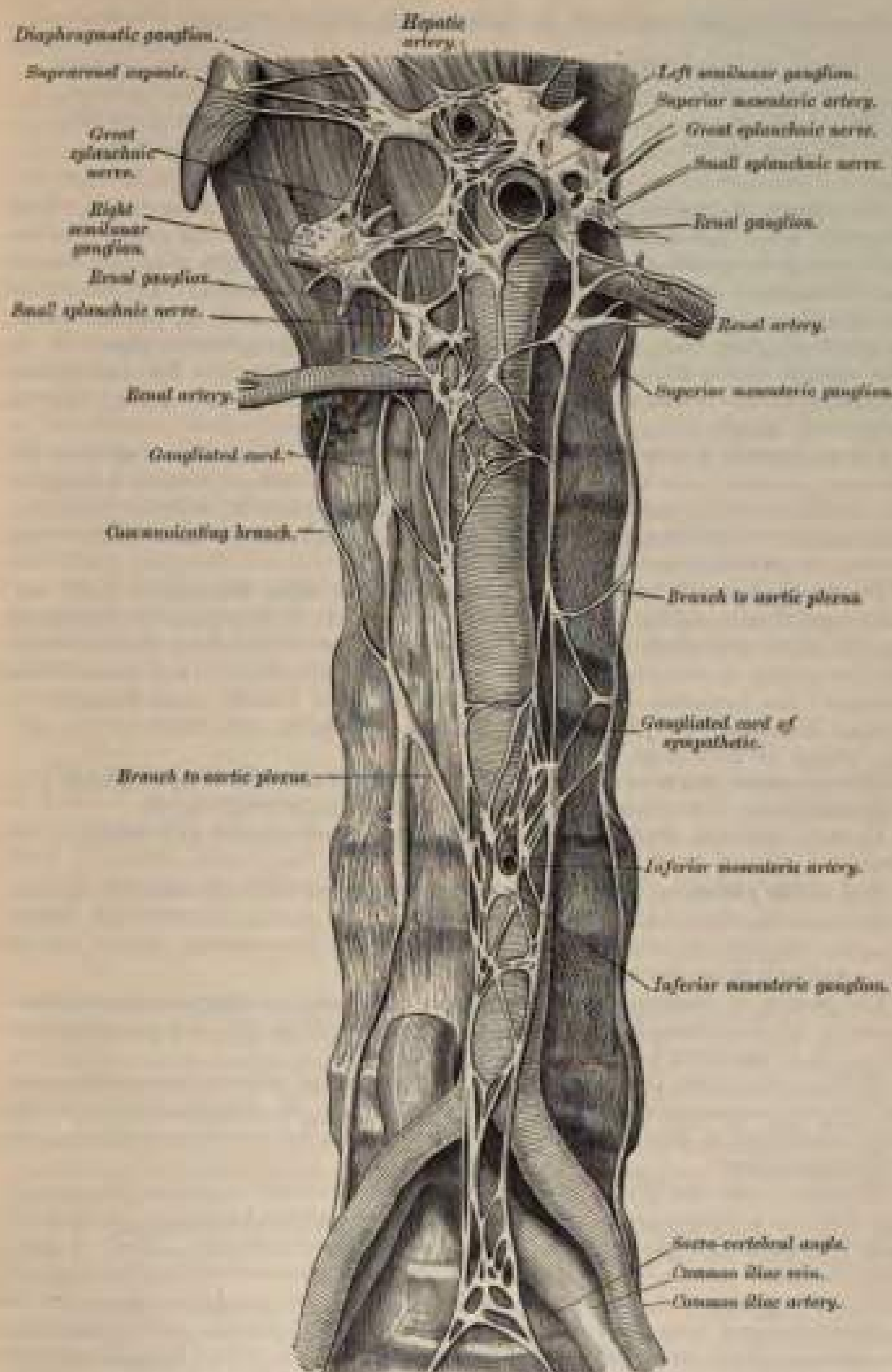


FIG. 427.—Lumbar portion of the gangliated cord, with the solar and hypogastric plexuses. (After Henle.)

They are situated in front of the crura of the Diaphragm, close to the suprarenal capsules: the one on the right side lies beneath the inferior vena cava; the upper part of each ganglion is joined by the greater splanchnic nerve, and to the inner side of each the branches of the solar plexus are connected.

From the epigastric or solar plexus are derived the following:

Phrenic or Diaphragmatic plexus.
Suprarenal plexus.
Renal plexus.
Spermatic plexus.
Cœliac plexus { Gastric plexus. Splenic plexus. Hepatic plexus.
Superior mesenteric plexus.
Aortic plexus.

The **phrenic plexus** accompanies the phrenic artery to the Diaphragm, which it supplies, some filaments passing to the suprarenal capsule. It arises from the upper part of the semilunar ganglion, and is larger on the right than on the left side. It receives one or two branches from the phrenic nerve. In connection with this plexus, on the right side, at its point of junction with the phrenic nerve, is a small ganglion (*ganglion diaphragmaticum*). This ganglion is placed on the under surface of the Diaphragm, near the suprarenal capsule. Its branches are distributed to the inferior vena cava, suprarenal capsule, and hepatic plexus. There is no ganglion on the left side.

The **suprarenal plexus** is formed by branches from the solar plexus, from the semilunar ganglion, and from the phrenic and great splanchnic nerves, a ganglion being formed at the point of junction of the latter nerve. It supplies the suprarenal capsule. The branches of this plexus are remarkable for their large size in comparison with the size of the organ they supply.

The **renal plexus** is formed by filaments from the solar plexus, the outer part of the semilunar ganglion, and the aortic plexus. It is also joined by filaments from the lesser and smallest splanchnic nerves. The nerves from these sources, fifteen or twenty in number, have numerous ganglia developed upon them. They accompany the branches of the renal artery into the kidney, some filaments on the right side being distributed to the inferior vena cava, and others to the spermatic plexus on both sides.

The **spermatic plexus** is derived from the renal plexus, receiving branches from the aortic plexus. It accompanies the spermatic vessels to the testes.

In the female the **ovarian plexus** is distributed to the ovaries and fundus of the uterus.

The **cœliac plexus**, of large size, is a direct continuation from the solar plexus: it surrounds the cœliac axis and subdivides into the gastric, hepatic, and splenic plexuses. It receives branches from the lesser splanchnic nerves, and, on the left side, a filament from the right pneumogastric.

The *gastric* or *coronary plexus* accompanies the gastric artery along the lesser curvature of the stomach, and joins with branches from the left pneumogastric nerve. It is distributed to the stomach

The *hepatic plexus*, the largest offset from the cœliac plexus, receives filaments from the left pneumogastric and right phrenic nerves. It accompanies the hepatic artery, ramifying in the substance of the liver upon its branches and upon those of the vena portæ.

Branches from this plexus accompany all the divisions of the hepatic artery. Thus there is a *pyloric plexus* accompanying the pyloric branch of the hepatic, which joins with the gastric plexus and pneumogastric nerves. There is also a *gastro-duodenal plexus*, which subdivides into the pancreatico-duodenal plexus, which accompanies the pancreatico-duodenal artery, to supply the pancreas and duodenum, joining with branches from the mesenteric plexus; and a *gastro-epiploic plexus*, which accompanies the right gastro-epiploic artery along the greater curvature of the stomach and anastomoses with branches from the splenic plexus. A *cystic plexus*, which supplies the gall-bladder, also arises from the hepatic plexus near the liver.

The *splenic plexus* is formed by branches from the cœliac plexus, the left semilunar ganglia, and from the right pneumogastric nerve. It accompanies the splenic artery and its branches to the substance of the spleen, giving off, in its course, filaments to the pancreas (*pancreatic plexus*) and the *left gastro-epiploic* *plexus*, which accompanies the gastro-epiploica sinistra artery along the convex border of the stomach.

The **superior mesenteric plexus** is a continuation of the lower part of the great solar plexus, receiving a branch from the junction of the right pneumogastric nerve with the cœliac plexus. It surrounds the superior mesenteric artery, which it accompanies into the mesentery, and divides into a number of secondary plexuses, which are distributed to all the parts supplied by the artery—viz. pancreatic branches to the pancreas; intestinal branches, which supply the whole of the small intestine; and ileo-colic, right colic, and middle colic branches, which supply the corresponding parts of the great intestine. The nerves composing this plexus are white in color and firm in texture, and have numerous ganglia developed upon them near their origin.

The **aortic plexus** is formed by branches derived, on each side, from the solar plexus and the semilunar ganglia, receiving filaments from some of the lumbar ganglia. It is situated upon the sides and front of the aorta, between the origins of the superior and inferior mesenteric arteries. From this plexus arise part of the spermatic, the inferior mesenteric, and the hypogastric plexuses; and it distributes filaments to the inferior vena cava.

The *inferior mesenteric plexus* is derived chiefly from the left side of the aortic plexus. It surrounds the inferior mesenteric artery, and divides into a number of secondary plexuses, which are distributed to all the parts supplied by the artery—viz. the left colic and sigmoid plexuses, which supply the descending and sigmoid flexure of the colon; and the superior hæmorrhoidal plexus, which supplies the upper part of the rectum and joins in the pelvis with branches from the pelvic plexus.

The Hypogastric Plexus.

The **Hypogastric Plexus** supplies the viscera of the pelvic cavity. It is situated in front of the promontory of the sacrum, between the two common iliac arteries, and is formed by the union of numerous filaments, which descend on each side from the aortic plexus and from the lumbar ganglia. This plexus contains no evident ganglia; it bifurcates, below, into two lateral portions, which form the *pelvic plexuses.*

The Pelvic Plexus.

The **pelvic plexus** (sometimes called *inferior hypogastric*) supplies the viscera of the pelvic cavity, is situated at the side of the rectum in the male, and at the side of the rectum and vagina in the female. It is formed by a continuation of the hypogastric plexus, by branches from the second, third, and fourth sacral nerves, and by a few filaments from the first two sacral ganglia. At the point of junction of these nerves small ganglia are found. From this plexus numerous branches are distributed to all the viscera of the pelvis. They accompany the branches of the internal iliac artery.

The **inferior hæmorrhoidal plexus** arises from the back part of the pelvic plexus. It supplies the rectum, joining with branches of the superior hæmorrhoidal plexus.

The **vesical plexus** arises from the fore part of the pelvic plexus. The nerves composing it are numerous, and contain a large proportion of spinal nerve-fibres. They accompany the vesical arteries, and are distributed at the side and base of the bladder. Numerous filaments also pass to the vesiculæ seminales and vas deferens; those accompanying the vas deferens join, on the spermatic cord, with branches from the spermatic plexus.

The **prostatic plexus** is continued from the lower part of the pelvic plexus. The nerves composing it are of large size. They are distributed to the prostate gland, vesiculæ seminales, and erectile structure of the penis. The nerves supplying the erectile structure of the penis consist of two sets, the small and large cavernous nerves. They are slender filaments, which arise from the fore part of the prostatic plexus, and, after joining with branches from the internal pudic nerve, pass forward beneath the pubic arch.

The *small cavernous nerves* perforate the fibrous covering of the penis near its roots.

The *large cavernous nerve* passes forward along the dorsum of the penis, joins with the dorsal branch of the pudic nerve, and is distributed to the corpus cavernosum and spongiosum.

The **vaginal plexus** arises from the lower part of the pelvic plexus. It is lost on the walls of the vagina, being distributed to the erectile tissue at its anterior part and to the mucous membrane. The nerves composing this plexus contain, like the vesical, a large proportion of spinal nerve-fibres.

The **uterine plexus** arises from the upper part of the pelvic plexus above the point where the branches from the sacral nerves join the plexus. Its branches accompany the uterine arteries to the side of the organ between the layers of the broad ligament, and are distributed to the cervix and lower part of the body of the uterus, penetrating its substance.

Other filaments pass separately to the body of the uterus and Fallopian tube. Branches from the plexus accompany the uterine arteries into the substance of the uterus. Upon these filaments ganglionic enlargements are found.

THE ORGANS OF SPECIAL SENSE.

THE Organs of the Senses are five in number, viz., those of Touch, of Taste, of Smell, of Hearing, and of Sight. The skin, which is the principal seat of the sense of touch, will be described in the section on General Anatomy. The remaining four are the Organs of Special Sense.

THE TONGUE.

The Tongue is the organ of the special sense of taste. It is situated in the floor of the mouth, in the interval between the two lateral portions of the body of the lower jaw.

Its base or root is directed backward, and connected with the os hyoides by the Hyo-glossi and Genio-hyo-glossi muscles and the hyo-glossal membrane; with the epiglottis by three folds (*glosso-epiglottic*) of mucous membrane; with the soft palate by means of the anterior pillars of the fauces; and with the pharynx by the Superior constrictors and the mucous membrane. Its apex or tip, thin and narrow, is directed forward against the inner surface of the lower incisor teeth. The under surface of the tongue is connected with the lower jaw by the Genio-hyo-glossi muscles; from its sides the mucous membrane is reflected to the inner surface of the gums; and from its under surface on to the floor of the mouth, where, in the middle line, it is elevated into a distinct vertical fold, the *frænum linguæ*. To the outer side of the frænum is a slight fold of the mucous membrane, the *plica fimbriata*, the free edge of which exhibits a series of fringe-like processes.

The tip of the tongue, part of the under surface, its sides, and dorsum are free.

The dorsum of the tongue is convex, marked along the middle line by a raphé, which divides it into symmetrical halves; this raphé terminates behind, about an inch from the base of the organ, in a depression, the *foramen cæcum*, from which a shallow groove, the *sulcus terminalis* of His, runs outward and forward on each side to the lateral margin of the tongue. The part of the dorsum of the tongue in front of this groove, forming about two-thirds of its upper surface, is rough and covered with papillæ; the posterior third is smoother, and contains numerous muciparous glands and lymphoid follicles.

Structure of the Tongue.—The tongue is partly invested by mucous membrane and a submucous fibrous layer. It consists of symmetrical halves, separated from each other, in the middle line, by a fibrous septum. Each half is composed of muscular fibres arranged in various directions (page 325), containing much interposed fat, and supplied by vessels and nerves.

The **mucous membrane** invests the entire extent of the free surface of the tongue. On the dorsum it is thicker behind than in front, and is continuous with the sheath of the muscles attached to it, through the submucous fibrous layer. On the under surface of the organ, where it is thin and smooth, it can be traced on each side of the frænum through the ducts of the submaxillary and the sublingual glands. As it passes over the borders of the organ it gradually assumes its papillary character.

The **structure of the mucous membrane of the tongue** differs in different parts. That covering the under surface of the organ is thin, smooth, and identical in structure with that lining the rest of the oral cavity. The mucous membrane covering the tongue behind the foramen cæcum and sulcus terminalis is thick and freely movable over the subjacent parts. It contains a large number of lymphoid follicles, which together constitute what is sometimes termed the *lingual tonsil*. Each follicle forms a rounded eminence, the centre of which is perforated by a minute orifice leading into a funnel-shaped cavity or recess; around this recess are grouped numerous oval or rounded nodules of lymphoid tissue, each enveloped by a capsule derived from the submucosa, while opening into the bottom of the recesses are also seen the ducts of mucous glands. The mucous membrane on the anterior part of the dorsum of the tongue is thin and intimately adherent to the

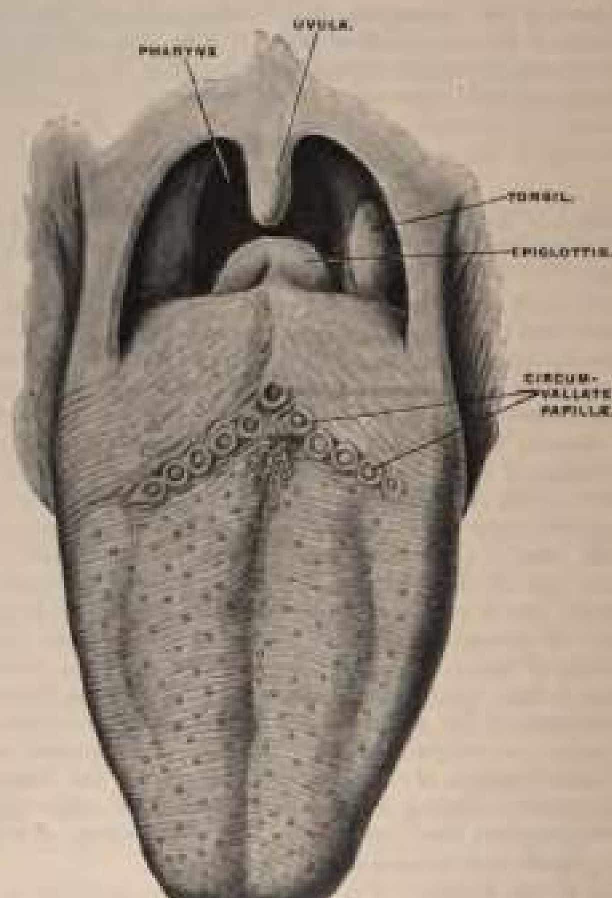


FIG. 428.—Upper surface of the tongue.

muscular tissue, and covered with minute eminences, the *papillæ* of the tongue. It consists of a layer of connective tissue, the *corium* or *mucosa*, supporting numerous papillæ, and covered, as well as the papillæ, with epithelium.

The epithelium is of the scaly variety, like that of the epidermis. It covers the free surface of the tongue, as may be easily demonstrated by maceration or boiling, when it can be easily detached entire: it is much thinner than on the skin: the intervals between the large papillæ are not filled up by it, but each papilla has a separate investment from root to summit. The deepest cells may sometimes be detached as a separate layer, corresponding to the rete mucosum, but they never contain coloring matter.

The *corium* consists of a dense feltwork of fibrous connective tissue, with numerous elastic fibres, firmly connected with the fibrous tissue forming the septa between the muscular bundles of the tongue. It contains the ramifications of the numerous vessels and nerves from which the papillæ are supplied, large plexuses of lymphatic vessels, and the glands of the tongue.

The Papillæ of the Tongue.—These are papillary projections of the corium. They are thickly distributed over the anterior two-thirds of its upper surface, giving to it its characteristic roughness. The varieties of papillæ met with are—the papillæ maximæ (*circumvallatæ*), papillæ mediæ (*fungiformes*), papillæ minimæ (*conicæ* or *filiformes*), and papillæ simplices.

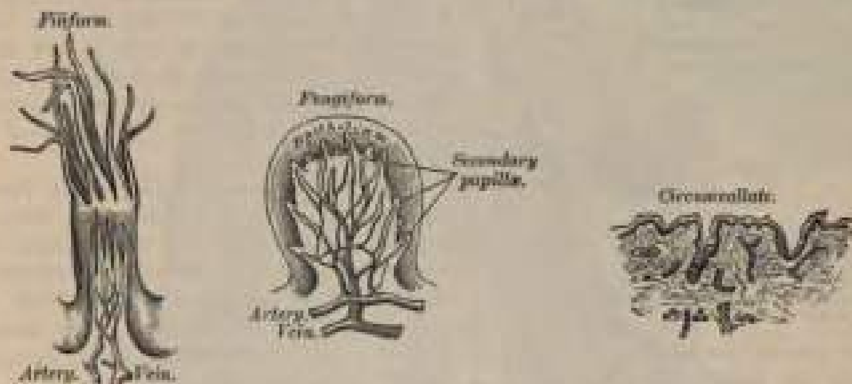


Fig. 423.—The three kinds of papillæ, magnified.

The *papillæ maximæ* (circumvallatæ) are of large size, and vary from eight to twelve in number. They are situated at the back part of the dorsum of the tongue, near its base, forming a row on each side, which, running backward and inward, meet in the middle line, like the two lines of the letter V inverted. Each papilla consists of a projection of mucous membrane from $\frac{1}{20}$ to $\frac{1}{12}$ of an inch wide, attached to the bottom of a cup-shaped depression of the mucous membrane; the papilla is in shape like a truncated cone, the smaller end being directed downward and attached to the tongue, the broader part or base projecting on the surface and being studded with numerous small secondary papillæ, which, however, are covered by a smooth layer of the epithelium. The cup-shaped depression forms a kind of fossa round the papilla, having a circular margin of about the same elevation covered with smaller papillæ.

Immediately behind the apex of the V is the foramen cæcum, mentioned above. This, according to His, represents the remains of the invagination which forms the median rudiment of the thyroid body, and for a time opens by a duct, the *thyro-glossal duct*, on to the dorsum of the tongue. It may extend downward toward the hyoid bone. Kanthack, however, disputes this view.[1]

The *papillæ mediæ* (fungiformes), more numerous than the preceding, are scattered irregularly and sparingly over the dorsum of the tongue, but are found chiefly at its sides and apex. They are easily recognized among the other papillæ, by their large size, rounded eminences, and deep-red color. They are narrow at their attachment to the tongue, but broad and rounded at their free extremities, and covered with secondary papillæ. Their epithelial investment is very thin.

The *papillæ minimæ* (conicæ or filiformes) cover the anterior two-thirds of the dorsum of the tongue. They are very minute, more or less conical or filiform in shape, and arranged in lines corresponding in direction with the two rows of the papillæ circumvallatæ, excepting at the apex of the organ, where their direction

[1] *Journal of Anat. and Physiol.*, 1891.

is transverse. Projecting from their apices are numerous filiform processes or secondary papillæ; these are of a whitish tint, owing to the thickness and density of the epithelium of which they are composed, and which has here undergone a peculiar modification, the cells having become cornified and elongated into dense, imbricated, brush-like processes. They contain also a number of elastic fibres, which render them firmer and more elastic than the papillæ of mucous membrane generally.

FIG. 430.—Circumvallate papillæ of tongue of rabbit, showing position of taste-goblets. (Stöhr.) *n.* Duct of gland. *d.* Serous gland. *g.* Taste-buds. *l.* Primary septa, and *l'.* secondary septa, of papillæ. *n.* Medullated nerve. *M.* Muscular fibres.

Simple papillæ, similar to those of the skin, cover the whole of the mucous membrane of the tongue, as well as the larger papillæ. They consist of closely set, microscopic elevations of the corium, containing a papillary loop, covered by a layer of epithelium.

Structure of the Papillæ.—The papillæ apparently resemble in structure those of the cutis, consisting of a cone-shaped projection of connective tissue, covered with a thick layer of squamous epithelium, and contain one or more capillary loops, amongst which nerves are distributed in great abundance. If the epithelium is removed, it will be found that they are not simple elevations like the papillæ of the skin, for the surface of each is studded with minute conical processes of the mucous membrane, which form secondary papillæ (Todd and Bowman). In the papillæ circumvallatæ the nerves are numerous and of large size; in the papillæ fungiformes they are also numerous, and terminate in a plexiform network, from which brush-like branches proceed; in the papillæ filiformes their mode of termination is uncertain. Buried in the epidermis of the papillæ circumvallatæ, and in some of the fungiformes, are certain peculiar bodies, called *taste-buds.*[1] They are flask-like in shape, their broad base resting on the corium, and their neck opening by an orifice, the *gustatory pore*, between the cells of the epithelium. They are formed by two kinds of cells; supporting cells and gustatory cells. The *supporting cells* are mostly arranged like the staves of a cask, and form an outer envelope for the bud. Some, however, are found in the interior of the bud between the gustatory cells. The *gustatory cells* occupy the central portion of the bud; they are spindle-shaped, and each possesses a large spherical nucleus near the middle of the cell. The peripheral end of the cell terminates at the gustatory pore in a fine, hair-like filament, the *gustatory hair*. The central process passes toward the deep extremity of the bud, and there ends in a single or bifurcated varicose filament, which was formerly supposed to be continuous with the terminal fibril of a nerve; the investigations of Lenhossék and others would seem to prove, however, that this is not so, but that the nerve-fibrils after losing their medullary sheaths enter the taste-bud, and terminate in a fine extremity between the gustatory cells. Other nerve-fibrils may be seen ramifying between the cortical cells and terminating in fine extremities; these, however, are believed to be nerves of ordinary sensation, and not gustatory.

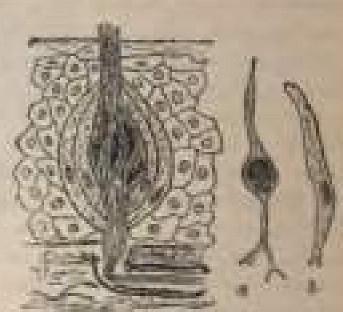


FIG. 431.—Taste-buds. *a.* Supporting cells. *b.* Gustatory cell.

[1] These bodies are also found in considerable numbers at the side of the base of the tongue, just in front of the anterior pillars of the fauces, and also on the posterior surface of the epiglottis and anterior surface of the soft palate.

Glands of the Tongue.—The tongue is provided with mucous and serous glands.

The *mucous glands* are similar in structure to the labial and buccal glands. They are found especially at the back part, behind the circumvallate papillæ, but are also present at the apex and marginal parts. In connection with these glands a special one has been described by Blandin or Nuhn. It is situated near the apex of the tongue on either side of the frænum, and is covered over by a

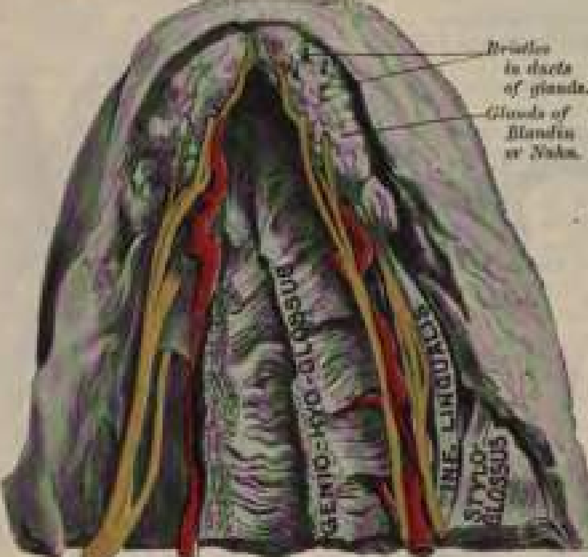


Fig. 492.—Under surface of tongue, showing position and relations of gland of Blandin or Nuhn. (From a preparation in the Museum of the Royal College of Surgeons of England.)

fasciculus of muscular fibre derived from the Stylo-glossus and Inferior lingualis. It is from half an inch to nearly an inch long and about the third of an inch broad. It has from four to six ducts, which open on the under surface of the apex.

The *serous glands* occur only at the back of the tongue in the neighborhood of the taste-buds, their ducts opening for the most part into the fossæ of the circumvallate papillæ. These glands are racemose, the duct branching into several minute ducts, which terminate in alveoli lined by a single layer of more or less columnar epithelium. Their secretion is of a watery nature, and probably assists in the distribution of the substance to be tasted over the taste-area (Ebner).

The *fibrous septum* consists of a vertical layer of fibrous tissue, extending throughout the entire length of the middle line of the tongue, from the base to the apex, though not quite reaching the dorsum. It is thicker behind than in front, and occasionally contains a small fibro-cartilage about a quarter of an inch in length. It is well displayed by making a vertical section across the organ.

The **Hyo-glossal membrane** is a strong fibrous lamina which connects the under surface of the base of the tongue to the body of the hyoid bone. This membrane receives, in front, some of the fibres of the Genio-hyo-glossi.

Vessels of the Tongue.—The *arteries of the tongue* are derived from the lingual, the facial, and ascending pharyngeal. The *veins* open into the internal jugular.

Muscles of the Tongue.—The muscular fibres of the tongue run in various directions. These fibres are divided into two sets, Extrinsic and Intrinsic, which have already been described (page 325).

The *lymphatic vessels from the tongue* pass to one or two small glands situated on the Hyo-glossus muscle in the submaxillary region, and thence to the deep glands of the neck.

The *nerves of the tongue* are five in number in each half: the lingual branch of the fifth, which is distributed to the papillæ at the fore part and sides of the tongue, and forms the nerve of ordinary sensibility for its anterior two-thirds; the chorda tympani, which runs in the sheath of the lingual, is generally regarded as

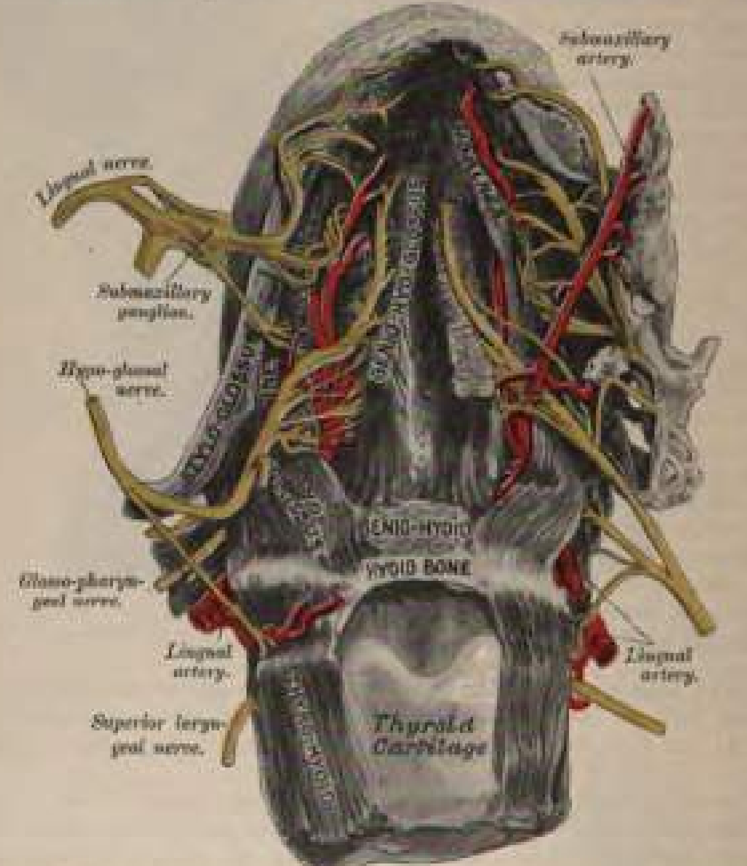


FIG. [illegible].—Undersurface of tongue, showing the distribution of nerves to this organ. (From a preparation in the Museum of the Royal College of Surgeons of England.)

the nerve of taste for the same area; the lingual branch of the glosso-pharyngeal, which is distributed to the mucous membrane at the base and sides of the tongue, and to the papillæ circumvallatæ, and which supplies both sensory and gustatory filaments to this region; the hypo-glossal nerve, which is the motor nerve to the muscular substance of the tongue; and the superior laryngeal, which sends some fine branches to the root near to the epiglottis. Sympathetic filaments also pass to the tongue from the nervi molles on the lingual and other arteries supplying it.

Surgical Anatomy.—The diseases to which the tongue is liable are numerous, and its surgical anatomy of importance, since any or all the structures of which it is composed—muscles, connective tissue, mucous membrane, glands, vessels, nerves, and lymphatics—may be the seat of morbid changes. It is not often the seat of congenital defects, though a few cases of vertical cleft have been recorded, and it is occasionally, though much more rarely than is commonly supposed, the seat of "tongue-tie," from shortness of the frænum. (See page 489.)

There is, however, one condition which must be regarded as congenital, though it does not sometimes evidence itself until a year or two after birth, which is not uncommon. This is an enlargement of the tongue which is due primarily to a dilatation of the lymph-channels and a greatly increased development of the lymphatic tissue throughout the tongue. This is often aggravated by inflammatory changes induced by injury or exposure, and the tongue may assume enormous dimensions and hang out of the mouth, giving the child an imbecile expression. The treatment consists in excising a **V**-shaped portion and bringing the cut surfaces together with deeply-placed silver sutures. Compression has been resorted to in some cases and with success, but it is difficult to apply. Acute inflammation of the tongue, which may be caused by injury and the introduction of some septic or irritating matter, is attended by great swelling from infiltration of its connective tissue, which is in considerable quantity. This renders the patient incapable of swallowing or speaking, and may seriously impede respiration. It may run on to suppuration and the formation of an acute abscess. Chronic abscess, which has been mistaken for cancer, may also occur in the substance of the tongue.

The mucous membrane of the tongue may become chronically inflamed, and presents different appearances in different stages of the disease, to which the terms leucoplakia, psoriasis, and ichthyosis have been given.

The tongue, being very vascular, is often the seat of nævoid growths, and these have a tendency to grow rapidly.

The tongue is frequently the seat of ulceration, which may arise from many causes, as from the irritation of jagged teeth, dyspepsia, tubercle, syphilis, and cancer. Of these the cancerous ulcer is the most important, and probably also the most common. The variety is the squamous epithelioma, which soon develops into an ulcer with an indurated base. It produces great pain, which speedily extends to all parts supplied with sensation by the fifth nerve, especially to the region of the ear. The pain in these cases is conducted to the ear and temporal region by the lingual nerve, and from it to the other branches of the inferior maxillary nerve, especially the auriculo-temporal. Possibly pain in the ear itself may be due to implication of the fibres of the glosso-pharyngeal nerve, which by its tympanic branch is conducted to the tympanic plexus.

Cancer of the tongue may necessitate removal of a part or the whole of the organ, and many different methods have been adopted for its excision. It may be removed from the mouth by the écraseur or the scissors. Probably the better method is by the scissors, usually known as Whitehead's method. The mouth is widely opened with a gag, the tongue transfixed with a stout silk ligature, by which to hold and make traction on it and the reflection of mucous membrane from the tongue to the jaw, and the insertion of the Genio-hyo-glossus first divided with a pair of curved blunt scissors. The Palato-glossus is also divided. The tongue can now be pulled well out of the mouth. The base of the tongue is cut through by a series of short snips, each bleeding vessel being dealt with as soon as divided, until the situation of the ranine artery is reached. The remaining undivided portion of tissue is to be seized with a pair of Wells's forceps, the tongue removed, and the vessel secured. In the event of the ranine artery being accidentally injured hæmorrhage can be at once controlled by passing two fingers over the dorsum of the tongue as far as the epiglottis and dragging the root of the tongue forcibly forward.

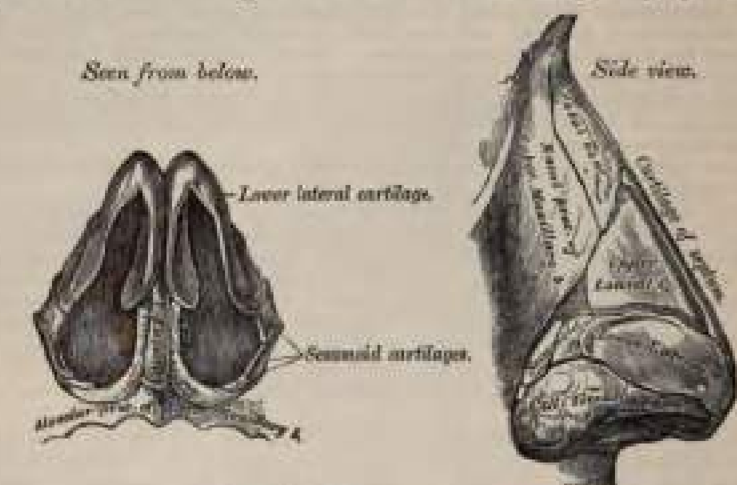
In cases where the disease is confined to one side of the tongue this operation may be modified by splitting the tongue down the centre and removing only the affected half. In cases where the submaxillary glands are involved Kocher's operation should be performed. He removes the tongue from the neck, having performed a preliminary tracheotomy, by an incision from near the lobule of the ear, down the anterior border of the Sterno-mastoid to the level of the great cornu of the hyoid bone, then forward to the body of the hyoid bone, and upward to near the symphysis of the jaw. The lingual artery is now secured, and by a careful dissection the submaxillary lymphatic glands and the tongue removed. Regnoli advocated the removal of the tongue by a semilunar incision in the submaxillary triangle along the line of the lower jaw, and a vertical incision from the centre of the semilunar one backward to the hyoid bone. Care must be taken not to carry the first incision too far backward, so as to wound the facial arteries. The tongue is thus reached through the floor of the mouth, pulled out through the external incision, and removed with the écraseur or knife. The great objection to this operation is that all the muscles which raise the hyoid bone and larynx are divided, and that therefore the movements of deglutition and respiration are interfered with.

Finally, where both sides of the floor of the mouth are involved in the disease, or where very free access is required on account of the extension backward of the disease to the pillars of the fauces and the tonsil, or where the lower jaw is involved, the operation recommended by Syme must be performed. This is done by an incision through the central line of the lip, across the chin, and down as far as the hyoid bone. The lower jaw is sawn through at the symphysis, and the two halves of the bone forcibly separated from each other. The mucous membrane is separated from the bone, and the Genio-hyo-glossi detached from the bone, and the Hyo-glossi divided. The tongue is then drawn forward and removed close to its attachment to the hyoid bone. Any glands which are enlarged can be removed, and if the bone is implicated in the disease, it can also be removed by freeing it from the soft parts externally and internally, and making a second section with the saw beyond the diseased part.

Formerly many surgeons before removing the tongue performed a preliminary tracheotomy: (1) to prevent blood entering the air-passages; and (2) to allow the patient to breathe through the tube and not inspire air which had passed over a sloughy wound, and which was loaded with septic organisms and likely to induce septic pneumonia. By the judicious use of iodoform this secondary evil may be obviated, and the preliminary tracheotomy is now usually dispensed with.

THE NOSE.

The nose is the peripheral organ of the sense of smell: by means of the peculiar properties of its nerves it protects the lungs from the inhalation of deleterious gases and assists the organ of taste in discriminating the properties of food.



FIGS. 434, 435.—Cartilages of the nose.

The organ of smell consists of two parts: one external, the *outer nose;* the other internal, the *nasal fossæ.*

The *outer nose* (nasus externus) is the more anterior and prominent part of the organ of smell. Of a triangular form, it is directed downward, and projects from the centre of the face, immediately above the upper lip. Its summit, or *root*, is connected directly with the forehead. Its inferior part, or *base*, presents two elliptical orifices, the nostrils or anterior nares, separated from each other by an antero-posterior septum, the *columna.* The margins of these orifices are provided with a number of stiff hairs, or *vibrissæ*, which arrest the passage of foreign substances carried with the current of air intended for respiration. The lateral surfaces of the nose form, by their union in the middle line, the *dorsum*, the direction of which varies considerably in different individuals. The lateral surface terminates below in a rounded eminence, the *ala nasi.*

The nose is composed of a framework of bones and cartilages, the latter being slightly acted upon by certain muscles. It is covered externally by the integument, internally by mucous membrane, and supplied with vessels and nerves.

The *bony framework* occupies the upper part of the organ: it consists of the nasal bones and the nasal processes of the superior maxillary.

The *cartilaginous framework* consists of five pieces, the two upper and the two lower lateral cartilages and the cartilage of the septum.

The *upper lateral cartilages* are situated below the free margin of the nasal bones; each cartilage is flattened and triangular in shape. Its anterior margin is thicker than the posterior, and continuous with the cartilage of the septum. Its posterior margin is attached to the nasal process of the superior maxillary and nasal bones. Its inferior margin is connected by fibrous tissue with the lower lateral cartilage; one surface is turned outward, the other inward toward the nasal cavity.

The *lower lateral cartilages* are two thin, flexible plates situated immediately below the preceding, and bent upon themselves in such a manner as to form the inner and outer walls of each orifice of the nostril. The portion which forms the inner wall, thicker than the rest, is loosely connected with the same part of the opposite cartilage, and forms a small part of the columna. Its inferior border, free, rounded, and projecting, forms, with the thickened integument and subjacent tissue and the corresponding parts of the opposite side, the septum mobile nasi. The part which forms the outer wall is curved to correspond with the ala of the nose; it is oval and flattened, narrow behind, where it is connected with the nasal process of the superior maxilla by a tough fibrous membrane, in which are found three or four small cartilaginous plates (sesamoid cartilages—*cartilagines minores*). Above, it is connected by fibrous tissue to the upper lateral cartilage and front part of the cartilage of the septum; below, it falls short of the margin of the nostril; the ala being formed by dense cellular tissue covered by skin. In front the lower lateral cartilages are separated by a notch which corresponds with the point of the nose.

The *cartilage of the septum* is somewhat quadrilateral in form, thicker at its margins than at its centre, and completes the separation between the nasal fossæ in front. Its anterior margin, thickest above, is connected with the nasal bones, and is continuous with the anterior margins of the two upper lateral cartilages. Below, it is connected to the inner portions of the lower lateral cartilages by fibrous tissue. Its posterior margin is connected with the perpendicular lamella of the ethmoid; its inferior margin with the vomer and the palate processes of the superior maxillary bones.

Fig. 436.—Bones and cartilages of septum of nose. Right side.

It may be prolonged backward (especially in children) for some distance between the vomer and perpendicular plate of the ethmoid, forming what is termed the *processus sphenoidalis*. The septal cartilage does not reach as far as the lowest part of the nasal septum. This is formed by the inner portions of the lower lateral cartilages and by the skin; it is freely movable, and hence is termed the *septum mobile nasi*.

These various cartilages are connected to each other and to the bones by a tough fibrous membrane, which allows the utmost facility of movement between them.

The *muscles of the nose* are situated beneath the integument: they are (on each side) the Pyramidalis nasi, the Levator labii superioris alæque nasi, the Dilatator naris, anterior and posterior, the Compressor nasi, the Compressor narium minor, and the depressor alæ nasi. They have been described above (page 306).

The *integument* covering the dorsum and sides of the nose is thin, and loosely connected with the subjacent parts: but where it forms the tip and the alæ of the nose it is thicker and more firmly adherent, and is furnished with a large number of sebaceous follicles, the orifices of which are usually very distinct.

The *mucous membrane* lining the interior of the nose is continuous with the skin externally and with that which lines the nasal fossæ within.

The *arteries of the nose* are the lateralis nasi from the facial, and the inferior artery of the septum from the superior coronary, which supply the alæ and septum, the sides and dorsum being supplied from the nasal branch of the ophthalmic and the infra-orbital.

The *veins of the nose* terminate in the facial and ophthalmic.

The *nerves* for the muscles of the nose are derived from the facial, while the skin receives its branches from the infra-orbital, infratrochlear, and nasal branches of the ophthalmic.

Nasal Fossæ.

The nasal fossæ are two irregular cavities situated in the middle of the face, and extending from before backward. They open in front by the two anterior nares, and terminate, behind, by the posterior nares in the naso-pharynx. The *anterior nares* are somewhat pear-shaped apertures, each measuring about one inch antero-posteriorly and half an inch transversely at their widest part. The *posterior nares* are two oval openings, which are smaller in the living or recent subject than in the skeleton, because they are narrowed by the mucous membrane. Each measures an inch in the vertical, and half an inch in the transverse direction in a well-developed adult skull.

For the description of the bony boundaries of the nasal fossæ see section on Osteology.

Inside the aperture of the nostril is a slight dilatation, the *vestibule*, which extends as a small pouch, the *ventricle*, toward the point of the nose. The fossa, above and behind the vestibule, has been divided into two parts: an *olfactory* portion, consisting of the upper and central part of the septum and probably the superior turbinated bone, and a *respiratory* portion, which comprises the rest of the fossa.

Outer Wall.—The sphenoidal air sinus opens into the *spheno-ethmoidal recess*, a narrow recess above the superior turbinated bone. The posterior ethmoidal cells open into the front and upper part of the superior meatus. On raising or cutting away the middle turbinated bone the outer wall of the middle meatus is fully exposed, and presents (1) a rounded elevation, termed the *bulla ethmoidalis*, opening on or immediately above which are the orifices of the middle ethmoidal cells; (2) a deep, narrow, curved groove, in front of the bulla ethmoidalis, termed the *hiatus semilunaris*, into which the anterior ethmoidal cells and the antrum of Highmore open, the orifice of the latter being placed near the level of its roof. The middle meatus is prolonged, above and in front, into the *infundibulum*, which leads into the frontal sinus. The anterior extremity of the meatus is continued into a depressed area, which lies above the vestibule and is named the *atrium*. The *nasal duct* opens into the anterior part of the inferior meatus, the opening being frequently overlapped by a fold of mucous membrane.

The inner wall or septum is frequently more or less deflected from the mesial plane, thus limiting the size of one fossa and increasing that of the other. Ridges or spurs of bone growing outward from the septum are also sometimes present. Immediately over the incisive foramen at the lower edge of the cartilage of the septum a depression, the *naso-palatine recess*, may be seen. In the septum close to this recess a minute orifice may be discerned: it leads into a blind pouch, the rudimentary *organ of Jacobson*, which is well developed in some of the lower animals, and is supported by a plate of cartilage, the *cartilage of Jacobson*.

The *mucous membrane* lining the nasal fossæ is called the *pituitary*, from the nature of its secretion; or *Schneiderian*, from Schneider, the first anatomist who showed that the secretion proceeded from the mucous membrane, and not, as was formerly imagined, from the brain. It is intimately adherent to the periosteum or perichondrium, over which it lies. It is continuous externally with the skin through the anterior nares, and with the mucous membrane of the naso-pharynx through the posterior nares. From the nasal fossæ its continuity may be traced with the conjunctiva through the nasal duct and lachrymal canals; with the lining membrane of the tympanum and mastoid cells through the Eustachian tube; and with the frontal, ethmoidal, and sphenoidal sinuses, and the antrum of Highmore through the several openings in the meatuses. The mucous membrane is thickest and most vascular over the turbinated bones. It is also thick over the septum, but in the intervals between the spongy bones and on the floor of the nasal fossæ it is very thin. Where it lines the various sinuses and the antrum of Highmore it is thin and pale.

Owing to the great thickness of this membrane, the nasal fossæ are much narrower, and the turbinated bones, especially the lower ones, appear larger and more prominent than in the skeleton. From the same circumstance also the various apertures communicating with the meatuses are considerably narrowed or completely closed.

The vestibule is lined by modified skin, and contains hairs or vibrissæ which guard the entrance of the nostril.

Structure of the Mucous Membrane.—The epithelium covering the mucous membrane differs in its character according to the functions of the part of the nose in which it is found. In the respiratory portion of the nasal cavity the epithelium is columnar and ciliated. Interspersed among the columnar ciliated cells are goblet or mucin cells, while between their bases are found smaller pyramidal cells. In this region, beneath the epithelium and its basement membrane, is a fibrous

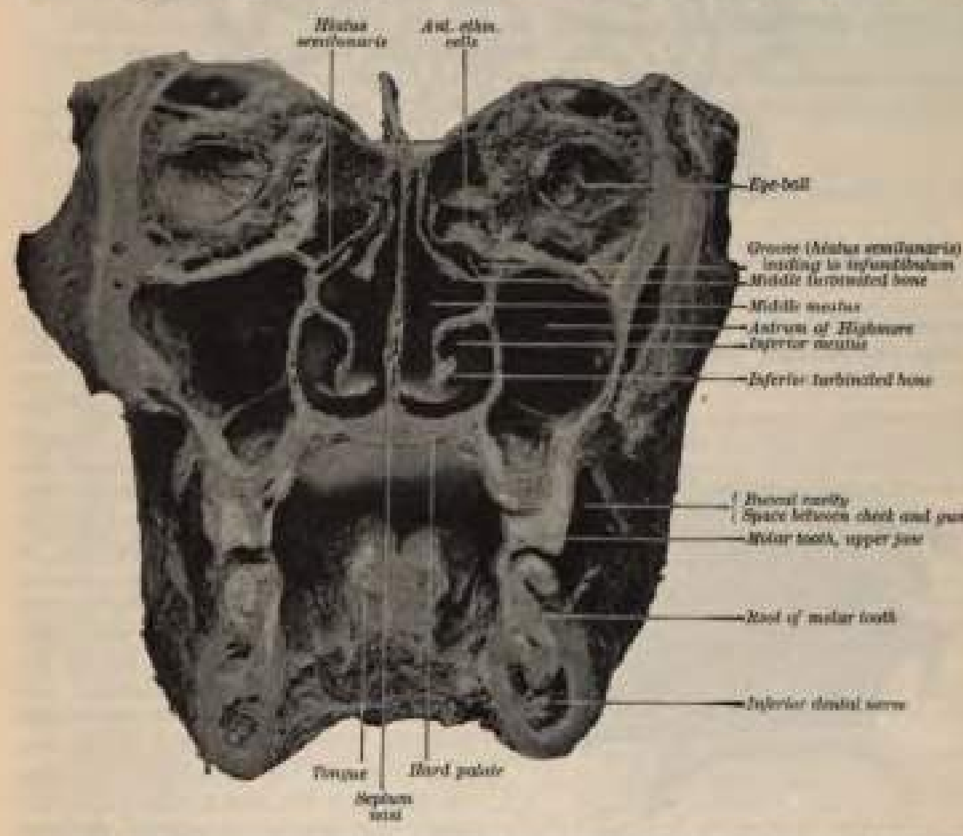


FIG. [illegible].—Transverse vertical section of the nasal fossæ. The section is made anterior to the superior turbinated bones. (Cryer.)

layer infiltrated with lymph-corpuscles, so as to form in many parts a diffuse adenoid tissue, and beneath this a nearly continuous layer of smaller and larger glands, some mucous and some serous, the ducts of which open upon the surface. In the olfactory region the mucous membrane is yellowish in color and the epithelial cells are columnar and non-ciliated; they are of two kinds, supporting cells and olfactory cells. The *supporting cells* contain oval nuclei, situated in the deeper parts of the cells: the free surface of each cell presents a sharp outline, and its deep extremity is prolonged into a process which runs inward, branching to communicate with similar processes from neighboring cells, so as to form a network in the deep part of the mucous membrane. Lying between these central processes of the supporting cells are a large number of spindle-shaped cells, the *olfactory cells*, which consist of a large spherical nucleus surrounded by a small amount of granular protoplasm, and possessing two processes, of which one runs outward between the columnar epithelial cells, and projects on the surface of the

FIG. 428.—Section of the olfactory mucous membrane. (Cadiat.) a. Epithelium. b. Glands of Bowman. c. Nerve bundles.

mucous membrane as a fine, hair-like process, the *olfactory hair;* the other or deep process runs inward, is frequently beaded like a nerve-fibre, and is believed by most observers to be in connection with one of the terminal filaments of the olfactory nerve. Beneath the epithelium, extending through the thickness of the mucous membrane, is a layer of tubular, often branched, glands, the *glands of Bowman*, identical in structure with serous glands.

FIG. 429.—Nerves of septum of nose. Right side.

The *arteries of the nasal fossæ* are the anterior and posterior ethmoidal, from the ophthalmic, which supply the ethmoidal cells, frontal sinuses, and roof of the nose; the spheno-palatine, from the internal maxillary, which supplies the mucous membrane covering the spongy bones, the meatuses, and septum; the inferior artery of the septum, from the superior coronary of the facial; and the infraorbital and alveolar branches of the internal maxillary, which supply the lining membrane of the antrum. The ramifications of these vessels form a close, plexiform network, beneath and in the substance of the mucous membrane.

The *veins of the nasal fossæ* form a close, cavernous-like network beneath the mucous membrane. This cavernous appearance is especially well marked over the lower part of the septum and over the middle and inferior turbinated bones. Some of the veins pass, with those accompanying the spheno-palatine artery, through the spheno-palatine foramen; and others, through the alveolar branch, to join the facial vein; some accompany the ethmoidal arteries, and terminate in the ophthalmic vein; and, lastly, a few communicate with the veins in the interior of the skull, through the foramina in the cribriform plate of the ethmoid bone, and the foramen cæcum.

The *lymphatics* can be injected from the subdural and subarachnoid spaces, and form a plexus in the superficial portion of the mucous membrane. The lymph is drained partly into one or two glands which lie near the great cornu of the hyoid bone and partly into a gland situated in front of the axis.

The *nerves* are: the olfactory, the nasal branch of the ophthalmic, filaments from the anterior dental branch of the superior maxillary, the Vidian, the naso-palatine, descending anterior palatine, and nasal branches of Meckel's ganglion.

The *olfactory*, the special nerve of the sense of smell, is distributed to the olfactory region, already referred to (page 820).

The *nasal branch of the ophthalmic* distributes filaments to the fore part of the septum and outer wall of the nasal fossæ.

Filaments from the anterior dental branch of the superior maxillary supply the inferior meatus and inferior turbinated bone.

The *Vidian nerve* supplies the upper and back part of the septum and superior spongy bone, and the *upper anterior nasal branches* from the spheno-palatine ganglion have a similar distribution.

The *naso-palatine nerve* supplies the middle of the septum.

The *larger* or *anterior palatine nerve* supplies the *lower nasal branches* to the middle and lower spongy bones.

Surgical Anatomy.—Instances of congenital deformity of the nose are occasionally met with, such as complete absence of the nose, an aperture only being present; or perfect development on one side, and suppression or malformation on the other; or there may be imperfect apposition of the nasal bones, so that the nose presents a median cleft or furrow. Deformities which have been acquired are much more common, such as flattening of the nose, the result of syphilitic necrosis, or imperfect development of the nasal bones in cases of congenital syphilis, or a lateral deviation of the nose may result from fracture.

The skin over the alæ and tip of the nose is thick and closely adherent to subjacent parts. Inflammation of this part is therefore very painful, on account of the tension. It is largely supplied with blood, and, the circulation here being terminal, vascular engorgement is liable to occur, especially in women at the menopause and in both sexes from disorders of digestion, exposure to cold, etc. The skin of the nose also contains a large number of sebaceous follicles, and these, as the result of intemperance, are apt to become affected and the nose reddened, congested, and irregularly swollen. To this the term "grog-blossom" is popularly applied. In some of these cases there is enormous hypertrophy of the skin and subcutaneous tissues, producing pendulous masses, termed lipomata nasi. Epithelioma and rodent ulcer may attack the nose, the latter being the more common of the two. Lupus and syphilitic ulceration frequently attack the nose, and may destroy the whole of the cartilaginous portion. In fact, lupus vulgaris begins more frequently on the ala of the nose than in any other situation.

Cases of congenital occlusion of one or both nostrils, or adhesion between the ala and septum may occur, and may require immediate operation, since the obstruction much interferes with sucking. Bony closure of the posterior nares may also occur.

To examine the nasal cavities, the head should be thrown back and the nose drawn upward, the parts being dilated by some form of speculum. It can also be examined with the little finger or a probe, and in this way foreign bodies detected. A still more extensive examination can be made by Rouge's operation, which was introduced for the cure of ozæna by the removal of any dead bone which may be present in this disease. The whole framework of the nose is lifted up by an incision made inside the mouth, through the junction of the upper lip with the bone; the septum nasi and the lateral cartilages are divided with strong scissors till the anterior nares are completely exposed. The posterior nares can be explored by reflected light from the mouth, by which the posterior nares can be illuminated. The examination is very difficult to carry out, and, as a rule, sufficient information regarding the presence of foreign bodies or tumors in the naso-pharynx can be obtained by the introduction of the finger behind the soft palate through the mouth. The septum of the nose may be displaced or deviate from the middle line: this may be the result of an injury or from some congenital defect in its development; in the latter case the deviation usually occurs along the line of union of the vomer and mesethmoid, and rarely occurs before the seventh year. Sometimes the deviation may be so great that the septum may come in contact with the outer wall of the nasal fossæ, and may even become adherent to it, thus producing complete obstruction. Perforation of the septum is not an uncommon affection and may arise from several causes: syphilitic or tubercular ulceration, blood-tumor or abscess of the septum, and especially in workmen exposed to the vapor of bichromate of potash, from the irritating and corrosive action of fumes. When small, the perforation may cause a peculiar whistling sound during respiration. When large, it may lead to the falling in of the bridge of the nose.

Epistaxis is a very common affection in children. It is rarely of much consequence, and will almost always subside, but in the more violent hæmorrhages of later life it may be necessary to plug the posterior nares. In performing this operation it is desirable to remember the size of the posterior nares. A ready method of regulating the size of the plug to fit the opening is to make it of the same size as the terminal phalanx of the thumb of the patient to be operated on.

Nasal polypus is a very common disease, and presents itself in three forms: the gelatinous, the fibrous, and the malignant. The first is by far the most common. It grows from the mucous membrane of the outer wall of the nasal fossa, where there is an abundant layer of highly vascular submucous tissue; rarely from the septum, where the mucous membrane is closely adherent to the cartilage and bone, without the intervention of much, if any, submucous tissue. Their most common seat is probably the middle turbinated bone. The fibrous polypus generally grows from the base of the skull behind the posterior nares or from the roof of the nasal fossæ. The malignant polypi, both sarcomatous or carcinomatous, may arise in the nasal cavities and the naso-pharynx; or they may originate in the antrum, and protrude through its inner wall into the nasal fossa.

Rhinoliths, or nose-stones, may sometimes be found in the nasal cavities, from the formation of phosphate of lime upon either a foreign body or a piece of inspissated secretion.

THE EYE.

The eyeball is contained in the cavity of the orbit. In this situation it is securely protected from injury, whilst its position is such as to ensure the most extensive range of sight. It is acted upon by numerous muscles, by which it is capable of being directed to different parts; it is supplied by vessels and nerves, and is additionally protected in front by several appendages, such as the eyebrow, eyelids, etc.

The eyeball is imbedded in the fat of the orbit, but is surrounded by a thin membranous sac, the *capsule of Tenon*, which isolates it, so as to allow of free movement.

The **capsule of Tenon** consists of a thin membrane which envelops the eyeball from the optic nerve to the ciliary region, separating it from the orbital fat and forming a socket in which it plays. Its inner surface is smooth, and is in contact with the outer surface of the sclerotic, the *perisclerotic lymph-space* only intervening. This lymph-space is continuous with the subdural and subarachnoid spaces, and is traversed by delicate bands of connective tissue which extend between the capsule and the sclerotic. The capsule is perforated behind by the ciliary vessels and nerves and by the optic nerve, being continuous with the sheath of the latter. In front it blends with the ocular conjunctiva, and with it is attached to the ciliary region of the eyeball. It is perforated by the muscles which move the eyeball and on each it sends a tubular sheath. The sheath of the Superior oblique is carried as far as the fibrous pulley of that muscle; that on the Inferior oblique reaches as far as the floor of the orbit, to which it gives off a slip. The sheaths on the recti are gradually lost in the perimysium, but they give off important expansions. The expansion from the Superior rectus blends with the tendon of the Levator palpebræ; that of the Inferior rectus is attached to the inferior tarsal plate. These two recti, therefore, will exercise some influence on the movements of the eyelids. The expansions from the sheaths of the Internal and External recti are strong, especially the one from the latter muscle, and are attached to the lachrymal and malar bones respectively. As they probably check the action of these two recti, they have been named the *internal* and *external check ligaments*.

Lockwood has also described a thickening of the lower part of the capsule of Tenon, which he has named the *suspensory ligament of the eye*. It is slung like a hammock below the eyeball, being expanded in the centre and narrow at its extremities, which are attached to the malar and lachrymal bones respectively.[1]

The eyeball is composed of segments of two spheres of different sizes. The anterior segment is one of a small sphere, and forms about one-sixth of the eyeball. It is more prominent than the posterior segment, which is one of a much larger sphere, and forms about five-sixths of the globe. The segment of the larger sphere

[1] See a paper by C. B. Lockwood, *Journal of Anatomy and Physiology*, vol. xx., part i., p. 1.

is opaque, and formed by the sclerotic, the tunic of protection to the eyeball; the smaller sphere is transparent, and formed by the cornea. The term *anterior pole* is applied to the central point of the anterior curvature of the eyeball, and that of *posterior pole* to the central point of its posterior curvature; a line joining the two poles forms its *sagittal axis*. The axes of the eyeballs are nearly parallel, and therefore do not correspond to the axes of the orbits, which are directed outward. The optic nerves follow the direction of the axes of the orbits, and are therefore not parallel; each enters its eyeball about 1 mm. below and 3 mm. to the inner or nasal side of the posterior pole. The eyeball measures rather more in its transverse and antero-posterior diameters than in its vertical diameter, the former amounting to nearly an inch, the latter to about nine-tenths of an inch.

The eyeball is composed of three investing tunics and of three refracting media.

TUNICS OF THE EYE.

From without inward the three tunics are:

1. Sclerotic and Cornea.
2. Choroid, Ciliary Body, and Iris.
3. Retina.

I. The Sclerotic and Cornea.

The sclerotic and cornea (Fig. 440) form the external tunic of the eyeball; they are essentially fibrous in structure, the sclerotic being opaque, and forming the posterior five-sixths of the globe; the cornea, which forms the remaining sixth, being transparent.

The **Sclerotic** (σκληρός, *hard*) has received its name from its extreme density and hardness; it is a firm, unyielding, fibrous membrane, serving to maintain the form of the globe. It is much thicker behind than in front. Its *external surface* is of a white color, and is in contact with the inner surface of the capsule of Tenon; it is quite smooth, except at the points where the Recti and Obliqui muscles are inserted into it, and its anterior part is covered by the conjunctival membrane: hence the whiteness and brilliancy of the front of the eyeball. Its *inner surface* is stained of a brown color, marked by grooves, in which are lodged the ciliary nerves and vessels; this is loosely connected by an exceedingly fine cellular tissue (*lamina fusca*) with the outer surface of the choroid, an extensive lymph-space (*perichoroidal*) intervening between the sclerotic and choroid. Behind it is pierced by the optic nerve, and is continuous with its fibrous sheath, which is derived from the dura mater. At the point where the optic nerve passes through the sclerotic, this tunic forms a thin cribriform lamina (the *lamina cribrosa*); the minute orifices in this region serve for the transmission of the nervous filaments, and the fibrous septa dividing them from one another are continuous with the membranous processes which separate the bundles of nerve-fibres. One of these openings, larger than the rest, occupies the centre of the lamella; it transmits the arteria centralis retinæ to the interior of the eyeball. Around the cribriform lamella are numerous small apertures for the transmission of the ciliary vessels and nerves, and about midway between the margin of the cornea and the entrance of the optic nerve are four or five large apertures, for the transmission of veins (*venæ vorticosæ*). In front, the fibrous tissue of the sclerotic is directly continuous with that of the cornea by direct continuity of tissue, but the opaque sclerotic slightly overlaps the outer surface of the transparent cornea.

Structure.—The sclerotic is formed of white fibrous tissue intermixed with fine elastic fibres, and of flattened connective-tissue corpuscles, some of which are pigmented, contained in cell-spaces between the fibres. These fibres are aggregated into bundles, which are arranged chiefly in a longitudinal direction. It yields gelatin on boiling. Its vessels are not numerous, the capillaries being of small size, uniting at long and wide intervals. Its nerves are derived from the ciliary nerves, but their exact mode of ending is not known.

The **Cornea** is the projecting transparent part of the external tunic of the eyeball, and forms the anterior sixth of the globe. It is almost circular in shape, occasionally a little broader in the transverse than in the vertical direction. It is convex anteriorly, and projects forward from the sclerotic in the same manner that a watch-glass does from its case. Its degree of curvature varies in different individuals, and in the same individual at different periods of life, it being more prominent in youth than in advanced life, when it becomes flattened. The cornea is dense and of uniform thickness throughout; its posterior surface is perfectly circular in outline, and exceeds the anterior surface slightly in extent, from the latter being overlapped by the sclerotic.

Structure.—The cornea consists of four layers—namely, (1) several strata of epithelial cells, continuous with those of the conjunctiva; (2) a thick central

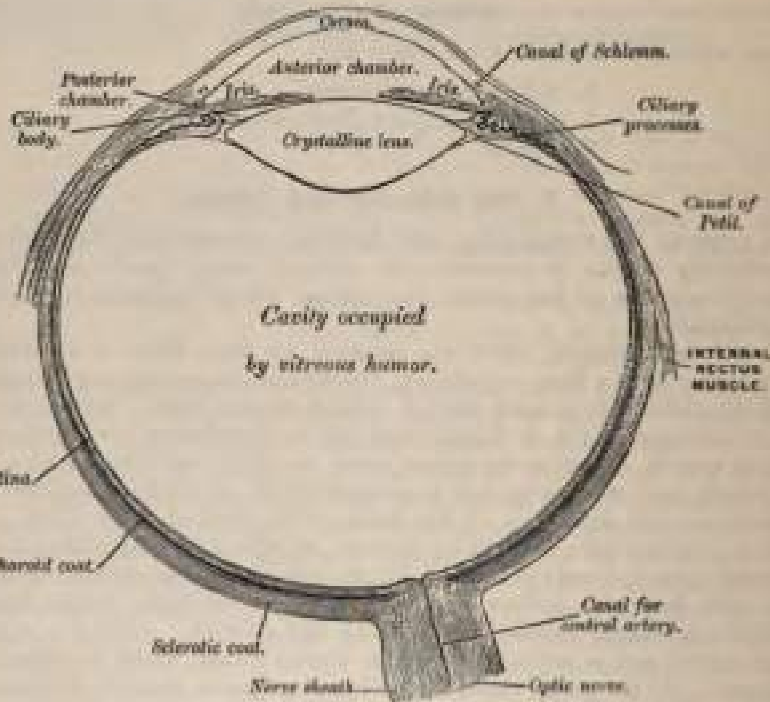


Fig. 440.—A horizontal section of the eyeball. (Allen.)

fibrous structure, the *substantia propria*; (3) a homogeneous elastic lamina; and (4) a single layer of endothelial cells forming part of the lining membrane of the anterior chamber of the eyeball.

The *conjunctival epithelium*, which covers the front of the cornea proper, consists of several strata of epithelial cells. The deepest layers are columnar; then follow two or three layers of polyhedral cells, the majority of which present finger-like processes (*i. e.*, prickle-cells), similar to those found in the cuticle. Lastly, there are three or four layers of scaly epithelium with flattened nuclei.

The *proper substance of the cornea* is fibrous, tough, unyielding, perfectly transparent, and continuous with the sclerotic. It is composed of about sixty flattened lamellæ, superimposed one on another. These lamellæ are made up of bundles of modified connective tissue, the fibres of which are directly continuous with the fibres of the sclerotic. The fibres of each lamella are for the most part parallel with each other; those of alternating lamellæ at right angles to each other. Fibres, however, frequently pass from one lamella to the next.

The lamellæ are connected with each other by an interstitial cement-substance, in which are spaces, the *corneal spaces.* The spaces are stellate in shape, and have numerous offsets by which they communicate with each other. Each contains a cell, the *corneal corpuscle,* which resembles in form the space in which it is lodged, but it does not entirely fill it.

Immediately beneath the conjunctival epithelium the cornea proper presents certain characteristics which have led some anatomists to regard it as a distinct membrane, and it has been named by Bowman the *anterior elastic lamina.* It differs, however, from the true elastic lamina or membrane of Descemet in many essential particulars, presenting evidence of fibrillar structure, and not having the same tendency to curl inward or to undergo fracture when detached from the other layers of the cornea. It consists of extremely closely interwoven fibrils, similar to those found in the rest of the cornea proper, but contains no corneal corpuscles. It ought, therefore, to be regarded as a part of the proper tissue of the cornea.[1]

The *posterior elastic lamina* (*membrane of Descemet or Demours*), which covers the proper structure of the cornea behind, presents no structure recognizable under the microscope. It consists of an elastic, and perfectly transparent homogeneous membrane, of extreme thinness, which is not rendered opaque by either water, alcohol, or acids. It is very brittle, but its most remarkable property is its extreme elasticity, and the tendency which it presents to curl up, or roll upon itself, with the attached surface innermost, when separated from the proper substance of the cornea. Its use appears to be (as suggested by Dr. Jacob) "to preserve the requisite permanent correct curvature of the flaccid cornea proper."

At the margin of the cornea this posterior elastic membrane breaks up into fibres to form a reticular structure at the outer angle of the anterior chamber, the intervals between the fibres forming small cavernous spaces, the *spaces of Fontana.* These little recesses communicate with a circular canal in the substance of the sclerotic close to its junction with the cornea. This is the *canal of Schlemm,* or *sinus venosus scleræ;* it communicates internally with the anterior chamber through the spaces of Fontana, and externally with the scleral veins. Some of the fibres of this reticulated structure are continued into the front of the iris, forming the *ligamentum pectinatum iridis;* while others are connected with the fore part of the sclerotic and choroid.

The *endothelial lining of the aqueous chamber* covers the posterior surface of the elastic lamina, is reflected on to the front of the iris, and also lines the spaces of Fontana. It consists of a single layer of polygonal flattened transparent nucleated cells, similar to those lining other serous cavities.

Arteries and Nerves.—The cornea is a non-vascular structure, the capillary vessels terminating in loops at its circumference. Lymphatic vessels have not as yet been demonstrated in it, but are represented by the channels in which the bundles of nerves run; these are lined by an endothelium and are continuous with the cell-spaces. The nerves are numerous, twenty-four to thirty-six in number (Kölliker), forty to forty-five (Waldeyer and Sämisch); they are derived from the ciliary nerves and enter the laminated tissue of the cornea. They ramify throughout its substance in a delicate network, and their terminal filaments form a firm and closer plexus on the surface of the cornea proper beneath the epithelium. This is termed the *subepithelial plexus,* and from it fibrils are given off which ramify between the epithelial cells, forming a network which is termed the *intra-epithelial plexus.*

Dissection.—In order to separate the sclerotic and cornea, so as to expose the second tunic, the eyeball should be immersed in a small vessel of water and held between the finger and thumb. The sclerotic is then carefully incised, in the equator of the globe, till the choroid is exposed. One blade of a pair of probe-pointed scissors is now introduced through the opening thus made, and the sclerotic divided around its entire circumference, and removed in separate portions. The front segment being then drawn forward, the handle of the scalpel should be pressed gently against it at its connection with the iris, and, these being separated, a quantity

[1] This layer has been called by Reichert the "anterior limiting layer"—a name which appears more applicable to it than that of "anterior elastic lamina."

of perfectly transparent fluid will escape; this is the aqueous humor. In the course of the dissection the ciliary nerves may be seen lying in the loose cellular tissue between the choroid and sclerotic or contained in delicate grooves on the inner surface of the latter membrane.

II. The Choroid, Ciliary Body, and Iris.

The Second Tunic of the Eye (*tunica vasculosa oculi*) is formed from behind forward by the choroid, the ciliary body, and the iris.

The choroid is the vascular and pigmentary tunic of the eyeball, investing the posterior five-sixths of the globe, and extending as far forward as the ora serrata of the retina; the ciliary body connects the choroid to the circumference of the iris. The iris is the circular muscular septum, which hangs vertically behind the cornea, presenting in its centre a large rounded aperture, the *pupil*.

The **Choroid** is a thin, highly vascular membrane, of a dark-brown or chocolate color, which invests the posterior five-sixths of the globe, and is pierced behind by the optic nerve, and in this situation is firmly adherent to the sclerotic. It is thicker behind than in front. Externally, it is loosely connected by the lamina fusca with the inner surface of the sclerotic. Its inner surface is attached to the retina.

Fig. 441.—The choroid and iris. (Enlarged.)

Structure.—The choroid consists mainly of a dense capillary plexus and of small arteries and veins, carrying the blood to and returning it from this plexus. On its external surface—*i. e.*, the surface next the sclerotic—is a thin membrane, the *lamina suprachoroidea*, composed of delicate non-vascular lamellæ, each lamella consisting of a network of fine elastic fibres, among which are branched pigment-cells. The spaces between the lamellæ are lined by endothelium, and open freely into the perichoroidal lymph-space, which, in its turn, communicates with the perisclerotic space by the perforations in the sclerotic through which the vessels and nerves are transmitted.

Internal to this is the *choroid proper*, and, in consequence of the small arteries and veins being arranged on the outer surface of the capillary network, it is customary to describe this as consisting of two layers: the outermost, composed of small arteries and veins, with pigment-cells interspersed between them, and the inner, consisting of a capillary plexus. The *external layer* or *lamina vasculosa* consists, in part, of the larger branches of the short ciliary arteries which run forward between the veins, before they bend inward to terminate in the capillaries; but is formed principally of veins, which are named, from their arrangement, *venæ vorticosæ*. They converge to four or five equidistant trunks, which pierce the sclerotic midway between the margin of the cornea and the entrance of the optic nerve. Interspersed between the vessels are dark star-shaped pigment-cells, the offsets from which, communicating with similar branchings from neighboring cells, form a delicate network or stroma, which toward the inner surface of the choroid loses its pigmentary character. The *internal layer* consists of an exceedingly fine capillary plexus, formed by the short ciliary vessels, and is known as the *lamina chorio-capillaris* or *tunica Ruyschiana*. The network is close, and finer at the hinder part of the choroid than in front. About half an inch behind the cornea its meshes become larger, and are continuous with those of the ciliary processes.

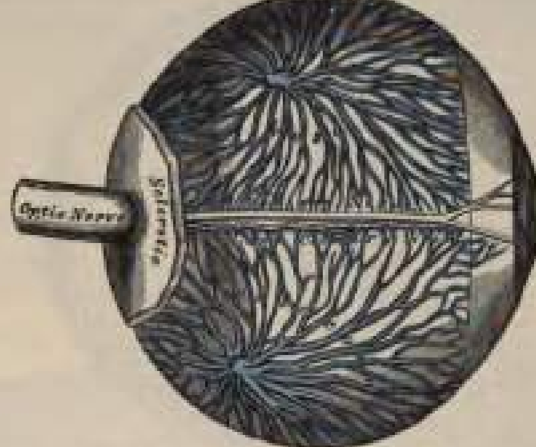


FIG. 442.—The veins of the choroid. (Enlarged.)

These two laminæ are connected by an *intermediate stratum*, which is destitute of pigment-cells and consists of fine elastic fibres. On the inner surface of the lamina chorio-capillaris is a very thin, structureless, or, according to Kölliker, faintly fibrous membrane, called the *lamina basalis* or membrane of Bruch; it is closely connected with the stroma of the choroid, and separates it from the pigmentary layer of the retina.

Tapetum.—This name is applied to the iridescent appearance which is seen in the outer and posterior part of the choroid of many animals.

The ciliary body should now be examined. It may be exposed, either by detaching the iris from its connection with the Ciliary muscle, or by making a transverse section of the globe, and examining it from behind.

The **ciliary body** comprises the orbiculus ciliaris, the ciliary processes, and the Ciliary muscle.

The *orbiculus ciliaris* is a zone of about one-sixth of an inch in width, directly continuous with the anterior part of the choroid; it presents numerous ridges arranged in a radial manner.

The *ciliary processes* are formed by the plaiting and folding inward of the various layers of the choroid—*i. e.*, the choroid proper and the lamina basalis—at its anterior margin, and are received between corresponding foldings of the suspensory ligament of the lens, thus establishing a connection between the choroid and inner tunic of the eye. They are arranged in a circle, and form a sort of plaited frill behind the iris, round the margin of the lens. They vary between sixty and eighty in number, lie side by side, and may be divided into large and small; the latter, consisting of about one-third of the entire number, are situated in the spaces between the former, but without regular alternation. The larger processes are each about one-tenth of an inch in length, and are attached by their periphery to three or four of the ridges of the orbiculus ciliaris, and are continuous with the layers of the choroid: the opposite margin is free, and rests upon the circumference of the lens. Their anterior surface is turned toward the back of the iris, with the circumference of which they are continuous. The posterior surface is connected with the suspensory ligament of the lens.

Structure.—The ciliary processes are similar in structure to the choroid, but the vessels are larger, and have chiefly a longitudinal direction. They are covered on their inner surface by two strata of black pigment-cells, which are continued forward from the retina, and are named the *pars ciliaris retinæ*. In the stroma of the ciliary processes there are also stellate pigment-cells, which, however, are not so numerous as in the choroid itself.

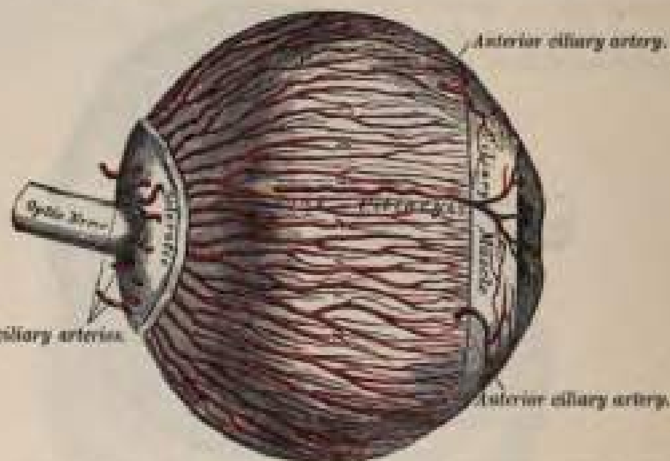


FIG. 443.—The arteries of the choroid and iris. The sclerotic has been mostly removed. (Enlarged.)

The *Ciliary muscle* (Bowman) consists of unstriped fibres: it forms a grayish, semitransparent, circular band, about one-eighth of an inch broad, on the outer surface of the fore part of the choroid. It is thickest in front, and gradually becomes thinner behind. It consists of two sets of fibres, radiating and circular. The former, much the more numerous, arise at the point of junction of the cornea and sclerotic, and partly also from the ligamentum pectinatum iridis, and, passing backward, are attached to the choroid opposite to the ciliary processes. One bundle, according to Waldeyer, is continued backward to be inserted into the sclerotic. The circular fibres are internal to the radiating ones and to some extent unconnected with them, and have a circular course around the attachment of the iris. They are sometimes called the "ring muscle" of Müller, and were formerly described as the ciliary ligament. They are well developed in hypermetropic, but are rudimentary or absent in myopic eyes. The Ciliary muscle is admitted to be the chief agent in accommodation,—*i. e.*, in adjusting the eye to the vision of near objects. Bowman believed that this was effected by its compressing the vitreous body, and so causing the lens to advance; but the view which now prevails is that the contraction of the muscle, by drawing on the ciliary processes, relaxes the suspensory ligament of the lens, thus allowing the anterior surface of the lens to become more convex. The pupil is at the same time slightly contracted.[1]

The **Iris** (*iris*, a rainbow) has received its name from its various colors in different individuals. It is a thin, circular-shaped, contractile curtain, suspended in

[1] See explanation and diagram in Power's *Illustrations of some of the Principal Diseases of the Eye*, p. 590.

the aqueous humor behind the cornea, and in front of the lens, being perforated a little to the nasal side of its centre by a circular aperture, the *pupil*, for the transmission of light. By its circumference it is continuous with the ciliary body, and is also connected with the posterior elastic lamina of the cornea by means of the pectinate ligament; its inner or free edge forms the margin of the pupil; its surfaces are flattened, and look forward and backward, the anterior toward the cornea, the posterior toward the ciliary processes and lens. The anterior surface of the iris is variously colored in different individuals, and marked by lines which converge toward the pupil. The posterior surface is of a deep purple tint, from being covered by two layers of pigmented, columnar epithelium, which are continuous posteriorly with the pars ciliaris retinæ. This pigmented epithelium is termed the *pars iridica retinæ*, though it is sometimes named *uvea*, from its resemblance in color to a ripe grape.

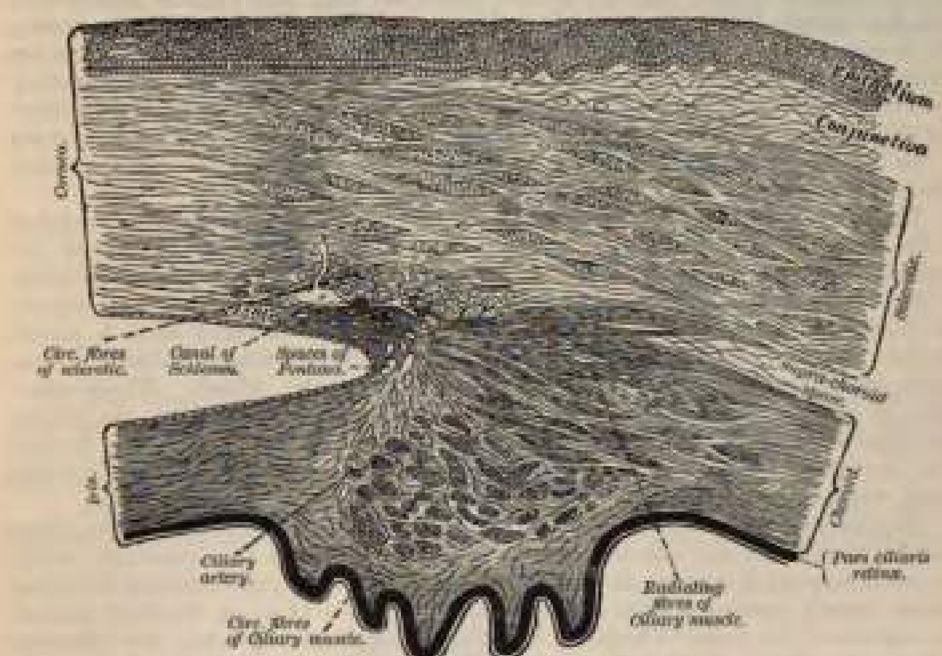


FIG. 444.—Section of the eye, showing the relations of the cornea, sclerotic, and iris, together with the Ciliary muscle and the cavernous spaces near the angle of the anterior chamber. (Waldeyer.)

Structure.—The iris is composed of the following structures:

1. In front is a layer of flattened endothelial cells placed on a delicate hyaline basement-membrane. This layer is continuous with the epithelial layer covering the membrane of Descemet, and in men with dark-colored irides the cells contain pigment-granules.

2. *Stroma.*—The stroma consists of fibres and cells. The former are made of fine, delicate bundles of fibrous tissue, of which some few fibres have a circular direction at the circumference of the iris, but the chief mass consists of fibres radiating toward the pupil. They form, by their interlacement, a delicate mesh, in which the vessels and nerves are contained. Interspersed between the bundles of connective tissue are numerous branched cells with fine processes. Many of them in dark eyes contain pigment-granules, but in blue eyes and the pink eyes of albinos they are unpigmented.

3. The *muscular fibre* is involuntary, and consists of circular and radiating fibres. The *circular fibres* (sphincter pupillæ) surround the margin of the pupil on the posterior surface of the iris, like a sphincter, forming a narrow band about one-thirtieth of an inch in width, those near the free margin being closely aggre-

gated; those more external somewhat separated, and forming less complete circles. The *radiating fibres* (dilator pupillæ) converge from the circumference toward the centre, and blend with the circular fibres near the margin of the pupil. These fibres are regarded by some as elastic, not muscular.

4. *Pigment.*—The situation of the pigment-cells differs in different irides. In the various shades of blue eyes the only pigment-cells are several layers of small round or polyhedral cells filled with dark pigment, situated on the posterior surface of the iris and continuous with the pigmentary lining of the ciliary processes. The color of the eye in these individuals is due to this coloring-matter showing more or less through the texture of the iris. In the albino even this pigment is absent. In the gray, brown, and black eye there are, as mentioned above, pigment-granules to be found in the cells of the stroma and in the epithelial layer on the front of the iris; to these the dark color of the eye is due.

The *arteries of the iris* are derived from the long and anterior ciliary and from the vessels of the ciliary processes (see page 509). The long ciliary arteries, two in number, having reached the attached margin of the iris, divide into an upper and a lower branch, and, encircling the iris, anastomose with corresponding branches from the opposite side; into this vascular zone (circulus major) the anterior ciliary pour their blood. From this zone vessels converge to the free margin of the iris, and these communicate by branches from one to another and thus form a second zone (circulus minor) in this situation.

The *nerves of the choroid and iris* are derived from the ciliary branches of the lenticular ganglion, and the long ciliary from the nasal branch of the ophthalmic division of the fifth. They pierce the sclerotic around the entrance of the optic nerve, and run forward in the perichoroidal space, and supply the blood-vessels of the choroid. After reaching the iris they form a plexus around its attached margin; from this are derived non-medullated fibres which terminate in the circular and radiating muscular fibres. Their exact mode of termination has not been ascertained. Other fibres from the plexus terminate in a network on the anterior surface of the iris. The fibres derived from the motor root of the lenticular ganglion (third nerve) supply the circular fibres, while those derived from the sympathetic supply the radiating fibres.

Membrana Pupillaris.—In the fœtus the pupil is closed by a delicate transparent vascular membrane, the *membrana pupillaris*, which divides the space into which the iris is suspended into two distinct chambers. This membrane contains numerous minute vessels, continued from the margin of the iris to those on the front part of the capsule of the lens. These vessels have a looped arrangement, and converge toward each other without anastomosing. Between the seventh and eighth months the membrane begins to disappear, by its gradual absorption from the centre toward the circumference, and at birth only a few fragments remain. It is said sometimes to remain permanent and produce blindness.

III. The Retina.

The **Retina** is a delicate nervous membrane, upon the surface of which the images of external objects are received. Its outer surface is in contact with the choroid; its inner with the vitreous body. Behind, it is continuous with the optic nerve; it gradually diminishes in thickness from behind forward; and, in front, extends nearly as far as the ciliary body, where it appears to terminate in a jagged margin, the *ora serrata*. Here the nervous tissues of the retina end, but a thin prolongation of the membrane extends forward over the back of the ciliary processes and iris, forming the *pars ciliaris retinæ* and *pars iridica retinæ*, already referred to. This forward prolongation consists of the pigmentary layer of the retina together with a stratum of columnar epithelium. The retina is soft, semi-transparent, and of a purple tint in the fresh state, owing to the presence of a coloring-material named *rhodopsin* or *visual purple*; but it soon becomes clouded, opaque, and bleached when exposed to sunlight. Exactly in the centre of the posterior part of the retina, corresponding to the axis of the eye, and at a point in which the sense of vision is most perfect, is an oval yellowish spot, called, after its discoverer, the *yellow spot* or *macula lutea* of Sömmerring, having a central depression, the *fovea centralis*. The retina in the situation of the fovea centralis is exceedingly thin, and the dark color of the choroid is distinctly seen through it; so that it presents more the appearance of a foramen, and hence the name "foramen of Sömmerring" at first given to it. It exists only in man, the quadrumana, and some saurian reptiles. About one-eighth of an inch (3 mm.) to the inner side of the yellow spot is the point of entrance of the optic nerve (*porus opticus*); here the nervous substance is slightly raised so as to form an eminence (*colliculus nervi optici*); the arteria centralis retinæ pierces its centre. This is the only part of the surface of the retina from which the power of vision is absent, and is termed the "blind spot."

Structure.—The retina is an exceedingly complex structure, and, when examined microscopically by means of sections made perpendicularly to its surface, is found to consist of ten layers, which are named from within outward, as follows:

1. Membrana limitans interna.
2. Layer of nerve-fibres (stratum opticum).
3. Ganglionic layer, consisting of nerve-cells.
4. Inner molecular, or plexiform, layer.
5. Inner nuclear layer, or layer of inner granules.
6. Outer molecular, or plexiform, layer.
7. Outer nuclear layer, or layer of outer granules.
8. Membrana limitans externa.
9. Jacob's membrane (layer of rods and cones).
10. Pigmentary layer (tapetum nigrum).

1. The *membrana limitans interna* is the most internal layer of the retina, and is in contact with the hyaloid membrane of the vitreous humor. It is derived from the supporting framework of the retina, with which tissue it will be described.

2. The *layer of nerve-fibres* is formed by the expansion of the optic nerve. This nerve passes through all the other layers of the retina, except the membrana

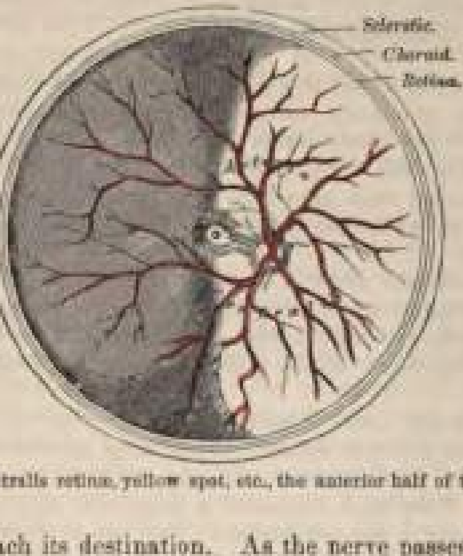


FIG. 445.—The arteria centralis retinæ, yellow spot, etc., the anterior half of the eyeball being removed. (Enlarged.)

limitans interna, to reach its destination. As the nerve passes through the lamina cribrosa of the sclerotic coat, the fibres of which it is composed lose their medullary sheaths and are continued onward, through the choroid and retina, as simple axis-cylinders. When these non-medullated fibres reach the internal surface of the retina, they radiate from their point of entrance over the surface of the retina, grouped in bundles, and in many places, according to Michel, arranged in plexuses. Most of the fibres in this layer are centripetal, and are the direct continuations of the axis-cylinder processes of the cells of the next layer, but a few of them (centrifugal fibres) pass through it and the next succeeding layer to ramify in the inner molecular and inner nuclear layers, where they terminate in enlarged extremities (Fig. 448, 1, *m*). The layer is thickest at the optic nerve entrance, and gradually diminishes in thickness toward the ora serrata.

3. The *ganglionic layer* consists of a single layer of large ganglion-cells; except in the macula lutea, where there are several strata. The cells are somewhat flask-shaped, their rounded internal margin resting on the preceding layer

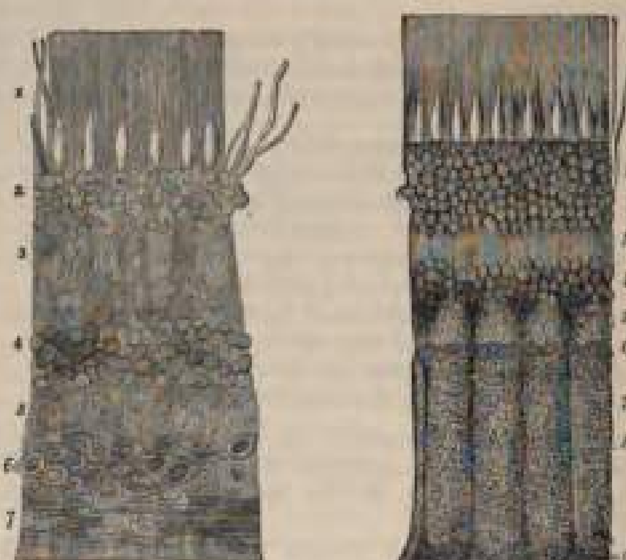


FIG. 446 and 447.—Vertical sections of the human retina. Fig. 446, half an inch from the entrance of the optic nerve. Fig. 447, close to the latter. 1. Layer of rods and cones, Jacob's membrane, bounded underneath by the membrana limitans externa. 2. Outer nuclear layer. 3. Outer molecular layer. 4. Inner nuclear layer. 5. Inner molecular layer. 6. Ganglionic layer. 7. Layer of nerve-fibres. 8. Sustentacular fibres of Müller. 9. Their attachment to the membrana limitans interna.

and sending off an axon which is prolonged as a nerve-fibre into the fibrous layer. From the opposite extremity numerous thicker processes (dendrites) extend into the inner molecular layer, where they branch out into flattened arborizations at different levels (Fig. 448, VII). The ganglion-cells vary much in size, and the dendrites of the smaller ones as a rule arborize in the inner molecular layer as soon as they enter it; while the processes of the larger cells ramify close to the inner nuclear layer.

4. The *inner molecular layer* is made up of a dense reticulum of minute fibrils, formed by the interlacement of the dendrites of the ganglion-cells with those of the cells contained in the next layer, immediately to be described. Within the reticulum formed by these fibrils a few branched spongioblasts are sometimes imbedded.

5. The *inner nuclear layer* is made up of a number of closely packed cells, of which there are three different kinds. (1) A large number of oval cells, which are commonly regarded as bipolar nerve-cells, and are much more numerous than either of the other kind. They each consist of a large oval body placed vertically to the surface, and containing a distinct nucleus: they are surrounded by a small amount of protoplasm, which is prolonged into two processes: one of these passes inward into the inner molecular layer, is varicose in appearance, and ends in a terminal ramification, which is often in close proximity to the ganglion-cells (Fig. 448 1, *c*).

The outer process passes outward into the outer molecular layer, and there breaks up into a number of branches. According to Cajal, there are two varieties of these bipolar cells: one in which the outer process arborizes around the knobbed ends of the rod-fibres, and the inner around the cells of the ganglionic layer; these he calls *rod-bipolars* (Fig. 448, 1, *c*, *d*); the others are those in which the outer process breaks up in a horizontal ramification, in contact with the end of a cone-fibre; these are the *cone-bipolars*, and their inner process breaks up into its terminal ramifications in the inner molecular layer (Fig. 448, 1, *e*). (2) At the innermost part of this inner nuclear layer is a stratum of cells, which are named by Cajal *amacrine* cells, from the fact that they have no axis-cylinder process, but they give a number of short protoplasmic processes which extend into the inner molecular layer and there ramify (Fig. 448, 1, *h*). There are also at the outermost part of this layer some cells, the processes of which extend into and ramify in the outer molecular layer. These are the *horizontal* cells of Cajal. (3) Some few cells are also found in this layer, connected with the fibres of Müller, and will be described with those structures.

6. The *outer molecular layer* is much thinner than the inner molecular layer; but, like it, consists of a dense network of minute fibrils, derived from the processes of the horizontal cells of the preceding layer and the outer processes of the bipolar cells, which ramify in it, forming arborizations around the ends of the rod-fibres and with the branched foot-plates of the cone-fibres.

7. *The Outer Nuclear Layer.*—Like the inner nuclear layer, this layer contains several strata of clear oval nuclear bodies; they are of two kinds, and on account of their being respectively connected with the rods and cones of Jacob's membrane are named rod-granules and cone-granules. The *rod-granules* are much the more numerous, and are placed at different levels throughout the layer. Their nuclei present a peculiar cross-striped appearance, and prolonged from either extremity of the granule is a fine process: the outer process is continuous with a single rod of Jacob's membrane; the inner passes inward toward the outer molecular layer and terminates in an enlarged extremity, and is embedded in the tuft into which the outer process of the rod-bipolars break up. In its course it presents numerous varicosities. The *cone-granules*, fewer in number than the rod-granules, are placed close to the membrana limitans externa, through which they are continuous with the cones of Jacob's membrane. They do not present any cross-striping, but contain a pyriform nucleus which almost completely fills the cell. From their inner extremity a thick process passes inward to the outer molecular layer, upon which it rests by a somewhat pyramidal enlargement, from which are given off numerous fine fibrils, which enter the outer molecular layer, where they come in contact with the outer processes of the cone-bipolars.

8. *The Membrana Limitans Externa.*—This layer, like the membrana limitans interna, is derived from the fibres of Müller, with which structures it will be described.

9. *Jacob's Membrane* (*Layer of Rods and Cones*).—The elements which compose this layer are of two kinds, *rods* and *cones*, the former being much more numerous than the latter. The *rods* are of nearly uniform size, and arranged perpendicularly to the surface. Each rod consists of two portions, an outer and inner, which are of about equal length. The segments differ from each other as regards refraction and in their behavior with coloring reagents, the inner portion becoming stained by carmine, iodine, etc., the outer portion remaining unstained with these reagents, but staining yellowish brown with osmic acid. The outer portion of each rod is marked by transverse striæ, and is made up of a number of thin disks superimposed on one another. It also exhibits faint longitudinal markings. The inner portion of each rod, at its deeper part where it is joined to the outer process of the rod-granule, is indistinctly granular; its more superficial part presents a longitudinal striation, being composed of fine, bright, highly refracting fibrils. The visual purple or rhodopsin is found only in the outer segments of the rods.

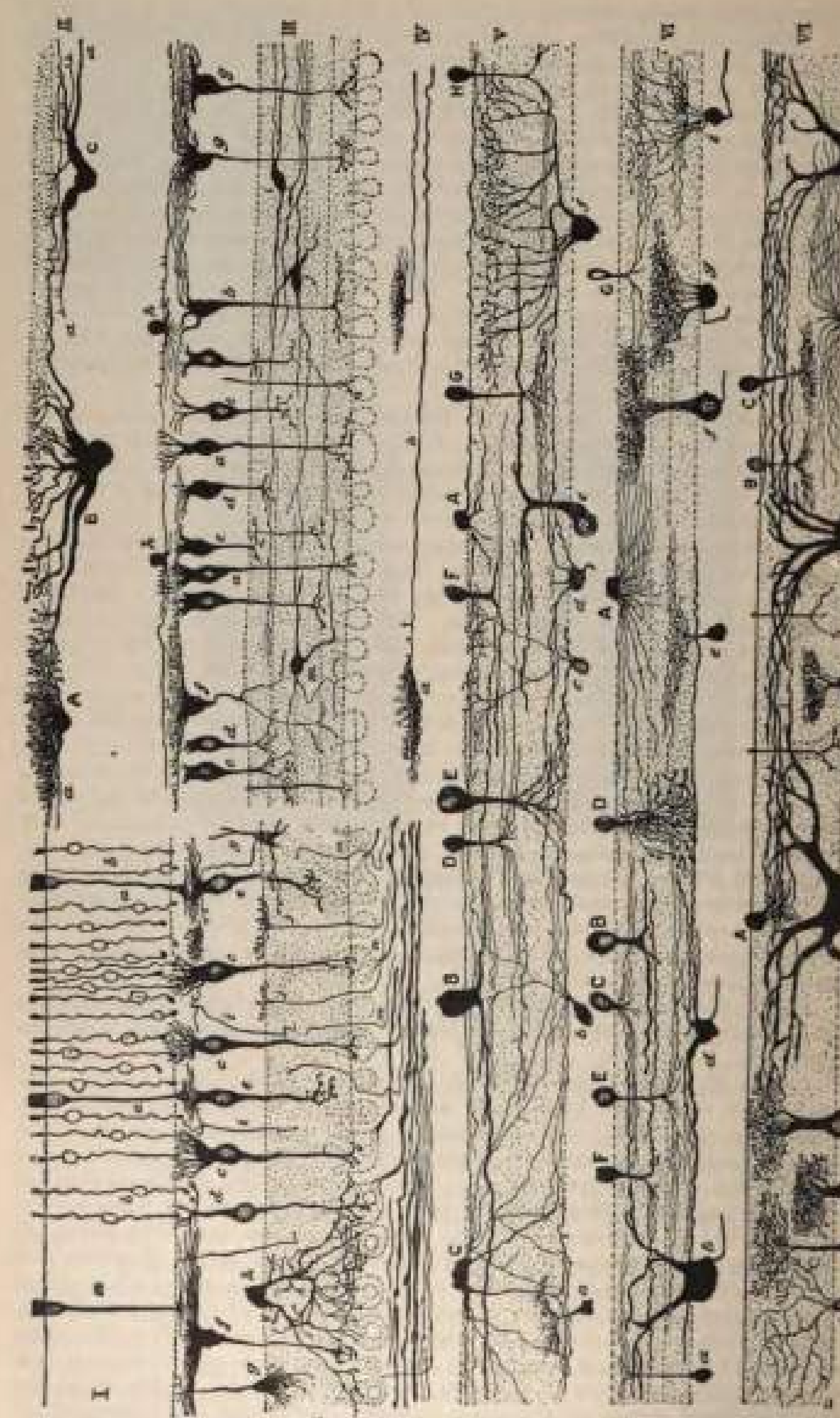


FIG. [illegible].—Elements of the retina of mammals, displayed by the chromate of silver method of Golgi. (Cajal.) (Copied from Quain's Anatomy.)

The *cones* are conical or flask-shaped, their broad ends resting upon the membrana limitans externa, the narrow pointed extremity being turned to the choroid. Like the rods, they are made up of two portions, outer and inner; the outer portion is a short conical process, which, like the outer segment of the rods, presents transverse striæ. The inner portion resembles the inner portion of the rods in structure, presenting a superficial striated and deeper granular part; but differs from it in size, being bulged out laterally and presenting a flask shape. The chemical and optical characters of the two portions are identical with those of the rods.

10. *The Pigmentary Layer, or Tapetum Nigrum.*—The most external layer of the retina, formerly regarded as a part of the choroid, consists of a single layer of hexagonal epithelial cells, loaded with pigment-granules. They are smooth externally, where they are in contact with the choroid, but internally they are prolonged into fine, straight processes, which extend between the rods, this being especially the case when the eye is exposed to light. In the eyes of albinos, the cells of the pigmentary layer are present, but they contain no coloring-matter. In many of the mammals also, as in the horse, and many of the carnivora, there is no pigment in the cells of this layer, and the choroid possesses a beautiful iridescent lustre, which is termed the *tapetum lucidum.*

Supporting Framework of the Retina.—Almost all these layers of the retina are connected together by a supporting framework, formed by the *fibres of Müller*, or *radiating fibres*, from which the membrana limitans interna et externa are derived. These fibres are found stretched between the two limiting layers, "as columns between a floor and a ceiling," and passing through all the nervous layers except Jacob's membrane. Each commences on the inner surface of the retina by a conical hollow base, which sometimes contains a spheroidal body, stained deeply with hæmatoxylin, the edges of the bases of adjoining fibres being united and thus forming a boundary line, which is the membrana limitans interna. As they pass through the nerve-fibre and ganglionic layers they give off few lateral branches; in the inner nuclear layer they give off numerous lateral processes for the support of the inner granules, while in the outer nuclear layer they form a network around the rod and cone-fibrils, and unite to form the external limiting membrane at the bases of the rods and cones. In the inner nuclear layer each fibre of Müller presents a clear oval nucleus, which is sometimes situated at the side of, sometimes altogether within, the fibre.

DESCRIPTION OF FIG. 448.

I. Section of the dog's retina. *a*, Cone-fibre. *b*, Rod-fibre and nucleus. *c*, *d*, Bipolar cells (inner granules) with vertical ramification of outer processes destined to receive the enlarged ends of rod-fibres. *e*, Bipolars with flattened ramification for ends of cone-fibres. *f*, Giant bipolar with flattened ramification. *g*, Cell sending a neuron or nerve-fibre process to the outer molecular layer. *h*, Amacrine cell with diffuse arborization in inner molecular layer. *i*, Nerve-fibrils passing to outer molecular layer. *j*, Centrifugal fibres passing from nerve-fibre layer to inner molecular layer. *m*, Nerve-fibril passing into inner molecular layer. *n*, Ganglionic cells.

II. Horizontal or basal cells of the outer molecular layer of the dog's retina. A, Small cell with dense arborization. B, Large cell, lying in inner nuclear layer, but with its processes branching in the outer molecular. *a*, Its horizontal neuron. C, Medium-sized cell of the same character.

III. Cells from the retina of the ox. *a*, Rod-bipolars with vertical arborizations. *b*, *c*, *d*, *e*, Cone-bipolars with horizontal ramification of outer process. *h*, Cells lying on the outer surface of the outer molecular layer, and ramifying within it. *i*, *j*, *m*, Amacrine cells within the substance of the inner molecular layer.

IV. Neurons or axis-cylinder processes belonging to horizontal cells of the outer molecular layer, one of them, *b*, ending in a close ramification at *a*.

V. Nervous elements connected with the inner molecular layer of the ox's retina. A, Amacrine cell, with long processes ramifying in the outermost stratum. B, Large amacrine with thick processes ramifying in second stratum. C, Flattened amacrine with long and fine processes ramifying mainly in the first and fifth strata. D, Amacrine with radiating tuft of fibrils destined for third stratum. E, Large amacrine, with processes ramifying in fifth stratum. F, Small amacrine, branching into second stratum. G, H, Other amacrines destined for fourth stratum. *a*, Small ganglion-cell sending its processes to fourth stratum. *b*, A small ganglion-cell with ramifications in three strata. *c*, A small cell ramifying ultimately in first stratum. *d*, A medium-sized ganglion-cell ramifying in fourth stratum. *e*, Giant-cell, branching in third stratum. *f*, A bistratified cell ramifying in second and fourth strata.

VI. Amacrines and ganglion-cells from the dog. A, Amacrine with radiating tuft. B, Large amacrine passing to third stratum. *c* and *d*, Small amacrines with radiations in second stratum. F, Small amacrine passing to third stratum. D, Amacrine with diffuse arborization. E, Amacrine belonging to fourth stratum. *a*, *d*, *e*, *g*, Small ganglion-cells, ramifying in various strata. *b*, *f*, Large ganglion-cells showing two different characters of arborization. *i*, Bistratified cell.

VII. Amacrines and ganglion-cells from the dog. A, B, C, Small amacrines ramifying in middle of molecular layer. *b*, *d*, *g*, *h*, *i*, Small ganglion-cells showing various kinds of arborization. *f*, A larger cell, similar in character to *a*, but with longer branch. *a*, *c*, *e*, Giant-cells with thick branches ramifying in the first, second, and third layers. L, L, Ends of bipolars branching over ganglion-cells.

Macula Lutea and Fovea Centralis.—The structure of the retina at the yellow spot presents some modifications. In the macula lutea (1) the nerve-fibres are

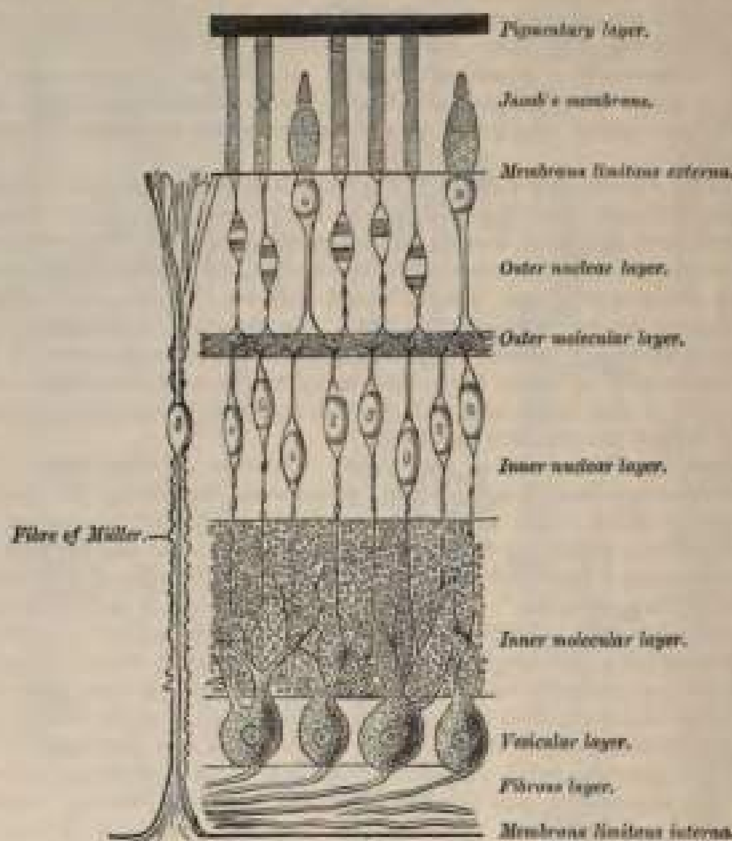


FIG. 449.—The layers of the retina (diagrammatic). (After Schultze.)

wanting as a continuous layer; (2) the ganglionic layer consists of several strata of cells, instead of a single layer; (3) in Jacob's membrane there are no rods, but only cones, and these are longer and narrower than in other parts; and (4) in the outer nuclear layer there are only cone fibres, which are very long and arranged in curved lines. At the fovea centralis the only parts which exist are the cones of Jacob's membrane, the outer nuclear layer, the cone-fibres of which are almost horizontal in direction, and an exceedingly thin inner granular layer, the pigmentary layer, which is thicker and its pigment more pronounced than elsewhere. The color of the macula seems to imbue all the layers except Jacob's membrane; it is of a rich yellow, deepest toward the centre, and does not appear to consist of pigment-cells, but simply a staining of the constituent parts.

At the ora serrata the nervous layers of the retina terminate abruptly, and the retina is continued onward as a single layer of elongated columnar cells covered by the pigmentary layer. This prolongation is known as the *pars ciliaris retinæ*, and can be traced forward from the ciliary processes on to the back of the iris, where it is termed the *pars iridica retinæ* or *uvea*.

From the description given of the nervous elements of the retina it will be seen that there is no direct continuity between the structures which form its different layers except between the ganglionic and nerve-fibre layers, the majority of the nerve-fibres being formed of the axons of the ganglionic cells. In the inner molecular layer the dendrites of the ganglionic layer interlace with those of the cells of the inner nuclear layer, while in the outer molecular layer a like synapsis occurs between the processes of the inner granules and the rod and cone elements.

The *arteria centralis retinæ* and its accompanying vein pierce the optic nerve, and enter the globe of the eye through the porus opticus. It immediately bifurcates into an upper and a lower branch, and each of these again divides into an inner, or nasal, and an outer, or temporal, branch, which at first run between the hyaloid membrane and the nervous layer; but they soon enter the latter, and pass forward, dividing dichotomously. From these branches a minute capillary plexus is given off, which does not extend beyond the inner nuclear layer. The macula receives small twigs from the temporal branches and others directly from the central artery; these do not, however, reach as far as the fovea centralis, which has no blood-vessels. The branches of the arteria centralis retinæ do not anastomose with each other—in other words, they are "terminal arteries." In the fœtus, a small vessel passes forward, through the vitreous humor, to the posterior surface of the capsule of the lens.

REFRACTING MEDIA.

The Refracting media are three, viz.:

Aqueous humor. Vitreous body. Crystalline lens.

I. Aqueous Humor.

The **aqueous humor** completely fills the anterior and posterior chambers of the eyeball. It is small in quantity (scarcely exceeding, according to Petit, four or five grains in weight), has an alkaline reaction, in composition is little more than water, less than one-fiftieth of its weight being solid matter, chiefly chloride of sodium.

The *anterior chamber* is the space bounded in front by the cornea; behind, by the front of the iris. The *posterior chamber* is a narrow chink between the peripheral part of the iris, the suspensory ligament of the lens, and the ciliary processes.

In the adult, these two chambers communicate through the pupil; but in the fœtus of the seventh month, when the pupil is closed by the membrana pupillaris, the two chambers are quite separate.

II. Vitreous Body.

The **vitreous body** forms about four-fifths of the entire globe. It fills the concavity of the retina, and is hollowed in front, forming a deep concavity, the *fossa patellaris*, for the reception of the lens. It is perfectly transparent, of the consistence of thin jelly, and is composed of an albuminous fluid enclosed in a delicate transparent membrane, the *membrana hyaloidea*. It has been supposed by Hannover, that from its inner surface numerous thin lamellæ are prolonged inward in a radiating manner, forming spaces in which the fluid is contained. In the adult, these lamellæ cannot be detected even after careful microscopic examination in the fresh state, but in preparations hardened in weak chromic acid it is possible to make out a distinct lamellation at the periphery of the body; and in the fœtus a peculiar fibrous texture pervades the mass, the fibres joining at numerous points, and presenting minute nuclear granules at their point of junction. In the centre of the vitreous humor, running from the entrance of the optic nerve to the posterior surface of the lens, is a canal, filled with fluid and lined by a prolongation of the hyaloid membrane. This is the *canal of Stilling*, which in the embryonic vitreous humor conveyed the minute vessel from the central artery of the retina to the back of the lens. The fluid from the vitreous body resembles nearly pure water; it contains, however, some salts and a little albumin.

The hyaloid membrane encloses the whole of the vitreous humor. In front of the ora serrata it is thickened by the accession of radial fibres and is termed the *zonule of Zinn* or *zonula ciliaris*. It presents a series of radially arranged furrows, in which the ciliary processes are accommodated and to which they are adherent, as evidenced by the fact that when removed some of their pigment remains attached to the zonule. The zonule of Zinn splits into two layers, one of which is thin and lines the fossa patellaris; the other is named the *suspensory ligament of the lens*; it is thicker, and passes over the ciliary body to be attached to the capsule of the lens a short distance in front of its equator. Scattered and delicate fibres are also attached to the region of the equator itself. This ligament retains the lens in position, and is relaxed by the contraction of the radial fibres of the Ciliary muscle, so that the lens is allowed to become more convex. Behind the suspensory ligament there is a sacculated canal, the *canal of Petit*, which encircles the equator of the lens and which can be easily inflated through a fine blow-pipe inserted through the suspensory ligament.

In the fœtus, the centre of the vitreous humor presents the canal of Stilling, already referred to, which transmits a minute artery to the capsule of the lens. *In the adult*, no vessels penetrate its substance; so that its nutrition must be carried on by the vessels of the retina and ciliary processes, situated upon its exterior.

III. Crystalline Lens.

The **crystalline lens**, enclosed in its capsule, is situated immediately behind the pupil, in front of the vitreous body, and encircled by the ciliary processes, which slightly overlap its margin.

The *capsule of the lens* is a transparent, highly elastic, and brittle membrane, which closely surrounds the lens. It rests, behind, in the fossa patellaris in the fore part of the vitreous body; in front, it is in contact with the free border of the iris, this latter receding from it at the circumference, thus forming the posterior chamber of the eye; and it is retained in its position chiefly by the suspensory ligament of the lens, already described. The capsule is much thicker in front than behind, and structureless in texture; when ruptured, the edges roll up with the outer surface innermost, like the elastic lamina of the cornea.

FIG. [illegible].—The crystalline lens, hardened and divided. (Enlarged.)

The anterior surface of the lens is covered by a single layer of transparent, polygonal, nucleated cells. At the circumference of the lens, these cells undergo a change in form: they become elongated, and Babucin states that he can trace the gradual transition of the cells into proper lens-fibres, with which they are directly continuous. There is no epithelium on the posterior surface.

In the fœtus, a small branch from the arteria centralis retinæ runs forward, as already mentioned, through the vitreous humor to the posterior part of the capsule of the lens, where its branches radiate and form a plexiform network, which covers its surface, and they are continuous round the margin of the capsule with the vessels of the pupillary membrane and with those of the iris. In the adult no vessels enter its substance.

The *lens* is a transparent, biconvex body, the convexity being greater on the posterior than on the anterior surface. The central points of its anterior and posterior surfaces are known as its *anterior* and *posterior poles*. It measures from 9 to 10 mm. in the transverse diameter, and about 4 mm. in the antero-posterior. It consists of concentric layers, of which the external in the fresh state are soft and easily detached (*substantia corticalis*); those beneath are firmer, the central ones forming a hardened nucleus (*nucleus lentis*). These laminæ are best demonstrated by boiling or immersion in alcohol, and consist of minute parallel fibres, which are hexagonal prisms, the edges being dentated, and the dentations fitting accurately into each other; their breadth is about $\frac{1}{5000}$ of an inch. Faint lines radiate from the anterior and posterior poles to the circumference of the lens. In the adult there may be six or more of these, but in the fœtus they are only three in number and diverge from each other at angles of 120° (Fig. 451). On the anterior surface one line ascends vertically and the other two diverge downward and outward. On the posterior surface one ray descends vertically

A B

FIG. 451.—Diagram to show the direction and arrangement of the radiating lines on the front and back of the fœtal lens. (A) from the front. (B) from the back.

and the other two diverge upward. They correspond with the free edges of an equal number of septa in the lens, along which the ends of the lens fibres come into apposition and are joined by transparent amorphous substance. The fibres run in a curved manner from the septa on the anterior surface to those on the posterior surface. No fibres pass from pole to pole, but they are arranged in such a way that fibres which commence near the pole on the one aspect of the lens terminate near the peripheral extremity of the plane on the other, and *vice versâ*. The fibres of the outer layers of the lens each contain a nucleus, which together form a layer (nuclear layer) on the surface of the lens, most distinct toward its circumference.

The *changes produced in the lens by age* are the following:

In *the fœtus* its form is nearly spherical, its color of a slightly reddish tint, it is not perfectly transparent, and is so soft as to break down readily on the slightest pressure.

In the adult the posterior surface is more convex than the anterior; it is colorless, transparent, and firm in texture.

In old age it becomes flattened on both surfaces, slightly opaque, of an amber tint, and increases in density.

The *arteries of the globe of the eye* are the short, long, and anterior ciliary arteries and the arteria centralis retinæ. They have been already described (see page 509).

The *ciliary veins* are seen on the outer surface of the choroid, and are named, from their arrangement, the *venæ vorticosæ*. They converge to four or five equidistant trunks, which pierce the sclerotic midway between the margin of the cornea and the entrance of the optic nerve. Another set of veins accompany the anterior ciliary arteries and open into the ophthalmic vein.

The *ciliary nerves* are derived from the nasal branch of the ophthalmic and from the ciliary or ophthalmic ganglion.

Surgical Anatomy.—From a surgical point of view the cornea may be regarded as consisting of three layers: (1) of an external epithelial layer, developed from the epiblast, and continuous with the external epithelial covering of the rest of the body, and therefore in its lesions resembling those of the epidermis; (2) of the cornea proper, derived from the mesoblast, and associated in its diseases with the fibro-vascular structures of the body; and (3) the posterior elastic layer with its endothelium, also derived from the mesoblast and having the characters of a serous membrane, so that inflammation of it resembles inflammation of the other serous and synovial membranes of the body.

The cornea contains no blood-vessels, except at its periphery, where numerous delicate loops, derived from the anterior ciliary arteries, may be demonstrated on the anterior surface of the cornea. The rest of the cornea is nourished by lymph, which gains access to the proper substance of the cornea and the posterior layer through the spaces of Fontana. This lack of a direct blood-supply renders the cornea very apt to inflame in the cachectic and ill-nourished. In cases of granular lids there is a peculiar affection of the cornea, called *pannus*, in which the anterior layers of the cornea become vascularized, and a rich network of blood-vessels may be seen on the cornea; and in interstitial keratitis new vessels extend into the cornea, giving it a pinkish hue, to which the term "salmon patch" is applied. The cornea is richly supplied with nerves, derived from the ciliary, which enter the cornea through the fore part of the sclerotic and form plexuses in the stroma, terminating between the epithelial cells by free ends or in corpuscles. In cases of glaucoma the ciliary nerves may be pressed upon as they course between the choroid and sclerotic, and the cornea becomes anæsthetic. The sclerotic has very few blood-vessels and nerves. The blood-vessels are derived from the anterior ciliary, and form an open plexus in its substance. As they approach the corneal margin this arrangement is peculiar. Some branches pass through the sclerotic to the ciliary body; others become superficial and lie in the episcleral tissue, and form arches, by anastomosing with each other, some little distance behind the corneal margin. From these arches numerous straight vessels are given off, which run forward to the cornea, forming its marginal plexus. In inflammation of the sclerotic and episcleral tissue these vessels become conspicuous, and form a pinkish zone of straight vessels radiating from the corneal margin, commonly known as the zone of ciliary injection. In inflammation of the iris and ciliary body this zone is present, since the sclerotic speedily becomes involved when these structures are inflamed. But in inflammation of the cornea the sclerotic is seldom much affected, though the cornea and sclerotic are structurally continuous. This would appear to be due to the fact that the nutrition of the cornea is derived from a different source from that of the sclerotic. The sclerotic may be ruptured subcutaneously without any laceration of the conjunctiva, and the rupture usually occurs near the corneal margin, where the tunic is thinnest. It may be complicated with lesions of adjacent parts—laceration of the choroid, retina, iris, or suspensory ligament of the lens—and is then often attended with hæmorrhage into the anterior chamber, which masks the nature of the injury. In some cases the lens has escaped through the rent in the sclerotic, and has been found under the conjunctiva. Wounds of the sclerotic are always dangerous, and are often followed by inflammation, suppuration, and by sympathetic ophthalmia.

One of the functions of the choroid is to provide nutrition for the retina and to convey vessels and nerves to the ciliary body and iris. Inflammation of the choroid is therefore followed by grave disturbance in the nutrition of the retina, and is attended with early interference with vision. In its diseases it bears a considerable analogy to those which affect the skin, and, like it, is one of the places from which melanotic sarcomata may grow. These tumors contain a large amount of pigment in their cells, and grow only from those parts where pigment is naturally present. The choroid may be ruptured without injury to the other tunics, as well as participating in general injuries of the eyeball. In cases of uncomplicated rupture the injury is usually at its posterior part, and is the result of a blow on the front of the eye. It is attended by considerable hæmorrhage, which for a time may obscure vision, but in most cases this is restored as soon as the blood is absorbed.

The iris is the seat of a malformation, termed *coloboma*, which consists in a deficiency or cleft, which in a great number of cases is clearly due to an arrest in development. In these cases it is found at the lower aspect, extending directly downward from the pupil, and the gap frequently extends through the choroid to the entrance of the optic nerve. In some rarer cases the gap is found in other parts of the iris, and is then not associated with any deficiency of the choroid. The iris is abundantly supplied with blood-vessels and nerves, and is therefore very prone to become inflamed. And when inflamed, in consequence of the intimate relationship which exists between the vessels of the iris and choroid this latter tunic is very apt to participate in the inflammation. And, in addition, inflammation of adjacent structures, the cornea and sclerotic, is apt to spread into the iris. The iris is covered with epithelium, and partakes of the character of a serous membrane, and, like these structures, is liable to pour out a plastic exudation when inflamed, and contract adhesions, either to the cornea in front (*synechia anterior*), or to the capsule of the lens behind (*synechia posterior*). In iritis the lens may become involved, and the condition known as secondary cataract may be set up. Tumors occasionally commence in the iris; of these, cysts, which are usually congenital and sarcomatous tumors, are the most common and require removal. Gummata are not unfrequently found in this situation. In some forms of injury of the eyeball, as the impact of a spent shot, the rebound of a twig, or a blow with a whip, the iris may be detached from the Ciliary muscle, the amount of detachment varying from the slightest degree to the separation of the whole iris from its ciliary connection.

The retina, with the exception of its pigment-layer and its vessels, is perfectly transparent, so as to be invisible when examined by the ophthalmoscope, so that its diseased conditions are recognized by its loss of transparency. In retinitis, for instance, there is more or less dense and extensive opacity of its structure, and not unfrequently extravasations of blood into its substance. Hæmorrhages may also take place into the retina from rupture of a blood-vessel without inflammation.

The retina may become displaced from effusion of serum between it and the choroid or by blows on the eyeball, or may occur without apparent cause in progressive myopia, and in this case the ophthalmoscope shows an opaque, tremulous cloud. Glioma, a form of sarcoma, and essentially a disease of early life, is occasionally met with in connection with the retina.

The lens has no blood-vessels, nerves, or connective tissue in its structure, and therefore is not subject to those morbid changes to which tissues containing these structures are liable. It does, however, present certain morbid or abnormal conditions of various kinds. Thus, variations in shape, absence of the whole or a part of the lens, and displacements are amongst its congenital defects. Opacities may occur from injury, senile changes, malnutrition, or errors in growth or development. Senile changes may take place in the lens, impairing its elasticity and rendering it harder than in youth, so that its curvature can only be altered to a limited extent by the Ciliary muscle. And, finally, the lens may be dislocated or displaced by blows upon the eyeball, and its relations to surrounding structures altered by adhesions or the pressure of new growths.

There are two particular regions of the eye which require special notice: one of these is known as the "filtration area," and the other as the "dangerous area." The *filtration area* is the circumcorneal zone immediately in front of the iris. Here are situated the cavernous spaces of Fontana, which communicate with the canal of Schlemm, through which the chief transudation of fluid from the eye is now believed to take place. The *dangerous area of the eye* is the region in the neighborhood of the ciliary body, and wounds or injuries in this situation are peculiarly dangerous; for inflammation of the ciliary body is liable to spread to many of the other structures of the eye, especially to the iris and choroid, which are intimately connected by nervous and vascular supplies. Moreover, wounds which involve the ciliary region are especially liable to be followed by sympathetic ophthalmia, in which destructive inflammation of one eye is excited by some irritation in the other.

The Appendages of the Eye.

The appendages of the eye (*tutamina oculi*) include the eyebrows, the eyelids, the conjunctiva, and the lachrymal apparatus—viz. the lachrymal gland, the lachrymal sac, and the nasal duct.

The **eyebrows** (*supercilia*) are two arched eminences of integument which surmount the upper circumference of the orbit on each side, and support numerous short, thick hairs, directed obliquely on the surface. In structure the eyebrows consist of thickened integument, connected beneath with the Orbicularis palpebrarum, Corrugator supercilii, and Occipito-frontalis muscles. These muscles serve, by their action on this part, to control to a certain extent the amount of light admitted into the eye.

The **eyelids** (*palpebræ*) are two thin, movable folds placed in front of the eye, protecting it from injury by their closure. The upper lid is the larger and the more movable of the two, and is furnished with a separate elevator muscle, the *Levator palpebræ superioris*. When the eyelids are opened an elliptical space (*fissura palpebrarum*) is left between their margins, the angles of which correspond to the junction of the upper and lower lids, and are called *canthi*.

The *outer canthus* is more acute than the inner, and the lids here lie in close contact with the globe; but the *inner canthus* is prolonged for a short distance inward toward the nose, and the two lids are separated by a triangular space, the *lacus lachrymalis*. At the commencement of the lacus lachrymalis, on the margin of each eyelid, is a small conical elevation, the *lachrymal papilla*, the apex of which is pierced by a small orifice, the *punctum lachrymale*, the commencement of the lachrymal canal.

The *eyelashes* (*cilia*) are attached to the free edges of the eyelids; they are short, thick, curved hairs, arranged in a double or triple row at the margin of the lids: those of the upper lid, more numerous and longer than the lower, curve upward; those of the lower lid curve downward, so that they do not interlace in closing the lids. Near the attachment of the eyelashes are the openings of a number of glands, *glands of Moll*, arranged in several rows close to the free margin of the lid. They are regarded as enlarged and modified sweat-glands.

Structure of the Eyelids.—The eyelids are composed of the following structures, taken in their order from without inward:

Integument, areolar tissue, fibres of the Orbicularis muscle, tarsal plate, and its ligament, Meibomian glands and conjunctiva. The upper lid has, in addition, the aponeurosis of the Levator palpebræ.

The *integument* is extremely thin, and continuous at the margin of the lids with the conjunctiva.

The *subcutaneous areolar tissue* is very lax and delicate, seldom contains any fat, and is extremely liable to serous infiltration.

The *fibres of the Orbicularis muscle*, where they cover the palpebræ, are thin, pale in color, and possess an involuntary action.

The *tarsal plates* are two thin elongated plates of dense connective tissue about an inch in length. They are placed one in each lid, contributing to their form and support.

The *superior*, the larger, is of a semilunar form, about one-third of an inch in breadth at the centre, and becoming gradually narrowed at each extremity. To the anterior surface of this plate the aponeurosis of the Levator palpebræ is attached.

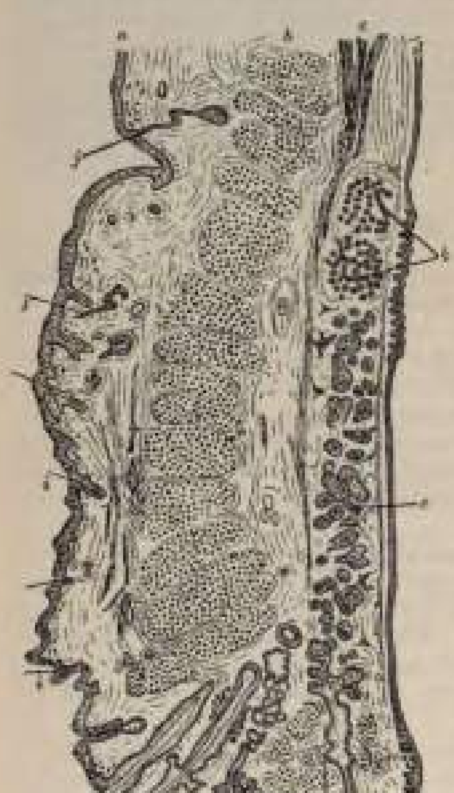


FIG. 452.—Vertical section through the upper eyelid. (After Waldeyer.) *a.* Skin. *b.* Orbicularis palpebrarum. *b'.* Marginal fasciculus of orbicularis (ciliary bundle). *c.* Levator palpebræ. *d.* Conjunctiva. *e.* Tarsal plate. *f.* Meibomian gland. *g.* Sebaceous gland. *h.* Eyelashes. *i.* Small hairs of skin. *j.* Sweat-glands. *k.* Posterior tarsal glands.

The *inferior tarsal plate*, the smaller, is thinner and of an elliptical form.

The *free* or *ciliary margin* of these plates is thick, and presents a perfectly straight edge. The *attached* or *orbital margin* is connected to the circumference of the orbit by the fibrous membrane of the lids, with which it is continuous. The outer angle of each plate is attached to the malar bone by the external tarsal ligament. The inner angles of the two plates terminate at the commencement of the lacus lacrimalis; they are attached to the nasal process of the superior maxilla by the internal tarsal ligament or tendo oculi.

The *palpebral* ligaments are membranous expansions situated one in each lid, and are attached marginally to the edge of the orbit, where they are continuous with the periosteum. The superior ligament blends with the tendon of the Levator palpebræ, the inferior with the inferior tarsal plate. Externally the two ligaments fuse to form the *external* tarsal ligament, just referred to; internally they are much thinner and, becoming separated from the internal tarsal ligament, are fixed to the lachrymal bone immediately behind the lachrymal sac. Together, the ligaments form an incomplete septum, the *septum orbitale*, which is perforated by the vessels and nerves which pass from the orbital cavity to the face and scalp.

The *Meibomian glands* (Fig. 453) are situated upon the inner surface of the eyelids between the tarsal plates and conjunctiva, and may be distinctly seen through the mucous membrane on everting the eyelids, presenting the appearance of parallel strings of pearls. They are about thirty in number in the upper eyelid, and somewhat fewer in the lower. They are imbedded in grooves in the inner surface of the tarsal plates, and correspond in length with the breadth of each plate; they are, consequently, longer in the upper than in the lower eyelid. Their ducts open on the free margin of the lids by minute foramina, which correspond in number to the follicles. The use of their secretion is to prevent adhesions of the lids.

Structure of the Meibomian Glands.—These glands are a variety of the cutaneous sebaceous glands, each consisting of a single straight tube or follicle, having a cæcal termination, and with numerous small secondary follicles opening into it. The tubes consist of basement-membrane, lined at the mouths of the tubes by stratified epithelium; the deeper parts of the tubes and the secondary follicles are lined by a layer of polyhedral cells. They are thus identical in structure with the sebaceous glands.

The **conjunctiva** is the mucous membrane of the eye. It lines the inner surface of the eyelids, and is reflected over the fore part of the sclerotic and cornea. In each of these situations its structure presents some peculiarities.

The *palpebral portion of the conjunctiva* is thick, opaque, highly vascular, and covered with numerous papillæ, its deeper parts presenting a considerable amount of lymphoid tissue. At the margin of the lids it becomes continuous with the lining membrane of the ducts of the Meibomian glands, and, through the lachrymal canals, with the lining membrane of the lachrymal sac and nasal duct. At the outer angle of the upper lid the lachrymal ducts open on its free surface; and at the inner angle of the eye it forms a semilunar fold, the *plica semilunaris*. The folds formed by the reflection of the conjunctiva from the lids on to the eye are called the *superior* and *inferior palpebral folds*, the former being the deeper of the two. Upon the *sclerotic* the conjunctiva is loosely connected to the globe: it becomes thinner, loses its papillary structure, is transparent, and only slightly vascular in health. Upon the *cornea* the conjunctiva consists only of epithelium, constituting the anterior layer of the cornea (conjunctival epithelium) already described (see page 826). Lymphatics arise in the conjunctiva in a delicate zone around the cornea, from which the vessels run to the ocular conjunctiva.

At the point of reflection of the conjunctiva from the lid on to the globe of the eye, termed the *fornix conjunctivæ*, are a number of mucous glands which are much convoluted. They are chiefly found in the upper lid. Other glands, analogous to

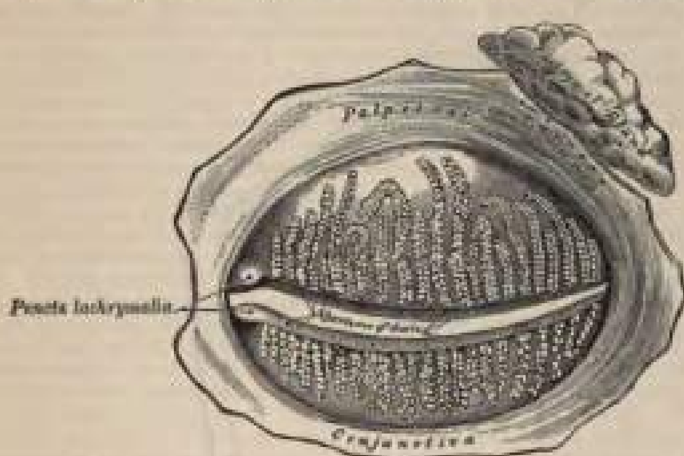


FIG. 453.—The Meibomian glands, etc., seen from the inner surface of the eyelids.

lymphoid follicles, and called by Henle *trachoma glands*, are found in the conjunctiva, and, according to Strohmeyer, are chiefly situated near the inner canthus of the eye. They were first described by Brush, in his description of Peyer's patches of the small intestines, as "identical structures existing in the under eyelid of the ox."

The nerves in the conjunctiva are numerous and form rich plexuses. According to Krause, they terminate in a peculiar form of tactile corpuscle, which he terms the "terminal bulb."

The *caruncula lachrymalis* is a small, reddish, conical-shaped body, situated at the inner canthus of the eye, and filling up the small triangular space in this situation, the *lacus lachrymalis*. It consists of a small island of skin containing sebaceous and sweat glands, and is the source of the whitish secretion which constantly collects at the inner angle of the eye. A few slender hairs are attached to its surface. On the outer side of the caruncula is a slight semilunar fold of mucous membrane, the concavity of which is directed toward the cornea; it is called the *plica semilunaris*. Müller found smooth muscular fibres in this fold, and in some of the domesticated animals a thin plate of cartilage has been discovered. This structure is considered to be the rudiment of the third eyelid in birds, the *membrana nictitans*.

The Lachrymal Apparatus (Fig. 454).

The lachrymal apparatus consists of the lachrymal gland, which secretes the tears, and its excretory ducts, which convey the fluid to the surface of the eye. This fluid is carried away by the lachrymal canals into the lachrymal sac, and along the nasal duct into the cavity of the nose.

The **lachrymal gland** is lodged in a depression at the outer angle of the orbit, on the inner side of the external angular process of the frontal bone. It is of an oval form, about the size and shape of an almond. Its upper convex surface is in contact with the periosteum of the orbit, to which it is connected by a few fibrous bands. Its under concave surface rests upon the convexity of the eyeball and upon the Superior and External recti muscles. Its vessels and nerves enter its posterior border, whilst its anterior margin is closely adherent to the back part of the upper eyelid, where it is covered to a slight extent by the reflection of the conjunctiva. The fore part of the gland is separated from the rest by a fibrous septum; hence it is sometimes described as a separate lobe, called the *palpebral portion of the gland* (*accessory gland of Rosenmüller*). Its ducts, from six to twelve in number run obliquely beneath the mucous membrane for a short distance, and, separating from each other, open by a series of minute orifices on the upper and outer half

FIG. 454.—The lachrymal apparatus. Right side.

of the conjunctiva near its reflection on to the globe. These orifices are arranged in a row, so as to disperse the secretion over the surface of the membrane.

Structure of the Lachrymal Gland.—In structure and general appearance the lachrymal resembles the serous salivary glands (page 885). In the recent state the cells are so crowded with granules that their limits can hardly be defined. They contain an oval nucleus, and the cell-protoplasm is finely fibrillated.

The **lachrymal canals** commence at the minute orifices, *puncta lachrymalia*, on the summit of a small conical elevation, the *lachrymal papilla*, seen on the margin of the lids at the outer extremity of the lacus lachrymalis. The *superior canal*, the smaller and shorter of the two, at first ascends, and then bends at an acute angle, and passes inward and downward to the lachrymal sac. The *inferior canal* at first descends, and then, abruptly changing its course, passes almost horizontally inward to the lachrymal sac. These canals are dense and elastic in structure and somewhat dilated at their angle. The mucous membrane is covered with scaly epithelium.

The **lachrymal sac** is the upper dilated extremity of the nasal duct, and is lodged in a deep groove formed by the lachrymal bone and nasal process of the superior maxillary. It is oval in form, its upper extremity being closed in and rounded, whilst below it is continued into the nasal duct. It is covered by a fibrous expansion derived from the tendo oculi, and on its deep surface it is crossed by the Tensor tarsi muscle (Horner's muscle, page 302), which is attached to the ridge on the lachrymal bone.

Structure.—It consists of a fibrous elastic coat, lined internally by mucous membrane, the latter being continuous, through the lachrymal canals, with the mucous lining of the conjunctiva, and, through the nasal duct, with the pituitary membrane of the nose.

The **nasal duct** is a membranous canal, about three-quarters of an inch in length, which extends from the lower part of the lachrymal sac to the inferior meatus of the nose, where it terminates by a somewhat expanded orifice, provided with an imperfect valve, the *valve of Hasner*, formed by the mucous membrane. It is contained in an osseous canal formed by the superior maxillary, the lachrymal, and the inferior turbinated bones, is narrower in the middle than at each extremity, and takes a direction downward, backward, and a little outward. It is lined by mucous membrane, which is continuous below with the pituitary lining of the nose. This membrane in the lachrymal sac and nasal duct is covered with columnar epithelium, as in the nose. This epithelium is in places ciliated.

Surface Form.—The palpebral fissure, or opening between the eyelids, is elliptical in shape, and differs in size in different individuals and in different races of mankind. In the Mongolian races, for instance, the opening is very small, merely a narrow fissure, and this makes the eyeball appear small in these races, whereas the size of the eye is relatively very constant. The normal direction of the fissure is slightly oblique, in a direction upward and outward, so that the outer angle is on a slightly higher level than the inner. This is especially noticeable in the Mongolian races, in whom, owing to the upward projection of the malar bone and the shortness of the external angular process of the frontal bone, the tarsal plate of the upper lid is raised at its outer part and gives an oblique direction to the palpebral fissure.

When the eyes are directed forward, as in ordinary vision, the upper part of the cornea is covered by the upper lid, and the lower margin of the cornea corresponds to the level of the lower lid, so that about the lower three-fourths of the cornea is exposed under ordinary circumstances. On the margins of the lids, about a quarter of an inch from the inner canthus, are two small openings, the *puncta lachrymalia*, the commencement of the lachrymal canals. They are best seen by everting the eyelids. In the natural condition they are in contact with the conjunctiva of the eyeball, and are maintained in this position by the Tensor tarsi muscle, so that the tears running over the surface of the globe easily find their way into the lachrymal canals. The position of the lachrymal sac into which the canals open is indicated by a little tubercle (page 119), which is plainly to be felt on the lower margin of the orbit. The lachrymal sac lies immediately above and to the inner side of this tubercle, and a knife passed through the skin in this situation would open the cavity. The position of the lachrymal sac may also be indicated by the tendo oculi or internal tarsal ligament. If both lids be drawn outward, so as to tense the skin at the inner angle, a prominent cord will be seen beneath the tightened skin. This is the *tendo oculi*, which lies immediately over the lachrymal sac, bisecting it, and thus forming a useful guide to its situation. A knife entered immediately beneath the tense cord would open the lower part of the sac. A probe introduced through this opening can be readily passed downward through the duct into the inferior meatus of the nose. The direction of the duct is downward, outward, and backward, and this course should be borne in mind in passing the probe, otherwise the point may be driven through the thin bony walls of the canal. A convenient plan is to direct the probe in such a manner that if it were pushed onward it would strike the first molar tooth of the lower jaw on the same side of the body. In other words, the surgeon standing in front of his patient should carry in his mind the position of the first molar tooth, and should push his probe onward in such a way as if he desired to reach this structure.

Beneath the internal angular process of the frontal bone the pulley of the Superior oblique muscle of the eye can be plainly felt by pushing the finger backward between the upper and inner angle of the eye and the roof of the orbit; passing backward and outward from this pulley, the tendon can be felt for a short distance.

Surgical Anatomy.—The eyelids are composed of various tissues, and consequently are liable to a variety of diseases. The skin which covers them is exceedingly thin and delicate, and is supported on a quantity of loose and lax subcutaneous tissue which contains no fat. In consequence of this it is very freely movable, and is liable to be drawn down by the contraction of neighboring cicatrices, and thus produce an eversion of the lid known as *ectropion*. Inversion of the lids (*entropion*) from spasm of the Orbicularis palpebrarum or from chronic inflammation of the palpebral conjunctiva may also occur. The eyelids are richly supplied with blood, and are often the seat of vascular growths, such as nævi. Rodent ulcer also frequently commences in this situation. The loose cellular tissue beneath the skin is liable to become extensively infiltrated either with blood or inflammatory products, producing very great swelling. Even from very slight injuries to this tissue the extravasation of blood may be so great as to produce considerable swelling of the lids and complete closure of the eye, and the same is the case when inflammatory products are poured out. The follicles of the eyelashes or the sebaceous glands associated with these follicles may be the seat of inflammation, constituting the ordinary "sty." The Meibomian glands are affected in the so-called "tarsal tumor;" the tumor, according to some, being caused by the retained secretion of these glands; by others it is believed to be a neoplasm connected with the gland. The ciliary follicles are liable to become inflamed, constituting the disease known as *blepharitis ciliaris*, or "blear-eye." Irregular or disorderly growth of the eyelashes not unfrequently occurs, some of them being turned toward the eyeball and producing inflammation and ulceration of the cornea, and possibly eventually complete destruction of the eye. The Orbicularis palpebrarum may be the seat of spasm, either in the form of slight quivering of the lids or repeated twitchings, most commonly due to errors of refraction in children, or more continuous spasm, due to some irritation of the fifth or seventh cranial nerve. The Orbicularis may be paralyzed, generally associated with paralysis of the other facial muscles. Under these circumstances the patient is unable to close the lids, and, if he attempts to do so, rolls the eyeball upward under the upper lid. The tears overflow from displacement of the lower lid, and the conjunctiva and cornea, being constantly exposed and the patient being unable to wink, become irritated from dust and foreign bodies. In paralysis of the Levator palpebræ superioris there is drooping of the upper eyelid and other symptoms of implication of the third nerve. The eyelids may be the seat of bruises, wounds, or burns. In these latter injuries adhesions of the margins of the lids to each other or adhesion of the lids to the globe may take place. The eyelids are sometimes the seat of emphysema after fracture of some of the thin bones forming the inner wall of the orbit. If shortly after such an injury the patient blows his nose, air is forced from the nostril through the lacerated structures into the connective tissue of the eyelids, which suddenly swell up and present the peculiar crackling characteristic of this affection.

Foreign bodies frequently get into the conjunctival sac and cause great pain, especially if they come in contact with the corneal surface, during the movements of the lid and the eye on each other. The conjunctiva is frequently involved in severe injuries of the eyeball, but is seldom ruptured alone; the most common form of injury to the conjunctiva alone is from a burn, either from fire, strong acids, or lime. In these cases union is liable to take place between the eyelid and the eyeball. The conjunctiva is often the seat of inflammation arising from many different causes, and the arrangement of the conjunctival vessels should be remembered as affording a means of diagnosis between this condition and injection of the sclerotic, which is present in inflammation of the deeper structures of the globe. The inflamed conjunctiva is bright red; the vessels are large and tortuous, and greatest at the circumference, shading off toward the corneal margin; they anastomose freely and form a dense network, and they can be emptied or displaced by gentle pressure.

The lachrymal gland is occasionally, though rarely, the seat of inflammation, either acute or chronic; it is also sometimes the seat of tumors, benign or malignant, and for these may require removal. This may be done by an incision through the skin just below the eyebrow; and the gland, being invested with a special capsule of its own, may be isolated and removed without opening the general cavity of the orbit. The canaliculi may be obstructed, either as a congenital defect or by some foreign body, as an eyelash or a dacryolith, causing the tears to run over the cheek. The canaliculi may also become occluded as the result of burns or injury; overflow of the tears may in addition result from deviation of the puncta or from chronic inflammation of the lachrymal sac. This latter condition is set up by some obstruction to the nasal duct frequently occurring in tubercular subjects. In consequence of this the tears and mucus accumulate in the lachrymal sac, distending it. Suppuration in the lachrymal sac is sometimes met with; this may be the sequel of a chronic inflammation; or may occur after some of the eruptive fevers in cases where the lachrymal passages were previously quite healthy. It may lead to lachrymal fistula.

THE EAR.

The organ of hearing is divisible into three parts—the external ear, the middle ear or tympanum, and the internal ear or labyrinth.

The External Ear.

The **external ear** consists of an expanded portion named *pinna* or *auricle*, and the auditory canal or *meatus*. The former serves to collect the vibrations of the air by which sound is produced; the latter conducts those vibrations to the tympanum.

The **pinna**, or **auricle** (Fig. 455), is of an ovoid form, with its larger end directed upward. Its outer surface is irregularly concave, directed slightly forward, and presents numerous eminences and depressions which result from the foldings of its fibro-cartilaginous element. To each of these, names have been assigned. Thus the external prominent rim of the auricle is called the *helix*. Another curved prominence, parallel with and in front of the helix, is called the *antihelix*; this bifurcates above, so as to enclose a triangular depression, the *fossa of the antihelix* (*fossa triangularis*). The narrow curved depression between the helix and antihelix is called the *fossa of the helix* (*Scapha*); the antihelix describes a curve round a deep, capacious cavity, the *concha*, which is partially divided into two parts by the *crus helicis* or the commencement of the helix; the upper part is termed the *cymba conchæ*, the lower part the *cavum conchæ*. In front of the concha, and projecting backward over the meatus, is a small pointed eminence, the *tragus*, so called from its being generally covered on its under surface with a tuft of hair resembling a goat's beard. Opposite the tragus, and separated from it by a deep notch (*incisura intertragica*) is a small tubercle, the *antitragus*. Below this is the *lobule*, composed of tough areolar and adipose tissue, wanting the firmness and elasticity of the rest of the pinna. Where the helix turns downward a small tubercle, the *tubercle of Darwin*, is frequently seen. This tubercle is very evident about the sixth month of fœtal life; at this stage the human pinna has a close resemblance to that of some of the adult monkeys.

The cranial surface of the pinna presents elevations which correspond to the depressions on its outer surface and after which they are named, *e. g.*, eminentia conchæ, eminentia triangularis, etc.

Structure of the Pinna.—The pinna is composed of a thin plate of yellow fibro-cartilage, covered with integument, and connected to the surrounding parts by the extrinsic ligaments and muscles; and to the commencement of the external auditory canal by fibrous tissue.

The *integument* is thin, closely adherent to the cartilage, and covered with hairs furnished with sebaceous glands, which are most numerous in the concha and scaphoid fossa. The hairs are most numerous and largest on the tragus and antitragus.

The *cartilage of the pinna* consists of one single piece: it gives form to this part of the ear, and upon its surface are found all the eminences and depressions above described. It does not enter into the construction of all parts of the auricle: thus it does not form a constituent part of the lobule; it is deficient also between the tragus and beginning of the helix, the notch between them being filled up by dense fibrous tissue. At the front part of the pinna, where the helix bends upward, is a small projection of cartilage, called the *spina helicis*, while the lower part of the helix is prolonged downward as a tail-like process, the *cauda helicis*; this is separated from the antihelix by a fissure, the *fissura antitragohelicina*. The cartilage of the pinna presents several intervals or fissures in its substance which partially separate the different parts. The fissure of the helix is a short vertical slit, situated at the fore part of the pinna. Another fissure, the fissure of the tragus, is seen upon the anterior surface of the tragus. The cartilage of the pinna is very pliable, elastic, of a yellowish color, and belongs to that form of cartilage which is known under the name of yellow fibro-cartilage.

The *ligaments of the pinna* consist of two sets: 1. The extrinsic set, or those connecting it to the side of the head. 2. The intrinsic set, or those connecting the various parts of its cartilage together.

The *extrinsic ligaments*, the most important, are two in number, anterior and posterior. The *anterior ligament* extends from the spina helicis and tragus to the root of the zygoma. The *posterior ligament* passes from the posterior surface of the concha to the outer surface of the mastoid process of the temporal bone.

The chief *intrinsic ligaments* are: (1) a strong fibrous band, stretching across from the tragus to the commencement of the helix, completing the meatus in front, and partly encircling the boundary of the concha; and (2) a band which extends between the anti-helix and the cauda helicis. Other less important bands are found on the cranial surface of the pinna.

The *muscles of the pinna* (Fig. 456) consist of two sets: 1. The *extrinsic*, which connect it with the side of the head, moving the pinna as a whole—viz., the Attollens, Attrahens, and Retrahens auriculum (page 301); and 2. The *intrinsic*, which extend from one part of the auricle to another, viz.:

Helicis major.	Antitragicus.
Helicis minor.	Transversus auriculæ.
Tragicus.	Obliquus auriculæ.

The *Musculus helicis major* is a narrow vertical band of muscular fibres, situated upon the anterior margin of the helix. It arises, below, from the cauda helicis, and is inserted into the anterior border of the helix, just where it is about to curve backward. It is pretty constant in its existence.

FIG. 455.—The pinna, or auricle. Outer surfaces.

FIG. 456.—The muscles of the pinna.

The *Musculus helicis minor* is an oblique fasciculus which covers the crus helicis.

The *Tragicus* is a short, flattened band of muscular fibres situated upon the outer surface of the tragus, the direction of its fibres being vertical.

The *Antitragicus* arises from the outer part of the antitragus: its fibres are inserted into the cauda helicis and antihelix. This muscle is usually very distinct.

The *Transversus auriculæ* is placed on the cranial surface of the pinna. It consists of scattered fibres, partly tendinous and partly muscular, extending from the convexity of the concha to the prominence corresponding with the groove of the helix.

The *Obliquus auriculæ* (Tod) consists of a few fibres extending from the upper and back part of the concha to the convexity immediately above it.

The *arteries of the pinna* are the posterior auricular from the external carotid, the anterior auricular from the temporal, and an auricular branch from the occipital artery.

The *veins* accompany the corresponding arteries.

The *nerves* are: the auricularis magnus, from the cervical plexus; the auricular branch of the pneumogastric; the auriculo-temporal branch of the inferior maxillary nerve; the occipitalis minor from the cervical plexus, and the occipitalis major or internal branch of the posterior division of the second cervical nerve. The muscles of the pinna are supplied by the facial nerve.

The **Auditory Canal** (*meatus auditorius externus*) extends from the bottom of the concha to the membrana tympani (Fig. 457). It is about an inch and a half in length if measured from the tragus; from the bottom of the concha its length is about an inch. It forms a sort of S-shaped curve, and is directed at first inward, forward, and slightly upward (*pars externa*); it then passes inward and backward (*pars media*), and lastly is carried inward, forward, and slightly downward (*pars interna*). It forms an oval cylindrical canal, the greatest diameter being in the vertical direction at the external orifice, but in the transverse direction at the tympanic end. It presents two constrictions, one near the inner end of the cartilaginous portion, and another, the *isthmus*, in the osseous portion, about three-quarters of an inch from the bottom of the concha. The membrana tympani, which occupies the termination of the meatus, is obliquely directed, in consequence of which the floor of the canal is longer than the roof, and the anterior wall longer than the posterior. The auditory canal is formed partly by cartilage and membrane, and partly by bone, and is lined by skin.

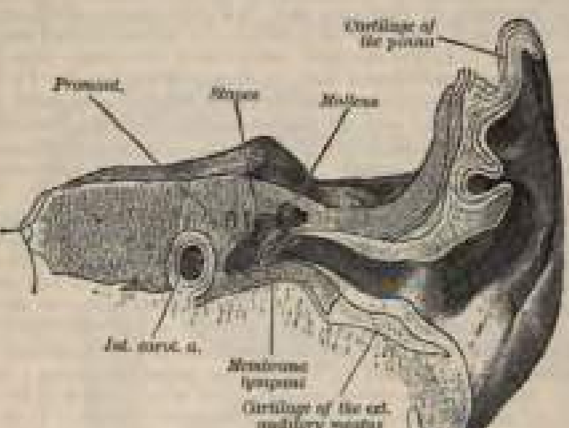


FIG. 457.—Transverse section of external auditory meatus and tympanum. Left side. (Gegenbaur.)

The *cartilaginous portion* is about one-third of an inch (8 mm.) in length, it is formed by the cartilage of the pinna, prolonged inward, and firmly attached to the circumference of the auditory process of the temporal bone. The cartilage is deficient at its upper and back part, its place being supplied by fibrous membrane. This part of the canal is rendered extremely movable by two or three deep fissures (*incisuræ Santorini*), which extend through the cartilage in a vertical direction.

The *osseous portion* is about two-thirds of an inch (16 mm.) in length, and narrower than the cartilaginous portion. It is directed inward and a little forward, forming a slight curve in its course, the convexity of which is upward and backward. Its inner end, which communicates, in the dry bone, with the cavity of the tympanum, is smaller than the outer and sloped, the anterior wall projecting beyond the posterior about two lines; it is marked, except at its upper part, by a narrow groove, the *sulcus tympanicus*, for the insertion of the membrana tympani. Its outer end is dilated and rough in the greater part of its circumference, for the attachment of the cartilage of the pinna. Its vertical transverse section is oval, the greatest diameter being from above downward. The front and lower parts of this canal are formed by a curved plate of bone, which, in the fœtus, exists as a separate ring (*annulus tympanicus*), incomplete at its upper part. See section on Osteology.

The *skin* lining the meatus is very thin, adheres closely to the cartilaginous and osseous portion of the tube, and covers the surface of the membrana tympani, forming its outer layer. After maceration the thin pouch of epidermis, when withdrawn, preserves the form of the meatus. In the thick subcutaneous tissue of the cartilaginous part of the meatus are numerous ceruminous glands, which secrete the ear-wax. They resemble in structure sweat-glands, and their ducts open on the surface of the skin.

Relations of the Meatus.—In front of the osseous part is the condyle of the mandible, which, however, is separated from the cartilaginous part by the retro-mandibular part of the parotid gland. The movements of the jaw influence to some extent the lumen of this latter portion. Behind the osseous part are the mastoid air-cells, separated from it by a thin layer of bone

The *arteries* supplying the meatus are branches from the posterior auricular, internal maxillary, and temporal.

The *nerves* are chiefly derived from the auriculo-temporal branch of the inferior maxillary nerve and the auricular branch of the pneumogastric.

Surface Form.—At the point of junction of the osseous and cartilaginous portions the tube forms an obtuse angle, which projects into the tube at its antero-inferior wall. This produces a sort of constriction in this situation, and renders it the narrowest portion of the canal—an important point to be borne in mind in connection with the presence of foreign bodies in the ears. The cartilaginous is connected to the bony part by fibrous tissue, which renders the outer part of the tube very movable, and therefore by drawing the pinna upward and backward the canal is rendered almost straight. At the external orifice are a few short, crisp hairs which serve to prevent the entrance of small particles of dust, or flies or other insects. In the external auditory meatus the secretion of the ceruminous glands serves to catch any small particles which may find their way into the canal, and prevent their reaching the membrana tympani, where their presence might excite irritation. In young children the meatus is very short, the osseous part being very deficient, and consisting merely of a bony ring (*annulus tympanicus*), which supports the membrana tympani. In the fœtus the osseous part is entirely absent. The shortness of the canal in children should be borne in mind in introducing the aural speculum, so that it be not pushed in too far, at the risk of injuring the membrana tympani; indeed, even in the adult the speculum should never be introduced beyond the constriction which marks the junction of the osseous and cartilaginous portions. In using this instrument it is advisable that the pinna should be drawn upward, backward, and a little outward, so as to render the canal as straight as possible, and thus assist the operator in obtaining, by the aid of reflected light, a good view of the membrana tympani. Just in front of the membrane is a well-marked depression, situated on the floor of the canal and bounded by a somewhat prominent ridge; in this foreign bodies may become lodged. By aid of the speculum, combined with traction of the auricle upward and backward, the whole of the membrana tympani is rendered visible. It is a pearly-gray membrane, slightly glistening in the adult, placed obliquely, so as to form with the floor of the meatus a very acute angle, (about 55°) while with the roof it forms an obtuse angle. At birth it is more horizontal, situated in almost the same plane as the base of the skull. About midway between the anterior and posterior margins of the membrane, and extending from the centre obliquely upward, is a reddish-yellow streak; this is the handle of the malleus, which is inserted into the membrane. At the upper part of this streak, close to the roof of the meatus, a little white rounded prominence is plainly to be seen; this is the processus brevis of the malleus, projecting against the membrane. The membrana tympani does not present a plane surface; on the contrary, its centre is drawn inward, on account of its connection with the handle of the malleus, and thus the external surface is rendered concave.

The Middle Ear, or Tympanum.

The **middle ear**, or **tympanum**, is an irregular cavity, compressed from without inward, and situated within the petrous bone. It is placed above the jugular fossa; the carotid canal lying in front, the mastoid cells behind, the meatus auditorius externally, and the labyrinth internally. It is filled with air, and communicates with the naso-pharynx by the Eustachian tube. The tympanum is traversed by a chain of movable bones, which connect the membrana tympani with the labyrinth, and serve to convey the vibrations communicated to the membrana tympani across the cavity of the tympanum to the internal ear.

The tympanic cavity consists of two parts: the *atrium* or *tympanic cavity* proper, opposite the tympanic membrane, and the *attic* or *epitympanic* recess, above the level of the upper part of the membrane; the latter contains the upper half of the malleus and the greater part of the incus. Its diameter, including the attic, measures about 15 mm. vertically and transversely. From without inward it measures about 6 mm. above and 4 mm. below; opposite the centre of the tympanic membrane it is only about 2 mm. It is bounded externally by the membrana tympani and meatus; internally, by the outer surface of the internal ear; and communicates, behind, with the mastoid antrum and through it with the mastoid cells; and in front with the Eustachian tube and canal for the Tensor tympani. Its roof and floor are formed by thin osseous laminæ, the one forming the roof being a thin plate situated on the anterior surface of the petrous portion of the temporal bone, close to its angle of junction with the squamous portion of the same bone.

The **roof** (*paries tegmentalis*) is broad, flattened, and formed of a thin plate of bone (*tegmen tympani*), which separates the cranial and tympanic cavities. It is prolonged backward so as to roof in the mastoid antrum; it is also carried forward to cover in the canal for the Tensor tympani muscle,

The **floor** (*paries jugularis*) is narrow, and is separated by a thin plate of bone (*fundus tympani*) from the jugular fossa. It presents, near the inner wall, a small aperture for the passage of Jacobson's nerve.

The **outer wall** is formed mainly by the membrana tympani, partly by the ring of bone into which this membrane is inserted. This ring of bone is incomplete at its upper part, forming a notch (*incisura Rivini*). Close to it are three small apertures; the iter chordæ posterius, the Glaserian fissure, and the iter chordæ anterius.

Fig. 458.—View of inner wall of tympanum. (Enlarged.)

The *iter chordæ posterius* is in the angle of junction between the posterior and external walls of the tympanum, immediately behind the membrana tympani and on a level with the upper end of the handle of the malleus; it leads into a minute canal, which descends in front of the aquæductus Fallopii, and terminates in that canal near the stylo-mastoid foramen. Through it the chorda tympani nerve enters the tympanum.

The *Glaserian fissure* opens just above and in front of the ring of bone into which the membrana tympani is inserted; in this situation it is a mere slit about a line in length. It lodges the long process and anterior ligament of the malleus, and gives passage to the tympanic branch of the internal maxillary artery.

The *iter chordæ anterius* is seen at the inner end of the preceding fissure; it leads into a canal (*canal of Huguier*), which runs parallel with the Glaserian fissure. Through it the chorda tympani nerve leaves the tympanum.

The **internal wall of the tympanum** (*paries labyrinthica*) (Fig. 458) is vertical in direction, and looks directly outward. It presents for examination the following parts:

Fenestra ovalis.	Promontory.
Fenestra rotunda.	Ridge of the aquæductus Fallopii.

The *fenestra ovalis* is a reniform opening leading from the tympanum into the vestibule; its long diameter is directed horizontally, and its convex border is upward. The opening in the recent state is occupied by the base of the stapes, which is connected to the margin of the foramen by an annular ligament.

The *fenestra rotunda* is an aperture placed at the bottom of a funnel-shaped depression leading into the cochlea. It is situated below and rather behind the fenestra ovalis, from which it is separated by a rounded elevation, the *promontory*; it is closed in the recent state by a membrane (*membrana tympani secundaria*, Scarpa). This membrane is concave toward the tympanum, convex toward the cochlea. It consists of three layers: the external, or mucous, derived from the mucous lining of the tympanum; the internal, from the lining membrane of the cochlea; and an intermediate, or fibrous layer.

The *promontory* is a rounded hollow prominence, formed by the projection outward of the first turn of the cochlea; it is placed between the fenestræ, and is furrowed on its surface by three small grooves, which lodge branches of the tympanic plexus. A minute spicule of bone frequently connects the promontory to the pyramid.

The *rounded eminence of the aquæductus Fallopii*, the prominence of the bony canal in which the facial nerve is contained, traverses the inner wall of the tympanum above the fenestra ovalis, and behind that opening curves nearly vertically downward along the posterior wall.

The **posterior wall of the tympanum** (*paries mastoidea*) is wider above than below, and presents for examination the

Opening of the antrum. Pyramid.

The *opening of the antrum* is a large irregular aperture, which extends backward from the epitympanic recess and leads into a considerable air space, the *antrum mastoideum* (see page 68). The antrum communicates with large irregular cavities contained in the interior of the mastoid process, the *mastoid air-cells*. These cavities vary considerably in number, size, and form; they are lined by mucous membrane continuous with that lining the cavity of the tympanum.

The *pyramid* is a conical eminence situated immediately behind the fenestra ovalis, and in front of the vertical portion of the eminence above described; it is hollow in the interior, and contains the Stapedius muscle; its summit projects forward toward the fenestra ovalis, and presents a small aperture which transmits the tendon of the muscle. The cavity in the pyramid is prolonged into a minute canal, which communicates with the aquæductus Fallopii and transmits the nerve which supplies the Stapedius.

The **anterior wall of the tympanum** (*paries carotica*) is wider above than below; it corresponds with the carotid canal, from which it is separated by a thin plate of bone, perforated by the tympanic branch of the internal carotid artery. It presents for examination the

Canal for the Tensor tympani. Orifice of the Eustachian tube.
The processus cochleariformis.

The orifice of the canal for the Tensor tympani and the orifice of the Eustachian tube are situated at the upper part of the anterior wall, being separated from each other by a thin, delicate, horizontal plate of bone, the *processus cochleariformis*. These canals run from the tympanum forward, inward, and a little downward, to the retiring angle between the squamous and petrous portions of the temporal bone.

The *canal for the Tensor tympani* is the superior and the smaller of the two; it is rounded and lies beneath the forward prolongation of the tegmen tympani. It extends on to the inner wall of the tympanum and ends immediately above the fenestra ovalis. The processus cochleariformis passes backward below this part of the canal, forming its outer wall and floor; it expands above the anterior extremity of the fenestra ovalis and terminates by curving outward so as to form a pulley over which the tendon passes.

The *Eustachian tube* is the channel through which the tympanum communicates with the pharynx. Its length is an inch and a half (36 mm.), and its direction downward, forward, and inward, forming an angle of about 45° with the sagittal plane and one of from 30° to 40° with the horizontal plane. It is formed partly of bone, partly of cartilage and fibrous tissue.

The *osseous portion* is about half an inch in length. It commences in the anterior wall of the tympanum, below the processus cochleariformis, and, gradually narrowing, terminates at the angle of junction of the petrous and squamous portions, its extremity presenting a jagged margin which serves for the attachment of the cartilaginous portion.

The *cartilaginous portion*, about an inch in length, is formed of a triangular plate of elastic fibro-cartilage, the apex of which is attached to the margin of the inner extremity of the osseous canal, while its base lies directly under the mucous membrane of the naso-pharynx, where it forms an elevation or cushion behind the pharyngeal orifice of the tube. The upper edge of the cartilage is curled upon itself, being bent outward so as to present on transverse section the appearance of a hook; a groove or furrow is thus produced, which opens below and externally, and this part of the canal is completed by fibrous membrane. The cartilage is fixed to the base of the skull, and lies in a groove between the petrous-temporal and the greater wing of the sphenoid; this groove ends opposite the middle of the internal pterygoid plate. The cartilaginous and bony portions of the tube are not in the same plane, the former inclining downward a little more than the latter. The diameter of the canal is not uniform throughout, being greatest at the pharyngeal orifice and least at the junction of the bony and cartilaginous portions, where it is named the *isthmus;* it again expands somewhat as it approaches the tympanic cavity. The position and relations of the pharyngeal orifice are described with the anatomy of the naso-pharynx. Through this canal the mucous membrane of the pharynx is continuous with that which lines the tympanum. The mucous membrane is covered with ciliated epithelium and is thin in the osseous portion, while in the cartilaginous portion it contains many mucous glands and near the pharyngeal orifice a considerable amount of adenoid tissue, which has been named by Gerlach the *tube-tonsil.* The tube is opened during deglutition by the Salpingo-pharyngeus and Dilator tubæ muscles.

The **membrana tympani** separates the cavity of the tympanum from the bottom of the external meatus. It is a thin, semi-transparent membrane, nearly oval in form, somewhat broader above than below, and directed very obliquely downward and inward so as to form an angle of about 55° with the floor of the meatus. The greater part of its circumference is thickened to form an annular ring which is fixed in a groove, the *sulcus tympanicus,* at the inner extremity of the meatus. This sulcus is deficient superiorly at the incisure or notch of Rivinus. From the extremities of this notch two bands, the *anterior* and *posterior malleolar folds,* are prolonged to the short process of the malleus. The small, somewhat triangular part of the membrane situated above these folds is lax and thin, and is named the *membrana flaccida* of Shrapnell; in it a small orifice is sometimes seen. The handle of the malleus is firmly attached to the inner aspect of the membrane as far as its centre, which it draws inward toward the cavity of the tympanum. The outer surface of the membrane is thus concave, and the most depressed part of this concavity is named the *umbo* or *navel.*

Structure.—This membrane is composed of three layers, an external (cuticular), a middle (fibrous), and an internal (mucous). The *cuticular lining* is derived from the integument lining the meatus. The fibrous layer consists of two strata, an external, of *radial fibres,* which diverge from the handle of the malleus, and an internal, of *circular fibres,* which are plentiful around the circumference but sparse and scattered near the centre of the membrane. Branched or *dendritic* fibres, as pointed out by Grüber, are also present, especially in the posterior half of the membrane.

The arteries are derived from the deep auricular branch of the internal maxillary, which ramifies beneath the cuticular layer and from the stylo-mastoid branch of the posterior auricular and tympanic branch of the internal maxillary, which are distributed on the mucous surface. The superficial veins open into the external jugular; those on the mucous surface drain themselves partly into the lateral sinus and veins of the dura mater and partly into a plexus on the Eustachian tube. The membrane receives its nervous supply from the auriculo-temporal branch of the inferior maxillary, the auricular branch of the vagus, and the tympanic branch of the glosso-pharyngeal.

Ossicles of the Tympanum (Fig. 459).

The tympanum is traversed by a chain of movable bones, three in number, the *malleus*, *incus*, and *stapes*. The first is attached to the membrana tympani, the last to the fenestra ovalis, the incus being placed between the two, and is connected to both by delicate articulations.

The **Malleus**, so named from its fancied resemblance to a hammer, consists of a head, neck, and three processes—the handle or manubrium, the processus gracilis, and the processus brevis.

The *head* is the large upper extremity of the bone; it is oval in shape, and articulates posteriorly with the incus, being free in the rest of its extent. The facet for articulation with the incus is constricted near the middle, and is divided by a ridge into an upper, larger, and lower, lesser part, which form nearly a right angle with each other. Opposite the constriction the lower margin of the facet projects in the form of a process, the *cog-tooth* or *spur* of the malleus.

The *neck* is the narrow contracted part just beneath the head; and below this is a prominence, to which the various processes are attached.

The *manubrium* is a vertical process of bone, which is connected by its outer margin with the membrana tympani. It is directed downward, inward, and backward; it decreases in size toward its extremity, where it is curved slightly forward, and flattened from within outward. On the inner side, near its upper end, is a slight projection, into which the tendon of the Tensor tympani is inserted.

The *processus gracilis* is a long and very delicate process, which passes from the eminence below the neck forward and outward to the Glaserian fissure, to which it is connected by ligamentous fibres. In the fœtus this is the longest process of the malleus, and is in direct continuity with the cartilage of Meckel.

FIG. 459.—The small bones of the ear, seen from the outside. (Enlarged.)

The *processus brevis* is a slight conical projection, which springs from the root of the manubrium; it is directed outward, and is attached to the upper part of the tympanic membrane.

The **Incus** has received its name from its supposed resemblance to an anvil, but it is more like a bicuspid tooth, with two roots, which differ in length, and are widely separated from each other. It consists of a body and two processes.

The *body* is somewhat quadrilateral but compressed laterally. On its anterior surface is a deeply concavo-convex facet, which articulates with the head of the malleus; in the fresh state it is covered with cartilage and the joint lined with synovial membrane.

The two processes diverge from one another nearly at right angles.

The *short process*, somewhat conical in shape, projects nearly horizontally backward, and articulates with a depression, the *fossa incudis*, in the lower and back part of the epitympanic recess.

The *long process*, longer and more slender than the preceding, descends nearly vertically behind and parallel to the handle of the malleus, and, bending inward, terminates in a rounded globular projection, the *os orbiculare* or *lenticular process*, which is tipped with cartilage, and articulates with the head of the stapes. In the fœtus the os orbiculare exists as a separate bone.

The **Stapes**, so called from its close resemblance to a stirrup, consists of a head, neck, two crura, and a base.

The *head* presents a depression, tipped with cartilage, which articulates with the os orbiculare.

The *neck*, the constricted part of the bone succeeding the head, receives the insertion of the Stapedius muscle.

The *two crura* diverge from the neck and are connected at their extremities by a flattened, oval-shaped plate (the *base*), which forms the foot-plate of the stirrup and is fixed to the margin of the fenestra ovalis by ligamentous fibres. Of the two crura, the anterior is shorter and less curved than the posterior.

Ligaments of the Ossicula.—These small bones are connected with each other and with the walls of the tympanum by ligaments, and moved by small muscles. The articular surfaces of the malleus and incus and the orbicular process of the incus and head of the stapes are covered with cartilage, connected together by delicate capsular ligaments and lined by synovial membrane. The ligaments connecting the ossicula with the walls of the tympanum are five in number—three for the malleus, one for the incus, and one for the stapes.

The *anterior ligament of the malleus* was formerly described by Sömmerring as a muscle (*Laxator tympani*). It is now, however, believed by most observers to consist of ligamentous fibres only. It is attached by one extremity to the neck of the malleus, just above the processus gracilis, and by the other to the anterior wall of the tympanum, close to the Glaserian fissure, some of its fibres being prolonged through the fissure to reach the spine of the sphenoid.

The *superior ligament of the malleus* is a delicate, round bundle of fibres which descends perpendicularly from the roof of the epitympanic recess to the head of the malleus.

The *external ligament of the malleus* is a triangular plane of fibres passing from the posterior part of the notch in the tympanic ring (incisura Rivini) to the short process of the malleus.

The *posterior ligament of the incus* is a short, thick, ligamentous band which connects the extremity of the short process of the incus to the posterior and lower part of the epitympanic recess, near the margin of the opening of the mastoid cells.

The inner surface and the circumference of the base of the stapes are covered with hyaline cartilage, and the *annular ligament of the stapes* connects the circumference of the base to the margin of the fenestra ovalis.

A *superior ligament of the incus* has been described by Arnold, but it is little more than a fold of mucous membrane.

The **muscles of the tympanum** are two:

Tensor tympani. Stapedius.

The *Tensor tympani*, the larger, is contained in the bony canal above the osseous portion of the Eustachian tube, from which it is separated by the processus cochleariformis. It arises from the under surface of the petrous bone, from the cartilaginous portion of the Eustachian tube, and from the osseous canal in which it is contained. Passing backward through the canal, it terminates in a slender tendon which enters the tympanum and makes a sharp bend outward round the extremity of the processus cochleariformis, and is inserted into the handle of the malleus near its root. It is supplied by a branch from the otic ganglion.

The *Stapedius* arises from the side of a conical cavity hollowed out of the interior of the pyramid; its tendon emerges from the orifice at the apex of the pyramid, and, passing forward, is inserted into the neck of the stapes. Its surface is aponeurotic, its interior fleshy, and its tendon occasionally contains a slender bony spine, which is constant in some mammalia. It is supplied by the tympanic branch of the facial nerve.

Actions.—The Tensor tympani draws the membrana tympani inward and thus heightens its tension. The Stapedius draws the head of the stapes backward, and thus causes the base of the bone to rotate on a vertical axis drawn through its own centre: in doing this the back part of the base would be pressed inward toward the vestibule, while the fore part would be drawn from it. It probably compresses the contents of the vestibule.

The **mucous membrane of the tympanum** is continuous with the mucous membrane of the pharynx through the Eustachian tube. It invests the ossicula, and the muscles and nerves contained in the tympanic cavity; forms the internal layer of the membrana tympani, and the outer layer of the membrana tympani secundaria, and is reflected into the mastoid antrum and cells, which it lines throughout. It forms several vascular folds, which extend from the walls of the tympanum to the ossicles; of these, one descends from the roof of the tympanum to the head of the malleus and upper margin of the body of the incus, a second invests the Stapedius muscle: other folds invest the chorda tympani nerve and the Tensor tympani muscle. These folds separate off pouch-like cavities, and give the interior of the tympanum a somewhat honey-comb appearance. One of these pouches is well marked—viz., the *pouch of Prussak*, which lies between the neck of the malleus and the membrana flaccida. In the tympanum this membrane is pale, thin, slightly vascular, and covered for the most part with columnar ciliated epithelium, but that covering the pyramid, ossicula, and membrana tympani possesses a flattened non-ciliated epithelium. In the antrum and mastoid cells its epithelium is also non-ciliated. In the osseous portion of the Eustachian tube the membrane is thin; but in the cartilaginous portion it is very thick, highly vascular, covered with ciliated epithelium, and provided with numerous mucous glands.

The **arteries supplying the tympanum** are six in number. Two of them are larger than the rest—viz., the tympanic branch of the internal maxillary, which supplies the membrana tympani; and the stylo-mastoid branch of the posterior auricular, which supplies the back part of the tympanum and mastoid cells. The smaller branches are—the petrosal branch of the middle meningeal, which enters through the hiatus Fallopii; a branch from the ascending pharyngeal and another from the Vidian, which accompany the Eustachian tube; and the tympanic branch from the internal carotid, given off in the carotid canal and perforating the thin anterior wall of the tympanum.

The **veins of the tympanum** terminate in the pterygoid plexus and in the superior petrosal sinus.

The **nerves of the tympanum** constitute the tympanic plexus, which ramifies upon the surface of the promontory. The plexus is formed by (1) the tympanic branch of the glosso-pharyngeal; (2) the small deep petrosal nerve; (3) the small superficial petrosal nerve; and (4) a branch which joins the great superficial petrosal.

The *tympanic branch of the glosso-pharyngeal* (Jacobson's nerve) enters the tympanum by an aperture in its floor close to the inner wall and divides into branches, which ramify on the promontory and enter into the formation of the plexus. The *small deep petrosal nerve* from the carotid plexus of the sympathetic passes through the wall of the carotid canal, and joins the branches of Jacobson's nerve. The branch to the great superficial petrosal passes through an opening on the inner wall of the tympanum in front of the fenestra ovalis. The *small superficial petrosal nerve*, derived from the otic ganglion, passes through a foramen in the middle fossa of the base of the skull (sometimes the foramen ovale), passes backward and enters the petrous bone through a small aperture, situated external to the hiatus Fallopii on the anterior surface of this bone; it then courses downward through the bone, and, passing by the gangliform enlargement of the facial nerve, receives a connecting filament from it and enters the tympanic cavity, where it communicates with Jacobson's nerve, and assists in forming the tympanic plexus.

The *branches of distribution* of the tympanic plexus are distributed to the mucous membrane of the tympanum; one special branch passing to the fenestra ovalis, another to the fenestra rotunda, and a third to the Eustachian tube. The small superficial petrosal may be looked upon as a branch from the plexus to the otic ganglion.

In addition to the tympanic plexus there are the nerves supplying the muscles. The Tensor tympani is supplied by a branch from the third division of the fifth through the otic ganglion, and the Stapedius by the tympanic branch of the facial.

The *chorda tympani* nerve crosses the tympanic cavity. It is given off from the facial as it passes vertically downward at the back of the tympanum, about a quarter of an inch before its exit from the stylo-mastoid foramen. It passes from below upward and forward in a distinct canal, and enters the cavity of the tympanum through an aperture, *iter chordæ posterius*, already described (page 853), and becomes invested with mucous membrane. It passes forward, through the cavity of the tympanum, crossing internal to the membrana tympani and over the handle of the malleus to the anterior inferior angle of the tympanum, and emerges from that cavity through the *iter chordæ anterius*, or *canal of Huguier*. It is invested by the fold of mucous membrane already mentioned, and therefore lies between the mucous and fibrous layers of the membrana tympani.

The Internal Ear or Labyrinth.

The **internal ear** is the essential part of the organ of hearing, receiving the ultimate distribution of the auditory nerve. It is called the **labyrinth,** from the complexity of its shape, and consists of two parts: the *osseous labyrinth*, a series of cavities channelled out of the substance of the petrous bone, and the *membranous labyrinth*, the latter being contained within the former.

The Osseous Labyrinth.

The **osseous labyrinth** consists of three parts: the *vestibule, semicircular canals*, and *cochlea*. These are cavities hollowed out of the substance of the bone, and

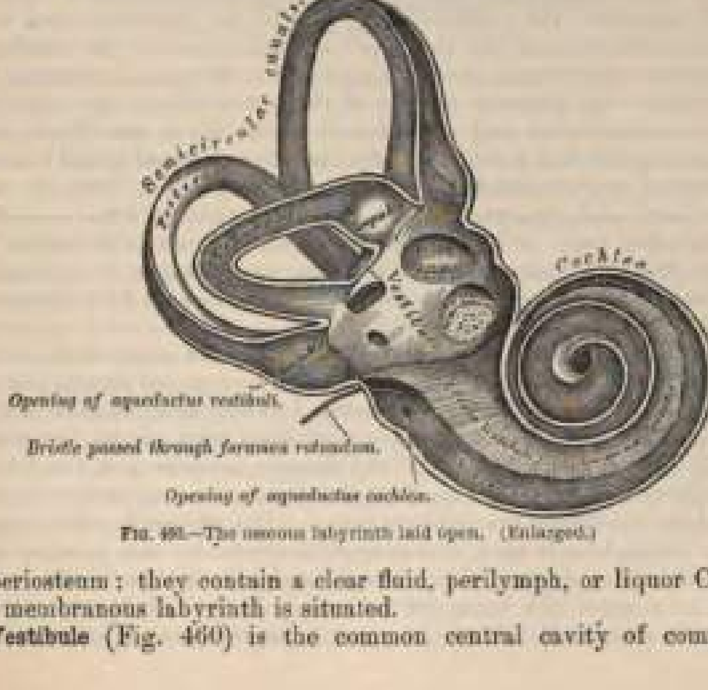


FIG. 460.—The osseous labyrinth laid open. (Enlarged.)

lined by periosteum; they contain a clear fluid, perilymph, or liquor Cotunnii, in which the membranous labyrinth is situated.

The **Vestibule** (Fig. 460) is the common central cavity of communication between the parts of the internal ear. It is situated on the inner side of the tympanum, behind the cochlea, and in front of the semicircular canals. It is somewhat ovoidal in shape from before backward, flattened from within outward, and measures about one-fifth of an inch from before backward, as well as from above downward, and about one-eighth of an inch from without inward. On its *outer* or *tympanic wall* is the fenestra ovalis, closed, in the recent state, by the base of the stapes, and its annular ligament. On its *inner wall*, at the fore part, is a small circular depression, *fovea hemisphærica* or *recessus sphæricus*, which is perforated, at its anterior and inferior part, by several minute holes (*macula cribrosa media*) for the passage of filaments of the auditory nerve to the saccule; and behind this depression is a vertical ridge, the *crista vestibuli*. This ridge bifurcates below to enclose a small depression, the *fossa cochlearis*, which is perforated by a number of holes for the passage of filaments of the auditory nerve which supply the posterior end of the ductus cochlearis. At the hinder part of the inner wall is the orifice of the *aquæductus vestibuli*, which extends to the posterior surface of the petrous portion of the temporal bone. It transmits a small vein, and contains a tubular prolongation of the lining membrane of the vestibule, the *ductus endolymphaticus*, which ends in a *cul-de-sac* between the layers of the dura mater within the cranial cavity. On the *upper wall* or *roof* is a transversely oval depression, *fovea semi-elliptica*, separated from the fovea hemisphærica by the crista vestibuli already mentioned. *Behind*, the semicircular canals open into the vestibule by five orifices. In *front* is an elliptical opening, which communicates with the scala vestibuli of the cochlea by an orifice, *apertura scalæ vestibuli cochleæ*.

The **Semicircular canals** are three bony canals situated above and behind the vestibule. They are of unequal length, compressed from side to side, and describe the greater part of a circle. They measure about one-twentieth of an inch in diameter, and each presents a dilatation at one end, called the *ampulla*, which measures more than twice the diameter of the tube. These canals open into the vestibule by five orifices, one of the apertures being common to two of the canals.

The *superior semicircular canal* is vertical in direction, and is placed transversely to the long axis of the petrous portion of the temporal bone, on the anterior surface of which its arch forms a round projection. It describes about two-thirds of a circle. Its outer extremity, which is ampullated, communicates by a distinct orifice in the upper part of the vestibule; the opposite end of the canal, which is not dilated, joins with the corresponding part of the posterior canal to form the *crus commune*, which opens into the upper and inner part of the vestibule.

The *posterior semicircular canal*, also vertical in direction, is directed backward, nearly parallel to the posterior surface of the petrous bone; it is the longest of the three; its ampullated end commences at the lower and back part of the vestibule, its opposite end joining to form the common canal already mentioned.

The *external* or *horizontal canal* is the shortest of the three, its arch being directed outward and backward; thus each semicircular canal stands at right angles to the other two. Its ampullated end corresponds to the upper and outer angle of the vestibule, just above the fenestra ovalis, where it opens close to the ampullary end of the superior canal; its opposite end opens by a distinct orifice at the upper and back part of the vestibule.

The **Cochlea** bears some resemblance to a common snail-shell: it forms the anterior part of the labyrinth, is conical in form, and placed almost horizontally in front of the vestibule; its apex is directed forward and outward, with a slight inclination downward, toward the upper and front part of the inner wall of the tympanum; its base corresponds with the anterior depression at the bottom of the internal auditory meatus, and is perforated by numerous apertures for the passage of the cochlear division of the auditory nerve. It measures nearly a quarter of an inch (5 mm.) from base to apex, and its breadth across the base is somewhat greater (about 9 mm.). It consists of a conical-shaped central axis, the *modiolus* or *columella*; of a canal, the inner wall of which is formed by the central axis, wound spirally around it for two turns and three-quarters, from the base to the apex, and of a delicate lamina (the *lamina spiralis ossea*) which projects from the modiolus, and, following the windings of the canal, partially subdivides into two. In the recent state certain membranous layers are attached to the free border of this lamina, which project into the canal and completely separate it into two passages, which, however, communicate with each other at the apex of the modiolus by a small opening, named the *helicotrema*.

The *modiolus* or *columella* is the central axis or pillar of the cochlea. It is conical in form, and extends from the base to the apex of the cochlea. Its base is broad, and appears at the bottom of the internal auditory meatus, where it corresponds with the area cochleæ; it is perforated by numerous orifices, which transmit filaments of the cochlear division of the auditory nerve, the nerves for the first turn and a half being transmitted through the foramina of the tractus spiralis foraminosus; the fibres for the apical turn passing up through the foramen centrale. The foramina of the tractus spiralis foraminosus pass up through the modiolus and successively bend outward to reach the attached margin of the lamina spiralis ossea. Here they become enlarged, and by their apposition form a spiral canal (*canalis spiralis modioli*), which follows the course of the attached margin of the lamina spiralis ossea and lodges the ganglion spirale. The foramen centrale is continued as a canal up the middle of the modiolus to its apex. The axis diminishes rapidly in size in the second and succeeding coil.

The bony canal of the cochlea (Fig. 461) takes two turns and three-quarters round the modiolus. It is a little over an inch in length (about 30 mm.), and

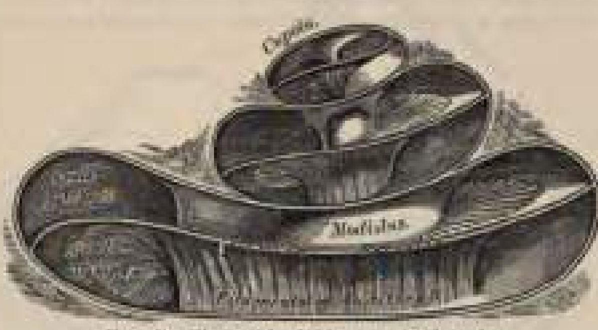


Fig. 461.—The cochlea laid open. (Enlarged.)

diminishes gradually in size from the base to the summit, where it terminates in a *cul-de-sac*, the *cupola*, which forms the apex of the cochlea. The commencement of this canal is about the tenth of an inch in diameter; it diverges from the modiolus toward the tympanum and vestibule, and presents three openings. One, the *fenestra rotunda*, communicates with the tympanum; in the recent state this aperture is closed by a membrane, the *membrana tympani secundaria*. Another aperture, of an elliptical form, enters the vestibule. The third is the aperture of the aquæductus cochleæ, leading to a minute funnel-shaped canal, which opens on the basilar surface of the petrous bone and transmits a small vein, and also forms a communication between the subarachnoidean space of the skull and the perilymph contained in the scala tympani.

The *lamina spiralis ossea* is a bony shelf or ledge which projects outward from the modiolus into the interior of the spiral canal, and, like the canal, takes two and three-quarter turns round the modiolus. It reaches about half-way toward the outer wall of the spiral tube, and partially divides its cavity into two passages or scalæ, of which the upper is named the *scala vestibuli*, while the lower is termed the *scala tympani*. Near the summit of the cochlea the lamina terminates in a hook-shaped process, the *hamulus*, which assists to form the boundary of a small opening, the *helicotrema*, by which the two scalæ communicate with each other. From the canalis spiralis modioli numerous foramina pass outward through the osseous spiral lamina as far as its outer or free edge. In the lower part of the first turn a second bony lamina (*lamina spiralis secundaria*) projects inward from the outer wall of the bony tube; it does not, however, reach the primary osseous spiral lamina, so that if viewed from the vestibule a narrow fissure, the *fissura vestibuli*, is seen between them.

The Membranous Labyrinth (Fig. 462).

The **membranous labyrinth** is contained within the bony cavities just described, having the same general form as the cavities in which it is contained, though considerably smaller, being separated from the bony walls by a quantity of fluid, the *perilymph*. It does not, however, float loosely in this fluid, but in places is fixed to the walls of the cavity. The membranous sac contains fluid, the *endolymph*, and on it the ramifications of the auditory nerve are distributed.

Within the osseous vestibule the membranous labyrinth does not quite preserve the form of the bony cavity, but presents two membranous sacs, the *utricle* and the *saccule*. The *utricle* is the larger of the two, of an oblong form, compressed laterally, and occupies the upper and back part of the vestibule, lying in contact with the fovea semi-elliptica and the part below it. That portion which is lodged in the fovea forms a sort of pouch or *cul-de-sac*, the floor and anterior wall of which are much thicker than elsewhere, and form the *macula acustica utricularis*, which receives the utricular filaments of the auditory nerve and has attached to its

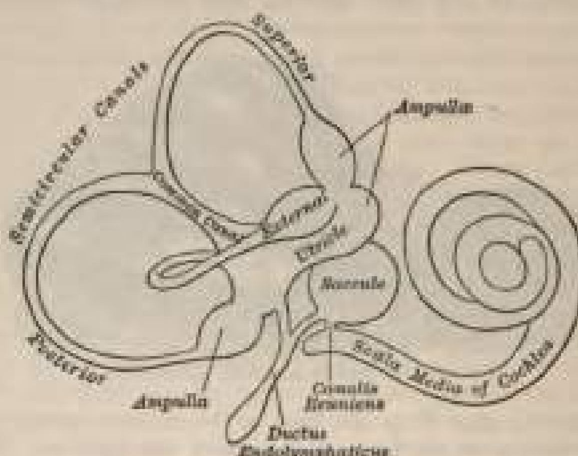


FIG. 462.—The membranous labyrinth. (Enlarged.)

internal surface a layer of calcareous particles (otoliths). The cavity of the utricle communicates behind with the membranous semicircular canals by five orifices. From its anterior wall is given off a small canal, which joins with a canal from the saccule to form the *ductus endolymphaticus*.

The *saccule* is the smaller of the two vestibular sacs; it is globular in form, lies in the fovea hemisphærica near the opening of the scala vestibuli of the cochlea. Its anterior part exhibits an oval thickening, the *macula saccularis*, to which are distributed the saccular filaments of the auditory nerve. Its cavity does not directly communicate with that of the utricle. From the posterior wall is given off a canal, which joins with a similar canal given off from the utricle to form the *ductus endo-lymphaticus*. This duct passes along the aquæductus vestibuli and ends in a blind pouch on the posterior surface of the petrous portion of the temporal bone, where it is in contact with the dura mater. From the lower part of the saccule a short tube, the *canalis reuniens* of Hensen, passes downward and outward to open into the ductus cochlearis (Fig. 462).

The *membranous semicircular canals* are about one-third the diameter of the osseous canals, but in number, shape, and general form they are precisely similar, and present at one end an ampullary enlargement. They open by five orifices into the utricle, one opening being common to two canals. In the ampullæ the wall is thickened, and projects into the cavity as a fiddle-shaped, transversely placed elevation, the *septum transversum*, in which the nerves end.

The utricle, saccule, and membranous canals are held in position by numerous fibrous bands which stretch across the space between them and the bony walls.

Structure.—The walls of the utricle, saccule, and semicircular canals consist of three layers. The *outer layer* is a loose and flocculent structure, apparently composed of ordinary fibrous tissue, containing blood-vessels and pigment-cells analogous to those in the pigment coat of the retina. The *middle layer*, thicker and more transparent, bears some resemblance to the hyaloid membrane, but it presents on its internal surface, especially in the semicircular canals, numerous papilliform projections, and, on the addition of acetic acid, presents an appearance of longitudinal fibrillation and elongated nuclei. The *inner layer* is formed of polygonal nucleated epithelial cells. In the maculæ of the utricle and saccule, and in the transverse septa of the ampullæ of the canals, the middle coat is thickened and the epithelium is columnar, and consists of *supporting cells* and *hair-cells*, the free ends of the latter being surmounted by a long, tapering filament (auditory hair) which projects into the cavity. The filaments of the auditory nerve enter these parts, and, having pierced the outer and thickened middle layer, they lose their medullary sheath, and their axis-cylinders ramify between the hair-cells.

Two small rounded bodies termed *otoliths*, and consisting of a mass of minute crystalline grains of carbonate of lime, held together in a mesh of delicate fibrous

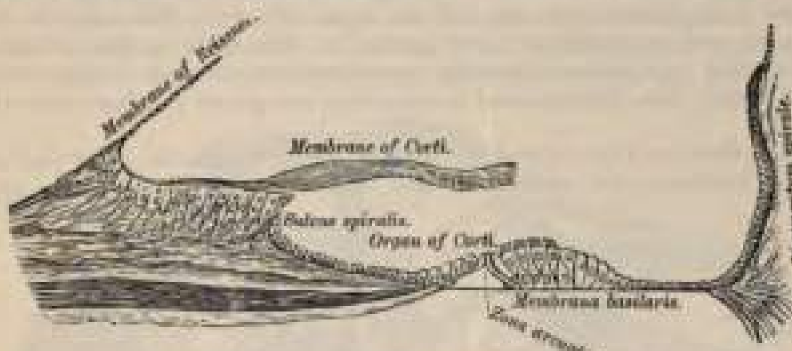


FIG. [illegible].—Floor of scala media, showing the organ of Corti, etc.

tissue, are contained in the walls of the utricle and saccule opposite the distribution of the nerves. A calcareous material is also, according to Bowman, sparingly scattered in the cells lining the ampullæ of the semicircular canals.

The **membranous cochlea, ductus cochlearis,** or **scala media** consists of a spirally arranged tube enclosed in the bony canal of the cochlea and lying along its outer wall. The manner in which it is formed will now be described.

The osseous spiral lamina, as above stated, extends only part of the distance between the modiolus and the outer bony wall of the cochlea. A membrane, the *membrana basilaris*, stretches from its free edge to the outer wall of the cochlea, and completes the roof of the scala tympani. A second and more delicate membrane, the *membrane* of *Reissner*, extends from the thickened periosteum covering the lamina spiralis ossea to the outer wall of the cochlea, to which it is attached at some little distance above the membrana basilaris. A canal is thus shut off between the scala tympani below and the scala vestibuli above; this is the *membranous canal of the cochlea, ductus cochlearis*, or *scala media*. It is triangular on transverse section, its roof being formed by the membrane of Reissner, its outer wall by the periosteum which lines the bony canal, and its floor by the membrana basilaris, and the outer part of the lamina spiralis ossea, on the former of which is placed the organ of Corti. Reissner's membrane is thin and homogeneous, and is covered on its upper and under surfaces by a layer of epithelium. The periosteum, which forms the outer wall of the ductus cochlearis, is greatly thickened and altered in character, forming what is called the *ligamentum spirale*. It projects inward below as a triangular prominence, the *crista basilaris*, which gives attachment to the outer edge of the membrana basilaris, and immediately above which is a concavity, the *sulcus spiralis externus*. The upper portion of the ligamentum spirale contains numerous capillary loops and small blood-vessels, and forms what is termed the *stria vascularis*.

The lamina spiralis ossea consists of two plates of bone extending outward: between these are the canals for the transmission of the filaments of the auditory nerve. On the upper plate of that part of the osseous spiral lamina which is outside Reissner's membrane the periosteum is thickened to form the *limbus laminæ spiralis*, and this terminates externally in a concavity, the *sulcus spiralis internus*, which presents, on section, the form of the letter C; the upper part of the letter, formed by the overhanging extremity of the limbus, is named the *labium vestibulare;* the lower part, prolonged and tapering, is called the *labium tympanicum*, and is perforated by numerous foramina (*foramina nervosa*) for the passage of the cochlear nerves. Externally, the labium tympanicum is continuous with the membrana basilaris. The upper surface of the labium vestibulare is intersected at right angles by a number of furrows, between which are numerous elevations; these present the appearance of teeth along the free margin of the labium, and have been named by Huschke the *auditory teeth*. The basilar membrane may be divided into two areas, inner and outer. The inner is thin, and is named the *zona arcuata:* it supports the organ of Corti. The outer is thicker and striated, and is termed the *zona pectinata*. The under surface of the membrane is covered by a layer of vascular connective tissue. One of these vessels is somewhat larger than the rest, and is named the *vas spirale;* it lies below Corti's tunnel.

Organ of Corti.[1]—This organ (Fig. 464) is situated upon the inner part of the membrana basilaris, and appears at first sight as a papilla, winding spirally

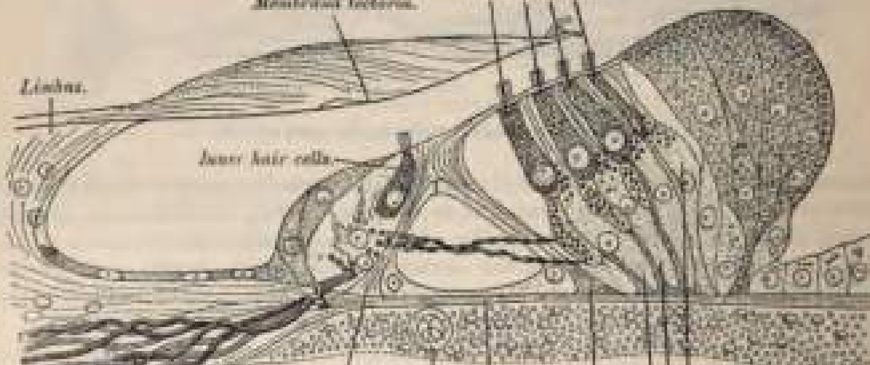


FIG. 464.—Section through the organ of Corti. Magnified. (G. Retzius.)

throughout the whole length of the ductus cochlearis, from which circumstance it has been designated the *papilla spiralis*. More accurately viewed, it is seen to be composed of a remarkable arrangement of cells, which may be likened to the keyboard of a pianoforte. Of these cells, the two central ones are rodlike bodies

[1] Corti's original paper is in the *Zeitschrift f. Wissen. Zool.*, iii., 109.

and are called the inner and outer *rods of Corti*. They are placed on the basilar membrane, at some little distance from each other, but are inclined toward each other, so as to meet at their opposite extremities, and form a series of arches roofing over a minute tunnel, the *tunnel of Corti*, between them and the basilar membrane, which ascends spirally through the whole length of the cochlea.

The *inner rods*, some 6000 in number, are more numerous than the outer ones, and rest on the basilar membrane, close to the labium tympanicum; they project obliquely upward and outward, and terminate above in expanded extremities which resemble in shape the upper end of the ulna, with its sigmoid cavity, coronoid and olecranon processes. On the outer side of the rod, in the angle formed between it and the basilar membrane, is a nucleated mass of protoplasm; while on the inner side is a row of epithelial cells (*inner hair-cells*), surmounted by a brush of fine, stiff, hairlike processes. On the inner side of these cells are two or three rows of columnar supporting cells, which are continuous with the cubical cells lining the sulcus spiralis internus.

The *outer rods*, numbering about 4000, also rest by a broad foot on the basilar membrane; they incline upward and inward, and their upper extremity resembles the head and bill of a swan: the back of the head fitting into the concavity—the analogue of the sigmoid cavity—of one or more of the internal rods, and the bill projecting outward as a phalangeal process of the membrana reticularis, presently to be described.

In the head of these outer rods is an oval portion, where the fibres of which the rod appears to be composed are deficient, and which stains more deeply with carmine than the rest of the rod. At the base of the rod, on its internal side—that is to say, in the angle formed by the rod with the basilar membrane—is a similar protoplasmic mass to that found on the outer side of the base of the inner rod; these masses of protoplasm are probably the undifferentiated portions of the cells from which the rods are developed. External to the outer rod are three or

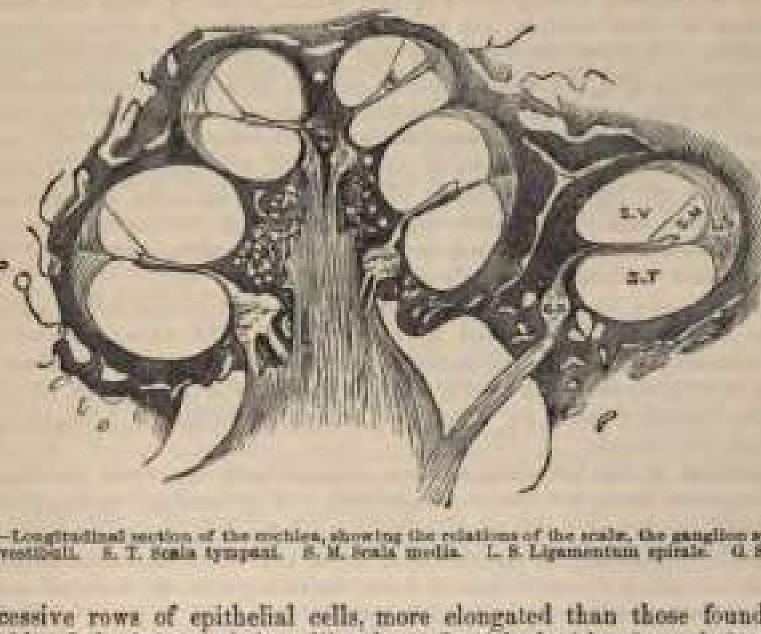


FIG. 465.—Longitudinal section of the cochlea, showing the relations of the scalæ, the ganglion spirale, etc. S. V. Scala vestibuli. S. T. Scala tympani. S. M. Scala media. L. S. Ligamentum spirale. G. S. Ganglion spirale.

four successive rows of epithelial cells, more elongated than those found on the internal side of the inner rod, but, like them, furnished with minute hairs or cilia. These are termed the *outer hair-cells*, in contradistinction to the *inner hair-cells* above referred to. There are about 12,000 outer hair-cells, and about 3500 inner hair-cells.

The hair-cells are somewhat oval in shape; their free extremities are on a level with the heads of Corti's rods, and from each some twenty fine hairlets project and are arranged in the form of a crescent, the concavity of which opens inward. The deep ends of the cells are rounded and contain large nuclei; they reach only as far as the middle of Corti's rods, and are in contact with the ramifications of the nervous filaments. Between the rows of the outer hair-cells are rows of supporting cells, called the *cells of Deiters*; their expanded bases are planted on the basilar membrane, while their opposite ends present a clubbed extremity or *phalangeal* process. Immediately to the outer side of Deiters's cells are some five or six rows of columnar cells, the *supporting cells of Hensen*. Their bases are narrow, while their upper parts are expanded and form a rounded elevation on the floor of the ductus cochlearis. The columnar cells lying outside Hensen's cells are termed the *cells of Claudius*. A space is seen between the outer rods of Corti and the adjacent hair-cells; this is called the *space of Nuel*.

The *lamina reticularis* or *membrane of Kölliker* is a delicate framework perforated by rounded holes. It extends from the inner rods of Corti to the external row of the outer hair-cells, and is formed by several rows of "minute fiddle-shaped cuticular structures," called *phalanges*, between which are circular apertures containing the free ends of the hair-cells. The innermost row of phalanges consists of the phalangeal processes of the outer rods of Corti; the outer rows are formed by the modified free ends of Deiters's cells.

Covering over these structures, but not touching them, is the *membrana tectoria*, or membrane of Corti, which is attached to the vestibular surface of the lamina spiralis close to the attachment of the membrane of Reissner. It is thin near its inner margin, and overlies the auditory teeth of Huschke. Its outer half is thick, and along its lower edge, opposite the inner hair-cells, is a clear band, named *Hensen's stripe*. Externally, the membrane becomes much thinner, and is attached to the outer row of Deiters's cells (Retzius).

The *inner surface of the osseous labyrinth* is lined by an exceedingly thin fibro-serous membrane, analogous to a periosteum, from its close adhesion to the inner surfaces of these cavities, and performing the office of a serous membrane by its free surface. It lines the vestibule, and from this cavity is continued into the semicircular canals and the scala vestibuli of the cochlea, and through the helicotrema into the scala tympani. A delicate tubular process is prolonged along the aqueduct of the vestibule to the inner surface of the dura mater. This membrane is continued across the fenestra ovalis and rotunda, and consequently has no communication with the lining membrane of the tympanum. Its attached surface is rough and fibrous, and closely adherent to the bone; its free surface is smooth and pale, covered with a layer of epithelium, and secretes a thin, limpid fluid, the *aqua labyrinthi, liquor Cotunnii*, or *perilymph* (Blainville).

The scala media is closed above and below. The upper blind extremity is termed the *lagena*, and is attached to the cupola at the upper part of the helicotrema; the lower end is lodged in the recessus cochlearis of the vestibule. Near this blind extremity, the scala media receives the *canalis reuniens of Hensen* (Fig. 462), a very delicate canal, by which the ductus cochlearis is brought into continuity with the saccule.

The **arteries of the labyrinth** are the internal auditory, from the basilar, and the stylo-mastoid, from the posterior auricular. The internal auditory divides at the bottom of the internal meatus into two branches: cochlear and vestibular.

The cochlear branch subdivides into from twelve to fourteen twigs, which traverse the canals in the modiolus, and are distributed, in the form of a capillary network, in the substance of the lamina spiralis.

The vestibular branches accompany the nerves, and are distributed, in the form of a minute capillary network, in the substance of the membranous labyrinth.

The **veins** (auditory) of the vestibule and semicircular canals accompany the arteries, and, receiving those of the cochlea at the base of the modiolus, terminate in the posterior part of the superior petrosal sinus or in the lateral sinus.

The **auditory nerve**, the special nerve of the sense of hearing, divides, at the bottom of the internal auditory meatus, into two branches, the cochlear and vestibular.

The *vestibular nerve*, the posterior of the two, presents, as it lies in the internal auditory meatus, a ganglion, the *ganglion of Scarpa;* it divides into three branches which pass through minute openings at the upper and back part of the bottom of the meatus (*area vestibular superior*), and, entering the vestibule, are distributed to the utricle and to the ampulla of the external and superior semicircular canals.

The nervous filaments enter the ampullary enlargements opposite the septum transversum, and arborize around the hair-cells. In the utricle and saccule the nerve-fibres pierce the membrana propria of the maculæ, and end in arborizations round the hair-cells.

The *cochlear nerve* gives off the branch to the saccule, the filaments of which are transmitted from the internal auditory meatus through the foramina of the *area vestibularis inferior*, which lies at the lower and back part of the floor of the meatus. It also gives off the branch for the ampulla of the posterior semicircular canal, which leaves the meatus through the *foramen singulare*.

The rest of the cochlear nerve divides into numerous filaments at the base of the modiolus; those for the basal and middle coils pass through the foramina in the tractus foraminosus, those for the apical coil through the canalis centralis, and the nerves bend outward to pass between the lamellæ of the osseous spiral lamina. Occupying the spiral canal of the modiolus is the *ganglion spirale*, consisting of bipolar nerve-cells, which really constitute the true cells of origin of this nerve, one pole being prolonged centrally to the brain and the other peripherally to the hair-cells of Corti's organ. Reaching the outer edge of the osseous spiral lamina, they pass through the foramina in the labium tympanicum, and end, some by arborizing around the bases of the inner hair-cells, while others pass between Corti's rods and through the tunnel, to terminate in a similar manner in relation to the outer hair-cells.

Surgical Anatomy.—Malformations, such as imperfect development of the external parts, absence of the meatus, or supernumerary auricles, are occasionally met with. Or the pinna may present a congenital fistula which is due to defective closure of the first visceral cleft, or rather of that portion of it which is not concerned in the formation of the Eustachian tube, tympanum, and meatus. The skin of the auricle is thin and richly supplied with blood, but in spite of this it is frequently the seat of frost-bite, due to the fact that it is much exposed to cold, and lacks the usual underlying subcutaneous fat found in most other parts of the body. A collection of blood is sometimes found between the cartilage and perichondrium (*hæmatoma auris*), usually the result of traumatism, but not necessarily due to this cause. It is said to occur most frequently in the ears of the insane. Keloid sometimes grows in the auricle around the puncture made for earrings, and epithelioma occasionally affects this part. Deposits of urate of soda are often met with in the pinna in gouty subjects.

The external auditory meatus can be most satisfactorily examined by light reflected down a funnel-shaped speculum; by gently moving the latter in different directions the whole of the canal and membrana tympani can be brought into view. The points to be noted are, the presence of wax or foreign bodies, the size of the canal, and the condition of the membrana tympani. The accumulation of wax is often the cause of deafness, and may give rise to very serious consequences, causing ulceration of the membrane and even absorption of the bony wall of the canal. Foreign bodies are not infrequently introduced into the ear by children, and, when situated in the first portion of the canal, may be removed with tolerable facility by means of a minute hook or loop of fine wire, with reflected light; but when they have slipped beyond the narrow middle part of the meatus, their removal is in no wise easy, and attempts to effect it, in inexperienced hands, may be followed by destruction of the membrana tympani and possibly the contents of the tympanum. The calibre of the external auditory canal may be narrowed by inflammation of its lining membrane, running on to suppuration; by periostitis; by polypi, sebaceous tumors, and exostoses. The membrana tympani, when seen in a healthy ear, "reflects light strongly, and, owing to its peculiar curvature, presents a bright spot of triangular shape at its lower and anterior portion." From the apex of this, proceeding upward and slightly forward, is a white streak formed by the handle of the malleus, while near the upper part of the membrane may be seen a slight projection, caused by the short process of the malleus. In disease alterations in color, lustre, curvature or inclination, and perforation must be noted. Such perforations may be caused by a blow, a loud report, a wound, or as the result of suppuration in the middle ear.

The upper wall of the meatus is separated from the cranial cavity by a thin plate of bone;

the anterior wall is separated from the temporo-mandibular joint and parotid gland by the bone forming the glenoid fossa; and the posterior wall is in relation with the mastoid cells; hence inflammation of the external auditory meatus may readily extend to the membranes of the brain, to the temporo-mandibular joint, or to the mastoid cells; and, in addition to this, blows on the chin may cause fracture of the wall of the meatus.

The nerves supplying the meatus are the auricular branch of the pneumogastric, the auriculo-temporal, and the auricularis magnus. The connections of these nerves explain the fact of the occurrence, in cases of any irritation of the meatus, of constant coughing and sneezing from implication of the pneumogastric, or of yawning from implication of the auriculo-temporal. No doubt also the association of earache with toothache in cancer of the tongue is due to implication of the same nerve, a branch of the fifth, which supplies also the teeth and the tongue. The vessels of the meatus and membrana tympani are derived from the posterior auricular, temporal, and internal maxillary arteries. The upper half of the membrana tympani is much more richly supplied with blood than the lower half. For this reason, and also to avoid the chorda tympani nerve and ossicles, incisions through the membrane should be made at the lower and posterior part.

The principal point in connection with the surgical anatomy of the tympanum is its relations to other parts. Its roof is formed by a thin plate of bone, which, with the dura mater, is all that separates it from the temporal lobe of the brain. Its floor is immediately above the jugular fossa behind and the carotid canal in front. Its posterior wall presents the openings of the mastoid cells. On its anterior wall is the opening of the Eustachian tube. Thus it follows that in disease of the middle ear we may get subdural abscess, septic meningitis, or abscess of the cerebrum or cerebellum from extension of the inflammation through the bony roof; thrombosis of the lateral sinus, with or without pyæmia, by extension through the floor; or mastoid abscess by extension backward. In addition to this, we may get fatal hemorrhage from the internal carotid in destructive changes of the middle ear; and in throat disease we may get the inflammation extending up the Eustachian tube to the middle ear. The Eustachian tube is accessible from the nose. If the nose and mouth be closed and an attempt made to expire air, a sense of pressure with dulness of hearing is produced in both ears, from the air finding its way up the Eustachian tube and bulging out the membrana tympani. During the act of swallowing, the pharyngeal orifice of the tube, which is normally closed, is opened, probably by the action of the Dilator tubæ muscle. This fact was employed by Politzer in devising an easy method of inflating the tube. The nozzle of an india-rubber syringe is inserted into the nostril; the patient takes a mouthful of water and holds it in his mouth; both nostrils are closed with the finger and thumb to prevent the escape of air, and the patient is then requested to swallow; as he does so the air is forced out of the syringe into his nose, and is driven into the Eustachian tube, which is now open. The impact of the air against the membrana tympani can be heard, if the membrane is sound, by means of a piece of india-rubber tubing, one end of which is inserted into the meatus of the patient's ear, the other into that of the surgeon. The direct examination of the Eustachian tube is made by the Eustachian catheter. This is passed along the floor of the nostril, close to the septum, with the point touching the floor, to the posterior wall of the pharynx. When this is felt, the catheter is to be withdrawn about half an inch, and the point rotated outward through a quarter of a circle, and pushed again slightly backward, when it will enter the orifice of the tube, and will be found to be caught, and air forced into the catheter will be heard impinging on the tympanic membrane if the ears of the patient and surgeon are connected by an india-rubber tube.

THE ORGANS OF DIGESTION.

THE Apparatus for the Digestion of the Food consists of the alimentary canal and of certain accessory organs.

The **alimentary canal** is a musculo-membranous tube, about thirty feet in length, extending from the mouth to the anus, and lined throughout its entire extent by mucous membrane. It has received different names in the various parts of its course: at its commencement, the mouth, we find provision made for the mechanical division of the food (*mastication*), and for its admixture with a fluid secreted by the salivary glands (*insalivation*); beyond this are the organs of deglutition, the pharynx and the œsophagus, which convey the food into that part of the alimentary canal (the stomach) in which the principal chemical changes occur, and in which the reduction and solution of the food take place; in the small intestines the nutritive principles of the food (the *chyle*) are separated, by its admixture with the bile, pancreatic and intestinal fluids, from that portion which passes into the large intestine, most of which is expelled from the system.

Alimentary Canal.

Mouth.	Small intestine	Duodenum.
Pharynx.		Jejunum.
Œsophagus.		Ileum.
Stomach.	Large intestine	Cæcum.
		Colon.
		Rectum.

Accessory Organs.

Teeth.		
Salivary glands	Parotid.	Liver.
	Submaxillary.	Pancreas.
	Sublingual.	Spleen.

THE MOUTH.

The **mouth** (*oral* or *buccal cavity*) is placed at the commencement of the alimentary canal; it is a nearly oval-shaped cavity, in which the mastication of the food takes place (Fig. 466). It consists of two parts; an outer, smaller portion, the vestibule (vestibulum oris), and an inner, larger part, the cavity proper of the mouth (cavum oris proprium).

The *vestibulum oris* is a slit-like aperture, bounded in front and laterally by the lips and cheeks; behind and internally by the gums and teeth. Above and below it is limited by the reflection of the mucous membrane from the lips and cheeks to the gum covering the upper and lower alveolar arch respectively. It receives the secretion from the parotid glands, and communicates, when the jaws are closed, with the cavum oris by an aperture on each side behind the wisdom teeth.

The *cavum oris proprium* is bounded laterally and in front by the alveolar arches with their contained teeth; behind it communicates with the pharynx by a constricted aperture termed the *isthmus faucium*. It is roofed in by the hard and soft palate, while the greater part of the floor is formed by the tongue, the remainder being completed by the reflection of the mucous membrane from the sides and under surface of the tongue to the gum lining the inner aspect of the mandible. It receives the secretion from the submaxillary and sublingual glands.

The *mucous membrane* lining the mouth is continuous with the integument at the free margin of the lips and with the mucous lining of the pharynx behind; it is of a rose-pink tinge during life, and very thick where it covers the hard parts bounding the cavity. It is covered by stratified epithelium.

The **lips** are two fleshy folds which surround the orifice of the mouth, formed externally by integument and internally by mucous membrane, between which are found the Orbicularis oris muscle, the coronary vessels, some nerves, areolar tissue, and fat, and numerous small labial glands. The inner surface of each lip is connected in the middle line to the gum of the corresponding jaw by a fold of mucous membrane, the *frænum labii superioris* and *inferioris*—the former being the larger of the two.

The *labial glands* are situated between the mucous membrane and the Orbicularis oris round the orifice of the mouth. They are rounded in form, about the size of small peas, their ducts opening by small orifices upon the mucous membrane. In structure they resemble the salivary glands.

The **cheeks** form the sides of the face and are continuous in front with the lips. They are composed externally of integument, internally of mucous membrane, and between the two of a muscular stratum, besides a large quantity of fat, areolar tissue, vessels, nerves, and buccal glands.

The *mucous membrane* lining the cheek is reflected above and below upon the gums, where its color becomes lighter; it is continuous behind with the lining mem-

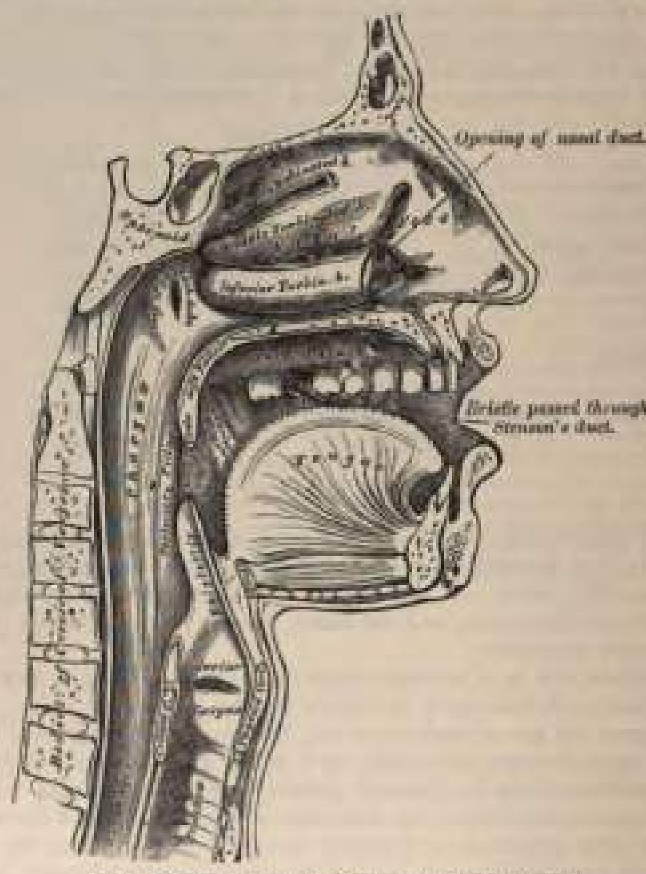


Fig. 486.—Sectional view of the nose, mouth, pharynx, etc.

gums, and it is continuous behind with the lining membrane of the soft palate. Opposite the second molar tooth of the upper jaw is a papilla, the summit of which presents the aperture of the duct of the parotid gland. The principal muscle of the cheek is the Buccinator, but numerous other muscles enter into its formation—viz., the Zygomatici, Risorius Santorini, and Platysma myoides.

The *buccal glands* are placed between the mucous membrane and Buccinator muscle: they are similar in structure to the labial glands, but smaller. Two or three of larger size than the rest are placed between the Masseter and Buccinator muscles; their ducts open into the mouth opposite the last molar tooth. They are called *molar glands.*

The **gums** are composed of a dense fibrous tissue closely connected to the periosteum of the alveolar processes and surrounding the necks of the teeth. They are covered by smooth and vascular mucous membrane, which is remarkable for its limited sensibility. Around the necks of the teeth this membrane presents numerous fine papillæ; and from this point it is reflected into the alveolus, where it is continuous with the periosteal membrane lining that cavity.

THE TEETH.

The human subject is provided with two sets of teeth, which make their appearance at different periods of life. The first set appear in childhood, and are called the *temporary*, *deciduous*, or *milk teeth*. The second set are named *permanent*.

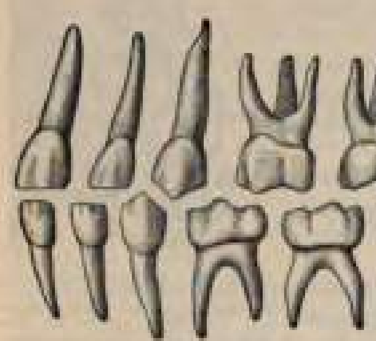


FIG. 467.—Deciduous teeth. Left side.

The *temporary teeth* are twenty in number—four incisors, two canine, and four molars, in each jaw (Fig. 467).

The *permanent teeth* are thirty-two in number—four incisors (two central and two lateral), two canines, four bicuspids, and six molars in each jaw (Fig. 468).

General Characters.—Each tooth consists of three portions: the *crown, or body*, projecting above the gum; the *root, or fang*, entirely concealed within the alveolus; and the *neck*, the constricted portion, between the root and crown.

The *surfaces* of a tooth are named thus: that which looks toward the lips is the *labial;* that toward the tongue is the *lingual;* that toward the mesial line, *proximal;* that away from the same, *distal;* that toward the cheek, the *buccal* surface. This applies to the roots as well as to the crowns of teeth.

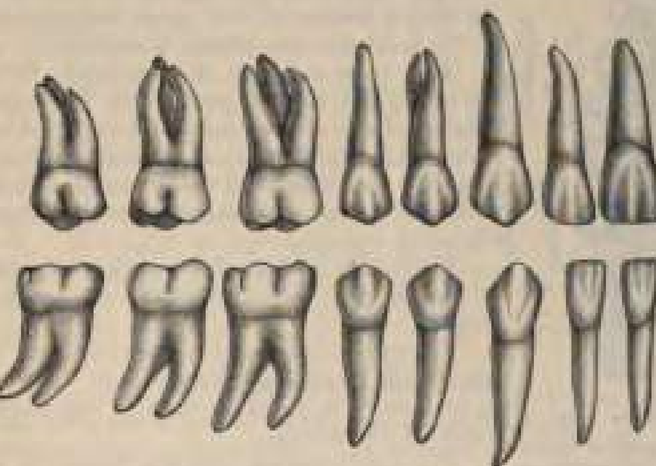


FIG. 468.—Permanent teeth. Right side (Burchard).

The *roots of the teeth* are firmly implanted within the alveoli (Fig. 472); these depressions are lined with periosteum (the pericementum) which is reflected on to the tooth at the point of the root and covers it as far as the neck. At the margin of the alveolus the periosteum becomes continuous with the fibrous structure of the gums.

Permanent Teeth (Figs. 469 and 470).

The **incisors**, or cutting teeth, are so named from their presenting a sharp cutting edge, adapted for incising the food. They are eight in number, and comprise the four front teeth in each jaw.

The *crown* is directed almost vertically and is spade-like in form; it has the form of a truncated cone whose top has been compressed into a sharp horizontal cutting edge. Before being subjected to attrition this edge presents three small elevations. *The labial* surface is convex, and marked by three longitudinal ridges extending from the edge tubercles toward the neck of the tooth. The *lingual* surface is concave, and is marked by two marginal ridges extending from an encircling ridge at the neck to the angles of the cutting edge of the tooth. The ridge at the neck is termed the cingulum or basal ridge.

Fig. 469.—Right half of upper jaw (from below), with the corresponding teeth. The letters and numbers point to the classes of teeth and the numbers in classes.

The *mesial* and *distal surfaces* are triangular, the apex of the triangle at the cutting edge.

The *neck* of the tooth is constricted.

The *root* is long, single, and has the form of a transversely flattened cone, thicker before than behind. The root may be curved.

The *incisors of the upper jaw* are altogether larger and stronger than those of the lower jaw, the central incisors being larger and flatter than the laterals. They are directed obliquely downward and forward.

The *incisors of the lower jaw* are smaller and flatter than the upper, and the elevations upon their lingual faces are not marked. The two central are smaller than the two lateral incisors, being the smallest of all the teeth. The roots of these teeth are flattened laterally.

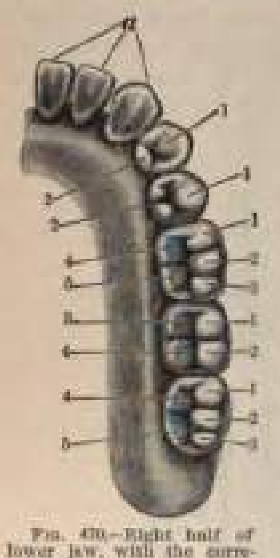


Fig. 470.—Right half of lower jaw, with the corresponding teeth. The letter and numbers point to the various cusps of their modifications on the different teeth (Burchard).

The *canine teeth* (cuspidati) are four in number, two in the upper, two in the lower jaw—one being placed distal to each lateral incisor. They are larger and stronger than the incisors, especially in the roots, which are deeply implanted and cause well-marked prominence of the process at the places of insertion.

The *crown* is large, of spear-head, form and its very convex labial surface is marked by three longitudinal ridges. The concave labial surface is also marked by three ridges which unite at a basal ridge. The point or cusp is longer than in the other teeth, and is the point of division between a short mesial and a long distal cutting edge.

The *root* is oval or elliptical in transverse section, and is longer and more prominent than the roots of the incisors.

The *upper canines* or cuspids (vulgarly called the eye teeth) are larger and longer than the two lower, and in occlusion are distal to them to the extent of half the width of the crown.

The *lower canines* (vulgarly called the stomach teeth) have the general form of the upper cuspids, but their lingual surfaces are much more flattened, owing to the absence of the elevations marking the upper. Their roots are more flattened and may be bifid at their apices.

The **bicuspid teeth** (premolars) are eight in number, four in each jaw; they are placed distal to the cuspid teeth, two upon each side. They are double cuspids in form.

The *crown* is surmounted by two cusps, one buccal and one lingual, separated by a groove, the buccal being more prominent and larger than the lingual. The lower bicuspids are not truly bicuspid, the first having but a primitive lingual cusp, the second having the lingual cusp divided into two sections—*i. e.* it is usually tricuspid.

The *necks* of the teeth are oval; the roots are laterally compressed, that of the first upper bicuspid being frequently bifid. The first upper bicuspid is usually the largest of the series.

The **molar teeth** (*multicuspidati*: or grinders) are the largest teeth of the denture. They are adapted by their forms for the crushing and grinding of the food. They are twelve in number, six in each jaw, three being placed posterior to each second bicuspid.

The *crowns* are cuboidal in form, are convex buccally and lingually; they are flattened mesially and distally. They are formed by the fusion of three primitive cuspids in the upper and four in the lower. To these are added in the first and second upper molars a disto-lingual tubercle, and in the first and third molars of the lower jaw a disto-buccal tubercle. The unions of the primitive forms are marked by sulci. The necks of these teeth are large and rhomboidal in form.

The *roots* of the upper molars are three in number—one large lingual and two smaller buccal roots. In the lower, two roots are found, a mesial and a distal, each of which is much flattened from before backward.

The *first molar teeth* are the largest of the dental series: they have four cusps on the upper and five in the lower—three buccal and two lingual.

The *second molars* are smaller; the crown of the upper is compressed until the disto-lingual cusp is reduced. The crowns of the lower are almost rectangular, with a cusp at each angle.

The *third molars* are called the wisdom teeth (*dentes sapientiæ*) from their late eruption: they have three cusps upon the upper and five upon the lower. The three roots of the upper are frequently fused together, forming a grooved cone, which is usually curved backward. The roots of the lower, two in number, are compressed together and curve backward.

Temporary Teeth (Figs. 467 and 471).

The **temporary** or **milk teeth** are smaller, but resemble in form those of the permanent set. The neck is more marked, owing to the greater degree of convexity of the labial and lingual surfaces of the crown. The hinder of the two temporary molars is the largest of all the deciduous teeth, and is succeeded by the second bicuspid. The first upper molar has only three cusps—two labial, one lingual; the second upper molar has four cusps. The first lower molar has four cusps; the second lower molar has five. The roots of the temporary molar teeth are smaller and more diverging than those of the permanent set, but in other respects bear a strong resemblance to them.

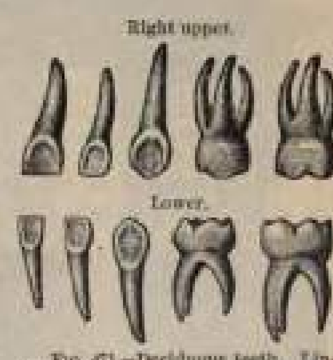


FIG. 471.—Deciduous teeth. Lingual view.

Arrangement of the Teeth.[1]

The human teeth are arranged in two parabolic arches, the upper arch being larger, its teeth overlapping the lower. The average distance between the centres of the condyles of the inferior maxillary bones is about four inches, which is also the distance from either of these points to the line of junction between the lower incisor teeth. Whether the jaw be large or small, the equilateral triangle indicated is included in it; the range of size is between $3\frac{1}{2}''$–$4\frac{1}{2}''$.

Owing to the smaller sizes of the lower incisors, the teeth of the lower jaw are each one half a tooth in advance of its upper fellow, so that each tooth of the dental series has two antagonists, with the exception of the lower central incisors and upper third molars (Figs. 472, 473).

The grinding faces of the upper bicuspids and molars curve progressively upward and point outward, the first molar being at the lowest point of the curve,

[1] After Dr. W. G. A. Bonwill.

the third molar at the highest. The curve of the lower dental arch is the reverse, the first molar at its deepest part, the third molar at its extremity. The greater the depth to which the upper incisors overlap the lower, the more marked this curve and the more pointed are the cusps of the grinding teeth.

FIG. 472.—View of teeth *in situ*, with the external plates of the alveolar processes removed (Cryer).

The movement of the human mandible is forward and downward, the resultant of these directions being an oblique line, upon an average 35° from the horizontal plane.[1] When the lower jaw is advanced until the cutting edges of the incisors are in contact, the jaws are separated, but as the highest point of the lower arch, its third molar advances, it meets and rests upon a high point, second molar of the upper arch, and thus undue strain of the incisors is obviated.

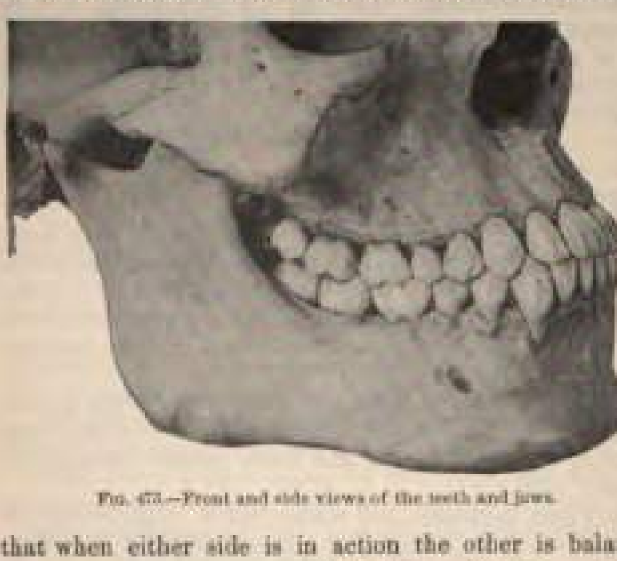


FIG. 473.—Front and side views of the teeth and jaws.

In the lateral movements of the mandible but one side is in effective action at one time; the oblique positions of the cusps of the opposite teeth are such that when either side is in action the other is balanced at two or more points.

[1] W. E. Walker, *Dental Cosmos*, 1896.

There is an anatomical correspondence between the forms and arrangement of the teeth, the form of the condyle of the inferior maxilla, and the muscular arrangement. Individuals who have teeth with long cusps have the head of the bone much rounded from before behind, and have a preponderance of the direct over the oblique muscles of mastication, and *vice versâ;* teeth with short or no cusps are associated with a flattened condyle and strong oblique muscles.

Very great aberrations in the dental arrangement are frequently followed by accomodative changes in the heads of the inferior maxilla.

Structure of the Teeth.

The Dental Pulp.—A longitudinal section of a tooth will show the presence of a central chamber having the general form of the crown of the tooth. Processes of the chamber pass from its body, one for each root and down each root, and open at

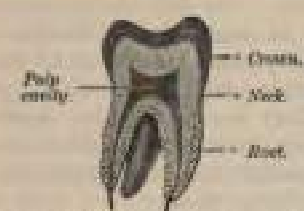


FIG. 474.—Vertical section of a molar tooth.

the apex by a minute orifice, the apical foramen. This cavity is known as the pulp-chamber, the minute canals the pulp-canals. The cavity contains a soft, vascular, and sensitive organ called the dental pulp. It is made up of myxomatous tissues, and contains numerous blood-vessels and nerves, which enter by way of the apical foramina. It does not possess lymphatics. The periphery of the pulp is bounded by a layer of cells arranged like columnar epithelium, each cell sending one or more branched processes through the basic substance of the dentine. These are the dentine-forming cells, the odontoblasts of Waldeyer. The blood-vessels break up into innumerable capillary loops which lie beneath the layer of odontoblasts. The nerve-fibrils break up into numberless non-medullary filaments, which spread out beneath the odontoblasts, and probably send terminal filaments to the extreme periphery of the pulp outside the odontoblasts.

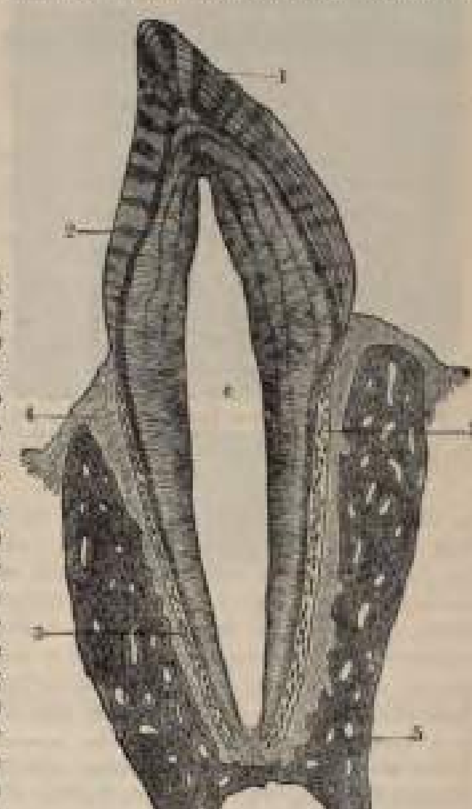


FIG. 475.—Vertical section of a tooth in situ (15 diameters). *c* is placed in the pulp-cavity, opposite the cervix or neck of the tooth; the part above is the crown, that below is the root (fang). 1. Enamel with radial and concentric markings. 2. Dentine with tubules and incremental lines. 3. Cement or crusta petrosa, with bon. corpuscles. 4. Dental periosteum. 5. Bone of lower jaw.

The matrix cells and their processes are irregularly arranged in the body of the pulp, but in the canal portion the fibrillæ are in the direction of the axis of the root.

The section will exhibit three hard tissues in a tooth, one forming the greater mass of the tooth; hence its name *dentine* (the ivory). The dentine upon the crown is sheathed by a layer called the enamel; the dentine of the root is enclosed in a distinct tissue, the cementum or crusta petrosa; both cementum and enamel are thinnest at the neck and thickest upon their distal portions.

The **solid portion** of the tooth consists of three distinct structures—viz. the proper dental substance, which forms the larger portion of the tooth, the *ivory* or *dentine*; a layer which covers the exposed part of the crown, the *enamel*; and a thin layer, which is disposed on the surface of the fang, the *cement* or *crusta petrosa*.

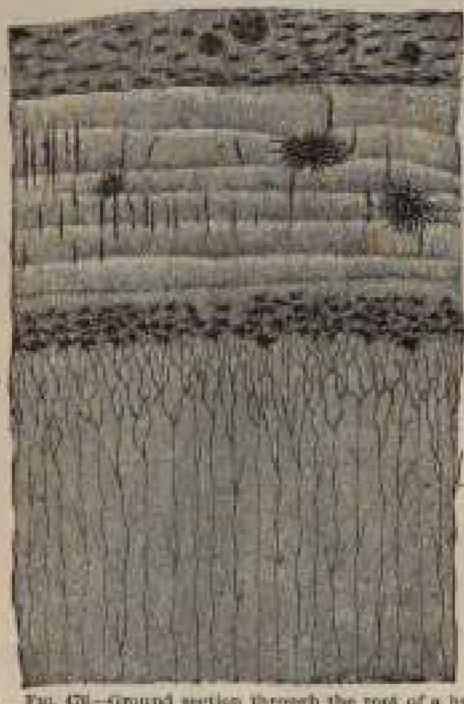


Fig. 476.—Ground section through the root of a human premolar: *D*, dentine; *K*, cement corpuscles; *O*, osteoblasts; *Ep*, remains of Hertwig's epithelial sheath, 300 diameters; *J*, interglobular spaces (Röse).

The **ivory**, or **dentine** (Fig. 475), forms the principal mass of a tooth; in its central part is the cavity enclosing the pulp. It is a modification of osseous tissue, from which it differs, however, in structure. On microscopic examination it is seen to consist of a number of minute wavy and branching tubes having *distinct parietes*. They are called the *dentinal tubuli*, and are imbedded in a dense homogeneous substance, the *intertubular tissue*.

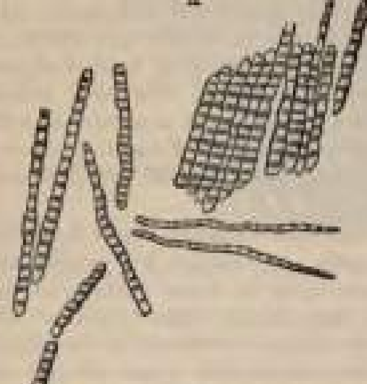
The *dentinal tubuli* (Fig. 476) are placed parallel with one another, and open at their inner ends into the pulp-cavity. In their course to the periphery they present two or three curves, and are twisted on themselves in a spiral direction. The direction of these tubes varies: they are vertical in the upper portion of the crown, oblique in the neck and upper part of the root, and toward the lower part of the root they are inclined downward. The tubuli, at their commencement, are about $\frac{1}{4500}$ of an inch in diameter; in their course they divide and subdivide dichotomously, so as to give to the cut surface of the dentine a striated appearance. From the sides of the tubes, especially in the root, ramifications of extreme minuteness are given off, which join together in loops in the intertubular substance, or terminate in small dilatations, from which branches are given off. Near the periphery of the dentine the finer ramifications of the tubuli terminate in a layer of irregular branched spaces which communicate with each other. These are called the *interglobular spaces of Czermak*, or the *granular layer of Tomes* (Fig. 476, *J*). The dentinal tubuli have comparatively thick walls, and contain slender cylindrical prolongations from the processes of the cells of the pulp-tissue already mentioned, and first described by Mr. Tomes and named Tomes's fibres or dentinal fibres. These dentinal fibres are analogous to the soft contents of the canaliculi of bone. Between Tomes's fibres and the ivory around the canals there is a tissue which is markedly resistant to the action of acids—the *dentinal sheath of Neumann*.

The *intertubular substance* or *tissue* is translucent, and contains the chief part of the earthy matter of the dentine. After the earthy matter has been removed by steeping a tooth in weak acid the animal basis remaining may be torn into laminæ which run parallel with the pulp-cavity across the direction of the tubules. These laminæ show the method of growth to be by deposition of successive strata of dentine. Fibrils have been found in the matrix of the intertubular substance, and are probably continuous with the dentinal fibres of Tomes. In a *dry* tooth a section of dentine often displays a series of lines—the *incremental lines of Salter*—which are parallel with the laminæ above mentioned. These lines are caused by two facts: (1) The imperfect calcification of the dentinal laminæ immediately adjacent to the line; (2) The drying process, which reveals these defects in the calcification. These lines are wide or narrow according to the number of laminæ involved, and along their course, in consequence of the imperfection in the calcifying process, little irregular cavities are left, which are the *interglobular spaces* already referred to. They have received their name from the fact that they are surrounded by minute nodules or globules of dentine. Other curved lines may be seen parallel to the surface. These are the *lines of Schreger*, and are due to the optical effect of simultaneous curvature of the dentinal tubules.

Chemical Composition.—According to Berzelius and Bibra, dentine consists of 28 parts of animal and 72 of earthy matter. The animal matter is resolvable by boiling into gelatin. The earthy matter consists of phosphate and carbonate with calcium, with a trace of fluoride of calcium, phosphate of magnesia, and other salts.

The **enamel** is the hardest and most compact part of a tooth, and forms a thin crust over the exposed part of the crown as far as the commencement of the root. It is thickest on the grinding surface of the crown until worn away by attrition, and becomes thinner toward the neck. It consists of a congeries of minute hexagonal rods, columns, or prisms. They lie parallel with one another, resting by one extremity upon the dentine, which presents a number of minute depressions for their reception, and forming the free surface of the crown by the other extremity. These fibres are directed vertically on the summit of the crown,

A



B

FIG. 477.—Enamel prisms (350 diameters). A. Fragments and single fibres of the enamel isolated by the action of hydrochloric acid. B. Surface of a small fragment of enamel, showing the hexagonal ends of the fibres.

horizontally at the sides; they are about the $\frac{1}{5000}$ of an inch in diameter, and pursue a more or less wavy course. Each enamel rod is crossed by a series of dark transverse lines, which mark the mode of the formation of the rods (Fig. 477). Another series of lines, having a brown appearance, and denominated the *parallel striæ of Retzius*, or the *colored lines*, are seen on a section of the enamel. These lines are concentric and *cross* the enamel rods. They are caused by the mode of enamel deposition. Inasmuch as the enamel columns, when near the dentine, cross each other and only become parallel farther away, a series of radial markings, light and dark alternately, is obtained (Fig. 475).

Numerous minute interstices intervene between the enamel-fibres near their dentinal surface. It is noted in rare cases that the dentinal fibres penetrate a certain distance between the rods of the enamel. No nutritive canals exist in the enamel.

Chemical Composition.—According to Bibra, enamel consists of 96.5 per cent. of earthy matter and 3.5 per cent. of animal matter. The earthy matter consists of the phosphate with the carbonate of calcium, with traces of fluoride of calcium, phosphate of magnesia, and other salts.

The **cortical substance**, or **cementum** (*crusta petrosa*), is disposed as a thin layer on the roots of the teeth, from the termination of the enamel as far as the apex of the root, where it is usually very thick. In structure and chemical composition it resembles bone. It contains, sparingly, the lacunæ and canaliculi which characterize true bone; the lacunæ placed near the surface have the canaliculi radiating from the side of the lacunæ toward the periodontal membrane, *dental periosteum*, and those more deeply placed join with adjacent dentinal tubuli. In the thicker portions of the crusta petrosa the lamellæ and Haversian canals peculiar to bone are also occasionally found.

As age advances the cement increases in thickness, and gives rise to those bony growths, or exostoses, so common in the teeth of the aged; the pulp-cavity becomes also partially filled up by a hard substance intermediate in structure between dentine and bone (*osteo-dentine*, Owen; *secondary dentine*, Tomes). It is formed by the odontoblasts, the dental pulp lessening in volume.

Development of the Teeth.

The teeth are an evolution from the dermoid system, and not of the bony skeleton: they are developed from two of the blastodermic layers, the epiblast and mesoblast. From the former the enamel is developed, from the latter the dental pulp, dentine, cementum, and pericementum. It is customary to view the development of the permanent and temporary teeth as separate studies.

The earliest evidence of tooth-formation in the human embryo is observed in about the seventh week. The mucous membrane covering the embryonic jaws is seen to rise as a longitudinal ridge along the summit of each jaw.[1] A transverse section through the jaws will show the elevation to be due to a linear and outlined activity of the germinal epithelial layer: a corresponding epithelial growth is seen to sink as a band into the mesoblastic tissue beneath. The local cell-activity continues, and in its descent the band appears to meet with a resistance which causes a flattening of its extremity into a continuous lamina. From the inner (toward the tongue) edge of the lamina epithelial cords are given off, ten in number, one for each temporary tooth.

The growth of each cord continues, and each expands into a flask-like form, the walls covered by a layer of germinal cells, its interior by swollen mature cells. The ingrowing bulb is now seen to flatten upon its lower surface, as though it had met with an outlined resistance from the mesoblastic tissue beneath. The epithelial ingrowth assumes the general form of the several teeth; it is the enamel-organ of the tooth (Fig. 478). At this period the mesoblastic tissue around each enamel-organ is seen to become differentiated into fibrous tissue surrounding the enamel-organs, but at some distance from them. Islets of bone are also seen to be forming the beginning of the bony maxillæ.

The indentation of the base of the enamel-organ continues until it assumes the form of the future teeth. The cells bounding the organ assume a cylindrical form; the cells of the interior become much expanded, irregular in size and form.

The mesoblastic tissue underlying the enamel-organ is much condensed; evidences of cellular differentiation and a vascular system appear. Bone continues to develop until all of the tooth-follicles are embraced in a gutter of bone. From the lingual side of the cords of the temporary teeth epithelial buds are given off, which sink into the mesoblastic tissue and form the enamel-organs of the permanent teeth. The condensation of fibrous tissue continues until each embryonic tooth is enveloped in a sac, the dental sac; this, together with all of its contents, is called the dental follicle.

The cells of the enamel-organ now undergo a series of differentiations: the inner layer is arranged as columnar epithelium, and is called the ameloblastic or

[1] The maxillary rampart of Kolliker Waldeyer.

enamel-forming layer (Figs. 479 and 480). The cells of the outer wall remain cuboidal; the cells which lie between become much distended, and on account of

FIG. 478.—Diagram of method of development of the teeth. 1. Early stage. 4. Later stage. 2, 3. Intermediate stages. *s.* Common dental germ. *o.* Special dental germ (milk). *o'.* Special dental germ (permanent). *p.* Papilla. *c.* Dental furrow. (Gegenbaur.)

their appearance when seen in section this portion of the organ is called the stellate reticulum (the enamel-jelly). The layer of cells immediately contiguous to the ameloblasts form a layer called the stratum intermedium (Fig. 480A—D).

The enclosed mesoblastic papilla (the future dental pulp) has its peripheral cells differentiated into columnar bodies disposed as a layer, each cell having a large

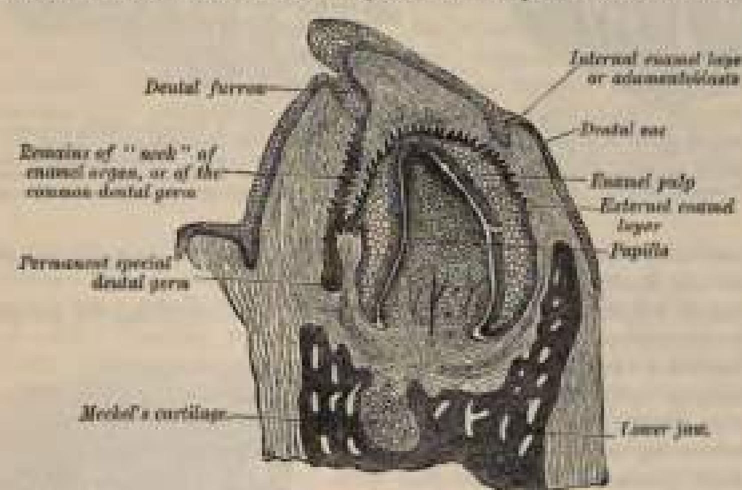


FIG. 479.—Vertical section of the inferior maxilla of an early human fœtus. (Magnified 25 diameters.)

nucleus. The vascular supply of the pulp is now well marked. A section of a follicle at this period will exhibit the follicular wall springing from the base of the dental papilla and having a well-marked blood-supply. The bony alveolar walls are well outlined, and evidences of a periosteum appear (Figs. 479 and 480).

Development of Enamel.—In point of time, the deposition of dentine actually begins before that of enamel, so that the first-formed layer of enamel is deposited against a layer of immature dentine. The enamel is built up of two distinct substances—globules of uniform size which are formed by the ameloblasts, and a cementing substance, probably an albuminate of calcium (calco-globulin), the basis of all the calcified tissues. At the ends of the ameloblasts, next to the dentine, the secretion calco-globulin is deposited, and into the plastic mass the enamel-globules are extruded, each globule remaining connected with the ameloblasts by plasmic strings, which also join the globules laterally.[1]

The first deposit of enamel begins in the tips of the cusps, and is quickly followed by a disappearance of the stellate reticulum at that point; the stellate reticulum now appears to atrophy, so that the vascular follicular wall is brought into direct apposition with the stratum intermedium, which becomes differentiated into a glandular (secreting) tissue which elaborates the calcic albuminous basis of the enamel. The secretion passes from the cells of the stratum intermedium through a membrane into the ameloblasts, where it is in part combined with the cellular

[1] J. L. Williams, *Dental Cosmos*, 1896.

globules, and irregular masses of it extruded as cementing substance. The deposition continues until the enamel-cap has its typical form. The deposition of the layers of globules is indicated by parallel lines transverse to the axes of the enamel-

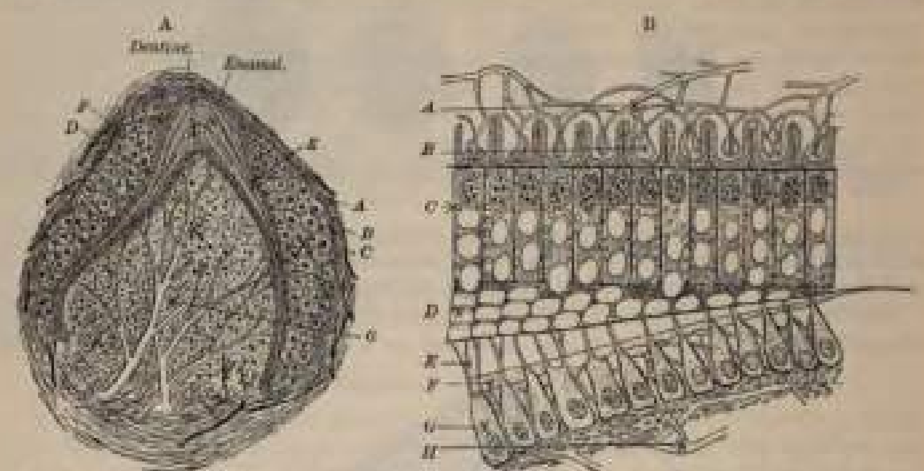


FIG. 480.—A. Section through tooth-follicle—human canine 7½ months: *A*, follicular wall; *B*, outer epithelial coat; *C*, stellate reticulum; *D*, stratum intermedium; *E*, ameloblasts; *F*, odontoblasts; *G*, pulp.
B. Diagram after Williams (*Dental Cosmos*, 1896), mode of enamel deposition: *A*, blood supply to *B*, secreting papilla; *C*, layer of ameloblasts containing enamel globules and droplets of calcoglobulin; *D*, enamel-globules deposited; *E*, formed dentine; *F*, forming dentine; *G*, layer of odontoblasts; *H*, blood supply to odontoblastic layer.

rods. At the completion of amelification the ameloblasts are partially calcified and form the *cuticula dentis* or Nasmyth's membrane.

Formation of Dentine.—The layer of columnar cells bounding the periphery of the pulp (the odontoblasts) are in apposition with a plexus of capillary vessels (Fig. 480, *A*). Each cell is a secreting body which selects the material for dentine-building. Against the layer of ameloblasts covering the dental papilla the odontoblasts deposit globules of the calcium albuminate, and, receding as the deposits are made, leave one or more protoplasmic processes in the calcic deposit (Tomes's fibres). The process continues until the normal dentine thickness is formed. The deposit is laid down in a scaffolding of finely fibrillated tissue. The layer of formative cells remains constant.

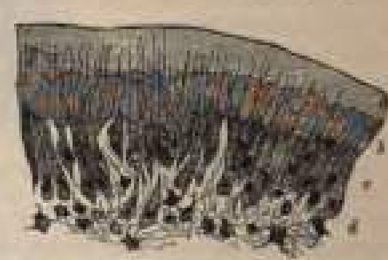


FIG. 481.—Part of section of developing tooth of young rat, showing the mode of deposition of the dentine (highly magnified). *a*. Outer layer of fully-calcified dentine. *b*. Uncalcified matrix with a few nodules of calcareous matter. *c*. Odontoblasts with processes extending into the dentine. *d*. Pulp. The section is stained with carmine, which colors the uncalcified matrix, but not the calcified part.

Formation of Cementum.—Hertwig asserts that the epithelial edge of the enamel-organ formed by the inner and outer epithelial layers of the organ grows downward, or rather the developing tooth grows upward until the future root-form of the tooth is outlined by a double layer of epithelial cells (the root-sheath of Hertwig). The growth of alveolar process is synchronous.

Upon the pulp side of the sheath a layer of odontoblasts is developed; upon the outer side the fibrous encasement becomes closely attached to the sheath and a layer of osteogenetic cells (cementoblasts) is differentiated. The growth of the dentine of the root is the same as in the crown. The epithelial sheath undergoes atrophic changes, leaving epithelial whorls which remain in the pericementum. The cementum is developed as subperiosteal bone. The cementum over the apex of the root is not formed until after the eruption of the tooth.

Formation of Alveoli.—By the time the crowns of the teeth have formed, each is enclosed in a loculus of bone which has developed around it and at some distance from it; the loculus is open at the top toward the gums, where it is closed by fibrous tissue; the developing permanent tooth is contained in the same loculus, but is later separated from the temporary tooth by a growth of bone. The alveolar process is not completed until after the eruption of the teeth. During eruption that portion of the process overlying the crown undergoes absorption, and as soon as the immature tooth has erupted the alveolar process is developed about the root, whose formation is also completed after eruption.

Development of the Permanent Teeth.—The permanent teeth as regards their development may be divided into two sets: (1) those which replace the temporary teeth, and which, like them, are ten in number; these are the *successional permanent teeth;* and (2) those which have no temporary predecessors, but are superadded at the back of the dental series. These are three in number on either side in each jaw, and are termed the *superadded permanent teeth.* They are the three molars of the permanent set, the molars of the temporary set being replaced by the premolars or bicuspids of the permanent set.

The development of the *successional permanent teeth*—the ten anterior ones in either jaw—will be first considered. As already stated, the germ of each milk tooth is a special thickening of the "free" edge of the common dental germ or dental lamina. In like manner is formed the special dental germ of each of the successional permanent teeth. But these thickenings are not at the "free" edge of the dental lamina, but occur behind and lateral to each of the milk-tooth germs (Fig. 478). There are ten of these, and they appear in order, about the sixteenth week, on each side, the central incisor germs being the first.

These special dental germs now go through the same transformations (and become enamel-organs) as were described in connection with those of the milk teeth; that is, they recede into the substance of the gum behind the germs of the temporary teeth. As they recede they become flask-shaped, form an expansion of their distal extremity, and finally meet a papilla, which has been formed in the mesoblast, just in the same manner as was the case in the temporary teeth. The apex of the papilla indentates the dental germ, which encloses it, and forming a cap for it, undergoes analogous changes to those described in the development of the milk teeth, and becomes converted into the enamel, whilst the papilla forms the dentine, of the permanent tooth. In its development it becomes enclosed in a dentinal sac which adheres to the *back* of the sac of the temporary tooth. The sac of each permanent tooth is also connected with the fibrous tissue of the gum by a slender band or *gubernaculum*, which passes to the margin of the jaw behind the corresponding milk tooth (see above).

The *superadded permanent teeth*—three on each side in each jaw—arise from successive extensions backward—*i. e.* along the line of the jaw—of the common dental germ from the back part of the special dental germ of the immediately preceding tooth. During the fourth month or seventeenth week, in that portion of the common dental germ which lies behind—*i. e.* lateral to the special dental germ of the last temporary molar tooth, and which has hitherto remained unaltered, there is developed the special dental germ of the first permanent molar into which a papilla projects. In a similar manner, about the fourth month after birth the second molar is formed, and about the third year the third molar.

Eruption.—When the calcification of the different tissues of the *milk* tooth is sufficiently advanced to enable it to bear the pressure to which it will be afterward subjected, its eruption takes place, the tooth making its way through the gum. The gum is absorbed by the pressure of the crown of the tooth against it, which is itself pressed up by the increasing size of the fang. At the same time the septa between the dentinal sacs, at first fibrous in structure, ossify and thus form the loculi or alveoli; these firmly embrace the necks of the teeth and afford them a solid basis.

Previous to the *permanent teeth* penetrating the gum, the bony partitions which separate their sacs from the deciduous teeth are absorbed, the roots of the temporary teeth disappear by absorption through the agency of particular multinucleated cells, called *odontoclasts*, which are developed at the time in the neighborhood of the root, and the permanent teeth become placed under the loose crown of the deciduous teeth; the latter finally become detached, and the permanent teeth take their place in the mouth (Fig. 482).

FIG. 482.—The milk-teeth in a child of about four years. The permanent teeth are seen in their alveoli. (Cryer.)

Calcification of the permanent teeth proceeds in the following order: First molar, soon after birth; the central incisor, lateral incisor, and cuspid, about six months after birth; the bicuspids, at the second year or later; second molar, end of second year; third molar, about the twelfth year.

The *eruption of the temporary teeth* commences at the seventh month, and is complete about the end of the second year.

The periods for the eruption of the temporary set are (C. S. Tomes)—

Lower central incisors	6 to 9 months.
Upper incisors	8 to 10 "
Lower lateral incisors and first molars	15 to 21 "
Canines	16 to 20 "
Second molars	20 to 24 "

The *eruption of the permanent teeth* takes place at the following periods the teeth of the lower jaw preceding those of the upper by a short interval:

6½ years, first molars.	10th year, second bicuspid.
7th year, two middle incisors.	11th to 12th year, canine.
8th year, two lateral incisors.	12th to 13th year, second molars.
9th year, first bicuspid.	17th to 21st year, third molars.