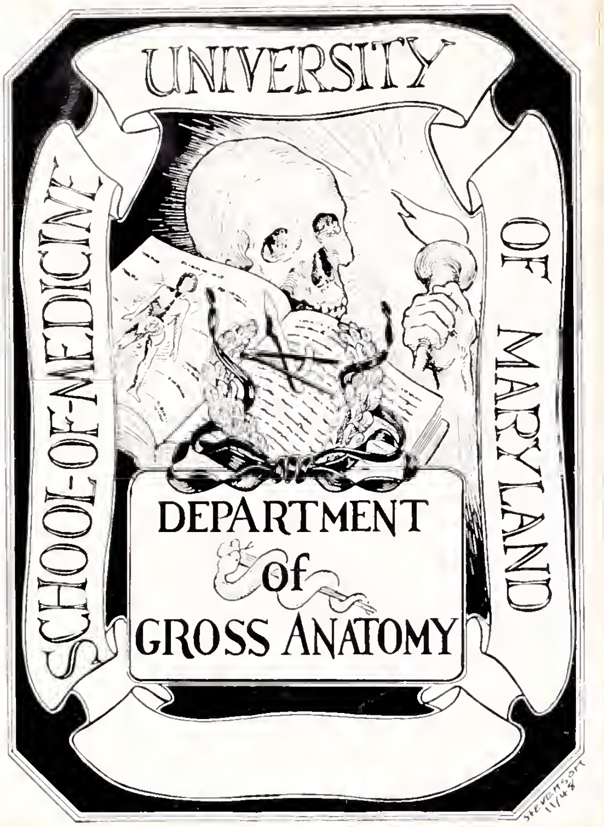
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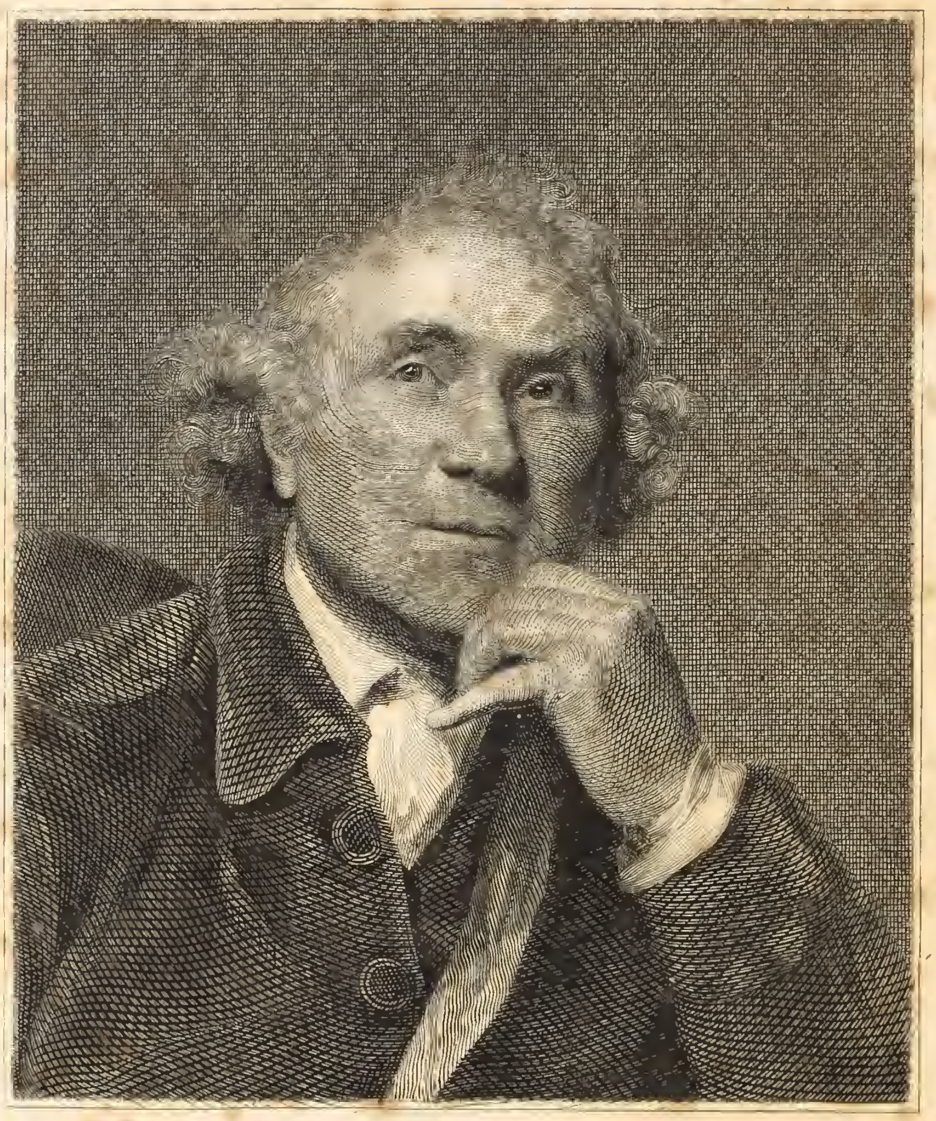

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A

TREATISE

ON

THE BLOOD,

INFLAMMATION,

AND

GUN-SHOT WOUNDS,

BY THE LATE

JOHN HUNTER.

TO WHICH IS PREFIXED,

A SHORT ACCOUNT OF THE AUTHOR'S LIFE,

BY HIS BROTHER-IN-LAW,

EVERARD HOME.

LONDON:

Printed by John Richardson,

FOR GEORGE NICOL, BOOKSELLER TO HIS MAJESTY, PALL-MALL.

1794.

TO THE KING.

MAY IT PLEASE YOUR MAJESTY,

In the year 1761, I had the honour of being appointed by your Majesty a surgeon on the staff in the expedition against Bellisle.

In the year 1790, your Majesty honoured me with one of the most important appointments in the medical department of the army, in fulfilling the duties of which every exertion shall be called forth to render me deserving of the trust reposed in me, and not unworthy of your Majesty's patronage.

The first of these appointments gave me extensive opportunities of attending to gun-shot wounds, of seeing the errors and defects in that branch of military surgery, and of studying to remove them. It drew my attention to inflammation in general, and enabled me to make observations which have formed the basis of the present Treatise. That office which I now hold has afforded me the means of extending my pursuits, and of laying this work before the public.

As the object of this book is the improvement of surgery in general, and particularly of that branch of it which is peculiarly directed to the service of the army, I am led by my situation, my duty, and my feelings, to address it, with all humility, to your Majesty.

That your Majesty may long live to enjoy the love and esteem of a happy people, is the fervent wish of

YOUR MAJESTY'S

MOST FAITHFUL SUBJECT,

AND MOST DUTIFUL SERVANT,

JOHN HUNTER.

Leicester Square,
May 20, 1793.

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ADVERTISEMENT.

As a considerable part of the present work was printed during Mr. Hunter's life, and the whole of the manuscript and dedication were then also prepared for the press, the work may be said to be laid before the public very nearly in the state intended by the author.

The only addition the executors have ventured to make, is an account of Mr. Hunter's life and writings, with an engraving of his head, which is prefixed to it. They were induced to do this from a desire to gratify the wishes of the public and preclude more imperfect attempts. Mr. Home, the brother-in-law of Mr. Hunter, who lived with him many years, and was his assistant in all his pursuits, was considered as the most proper person to be the biographer of his deceased friend.

A SHORT ACCOUNT OF THE LIFE OF THE AUTHOR.

John Hunter was the son of John and Agnes Hunter of Kilbride, in the county of Lanerk; he was the youngest of ten children, and was born on the fourteenth of July, 1728, at Long Calderwood, a small estate belonging to the family. His father was descended from Hunter of Hunterston, an old family in Ayrshire, and his mother was the daughter of Mr. Paul, a very respectable man, and treasurer of the city of Glasgow.

He had four brothers, John, Andrew, James, and William; and five sisters, Elizabeth, Janet, Agnes, Dorothea, and Isabella; of these, John, Andrew, Elizabeth, Agnes, and Isabella died, while children. James was born in 1715; was brought up to the law, as a writer to the signet in Edinburgh, but in the year 1742 went to London on a visit to his brother William, who was at that time a teacher of anatomy, and so much was he captivated by the pursuits in which he found his brother engaged, that he purposed to follow them himself, and become a practitioner in physic. His health however was so much impaired by his application to anatomy, that he was obliged to return to Long

Calderwood, where he died of a spitting of blood, in the twenty-eighth year of his age*.

William was born on the twenty-third of May, 1718, who became unrivalled as a teacher of anatomy, and it was under his fostering care that his younger brother John was initiated in these pursuits, in which he afterwards became so distinguished. His history is already in the hands of the public †.

Janet married Mr. Buchanan of Glasgow, and died in 1749. Dorothea, who is still alive, married the Rev. Doctor James Baillie, professor of divinity in the university of Glasgow, by whom she has one son, Matthew, doctor of physic, successor to Dr. Hunter, as a teacher of anatomy and one of the physicians to St. George's Hospital, and two daughters, Agnes and Joanna.

John Hunter was about ten years old at his father's death, and was left under the direction of his mother, who was particularly indulgent to this her youngest son.

He was sent to the grammar-school, but not having a turn for languages, nor being sufficiently under controul, he neglected his studies, and spent the greatest part of his time in country amusements. About this time Mr. Buchanan, who had lately come from London to settle at Glasgow as a cabinet-maker, paid his addresses to Mr. Hunter's sister Janet, and having many agreeable qualities, she was induced to marry him, although contrary to the advice of her relations. This marriage gave the family great concern; for the qualities which

* Mr. James Hunter was a young man of an uncommonly pleasing address, and of very quick parts. The late Dr. Hunter has been heard to remark, that if he had lived to practice physic in London, nothing could have prevented him from rising to the top of his profession. It would have been a remarkable circumstance that three brothers should have acquired the first reputation in three different branches of the same profession.

† Written by Dr. S. Foart. Simmons, and published in 1783.

had rendered Mr. Buchanan agreeable, led him into dissipation, and made him neglect his business. Mr. John Hunter, who was now seventeen, went to Glasgow upon a visit to his sister, for whom he had the greatest affection, to comfort her in her distress, and endeavour to assist her husband in extricating himself from his difficulties; but finding, after some time, all his efforts ineffectual, he returned to Long Calderwood.

Tired of living idle in the country he began to turn his mind to some more active employment; and hearing much of the reputation which his brother William had acquired as a teacher of anatomy, he wrote to request that he would allow him to come to London upon a visit, making at the same time an offer to be his assistant in his anatomical researches; or, if that proposal should not be accepted, expressing a wish to go into the army. In answer to this letter, he received a very kind invitation from his brother, and immediately set off for London, accompanied by Mr. Hamilton, a friend of the family who was going upon business; they rode up together on horseback.

Mr. Hunter arrived in London in September, 1748, about a fortnight before his brother began his course of lectures; and Dr. Hunter, who was very anxious to form some opinion of his talents for anatomy, gave him an arm to dissect for the muscles, with the necessary directions how it was to be done; and he found the performance such as greatly exceeded his expectation.

His first essay in anatomy having thus gained him some credit, Mr. Hunter was now employed in a dissection of a more difficult nature; this was an arm in which all the arteries were injected, and these, as well as the muscles were to be exposed and preserved; the manner in which this was performed, gave Dr. Hunter so much satisfaction, that he did not scruple to say, that his brother would become a good anatomist, and that he should not want for employment.

From this period we may consider Mr. Hunter as having seriously engaged in anatomy and under the instructions of Dr. Hunter and his assistant Mr. Symonds, he had every opportunity of improvement, as all the dissections at this time carried on in London were confined to that school.

In the summer 1749, Mr. Cheselden, at the request of Dr. Hunter, permitted him to attend at Chelsea Hospital, and he there learnt the first rudiments of surgery.

The following winter he was so far advanced in the knowledge of human anatomy, as to instruct the pupils in dissection, to whom Dr. Hunter had very little time to pay attention. This office, therefore, fell almost entirely upon him, and was his constant employment during the winter season.

In the summer months of 1750, Mr. Hunter attended the hospital at Chelsea; in 1751, he became a pupil at St. Bartholomew's, and in the winter was present at operations occasionally, whenever any thing extraordinary occurred. The following summer he went to Scotland, and brought up his sister Dorothea, and in 1753 entered as a gentleman commoner at St. Mary Hall, Oxford. In 1754, he became a surgeon's pupil, at St. George's Hospital, where he continued during the summer months, and in 1756, was appointed house-surgeon.

In the winter, 1755, Dr. Hunter admitted him to a partnership in his lectures, and a certain portion of the course was allotted to him, besides which, he gave lectures when the doctor was called away to attend his patients.

Making anatomical preparations was at this time a new art, and very little known; every preparation, therefore, that was skilfully made, became an object of admiration; many were wanting for the use of the lectures, and the doctor having himself an enthusiasm for the art, left no means untried to infuse into his brother a love for his favourite pursuits. How well he succeeded, the collection afterwards made by Mr. Hunter will sufficiently evince.

Anatomy seems to have been a pursuit for which Mr. Hunter's mind was peculiarly fitted, and he applied to it with an ardor and perseverance of which there is hardly any example. His labours were so useful to his brother's collection, and so gratifying to his disposition, that although in many other respects they did not agree, this simple tie kept them together for many years.

Mr. Hunter worked for ten years on human anatomy, during which period he made himself master of what was already known, as well as made some addition to that knowledge*. He traced the ramifications of the olfactory nerves upon the membranes of the nose, and discovered the course of some of the branches of the fifth pair of nerves. In the gravid uterus, he traced the arteries of the uterus to their termination in the placenta. He was also the first who discovered the existence of the lymphatic vessels in birds.

Many parts of the human body being so complex, that their structure could not be understood, nor their uses ascertained, Mr. Hunter was led to examine similar parts in other animals, in which the structure was more simple, and more within the reach of investigation; this carried him into a wide field, and laid the foundation of his collection in comparative anatomy.

In this new line of pursuit this active inquirer began with the more common animals, and preserved such parts as appeared by their analogy, or in some other way, to elucidate the human œconomy. It was not his intention to make dissections of particular animals, but

* An account of his injecting the testis, his description of the descent of that body, with observation on the hernia congenita, and his experiments in proof of the veins not being absorbents, are published in Dr. Hunter's Medical Commentaries.

to institute an inquiry into the various organizations by which the functions of life are performed, that he might thereby acquire some knowledge of general principles. This, I believe, had never been before attempted, or certainly had never been carried far into execution.

So eagerly did Mr. Hunter attach himself to comparative anatomy, that he sought by every means in his power the opportunities of prosecuting it with advantage. He applied to the keeper of wild beasts in the Tower for the bodies of those which died there, and he made similar applications to the men who showed wild beasts. He purchased all rare animals which came in his way; and these, with such others as were presented to him by his friends, he entrusted to the showmen to keep till they died, the better to encourage them to assist him in his labours.

His health was so much impaired by excessive attention to his pursuits, that in the year 1760 he was advised to go abroad, having complaints in his breast, which threatened to be consumptive. In October of that year, Mr. Adair, inspector-general of hospitals, appointed him a surgeon on the staff; and in the following spring he went with the army to Bellisle, leaving Mr. Hewson to assist his brother during his absence.

Mr. Hunter served, while the war continued, as senior surgeon on the staff, both in Bellisle and Portugal, till the year 1763; and in that period acquired his knowledge of gun-shot wounds; a subject which makes no inconsiderable part of the present work.

On his return to England he settled in London; where not finding the emoluments from his half-pay and private practice sufficient to support him, he taught practical anatomy and operative surgery for several winters. He returned also with unabated ardour to comparative anatomy, and as his experiments could not be carried on in a large town, he purchased, for that purpose, about two miles from London, a piece of ground near Brompton, at a place called Earl's Court, on which he built a house.

In the course of his inquiries this excellent anatomist ascertained the changes which animal and vegetable substances undergo in the stomach when acted on by the gastric juice; he discovered, by means of feeding young animals with madder, (which tinges growing bones red) the mode in which a bone retains its shape during its growth; and explained the process of exfoliation by which a dead piece of bone is separated from the living.

His fondness for animals made him keep several of different kinds in his house which by attention he rendered familiar with him, and amused himself by observing their peculiar habits, and instincts; but this familiarity was attended with considerable risk, and sometimes led him into situations of danger, of which the following is a remarkable instance.

Two leopards, which were kept chained in an out-house, had broken from their confinement, and got into the yard among some dogs, which they immediately attacked; the howling this produced, alarmed the whole neighbourhood; Mr. Hunter ran into the yard to see what was the matter, and found one of them getting up the wall to make his escape, the other surrounded by the dogs; he immediately laid hold of them both, and carried them back to their den; but as soon as they were fecured, and he had time to reflect upon the risk of his own situation, he was so much agitated that he was in danger of fainting.

On the fifth of February, 1767, he was chosen a Fellow of the Royal Society. His desire for improvement in thofe branches of knowledge which might assist in his researches led him at this time to propofe to Dr. George Fordyce and Mr. Cumming an eminent mechanic, that they should adjourn from the meetings of the Royal Society, to some coffee-houfe, and discuss such subjects as were connected with science. This plan was no sooner established, than they found their numbers increased; they were joined by Sir Joseph Banks, Dr. Solander, Dr. Maskelyne, Sir George Shuckburgh, Sir Harry Englefield, Sir Charles Blagden, Dr. Noothe, Mr. Ramsden, Mr. Watt of Birmingham, and many others. At these meetings discoveries and improvements in different branches of philofophy were the objects of their consideration; and the works of the members were read over and criticised, before they were given to the public.

It was in this year that by an exertion in dancing, after the muscles of the leg were fatigued, he broke his tendo achillis. This accident, and the confinement in consequence of it, led him to pay attention to the subject of broken tendons, and to make a series of experiments to ascertain the mode of their union. He did not, according to the common practice, confine himself to his bed, but by compressing the muscles, and raising the heel, he was enabled, with the knee being kept straight, to walk about the third day after receiving the accident. He divided the tendo achillis of several dogs, by introducing a couching needle through the skin at some distance from it, and with the edge cut through the tendon; in this way the orifice in the skin healed up, and made it similar to a broken tendon. The dogs were killed at different periods to show the progress of union, which was exactly similar to that of a fractured bone when there is no wound in the skin.

In the year 1768, Dr. Hunter having completed the house in Windmill-street, in which his collection is at present deposited, and where he afterwards carried on his anatomical lectures, he gave up to Mr. Hunter the lease of his house in Jermyn-street, which was commodious and well situated for private practice. In this house Mr. Hunter lived ten years; the same year too he became a member of the corporation of surgeons; and in the year following, through his brother's interest, he was elected one of the surgeons of St. George's Hospital.

As he was always engaged in the improvement of his profession, young gentlemen who came to London to finish their education were very desirous of living in his house, and several gentlemen, very eminent in practice in different parts of the country, received part of their education as his house-pupils. Dr. Edward Jenner of Berkley, Mr. William Guy of Chichester, and Mr. John Kingston, boarded in his house in 1770 and 1771, and lived in habits of intimacy with him till his death.

In May 1771, his Treatise on the natural History of the Teeth was published; and in July of the same year he was married to Miss Home, the eldest daughter of Mr. Home, surgeon to Burgoyne's regiment of light horse. The expence of his pursuits had been so great, that it was not till several years after his first engagement with this lady, that his affairs could be sufficiently arranged to admit of his marrying.

In June 1772, his son John was born, who is now an officer in the army*. In the autumn of the same year I came to him as an apprentice.

While he was paying his addresses to my sister Miſs Home, I was a boy at Westminster-school. During the holidays I came home, and Mr.

* He had another son who died an infant, and two daughters, of which Mary Anne died while very young; and Agnes, who is still alive, is married to Capt. James Campbell, eldest son of Sir James, brother of the late Sir Archibald Campbell.

Hunter who was frequently there, always shewed me particular kindness; he made my father an offer to bring me up to his profession; a proposal which I readily accepted. I was struck with the novelty, and extent of his researches, had the highest respect and admiration for his talents, and was ambitious to tread the paths of science under so able a master. It is a tribute which I owe to his memory to declare, that an intimate knowledge of him for one-and-twenty years has increased my admiration of his uncommon exertions, and my respect for his abilities.

After finishing my education at Westminster-school as a king's scholar, and being elected off to Trinity College, Cambridge, I found that no advantages which could have been derived from a scholarship in the University would compensate for the time I must have given up in keeping my terms, to the disadvantage of my chirurgical education; I therefore thought it prudent to forego my claims upon the University as a king's scholar, and instead of going down to Cambridge, though elected, went immediately to Mr. Hunter.

At this time his private practice and his professional character were advancing very fast, and his family had begun to increase, but still no small part of his time was devoted to his collection, which, as it daily became larger, was also attended with greater expence. The whole suite of the best rooms in his house were occupied by his preparations; and he dedicated his mornings, from sun-rise to eight o'clock, (the hour for breakfast) entirely to his pursuits. To these he added such parts of the day as were not engaged in attending his patients.

The knowledge he derived from his favourite studies he constantly applied to the improvement of the art of surgery, and omitted no opportunity of examining morbid bodies, from which he made a collection of facts which are invaluable, as they tend to explain the real causes of symptoms, which, during life could not be exactly ascertained, the judgment of the practitioner being too frequently misled by theoretical opinions, and delusive sensations of the patients.

In the practice of surgery, where cases occurred in which the operations proved inadequate to their intention, he always investigated with uncommon attention the causes of that want of success, and in this way detected many fallacies, as well as made some important discoveries in the healing art.

He detected the cause of failure, common to all the operations in use for the radical cure of the hydrocele, and was enabled to propose a mode of operating, in which that event can with certainty be avoided. He ascertained, by experiments and observations, that exposure to atmospherical air simply, can neither produce nor increase inflammation. He discovered in the blood so many phænomena connected with life, and not to be referred to any other cause, that he considered it as alive in its fluid state. This opinion seems to be advanced in the Old Testament*, and, what is very extraordinary, in the Alcoran†

* "Ye shall eat the blood of no manner of flesh, for the life of all flesh is the blood "thereof." Leviticus, chap. xvii. verse 14.

† Alcoran, chap. xxiii. intitled, "The true Believer's revealed at Mecca."

"We formerly created man of a finer sort of clay; afterwards we placed him in the "form of seed in a ſure resceptacle: afterwards we made the seed coagulated blood; "and we formed the coagulated blood into a piece of flesh; then we formed the piece "of flesh into bones, and we cloathed those bones with flesh; then we produced the "same by another creation, wherefore, blessed be God, the most excellent Creator."

Chap. xcvi. intitled "Conjealed Blood revealed at Mecca."

"Read in the name of thy Lord, who hath created all things, who hath created man "of congealed blood."

of Mohammed, it also appears to have been entertained by the celebrated Harvey *; but the mode in which this subject is considered in the following work will sufficiently shew that in Mr. Hunter's mind this was not an opinion adopted, but one which arose from his own investigation of the properties of the blood.

He improved the operation for the fistula lacrymalis, by removing a circular portion of the os unguis instead of breaking it down with the point of a trochar. He also discovered that the gastric juice had a power when the stomach was dead of dissolving it, and gave to the Royal Society a paper on this subject, which is published in the Philosophical Transactions †.

In the winter 1773, he formed a plan of giving a course of lectures on the theory and principles of surgery, with a view of laying before the public his own opinions upon that subject. For two winters he read his lectures gratis to the pupils of St. George's Hospital, and in 1775, gave a course for money upon the same terms as the other teachers in the different branches of medicine and surgery.

Giving lectures was always particularly unpleasant to him; so that the desire of submitting his opinions to the world, and learning their general estimation, were scarcely sufficient to overcome his natural dislike to speaking in public. He never gave the first lecture of his course without taking thirty drops of laudanum to take off the effects of his uneasiness. He was so diffident of himself that he

* Quinimo ex vario ipsius motu, in celeritate aut tarditate vehementia aut debilitate et cætera, eum et irritantis injuriam et foventis commodum persentiscere manifestum est. Ideoque concludimus sanguinem per se vivere et nutriri;

GUELIELMI HARVEII,
Operum, tom. ii. Exercitatio 52.

† There are several preparations both in Dr. Hunter's and Mr. Hunter's collection illustrating this fact.

trusted nothing to memory, and made me draw up a short abstract of each lecture, which he read on the following evening as a recapitulation, to connect the subject in the minds of the students.

It is curious that the fundamental doctrines of these lectures, which constitute the principal part of the present work, should be the last of his publications; and that his anxiety to render them complete, should make him patiently revise and correct them for twenty years before he gave them to the press. We learn from these circumstances both his diffidence respecting himself, and the value which he placed upon his future reputation.

Comparative anatomy may be considered as the pursuit in which Mr. Hunter was constantly employed. No opportunity escaped him. In the year 1773, at the request of his friend Mr. Walsh, he dissected the torpedo, and laid before the Royal Society an account of it's electrical organs.

A young elephant which had been presented to the Queen by Sir Robert Barker died, and the body was given to Dr. Hunter, which afforded Mr. Hunter an opportunity of examining the structure of that animal by assisting his brother in the dissection; since that time two other elephants died in the Queen's menagerie, both of which came under Mr. Hunter's examination.

In 1774, he published in the Philosophical Transactions an Account of certain Receptacles of Air in Birds, which communicate with the Lungs, and are lodged both among the fleshy Parts and hollow Bones of these Animals; and a paper on the Gillaroo-trout, commonly called in Ireland, the Gizzard-trout.

In 1775, several animals of that species, called the gymnotus electricus of Surinam was brought alive to this country, and by their electrical properties excited very much the public attention. Mr. Walsh, desirous of pursuing his investigation of animal electricity, made a number of experiments on the living animals; and, to give his friend Mr. Hunter an opportunity of examining them, purchased those that died. An anatomical account of their electrical organs was drawn up by Mr. Hunter, and published in the Philosophical Transactions. In the same volume there is a paper of his containing, Experiments on Animals and Vegetables respecting their Power of producing Heat.

In the course of his pursuits, Mr. Hunter met with many parts of animals where natural appearances could not be preserved, and others, in which the minuter vessels could not be diftinctly seen when kept in spirits; it was therefore necessary to have them drawn, either at the moment, or before they were put into bottles. The expence of employing professed draftsmen, the difficulty of procuring them, and the disadvantage which they laboured under in being ignorant of the subject they were to represent, made him desirous of having an able person in his house entirely for that purpose.

With this view he engaged an ingenious young artist to live with him for ten years; his time to be wholly employed as a draftsman, and in making anatomical preparations. This gentleman, whofe name was Bell, foon became a very good practical anatomist, and from that knowledge was enabled to give a spirited and accurate resemblance of the subjects he drew; such as is rarely to be met with in representations of anatomical subjects. By his labours Mr. Hunter's collection is enriched with a considerable number of very valuable drawings, and a great variety of curious and delicate anatomical preparations*.

* The engravings inserted in Mr. Hunter's Treatise on the Venereal Disease, in his book upon the Animal Œconomy, and most of these contained in the present work, are taken from Mr. Bell's drawings, and will remain as proofs of his abilities in that particular line of drawing.

In January 1776, Mr. Hunter was appointed surgeon-extraordinary to his Majesty, and in the spring he gave to the Royal Society a paper on the best Mode of recovering drowned Persons.

In the autumn he was taken extremely ill, and the nature of his complaints made his friends, as well as himself, consider his life to be in danger. When he reflected upon his own situation, that all his fortune had been expended in his pursuits, and that his family had no provision but what should arise from the sale of his collection, he became very solicitous to give it its full value, by leaving it in a state of arrangement.

As soon as he was able to leave his room, his firſt object was to make a catalogue of his collection; but his health requiring him to go to Bath, I was employed, with the assistance of Mr. Bell, during his absence, in making descriptions of the preparations, leaving blanks for such as I was not acquainted with. His complaints were a good deal relieved, but his impatience to return to town, made him come back before he was well; he continued, however, to amend, and very soon recovered.

In 1778, he published the second part of his Treatise on the Teeth, in which their diseases, and the mode of treatment are considered. This rendered his work upon that subject complete. He published also in the Philosophical Transactions a paper on the Heat of Animals Vegetables.

I had now lived six years with Mr. Hunter, and had completed my education; his expences had always exceeded his income, I had therefore no emolument to expect from remaining in his house, which made it necessary for me to take up some line for my own support, and Admiral Keppel's action with the French fleet was the means of procuring me a very eligible situation.

The newly finished naval hospital at Plymouth received the whole of the wounded men from Admiral Keppel's fleet, and Dr. Farquarson, the first commissioner of sick and hurt, at the request of Mr. Adair, the present surgeon-general to the garrison of Gibraltar, gave me the appointment of assistant-surgeon, with apartments to reside at the hospital. From the circumstance of my being the only surgeon on that establishment, who was a member of the corporation, I was authorized by the sick and hurt board to perform operations, and assist the surgeon in the more important parts of his duty.

In this situation many opportunities occurred to me of adding to Mr. Hunter's collection; the sea furnishing curious fish and other marine productions, and the hospital practice preparations of morbid parts.

Mr. Hunter was now wholly assisted by Mr. Bell. In 1779, he published his Account of the Free Martin in the Philosophical Transactions.

In 1780, he laid before the Royal Society an Account of a Woman who had the Small-pox during Pregnancy, where the disease seemed have been communicated to the fœtus.

In 1781, he was elected a Fellow of the Royal Society of Sciences and Belles Lettres, at Gottenburg.

In 1782, he gave the Royal Society a paper on the Organ of Hearing in Fish. Besides the papers which he presented to that learned body, he read six Croonion lectures upon the subject of Muscular Action, for the years 1776, 1778, 1779, 1780, 1781, and 1782. In these lectures he collected all his observations upon muscles, respecting their powers and effects, and the stimuli by which they are affected; and to these he added Comparative Observations upon the moving Powers of Plants.

These lectures were not published in the Philosophical Transactions, for they were withdrawn as soon as read, not being considered by the author as complete dissertations, but rather as materials for some future publication.

It is much to be regretted that Mr. Hunter was so tardy in giving his observations to the public; but such was his turn for investigation, and so extensive the scale upon which he instituted his inquiries, that he always found something more to be accomplished, and was unwilling to publish any thing which appeared to himself unfinished. His observations on the Muscular Action of the Blood-vessels were laid before the Royal Society in 1780, and yet he delayed publishing them till his Observations on the Blood and Inflammation were arranged, and they will be found to make a part of the present work.

In 1783, he was chosen into the Royal Society of Medicine, and Royal Academy of Surgery in Paris.

In this year the lease of his house in Jermyn-ſtreet having expired, and his collection being now too large to be contained in his dwelling-house, he purchased the lease of a large house on the east side of Leicester-square, and the whole lot of ground extending to Castle-street, on which there was another house. In the middle space between the two houses he erected a building for his collection.

Upon this building he expended above three thousand pounds, and unfortunately for his family, the lease did not extend beyond twenty-four years.

In excuse for so inconsiderate a transaction, it can only be said, that the difficulties he had met with in finding ground in an eligible situation, had harrassed his mind, already too much occupied, to such a degree, that he was glad to be relieved from that embarrassment, and made the interest of his family give way to his present accommodation.

In the building formed for the collection there was a room fifty-two feet long, by twenty-eight feet wide, lighted from the top, and having a gallery all round, for containing his preparations. Under this were two apartments; one for his lectures, and the other, with no particular destination at first, but afterwards made use of for weekly meetings of medical friends during the winter. To this building the house in Castle-street was entirely subservient; and the rooms in it were used for the different branches of human and comparative anatomy.

During the execution of this extensive plan I returned to England from Jamaica, where at the close of the war I had been appointed staff surgeon. Sir Archibald Campbell, the governor, coming home, gave me leave of abſence on account of my health, and allowed me to attend him. We arrived in August 1784, and I was permitted to exchange upon half pay.

I found Mr. Hunter now advanced to a very considerable share of private practice, and a still greater share of the public confidence. His collection had increased with his income. In this he was materially assisted by the friendship of Sir Joseph Banks, who not only allowed him to take any of his own specimens, but procured him every curious animal production in his power, and afterwards divided between him and the British Museum all the specimens of animals he had collected in his voyage round the world. To his friends the honourable Mr. Charles Greville and Mr. Walsh, he was also under particular obligations.

Drawing materials from such ample sources, standing alone in this branch of science, and high in the public estimation, he had so much attention paid to him, that no new animal was brought to this country which was not shewn to him; many were given to him; and of those that were for sale he commonly had the refusal: under these circumstances, his collection made a progress, which would otherwise have been impossible.

In April 1785, the new room was completed, and I devoted the whole of the summer to the object of assisting him in moving his preparations, and arranging them in their proper order. Mr. Bell and Mr. Andre, a gentleman who had been the greater part of his life engaged in anatomical pursuits, were constantly employed in this business.

At this period Mr. Hunter may be considered as at the height of his chirurgical career; his mind and body were both in their full vigor. His hands were capable of performing whatever was suggested by his mind; and his judgment was matured by former experience. Some instances of his extraordinary skill may very properly be mentioned.

He removed a tumor from the side of the head and neck of a patient at St. George's Hospital, as large as the head to which it was attached; and by bringing the cut edges of the skin together, the whole was nearly healed by the first intention.

He dissected out a tumor on the neck, which one of the best operating surgeons in this country had declared, rather too ſtrongly, that no one but a fool or a madman would attempt; and the patient got perfectly well.

He discovered a new mode of performing the operation for the popliteal aneurism, by taking up the femoral artery on the anterior part of the thigh, without doing any thing to the tumor in the ham. The safety and efficacy of this mode have been confirmed by many subsequent trials; and it must be allowed to stand very high among the modern improvements in surgery *.

I believe Mr. Hunter was one of the first who taught, that cutting out the part was the only mode of preventing the hydrophobia; and he extended the time in which that might be done with every probability of success, beyond the period generally believed. This doctrine, in favour of cutting out the part, met with the strongest confirmation by two melancholy cases, in which, from the nature of the parts, and numberless scratches on the skin, it was impossible to remove them. Though caustic was applied to every part that had a visible mark, and every other precaution that could be thought of was used, the wounds in both instances proved fatal.

If we consider Mr. Hunter at this period of his life, it will afford us a strong picture of the turn of his mind, of his desire to acquire knowledge, and his unremitting assiduity inprosecuting whatever was the object of his attention.

He was engaged in a very extensive private practice; he was surgeon to St. George's Hospital; he was giving a very long course of lectures in the winter; he was carrying on his inquiries in comparative anatomy; had a school of practical human anatomy in his house; and was always employed in some experiments respecting the animal œconomy.

He was always solicitous for some improvement in medical education; and, with the assistance of Dr. Fordyce, instituted a medical

* An account of this operation is published in the Transactions of a Society for improving Medical and Chirurgical Knowledge.

society, which he allowed to meet in his lecture-rooms, and of which he was chosen one of the patrons. This society, called the Lyceum Medicum Londinense, under his auspices and those of Dr. Fordyce, has acquired considerable reputation, both from the numbers and merits of its members.

In the year 1786, in consequence of the death of Mr. Middleton, Mr. Hunter was appointed deputy surgeon-general to the army. He now published his work upon the Venereal Disease, which had been long expected by the public; and, if we may judge from the rapid sale of the first edition, these expectations have not been disappointed. He alſo published a work entitled, Observations on certain Parts of the Animal Œconomy. In this work he has collected several of his papers inserted in the Philosophical Transactions, which related to that subject, having permission from the president and council of the Royal Society to reprint them; there are also Observations upon some other Parts of the Animal Œconomy, which had not before been published. This work met with a very ready sale. It is to be considered among the peculiarities of his character, that he chose to have his works printed and published in his own house, where they were also sold; but finding this measure to bear hard upon the booksellers, in a way which had not been explained, and which was not intended, the second editions were sold by Mr. Johnson in St. Paul's Church-yard, and Mr. Nicol in Pall-mall.

In the spring of this year he had a very severe illness, which confined him to his bed, and rendered him incapable of attending to any kind of business. In this state I was obliged to take upon myself the charge of his patients, as well as of his other affairs, and these were so extensive that my residence in his house became absolutely necessary.

His recovery was very slow; and his health received so severe a shock that he was never afterwards entirely free from complaint, or capable of his usual bodily exertions.

After his recovery from this illness, he was subject to affections of his heart, upon every occasion which agitated his mind, or required any sudden exertion of the body. In this infirm state he was unable to attend his patients upon sudden calls in the night, or to perform operations without assistance; and for these reasons I continued to live with him till within a year of his death, and then took a house within a few doors, which in no respect detached me from his pursuits, or prevented me taking a part in his private practice.

In the year 1787, he gave a paper to the Royal Society, containing an Experiment to determine the Effect of extirpating one Ovarium on the Number of Young; a paper in which the Wolfe, Jackall, and Dog, are proved to be of the same Species; and a third upon the Anatomy of the Whale Tribe. These papers procured him the honour of receiving Sir John Copley's annual gold medal, given as a mark of distinguished abilities.

These labors shew that the decline of his health, although it diminished his exertions, by no means abated his ardour for the inquiries in which he was always engaged.

In July, he was chosen a member of the American Philosophical Society. He now applied to the governors of St. George's Hospital, to be allowed, on account of his health, an assistant-surgeon, which they very readily granted, and I was appointed to that office.

His collection, which had been the great object of his life, both as a pursuit and an amusement, was now brought into a state of arrangement; and gave him at length the satisfaction of shewing to the public a series of anatomical facts formed into a system, by which the œconomy of animal life was illustrated. He shewed it to his friends and acquaintances twice a year, in October to medical gentlemen, and in May to noblemen and gentlemen, who were only in town during the spring. This custom he continued to his death.

Several of his friends had long been desirous of having an engraving of him, and requested him to sit for a picture to some painter of eminence whom they would employ. This he always declined, not choosing that it should be done at the expence of others; and thinking the price too high for himself to pay. His scruples were, however, at length surmounted, by a desire to oblige Mr. Sharp, the engraver, of whose works he was an admirer. This artist made a request that he would sit to Sir Joshua Reynolds, who had promised to take unusual pains with the picture; as the engraving was proposed more as a test of the artist's abilities upon which he might establish a character, than as a print for sale.

This picture, which is one of the very last works of that eminent painter, and one of his best, remains in the possession of Mr. Hunter's son; and the print which Mr. Sharp engraved from it, is considered as one of the most spirited heads, and finest engravings, which have been produced in this country.

In the year 1789, Mr. Bell, who was become a very skilful anatomist, and good practical surgeon, received an appointment as assistant-surgeon to the Island of Sumatra, in the service of the Honourable East India Company. This appointment, procured by the friendship of Sir Joseph Banks, he accepted with a double view, the one to improve his fortune, the other to collect specimens in natural history. In both of these pursuits he was successful beyond his most sanguine expectations; he sent home some very rare specimens of animals and corals, and two papers, since printed in the Philosophical Transactions, one on the Double horned Rhinoceros, the other giving a Description of an uncommonly formed Fish; but, unfortunately for science, he died of a fever, very much regretted by his friends, in the year 1792.

In the year 1792, Mr. Hunter found that his course of lectures took up so much of his time, that he was unable to correct his other papers. He therefore gave it up to me. As a previous step to this arrangement I had given it for the two preceding summers. Mr. Hunter now began to prepare the present work for the press, and intended as soon as it was in the hands of the public, to give a course of practical lectures in surgery, for which he had many years been collecting materials; these were so far advanced, that another winter, had he lived, would have finished them. The materials of these lectures having come into my hands; that they may not be entirely lost to the public, I mean to avail myself of them, and am preparing my arrangements for that purpose.

Upon the death of Mr. Adair, which happened in this year, Mr. Hunter was appointed inspector-general of hospitals, and surgeon-general of the army. He was also elected a member of the Royal College of Surgeons in Ireland.

In the year 1791, he was so much engaged in the duties of his office, as surgeon-general to the army, and his private practice, that he had little time to bestow upon his scientifical objects; but his leisure time, small as it was, he wholly devoted to them.

In 1792, he was elected an honorary member of the Chirurgo Physical Society of Edinburgh, and was chosen one of the vice-presidents of the Veterinary College, then first established in London. He published in the Transactions of the Society for the Improvement of medical and chirurgical Knowledge, of which society he was one of the original members and a zealous promoter, three papers, on the following subjects: Upon the Treatment of inflamed Veins, on Introsusception, and on a Mode of conveying Food into the Stomach, in Cases of Paralysis of the Œsophagus.

He finished his Observations on the Œconomy of Bees, and presented them to the Royal Society. These observations were made at Earl's Court, and had engaged his attention for many years; every inquiry into the œconomy of these insects had been attended by almost unsurmountable difficulties; but these proved to him only an incitement, and the contrivances he made use of to bring the different operations of these indefatigable animals to view were almost without end.

Earl's Court to Mr. Hunter was a retirement from the fatigues of his profession; but in no respect a retreat from his labours; there, on the contrary, they were carried on with less interruption, and with an unwearied perseverance. From the year 1772 till his death, he made it his custom to sleep there during the autumn months, coming to town only during the hours of business in the forenoon, and returning to dinner.

It was there he carried on his experiments on digestion, on exfoliation, on the transplanting of teeth into the combs of cocks, and all his other investigations on the animal œconomy, as well in health as in disease. The common bee was not alone the subject of his observation, but the wasp, hornet, and the less known kinds of bees were also objects of his attention. It was there he made the series of preparations of the external and internal changes of the silk-worm; also a series of the incubation of the egg, with a very valuable set of drawings of the whole series.

The growth of vegetables was also a favorite subject of inquiry, and one on which he was always engaged in making experiments.

In this retreat he had collected many kinds of animals and birds, and it was to him a favorite amusement in his walks to attend to their actions and their habits, and to make them familiar with him. The fiercer animals were those to which he was most partial, and he had several of the bull kind from different parts of the world. Among these was a beautiful small bull he had received from the Queen, with which he used to wrestle in play, and entertain himself with its exertions in its own defence. In one of these contests the bull overpowered him, and got him down, and had not one of the servants accidentally come by and frightened the animal away, this frolic would probably have cost him his life.

The collection of comparative anatomy which Mr. Hunter has left, and which may be considered as the great object of his life, must be allowed to be a proof of talents, assiduity, and labour, which cannot be contemplated without surprize and admiration.

It remains an unequivocal test of his perseverance and abilities, and an honor to the country in whose schools he was educated, and by the patronage of which he was enabled on so extensive a scale to carry on his pursuits.

In this collection we find an attempt to expose to view the gradations of nature, from the most simple state in which life is found to exist, up to the most perfect and most complex of the animal creation —man himself.

By the powers of his art, this collector has been enabled so to expose, and preserve in spirits or in a dried state, the different parts of animal bodies intended for similar uses, that the various links of the chain of perfection are readily followed and may be clearly understood.

This collection of anatomical facts is arranged according to the subjects they are intended to illustrate, which are placed in the following order: First, parts constructed for motion. Secondly, parts essential to animals respecting their own internal œconomy. Thirdly, parts superadded for purposes connected with external objects. Fourthly, parts for the propagation of the species and maintenance or support of the young.

The first class exhibits the sap of vegetables and blood of animals, from which fluids all the different parts of the vegetable and animal creation are formed, supported, and increased.

These fluids being more and more compounded, as the vegetables and animals become more perfect, are coagulated and form a regular series. The sap of many plants does not coagulate spontaneously, but is made to undergo this change by adding the extract of Gowlard, in this respect differing from water: the sap of such plants is considered as the most simple: in the onion there is a spontaneous coagulation: in insects the blood coagulates, but is without colour: in the amphibia, colour is superadded. The moving powers of animals from the simple straight muscle, to the most complicated structure of that organ, with the different applications of elastic ligaments, form a second series. The growth of bone, horn, and shell, come next in order; and the joints which admit of their moving readily on one another, finish this subject.

The second class begins with those animals of the hydatid kind, which receive nourishment, like vegetables, from their external surface, having no mouth. Then follow those which are simply a bag or stomach, with one opening, as the polypus, having no organs of generation, as every part of the bag is endowed with that power; but in the leech the structure becomes more complex, for although the animal is composed of a bag with only one opening, the organs of generation, brain, and nerves, are superadded, and thence a gradual series is continued to those animals in which the stomach forms only a distinct part of the animal, for the purpose of digestion. The stomachs themselves are also arranged in the order of their simplicity. First, the true membranous digesting stomach, then those with the addition of crops, and other bags, to prepare the food for digestion, as in the ruminating tribe, and, lastly, those with gizzards. Annexed to the stomachs, is a very complete and extensive series of teeth, which are varied according to the kind of food and stomach.

After the stomachs, are the different appearances of the intestinal canal, which exhibit almost an infinite variety in the structure of their internal surface from which the aliment is absorbed. The quantity of surface is increased in some by transverse folds, in some by spiral or longitudinal ones, and in others puts on a loculated appearance, as in the whale.

To these are added the glands, connected with the intestines, as the liver, pancreas, and spleen, which may properly be considered as appendages.

After digestion, follows the system of absorbing vessels, the simplest being the roots of plants, after which are the lymphatic and lacteal vessels of different animals. These in the human subject and the elephant are small, and in the turtle large and more numerous; but in the spermaceti whale, where they are employed for conveying the spermaceti, of a size infinitely beyond what is met with in any other animal. To these are annexed the thoracic ducts in different animals.

The natural order, in following the course of the aliment from the stomach as a guide, leads from the absorbents to the heart, which in the catarpillar is a simple canal or artery running along the middle of the back of the animal, admitting of undulation of the blood; from this simple structure it becomes, in different animals, by ſmall additions, more and more complex, till it arrives at the degree of perfection which is displayed in the organization of the human heart. These are followed by the different structures of valves in the arteries and veins, and the coats of these vessels. Then the lungs are ſhown in all their gradations from the simple vascular lining of the eggshell, which serves as lungs for the chicken, to those of the more perfect animals. In one instance, viz. that of the syren, both gills and lungs are seen in the same animal. The windpipe and larynx are then shown, under all their different forms. The kidnies, which separate the superfluous fluids from the circulation, make the last part of this subject.

The third class takes up the most simple state of the brain, which is in the leech a single nerve with ramifications. In the snail, the brain forms a circular nerve, through the middle of which passes the œsophagus, from which circle there are branches going to every part of the skin of the animal. In the insect, the brain has a more compact form, is larger in fish, but still more so in birds, gradually increasing in size as the animal is endowed with a greater degree of sagacity, till at last it becomes the large complex organ found in the elephant and in the human subject. The coverings of the brain, and the ganglions and peculiarities of the nerves are annexed.

The organs of sense are arranged in the order of their simplicity, beginning with that of touch, which is only a villous vascular surface, the villi very short where the impression is to be made through a thin cuticle, as in the human finger; very long where the covering is thick, as the hoof of the horse. The organ of taste is only a modification of touch, and therefore nothing in the organization is different, but the varieties in structure adapting the tongue for different purposes are numerous; in many animals it answers the purpose of a hand, to bring the food to the mouth, as in many shell-fish, the ant-bear, woodpecker, and camelion. Connected with the tongue are the fauces, which in many animals have peculiarities; in the electric eel, they have a very curious carrunculated irregular appearance; but they are yet more extraordinary in the camel, which has an apparatus to moisten the parts, so as to prevent the painful sensation of thirst, thus adapting the animal to the sandy desarts which it is destined to inhabit; this apparatus consists of a large bag hanging down seve ral inches in the fauces, and attached to the palate, which the animals can at pleasure move up and down, and lubricate the fauces. The organ of smell is variously constructed, and is more complicated in many animals than in man, as in the lion, and sea-cow. The organ of hearing in fish consists of three semicircular canals; but is much more complex in land animals. The organ of seeing is different in those animals which are formed to see in water, and in those which see in air; it differs again in those which are to see with little or with much light; all those peculiarities are illustrated by preparations. The pigmentum of the eye in some fish resembles polished silver; in ruminating animals as the bottom of the eye it has a greenish hue, in the lion and cat kind, a portion of the bottom is white; but, as a general principle, the colour of the pigmentum is the same as the rete mucosum of the skin of the animal, being white in white animals and black in very dark ones.

After the brain and senses are arranged the cellular membrane and animal oils, which are followed by the external coverings. These are divided into the different kinds, as hair, feathers, scales, etc. with the rete mucosum, or that membrane which is interposed between the true skin and the scarf-skin, for the purpose of giving the peculiar colour. Added to these are the parts peculiar to different animals, for offence and defence, as spurs, hoofs, horns, stings, and also electric organs. There follow next such peculiar structures as occur in certain tribes of animals, as the air-bladders in fish, etc.

The fourth class begins with those animals which have no distinct parts allotted for generation, that power being diffused over the whole animal. In these the young grow out of the old, as in the coral and polypi; and next in order come the hermaphrodite organs both of plants, and of animals. The male organs are then taken up as a distinct subject, first in plants and then in animals, both at the times in which they do not breed, and in the breeding season, to show their different states; to these are added a number of parts which answer secondary purposes in generation, and may be considered as appendages.

The female organs are first exhibited in the maiden state, in every class of animals, demonstrating the shape and length of the oviducts, the form of the uterus, the length of its horns, with the varieties in their structure, and the instances in which these horns are entirely wanting, as in some monkeys; to which are added, the peculiarities respecting the hymen. They are then exemplified in the impregnated state, beginning with the seeds of vegetables and those which have both seeds and young shoots, as the onion. The eggs of insects follow next, with their changes, particularly of the silkworm. The ſpawn of fish, are next shown, first in those which have eggs, and then in those which have their eggs hatched in the oviducts, as the dog-fish.

The arrangement then proceeds to the formation and incubation of the egg in the fowl, and the process of fœtation in the quadruped, with their peculiarities and the different structures and appearances of the afterbirth. Added to these are the peculiarities of the fœtus, and the different modes by which the mother gives nourishment to her young.

In this collection, besides the preparations of the parts themselves in spirits, in a dried state or corroded, so as to give the most accurate ideas of their structure, there is a considerable number of very valuable drawings to show the progress of different processes in the animal œconomy, together with such appearances as were not capable of being preserved.

This sketch will give an idea, but a very inadequate one, of the system which is comprehended in Mr. Hunter's collection. It also includes a very large series of whole animals in spirits, arranged according to their internal structure, and many of the most rare specimens of preserved animals in this country, as the camelopardos, guanica, hippopotamus, tapir, argus-pheasant, etc.

There is also a series of sculls of different animals, to show their peculiarities, and skeletons of almost every known genus of animals. There is a large collection of shells and insects; a prodigious number of calculi of different sorts from the urinary and gall-bladders, the stomach, and intestinal canal; there are likewise the most uncommon deviations from the natural structure, both in man and in other animals, preserved in spirits or in a dried state; the most extraordinary specimens of this kind are a double human uterus, one of the parts pregnant, and a double human scull perfectly formed, the one upon the top of the other. To make this collection more complete in every subject connected with comparative anatomy, is added one of the largest and moft select collections of extraneous fossils that can be seen in this country.

The symptoms of Mr. Hunter's complaint, for the last twenty years of his life, may be considered as those of the angina pectoris; and form one of the most complete histories of that disease upon record. I have chosen to give this account a place by itself distinct from the general history of his life, of which it forms an important part, more especially when prefixed to a medical work.

Each symptom was described at the time it occurred, and either noted by himself, or dictated to me, when Mr. Hunter was too ill to write; they will therefore be found more accurately detailed than in ordinary cases *.

Mr. Hunter was a very healthy man for the first forty years of his life; and, if we except an inflammation of his lungs in the year 1759, occasioned most probably by his attention to anatomical pursuits, he had no complaint of any consequence during that period. In the

* As the statement of the following case is made up from detached notes which were not written with a view to publication, it will appear in point of language extremely deficient; it was, however, thought better to leave it in its present form, lest, by altering the language, the effect of some of the expressions might he diminished, or misunderstood; it was also believed, that an account, however crude, coming directly from the author, would be more acceptable to the public, than one a little more finished from any other hand.

ſpring of 1769, in his forty-first year, he had a regular fit of the gout, which returned the three following springs, but not the fourth; and in the spring of 1773, having met with something which very forcibly affected his mind, he was attacked at ten o'clock in the forenoon with a pain in the stomach, about the pylorus; it was the sensation peculiar to those parts, and became so violent that he tried change of position to procure ease, he sat down, then walked, laid himself down on the carpet, then upon chairs, but could find no relief; he took a spoonful of tincture of rhubarb, with thirty drops of laudanum, without the smallest benefit. While he was walking about the room he cast his eyes on the looking-glass, and observed his countenance to be pale, his lips white, giving the appearance of a dead man; this alarmed him, and led him to feel for his pulse, but he found none in either arm; he now thought his complaint serious; several physicians of his acquaintance were then sent for, Dr. William Hunter, Sir George Baker, Dr. Huck Saunders, and Sir William Fordyce, all came, but could find no pulse; the pain still continued, and he found himself at times not breathing. Being afraid of death soon taking place if he did not breathe, he produced the voluntary act of breathing, by working his lungs by the power of the will; the sensitive principle, with all its effects on the machine not being in the least affected by the complaint. In this state he continued for three quarters of an hour, in which time frequent attempts were made to feel the pulse, but in vain; however, at last, the pain lessened, and the pulse returned, although at first but faintly, and the involuntary breathing began to take place; while in this state, he took Madeira, brandy, ginger, etc. but did not believe them of any service, as the return of health was very gradual; in two hours he was perfectly recovered.

In this attack there was a suspension of the most material involuntary actions, even involuntary breathing was stopped, while sensation with its consequences, as thinking and acting with the will, were perfect, and all the voluntary actions were as strong as before.

Quere. What would have been the consequence of his not having breathed by means of the voluntary muscles? It struck him at the time that he would have died; but we cannot suppose that would have been the consequence, as breathing most probably is only necessary for the blood while circulating, and as the circulation was stopped, no good could have arisen from breathing.

From this case it appears that, the involuntary actions of the body are not a regular series of actions depending absolutely on one another, but each part can and often does act independently, or leaves off acting while other actions are going on; but although there is not an absolute dependance, there is a necessary connexion among them, without which their actions cannot long continue. The stomach was probably the seat, or origin of this cessation of action; as we know that affections of the stomach have the greatest influence on every part of the body, and that affections of every part, have the power of influencing the stomach.

Mr. Hunter never had any return of these affections of the stomach, though frequently troubled with slight complaints both in the stomach and bowels, which were readily removed by small doses of rhubarb. In other respects he enjoyed his health till the year 1776. Towards the end of the spring he was seized with a very severe and dangerous illness, in consequence of anxiety of mind from being obliged to pay a large sum of money for a friend, for whom he had been security, and which his circumstances made extremely inconvenient.

At two o'clock in the forenoon he eat some cold chicken and ham, and drank a little weak punch; immediately after this he went eight miles in a post-chaise. While he was on the journey he had the feel of having drank too much, but passed the remainder of the day tolerably well; at twelve o'clock at night his stomach was a little disordered, for which he took some caraways, and went to bed; he had no sooner lain down than he felt as if suspended in the air, and soon after the room appeared to go round; the quickness of this motion seemed to increase, and at last was very rapid; it continued for some time, then became slower and slower till the whole was at rest; this was succeeded by vomiting, which was encouraged, and gave him a good night's rest; next day he was tolerably well, but fatigued; the morning after, thinking himself quite recovered, he went out before breakfast, drank some tea and eat some bread and butter, which he was not accustomed to do. At eleven o'clock, he felt his stomach much in the same state as before; in about half an hour, the sensation of the room appearing to turn, recommenced, and continued for some time, but not with such violence as in the last attack; he became sick and vomited; the sensation of himself and every thing else going round, went off, but that of being suspended in the air continued, with a giddiness; he now could hardly move his head from an horizontal position, and about two o'clock was brought home in his carriage, the motion of which was very disagreeable, giving the sensation of going down, or sinking*.

After he went to bed, the giddiness and the idea of being suspended

* It is very curious that, the sensation of sinking is very uneasy to most animals. When a person is tossed in a blanket, the uncomfortable part is falling down; take any animal in the hand and raise it up, it is very quiet, but bring it down, and it will exert all its powers of resistance, every muscle in the body is in action; this is the case even with a child as early as its birth.

in the air increased, and the least motion of the head upon the pillow appeared to be so great that he hardly durst attempt it; if he but moved his head half round, it appeared to be moving to some distance with great velocity; the idea he had of his own size was that of being only two feet long, and when he drew up his foot, or pushed it down, it appeared to him to be moving a vast way. His sensations became extremely acute or heightened; he could not bear the least light, so that although the window-blinds were shut, a curtain and blanket were obliged to be hung up against it, the fire to have a skreen before it, and the bed-curtains to be drawn; he kept his eyelids closed, yet if a lighted candle came across the room, he could not bear it; his hearing was also painfully acute, but not so much increased as his sight; the smell and taste were also acute, every thing he put into his mouth being much higher flavoured than common, by which means he relished what he eat; his appetite at first was very indifferent, but soon became good; his pulse was generally about sixty, and weak, and a small degree of heat on the skin, especially on the hands and feet; he remained in this state for about ten days, and was obliged to be fed as he lay; by this time he was rather better; that is, he could move his head more freely.

When he was first attacked, the pulse was full, and eight ounces of blood were taken away, but this did not appear to be of service; the day following he was cupped between the shoulders, and had a large blister applied upon the part; he took an emetic, and several times purging medicines, and bathed his feet in warm water, but nothing appeared to be of the least use. The purging and vomiting distressed him greatly, for both the stomach and intestines were so irritable, that less than half the usual quantity had the desired effect. He took some

James's powder, and drank some white wine whey on account of the heat in the skin, especially in the feet and hands, which took it off, and gave him for the first time a comfortable feel. At the end of ten days all his ideas of his present state became more natural, the strange deception concerning his own size was in part corrected, and the idea of suspension in the air became less; but for some time after, the fire appeared of a deep purple red. When he got so well as to be able to stand without being giddy, he was unable to walk without support, for his own feelings did not give him information respecting his centre of gravity, so that he was unable to balance his body, and prevent himself from falling.

He gradually recovered from this state, and as soon as he was able went to Bath, where he staid some time and drank the waters, which were thought to be of service to him; but did not stay long enough to give them a fair trial; he returned to town much better, and in a few weeks got quite well. From this period to 1785, he had no particular indisposition, but certainly did not enjoy perfect health, for in 1785, he appeared much altered in his looks, and gave the idea of having grown much older than could be accounted for from the number of years which had elapsed.

About the beginning of April 1785, he was attacked with a spasmodic complaint, which at first was slight, but became afterwards very violent, and terminated in a fit of the gout in the ball of the great toe; this, like his other attacks, was brought on by anxiety of mind; the first symptom was a sensation of the muscles of the nose being in action, but whether they really were, or not, he was never able to determine; this sensation returned at intervals for about a fortnight, attended with an unpleasant sensation in the left side of the face, lower jaw, and throat, which seemed to extend into the head on that side, and down the left arm, as low as the ball of the thumb, where it terminated all at once; these sensations were not constant, but returned at irregular times; they became soon more violent, attacking the head, face, and both sides of the lower jaw, giving the idea that the face was swelled, particularly the cheeks, and sometimes slightly affected the right arm. After they had continued for a fortnight they extended to the sternum, producing the same disagreeable sensations there, and giving the feel of the sternum being drawn backwards toward the spine, as well as that of oppression in breathing, although the action of breathing was attended with no real difficulty; at these times the heart seemed to miss a stroke, and upon feeling the pulse, the artery was very much contracted, often hardly to be felt, and every now and then the pulse was entirely stopt; he was afterwards attacked with a pain in the back, about that part where the œsophagus passes through the diaphragm, the sensation being that of something scalding hot passing down the œsophagus; he was next seized with a pain in the region of the heart itself, and last of all with a sensation in the left side, nearly in the seat of the great end of the stomach, attended with considerable eructations of wind from that viscus; these seemed to be rather spasmodic than a simple discharge of wind, a kind of mixture of hiccough and eructation, which last symptoms did not accompany the former, but came on by themselves. In every attack there was a raw sore feel, as if the fauces were excoriated. All these succeeding symptoms (those in the stomach and nose only excepted) were, in addition to the first, for every attack began with the first symptoms. The complaint appeared to be in the vascular system, for the larger arteries were sensibly contracted, and sore to the touch, as far as they could be touched, principally in the left arm; the urine at those times was in general very pale.

These symptoms increased in violence at every return, and the attack which was the most violent, came on one morning about the end of April, and lasted above two hours; it began as the others had done, but having continued about an hour, the pain became excruciating at the apex of the heart; the throat was so sore as not to allow of an attempt to swallow any thing, and the left arm could not bear to be touched, the least pressure upon it giving pain, the sensation at the apex of the heart was that of burning or scorching, which, by its violence, quite exhausted him, and he sunk into a swoon or doze, which lasted about ten minutes, after which he started up, without the least recollection of what had passed, or of his preceding illness. I was with him during the whole of this attack, and never saw any thing equal to the agonies he suffered; and when he fainted away, I thought him dead, as the pain did not seem to abate, but to carry him off, having first completely exhausted him.

He then fell asleep for half an hour, and awoke with a confusion in his head, and a faint recollection of something like a delirium; this went off in a few days.

The affections above-described were, in the beginning, readily brought on by exercise, and he even conceived that if he had continued at rest, they would not have come on; but they at last seized him when lying in bed, and in his sleep, so as to awaken him; affections of the mind also brought them on; but coolly thinking or reasoning did not appear to have that effect. While these complaints were upon him, his face was pale, and had a contracted appearance, making him look thinner than ordinary, and after they went off his colour returned, and his face recovered its natural appearance. On the commencement of the complaint, he suspected it to be rheumatism, and applied electricity to his arm, which took it off for the time only; he then, for two or three nights successively, took three grains of James's powder, without any abatement of the symptoms; he next had recourse to the camphorated julep, both at the commencement of the spasm, and while it was upon him, but obtained no relief; he tried Hoffman's anodyne liquor, in the dose of a tea-spoonful, and not finding it to answer alone, joined to it the camphorated julep, but the spasms seemed to be more violent; one night he took twenty drops of thebaic tincture, which made his head confused all the following day, but did not at all abate the spasms; the following day he took two tea-spoonfuls of the bark, which heated him, and gave him a head-ach, thirst, and dryness of his mouth, which prevented his continuing it. At the desire of Dr. David Pitcairn, he took the powder of valerian, an ounce a day, which seemed for the first two days to remove his spasms, but they returned on the third with more violence than usual, especially one evening at the Royal Society, which induced him to leave off the valerian, and he bathed his feet on going to bed in warm water, mixed with half a pound of flour of mustard, and took a tea-spoonful of tincture of rhubarb in ginger-tea; also wore worsted stockings all night.

On Friday morning, the twentieth of May, between six and seven o'clock, he had a violent spasm, attended with most violent eructations of wind from the stomach for nearly a quarter of an hour. Dr. Pitcairn, who was sent for upon this occasion, asked him, if there was any distress upon his mind that had brought on this attack; and he confessed his mind to have been much harrassed, in consequence of having opened the body of a person who died from the bite of a mad dog, about six weeks before, in doing which he had wounded his hand; and for the last fortnight his mind had been in continual suspense, conceiving it possible that he might be seized with symptoms of hydrophobia. This anxiety preying upon his mind for so long a time, there is every reason to believe was the cause of the present attack, and probably had also brought on the former ones, which were all after the accident which had impressed his mind with this horrible idea.

At the desire of Dr. Pitcairn, he took at two doses in the forenoon, ten grains of asafœtida, and three grains of opium, and in the afternoon fifteen of asafœtida, and one of opium; in the evening he had a head-ach, which was supposed to be brought on by the opium, his bowels were loaded and oppressed with wind, and he endeavoured in vain to procure a motion by laxative clysters, although repeated, and ten grains of jalap were taken by the mouth; he passed a very restless night. On Saturday morning he was visited by Sir George Baker, Dr. Warren, and the late Dr. Pitcairn; he repeated the asafœtida twice in the course of the day, and two spoonfuls of the following mixture were taken every hour, without producing a motion till about half an hour after the whole was used.

Infusion of senna, six ounces;
Tincture of senna, one drachm and a half;
Soluble tartar, three drachms.

M.

In the afternoon he had another evacuation, soon after which, the most violent attack of spasm which he experienced, came on; nothing was attempted internally during the attack, which lasted two hours; a bladder of hot water was applied to the heart, and afterwards to the feet, without any effect.

The asafœtida was now left off, and this evening he began the oleum succini in saline draughts fifteen drops every six hours. On Sunday morning he continued the oleum succini, but the saline draught was changed to cinnamon-water, and a large blister was put upon the back close to the neck; he continued pretty free from spasm. On Monday the blister was taken off, and the oleum succini continued; but about nine o'clock at night he had threatenings of spasm, with head-ach, and the feel of a load in his bowels; he had a pain in the left fide and region of the stomach, with violent eructations of wind from the stomach, which lasted about two hours; he took thebaic tincture, twenty-five drops, in the warm tincture of rhubarb, and afterwards some baume de vie, but the eructations continuing, sinapisms were applied to the feet, after which they ceased, and the sinapisms were so troublesome that he had them taken off five hours after they were applied. On Tuesday morning he felt himself easier, the oleum succini was continued, five drops of laudanum being added to each dose; in the evening he bathed his feet in warm water, to clean them from the sinapisms, and both the great toes appeared a little inflamed, and very tender; they were more painful after being bathed, and were very troublesome all night. On Wednesday morning the inflammation and swelling in the great toes appeared evidently to be the gout, and the pain continued very acute till Thursday, when it began to abate; and on Friday was very much diminished: he continued the oleum succini on Wednesday, and took a bolus of aromatic species before each dose; but on Friday the oleum succini made him sick, and was left off. On Saturday he began the bark in tincture and decoction with the species aromaticæ; Sunday continued the bark, and having eructations and flatulencies after his meals, he was ordered every day before dinner, rhubarb fifteen grains, ginger ten grains, in a bolus. He had no spasm after Monday the thirtieth of May; he however had threatenings, or slight sensations, similar to those which preceded the spasms, and occasional eructations. Although evidently relieved from the violent attacks of spasm by the gout in his feet, yet he was far from being free from the disease, for he was still subject to the spasms, upon exercise or agitation of mind; the exercise that generally brought it on, was walking, especially on an ascent, either of stairs or rising ground, but never on going down either the one or the other; the affections of the mind that brought it on were principally anxiety or anger: it was not the cause of the anxiety, but the quantity that most affected him; the anxiety about the hiving of a swarm of bees brought it on; the anxiety lest an animal should make its escape before he could get a gun to shoot it, brought it on; even the hearing of a story, in which the mind became so much engaged as to be interested in the event, although the particulars were of no consequence to him, would bring it on; anger brought on the same complaint and he could conceive it possible for that passion to be carried so far as totally to deprive him of life; but what was very extraordinary, the more tender passions of the mind did not produce it; he could relate a story which called up the finer feelings, as compassion, admiration for the actions of gratitude in others, so as to make him shed tears, yet the spasm was not excited: it is extraordinary that he eat and slept as well as ever, and his mind was in no degree depressed; the want of exercise made him grow unusually fat.

As he had not drank wine for four or five years he was advised to try it, which he complied with, but found the spasms more easily brought on after using it, than on those days on which he drank none; and

and they were always more readily produced after eating a hearty meal. He continued very much in the same way till August, when he went to Tunbridge and drank the waters for about a fortnight, without the the least benefit, but rather conceived he was worse. From thence he hurried to Bath, the first week in September, and drank the waters for four weeks, twice before breakfast, and once at noon; having drank them for about a fortnight, he began to bathe every other night in the hot-bath, and on the intermediate nights put his feet into the hot-bath waters, and sometimes rode on horseback. After being there three weeks he did not find the least benefit, but on Monday, the beginning of the fourth week, he found that his walking to the pump-room in a morning did not bring on the spasm as usual, and found also that he could extend his walk very considerably on that day; on Tuesday, he was not quite so well, although when he compared that day with the preceding days, or rather months, he could say that he was better; this seemed to be a step gained; in this state he left Bath, and continued the same through the whole winter. About the beginning of May 1786, he began to believe that the exercise he was able to make use of affected him less; he found that in the months of June, July, August, and September, he was able to take a long walk slowly; he could, however, at any time, bring on the complaint, for upon using the least exercise he felt as if it was coming on; and often, by forgetting himself, he brought it on slightly, which made him slacken his pace. In the month of October, when the weather became cold, he was obliged constantly to use his carriage, because he could not walk sufficiently fast to keep himself warm, although in other respects he was not affected by it. What appeared very extraordinary was, that the spasm did not come on equally upon all kinds of exercise; he often performed an operation, as cutting for the stone, or extirpation of a breast, which, from peculiar circumstances, required a considerable deal of fatigue, and lasted near an hour each time, yet the spasm did not come on. He was employed in embalming the Princess Amelia for three hours, in which time he was really fatigued, but had no spasm the whole time; yet, by going the length of Cavendish-square, and on towards Oxford-road, he was seized with a considerable spasm; but the fatigue he had undergone acted, probably, as a predisposing cause.

Thefe spasms, although they did not increase in violence, were uniformly more frequent, and came on upon a greater variety of occasions; but as he became accustomed to their effects, less attention was paid to them. Nothing particular occurred from this period till about the beginning of December 1789, in the evening, when at the house of a friend on a visit, he was attacked with a total loss of memory; he did not know in what part of the town he was, not even the name of the street when told it, nor where his own house was; he had not a conception of any place existing beyond the room he was in, and yet was perfectly conscious of the loss of memory. He was sensible of impressions of all kinds from the senses, and therefore looked out of the window, although rather dark, to see if he could be made sensible of the situation of the house; this loss of memory gradually went off, and in less than half an hour his memory was perfectly recovered. About a fortnight after, as he was visiting his patient one forenoon, he observed occasionally a little giddiness in his head, and by three o'clock it was attended with an inclination to vomit. He came home and drank some warm water, which made him vomit severely, but nothing came off his stomach except the water. The giddiness became severe, but went off again about seven or eight o'clock; about nine or ten it returned with more severity, and when going to bed, about eleven o'clock, he had entirely lost the centre of gravity, although he could move his limbs as the will directed; light became offensive, and every thing had a kind of yellow cast; sounds were more acute than natural, objects had lost their true direction; a perpendicular, for instance, seemed to lean to the left, making, as nearly as he could conjecture, an angle with the horizon of fifty or sixty degrees; objects were also smaller than the natural recollection of them; his idea of his own size was that of only being four feet high; also objects appeared to be at an unusual distance, as if seen through a concave glass; he had a slight sound in the right ear, at every stroke of the pulse; motion in his head was extremely disagreeable, he therefore moved with great caution; although coughing and sneezing did not affect it: during this illness Dr. Pitcairn and Dr. Baillie attended him. It is difficult to describe sensations, especially when they are not common; the sensation which he had in his head was not pain, but rather so unnatural as to give him the idea of having no head; with all this, neither the mind nor the reasoning faculty were affected, which is not the case when such effects are produced from liquor. Objects in the mind were very lively, and often disagreeably so; dreams had the strength of reality, so much so, as to awaken him; the remembrance of them was very perfect. The disposition to sleep was a good deal gone, an hour or two in the twenty-four being as much as could be obtained; these symptoms were much the same for about a week, and began gradually to diminish, so that in a fortnight he was able to sit up, and in three weeks went an airing in the carriage; cordial medicines were given, and the body kept open; he felt a pain in the joint of the great toe, which inflamed gently, but soon left it; his pulse was rather increased in frequency, the urine at first was high coloured, deposited a sediment, and was rather diminished in quantity; but the retention in the bladder was very great, as he was not able to make water from ten o'clock in the evening till the same time the next evening, the quantity being very considerable, although not so much as would have been made in the same time had he been in health. The urine became of a yellow colour, and afterwards pale; the stools were solid; the taste of victuals was not impaired, except tea, for which he had no relish. Although he had no particular inclination to eat, yet his appetite was not much diminished. To excite the action of the gout, sinapisms were applied to the feet, but had not the desired effect; in the fourth week the head not recovering so fast as was expected, a blister was applied between the shoulders, but had no immediate effect, probably did harm, by producing irritation and want of sleep; one night, not having above an hour's sleep, he drank a tumbler full of hot water, which set him immediately to sleep, in which state he continued near four hours; he took a hint from this and drank a tumbler full of hot water every night, just before he went to bed, which did not fail of putting him soon to sleep, and giving him a good night's rest*.

The apparent obliquity of objects he accounted for by supposing that the two corresponding oblique muscles had an unnatural contraction which moved the two eyes round near thirty or forty degrees; we shall suppose that the obliquus ſuperior of the left eye brought the eye-ball forwards towards the nose, while the obliquus inferior of

* He took advantage of this circumstance, and in all cases of irritable stomachs, from whatever cause, prescribed warm water, which in general gave relief; one remarkable case of bleeding from the stomach, in consequence of irritation, was entirely cured by the internal use of warm water.

the right eye contracted equal to the superior of the left ; this turned the under part of the right eye inwards towards the nose, and the upper part outwards, which moved a lateral part of the eye upon the object, and gave it that obliquity.

His recovery from this indisposition was less perfect than from any of the others ; he never lost entirely the oblique vision ; his memory was in some respects evidently impaired, and the spasms became more constant ; he never went to bed without their being brought on by the act of undressing himself; they came on in the middle of the night; the least exertion in conversation after dinner was attended by them; he felt therefore obliged to confine himself within a certain sphere of action, and to avoid dining in large companies. Even operations in surgery, if attended with any nicety, now produced the same effects.

In the autumn 1790, and in the spring and autumn 1791, he had more severe attacks than during the other periods of the year, but of not more than a few hours duration: in the beginning of October 1792, one, at which I was present, was so violent that I thought he would have died. On October the 16th, 1793, when in his usual state of health, he went to St. George's Hospital, and meeting with some things which irritated his mind, and not being perfectly master of the circumstances, he withheld his sentiments, in which state of restraint he went into the next room, and turning round to Dr. Robertson, one of the physicians of the hospital, he gave a deep groan, and dropt down dead.

It is a curious circumstance that, the first attack of these complaints was produced by an affection of the mind, and every future return of any consequence arose from the same cause ; and although bodily exercise, or distention of the stomach, brought on slighter affections, it still required the mind to be affected to render them severe ; and as his mind was irritated by trifles, these produced the most violent effects on the disease. His coachman being beyond his time, or a servant not attending to his directions, brought on the spasms, while a real misfortune produced no effect.

At the time of his death he was in the 65th year of his age, the same age at which his brother, the late Dr. Hunter, died.

Upon inspecting the body after death, the following were the appearances: the skin in several places was mottled, particularly on the sides and neck, which arose from the blood not having been completely coagulated, but remaining nearly fluid.

The contents of the abdomen were in a natural state, but the coats of the stomach and intestines were unusually loaded with blood, giving them a fleshy appearance, and a dark reddish colour; those parts, which had a depending situation, as in the bottom of the pelvis, and upon the loins, had this in a greater degree than the others; this evidently arose from the fluid state of the blood. The stomach was rather relaxed, but the internal surface was entirely free from any appearance of disease; the orifice at the pylorus was uncommonly open. The gall-bladder contained five or six small stones of a light yellow colour. The liver and the other viscera exhibited nothing unusual in their appearance.

The cartilages of the ribs hadin many places become bone, requiring a saw to divide them. There was no water in the cavity of the chest, and the lungs of the right side were uncommonly healthy; but those of the left had very strong adhesions to the pleura, extending over a considerable surface, more especially towards the sternum.

The pericardium was very unusually thickened, which did not allow it to collapse upon being opened; the quantity of water contained in it was scarcely more than is frequently met with, although it might probably exceed that which occurs in the most healthy state of these parts.

The heart itself was very small, appearing too little for the cavity in which it lay, and did not give the idea of its being the effect of an unusual degree of contraction, but more of its having shrunk in its size. Upon the under surface of the left auricle and ventricle, there were two spaces nearly an inch and half square, which were of a white colour, with an opaque appearance, and entirely distinct from the general surface of the heart: these two spaces were covered by an exudation of coagulating lymph, which at some former period had been the result of inflammation there. The muscular structure of the heart was paler and looser in its texture than the other muscles in the body. There were no coagula in any of its cavities. The coronary arteries had their branches which ramify through the substance of the heart in the state of bony tubes, which were with difficulty divided by the knife, and their transverse sections did not collapse, but remained open. The valvulæ mitrales, where they come off from the lower edge of the auricle, were in many places ossified, forming an imperfectly bony margin of different thicknesses, and in one spot so thick as to form a knob; but these ossifications were not continued down upon the valve towards the chordæ tendineæ.

The semilunar valves of the aorta had lost their natural pliancy, the previous stage to becoming bone, and in several spots there were evident ossifications.

The aorta immediately beyond the semilunar valves had its cavity larger than usual, putting on the appearance of an incipient aneurism; this unusual dilatation extended for some way along the ascending aorta, but did not reach so far as the common trunk of the axillary and carotid artery. The increase of capacity of the artery might be about one-third of its natural area ; and the internal membrane of this part had lost entirely the natural polish, and was studded over with opaque white spots, raised higher than the general surface.

On inspecting the head, the cranium and dura mater were found in a natural state. The pia mater had the vessels upon the surface of the two hemispheres of the brain turgid with blood, which is commonly found to be the case after sudden death.

The internal structure of the brain was very carefully examined, and the different parts both of the cerebrum and cerebellum were found in the most natural and healthy state ; but the internal carotid arteries as they pass by the sides of the cella tursica were ossified, and several of the ramifications which go off from them had become opaque and unhealthy in their appearance. The vertebral arteries lying upon the medulla oblongata had also become bony, and the basillary artery, which is formed by them, had opaque white spots very generally along its coats.

From this account of the appearances observed after death, it is reasonable to attribute the principal symptoms of the disease to an organic affection of the heart. That organ was rendered unable to carry on its functions, whenever the actions were disturbed, either in consequence of bodily exertion, or affections of the mind.

The stoppage of the pulse arose from a spasm upon the heart, and in this state the nerves were probably pressed against the ossified arteries, which may account for the excruciating pain he felt at those times.

The other symptoms may be explained from the defect in the valves and the dilatation of the aorta, which had lost its elasticity.

In the last attack the spasm upon the heart was either too violent in the degree of contraction, or too long continued to admit of relaxation, so that death immediately ensued.

His remains were interred in a vault under the parish church of St. Martin in the Fields, attended by a few of his oldest medical friends.

Mr. Hunter was of a short stature, uncommonly strong and active, very compactly made, and capable of great bodily exertion. His countenance was animated, open, and in the latter part of his life deeply impressed with thoughtfulness. When his print was shewn to Lavator, he said, "That man thinks for himself." In his youth he was cheerful in his disposition, and entered into youthful follies like others of the same age; but wine never agreed with his stomach, so that after some time he left it off altogether, and for the last twenty years drank nothing but water.

His temper was very warm and impatient, readily provoked, and when irritated, not easily soothed. His disposition was candid, and free from reserve, even to a fault. He hated deceit, and as he was above every kind of artifice, he detested it in others, and too openly avowed his sentiments. His mind was uncommonly active; it was naturally formed for investigation, and that turn displayed itself on the most trivial occasions, and always with mathematical exactness. What is curious, it fatigued him to be long in a mixed company which did not admit of connected conversation; more particularly during the last ten years of his life.

He required less relaxation than most other men; seldom sleeping more than four hours in the night, but almost always nearly an hour after dinner; this, probably, arose from the natural turn of his mind being so much adapted to his own occupations, that they were in reality his amusement, and therefore did not fatigue.

To his own abilities alone was he indebted for the eminence which he acquired in his profession; for although his medical education, his situation as surgeon to St. George's Hospital, and above all, his brother's recommendation entitled him to notice, yet the increase of his private practice was at first but slow. The natural independence of his mind, led him rather to indulge in his own pursuits, than to cultivate the means of enlarging the sphere of his business; but the proofs which he afterwards gave of his talents commanded the attention of the public and procured him a very liberal income.

In the first eleven years of his practice, from 1763 to 1774, his income never amounted to a thousand pounds a year; in the year 1778 it exceeded that sum; for several years before his death it had increased to five, and at that period was above six thousand pounds.

In private practice he was liberal, scrupulously honest in saying what was really his opinion of the case, and ready upon all occasions to acknowledge his ignorance whenever there was any thing which he did not understand.

In conversation he spoke too freely, and sometimes harshly of his cotemporaries; but if he did not do justice to their undoubted merits, it arofe not from envy, but from his thorough conviction that surgery was as yet in its infancy, and he himfelf a novice in his own art; and his anxiety to have it carried to perfection, made him think meanly and ill of every one whose exertions in that respect did not equal his own.

Public-spirited to an extreme, he valued money no farther than as it enabled him to prosecute and extend his various, and nearly universal researches ; and hurried on by the ambition of benefiting mankind at large, he paid too little attention to his own and his family's interests. But imprudence almost always goes hand in hand with genius ; if it deserves a harsher name, let it be remembered, that his immediate relatives alone, and not the public, have a right to complain; for viewed in a professional light, and as a man of science, his zeal for the improvement of surgery in particular, and for the advancement of knowledge in general, to both of which he himself materially contributed, entitles him at least to the gratitude, if not to the veneration of posterity.

INTRODUCTION.

THE following pages, treating of inflammation, were firſt arranged in the year 1762, at Bellisle, after the complete reduction of that place. They were compiled from notes, and memorandums of observations, made in the course of twelve years residence in London. During this space, my time was occupied partly in my education under the late Dr. Hunter, and partly in assisting him. In the winter season I was principally employed in the dissecting-room, where I taught the practical part of anatomy; in the summer I attended the hospitals. The truth of these observations was, during the siege of Bellisle, in some degree put to the test, by compairing them with many cases of wounds, which were attended with inflammation. From the frequency of gun-ſhot wounds at that place, I was naturally led to arrange my thoughts upon the subject, and was induced to select them more particularly, for the illustration of my opinions on inflammation. About the year 1770, when I began my lectures on the principles of disease, inflammation was the subject of a considerable part of them; and, from that time till this, though I have been extending and correcting the materials, my principles remain the same. To distinguish the different species of inflammation*, and to express my own ideas the better, I was naturally led to substitute such terms as appeared to me more expressive of what was meant, than those usually employed. The

* In the course of this work I very often make use of the word species or specific, by which I only mean peculiarities or distinctions; and probably the term is much too loose in its application; for as we are not entirely acquainted with the specific differences in disease, we may call that a species which more properly ranks as a genus, claſs, &c. Of morbid poisons we can make a correct arrangement; but, with regard to disease ariſing from peculiarities in the constitution, we have no such absolute guides.

best test of the propriety of these terms is, that they have been adopted by many medical writers since that period; and indeed my principles have undergone the same kind of test. In this some medical writers have been very liberal, for, not contented with taking hints, they have even laid hold of large portions of my lectures, screening themselves under the very honourable protection of their not being in print; and, at the same time, quoting authors to show their reading and their *candour*. It would appear that they consider the discoveries and opinions of a lecturer, found probably in a manuscript, as fair game; though their delicate attention to the rights of another would, no doubt, have prevented them from adopting the same doctrines, had they been actually in print. Such freedoms have made me anxious to publish, not only because the public interests itself in the origin of every discovery or opinion, but because I wish to preserve my right, and also to give in a more perfect form, what was thought worthy of the public, even in a mutilated state. My respect for that public, however, has withheld me hitherto from publishing, that I might first be able to complete my subject, as far as time and other circumstances would allow me. I hope this publication will, at least, have equal good effects with those I have before produced, not only enabling persons to write on the same subject, who could not otherwise have done it, but even to become critics in matters of which, till then, they were entirely ignorant.

I have endeavoured, as far as my other pursuits would permit, to form this work into a regular system, one part exactly depending on another; how far I have succeeded the world must judge; but at the same time it ought to be considered as a new figure composed from rough materials, in which process little or no assistance could be had from any quarter, wherein the author is conscious of many imperfections, more of which he is persuaded he shall himself observe at every successive review.

There are many opinions respecting the animal œconomy peculiar to myself, which are introduced, or frequently referred to, in the course of this work. It is therefore neceſſary to premise a short explanation of some of them, that the ideas and terms which are employed may be better understood. To others of them, however, this method cannot be applied, as they belong essentially to the body of the work, or are so immediately connected with it, as to be best understood when treated in connection with that part.

I shall carry my ideas of life further than has commonly been done: life I believe to exist in every part of an animal body, and to render it susceptible of impressions which excite action; there is no part which has not more or less of this principle, and consequently no part which does not act according to the nature of the principle itself, and the impressions thence arising, producing thereby infinite variety, both in all natural and diseased acts. How far every part has an equal quantity of life, or of the powers of life, is not easily ascertained; but if we were to estimate them by the powers of action, we should judge tolerably well. Disease would seem to give some intelligence with regard to this matter; but how far resistance to disease, and powers of restoration, depend on the powers of life, or simply on the powers of action, I cannot say; but I believe it may be set down as a rule, that those parts that are endowed with most action resist disease most strongly, and in disease restore themselves more readily to a healthy state.

I. OF DISEASED ACTIONS, AS BEING INCOMPATIBLE WITH EACH OTHER.

As I reckon every operation in the body an action, whether universal or partial, it appears to me, beyond a doubt, that no two actions can take place in the same constitution, nor in the same part at one and the same time; the operations of the body are similar in this respect to actions or motions in common matter. It naturally results from this principle, that no two different fevers can exist in the same constitution, nor two local diseases in the same part at the same time. There are many local diseases which have dispositions totally different, but having very similar appearances, have been supposed by some to be one sort of disease, by others to be a different kind, and by others again a compound of two diseases. Thus the venereal disease, when it attacks the skin, is very similar to those diseases which are vulgarly called scorbutic, and vice versâ. These, therefore, are often supposed to be mixed, and to exist in the same part. Thus we hear of a pocky-scurvy, a pocky-itch, rheumatic-gout, etc. etc. which names, according to my principle, imply a union that cannot possibly exist.

It has been considered as contradictory to this opinion, that a patient might have the scrofula, scurvy, venereal disease, small-pox, etc. at the same time; all of this is indeed possible; but then no two of them can exist in the same part of the body at the same time; but before one of them can occupy the place of another, that other must be first destroyed, or it may be superseded for a time, and may afterwards return.

When a constitution is susceptible of any one disease, this does not hinder it from being also susceptible of others. I can conceive it possible that a man may be very susceptible of every disease incident to the human body, although it is not probable; for I should believe that one susceptibility is in some degree incompatible with another, in a manner similar to the incompatibility between different actions, though not of so strict a kind.

A man may have the lues and the small-pox at the same time; that is, parts of his body may be contaminated by the venereal poison; the small-pox may at the same time take place, and both diseases may appear together, but still not in the same part.

In two eruptive diseases, where both are necessarily the consequence of fever, and where both naturally appear after the fever nearly at the same distance of time, it would be impossible for the two to have their respective eruptions, even in different parts, because it is impossible that the two preceding fevers should be co-existent.

From this principle I think I may fairly put the following queries:—Does not the failure of inoculation, and the power of resisting many infections, arise from the existence of some other disease at that time in the body, which is therefore incapable of another action?

Does not the great difference in the time, from the application of the cause to the appearance of the disease, in many cases, depend upon the same principle? For instance, a person is inoculated, and the puncture does not inflame for fourteen days, cases of which I have seen, is not this deviation from the natural progress of the disease to be attributed to another disease in the constitution at the time of inoculation?

Does not the cure of some diseases depend upon the same principle as the suspension or cure of a gonorrhœa by a fever?

Let me illustrate this principle still further, by one of many cases which have come under my own observation. On Thursday, the sixteenth of May, one thousand seven hundred and seventy-five, I inoculated a gentleman's child, and it was observed that I made pretty large punctures. On the Sunday following, viz. the nineteenth, he appeared to have received the infection, a small inflammation or redness appearing round each puncture, and a small tumor. On the twentieth and the twenty-first the child was feverish; but I declared that it was not the variolous fever, as the inflammation had not at all advanced since the nineteenth. On the twenty-second a considerable eruption appeared, which was evidently the measles, and the sores on the arms appeared to go back, becoming less inflamed.

On the twenty-third he was very full of the measles; but the punctures on the arms were in the same state as on the preceding day.

On the twenty-fifth the measles began to disappear. On the twenty-sixth and twenty-seventh the punctures began again to look a little red. On the twenty-ninth the inflammation increased, and there was a little matter formed. On the thirtieth he was seized with fever. The small-pox appeared at the regular time, went through its usual course, and terminated favourably.

II. OF PARTS SUSCEPTIBLE OF PARTICULAR DISEASES.

There are some parts much more susceptible of specific diseases than others. Poisons take their different seats in the body as if they were allotted to them. Thus the skin is attacked by what are vulgarly called scorbutic-eruptions, as well as many other diseases; it is also the seat of the small-pox and the measles; the throat is the seat of action in the hydrophobia and the hooping-cough. The absorbent system, especially the glands, are more susceptible of scrofula than most other parts of the body. The breasts, testicles, and the conglomerate glands, are most commonly the seat of cancer. The skin, throat, and nose, are more readily affected by the lues venerea, than the bones and periosteum, which however suffer sooner than many other parts, particularly the vital parts, which perhaps are not at all susceptible of this disease. These differences may arise from the nature of the parts themselves, or from some regular circumstances, which must act as an existing cause.

III. OF SYMPATHY.

It is unnecessary to give a definition of sympathy, for it is generally very well understood when applied to the mind, and also by medical men when applied to the body. In the mind its reference is external, it depends upon the state of others, and one of its chief uses is to excite an active interest in favour of the distressed, the mind of the spectators taking on nearly the same action with that of the sufferers, and disposing them to give relief or consolation; it is, therefore, one of the firſt of the social feelings, and by many useful operations, incline mankind to union. In the body, ſympathy has only a reference internally to the body itſelf, and is not ſo evident as the ſympathy of the mind; although in ſome caſes we ſee its effects. It is either natural or diseased; but it is the diseased only that I propose at present to consider. I shall divide the sympathy of the body into two kinds, universal and partial.

By the universal sympathy is meant, where the whole constitution sympathizes with some sensation or action of a part. By partial sympathy is meant, when one or more distinct parts sympathize with some local sensation or action. The universal sympathies are various in different diseases; but those which arise in consequence of local violence, are principally three, viz. the symptomatic, the nervous, and the hectic fever. The symptomatic fever is an immediate effect of some local injury, and therefore is an universal sympathy arising from a local cause; the nervous has no determined form nor stages of the disease from the firft cause, as delirium, spasm, almoft of all kinds and in all parts, locked-jaw, etc. The hectic fever is also an universal sympathy, attended with a local disease, which the constitution is not able to overcome. Most of these will be more fully treated when I have occafion to describe their causes.

I divide partial sympathy into three kinds; the remote, the contiguous, and the continuous.

The remote sympathy is where there appears no visible connection of parts that can account for such effects. In these cases there is commonly a sensation in the sympathizer which appear to be delusive, and produces a wrong reference of the mind to the seat of the disease, such as the pain of the shoulder in an inflammation of the liver.

The contiguous sympathy is that which appears to have no other connection than arises from the contact of separate parts. An instance of which we have in contained parts sympathizing with the containing; such as the stomach and intestines sympathizing with the integuments of the abdomen, the lungs with the chest, the brain with the scalp, and the testicles with the scrotum.

The continuous sympathy is where there is no interruption of parts, and the sympathy runs, or is continued along from the irritating point as from a centre, so as to be gradually lost in the surrounding parts, in proportion to the distance; and this is the most common of all the sympathies; an example of it we have in the spreading of inflammation, which will be often mentioned in this treatise.

IV. OF MORTIFICATION.

MORTIFICATION is of two kinds, the one without inflammation, and the other preceded by it; but as the cases of mortification, which will be mentioned in this work, are all of the second kind, I shall confine my observations to that species.

I consider inflammation as an increased action of that power which a part naturally possesses; and, in healthy inflammations at least, it is probably attended with an increase of power; but in inflammations which terminate in mortification, there is no increase of power; but, on the contrary, a diminution of it. This, when joined to an increased action, becomes a cause of mortification, by destroying the balance which ought to subsist between the power and action of every part. There are besides, cases of mortification preceded by inflammation, which do not arise wholly from that, as a cause, but rather seem to have something in their nature; of this kind is the carbuncle, and the slough formed in the small-pox pustule.

If this account of mortifications, ariſing from no specific nature, be just we shall find it no difficult matter to establish a rational mode of cure; but, before we attempt this, let us take a view of the treatment which has been hitherto recommened, and see how far it agrees with our theory. It is plain, from the common practice, that the weakness has been attended to; but it is plain that the increased action has been overlooked; and, therefore, the whole aim has been to increase the action in order to remove the weakness. The Peruvian bark, confectio cardiaca, serpentaria, etc. have been given in large quantities, as the case appeared to require, or the constitution could bear; by which means an artificial or temporary appearance of strength has been produced, while it was only an increased action. Cordials and wine, upon the principle on which they have been given, are rationally administered; but there are strong reasons for not recommending them, arising from the general effect which they possess, of increasing the action without giving real strength. The powers of the body are, by this treatment, sunk afterwards in the same proportion as they had been raised, by which nothing can be gained, but a great deal may be lost; for, in all cases, if the powers are allowed to sink below a certain point, they are irrecoverable.

The local treatment has been as absurd as the constitutional; scarifications have been made down to the living parts, that stimulating and antiseptic medicines might be applied to them, as turpentines, the warmer balsams, and sometimes the essential oils; warm fomentations have been also applied, as being congenial to life; but warmth always increases action, and, therefore, should be well adjusted to the case; for, on the other hand, cold debilitates, or lessens powers when carried too far, but at first lessens action. Stimulants likewise are improper where the actions are already too violent.

Upon the principles here laid down, the bark is the principal medicine, as yet known, that we depend upon, as it increases the powers and lessens the degree of action. Upon many occasions opium will be of singular service, by lessening the action; although it does not give real strength. I have seen good effects from it, both when given internally in large doses, and when applied to the part. It is proper also to keep the parts cool, and all the applications should be cold.

PART I.

CHAPTER I.

GENERAL PRINCIPLES OF THE BLOOD.

As the blood is allowed by all to have a considerable share in inflammation, or at least to be particularly affected by it, becoming, by its appearances, one of the signs or symptoms of its existence; and, as the blood is a material object with me in the theory of inflammation, I shall begin my treatise with its natural history, a previous knowledge of which is the more requisite, because the accounts of this fluid, hitherto given, will hardly explain any of its uses in the machine in health, or of its changes in disease.

The heart and vessels are very active in inflammations; and as their structures and actions have not hitherto been understood, I have subjoined to the natural history of the blood an account of the structure of the heart and vessels, together with their actions in the machine; to which I have added one use of the absorbents not hitherto known.

As every natural action of the body depends, for its perfection, on a number of circumstances, we are led to conclude, that all the various combining actions are established while the body is in health, and well-disposed; but this does not take place in diseased actions, for disease, on the contrary, consists in the want of this very combination; and diseased actions, therefore, vary according to many natural circumstances, of which I propose to point out a few of the most striking instances.

Inflammation must have some exciting cause, and the same cause will produce an effect under one circumstance, which it will not under another. I have, therefore, begun with the supposition of an injury, attended with such circumstances as do not excite inflammation, which will form a strong contrast to those which do, the opposite effects mutually illustrating each other; but as inflammation is a very general action of the vessels in disease, and is of various kinds, I have previously given a short account of several of the most common sorts of inflammation, which will explain the rest.

The whole material world has been very properly divided into solids and fluids; these being the only essentially different states of matter we are able to observe. From one of these states, to the other, matter appears to be continually passing, but with these restrictions, that no species of matter can assume a solid form, without having first been in a fluid state; nor can any change take place in a solid till it be first formed into, or suspended in a fluid. The living animal body is obedient to these general laws, for all solid and animal matter has first been fluid, and having passed into this solid form, becomes a recipient for other fluids, out of which the solids may themselves be renovated and increased.

The solids of an animal, although composed of one species of matter, yet admit of great variety in their appearance, and this variety takes place in some animals more than in others. But the fluid part of an animal body, in its natural state, has but one appearance, which is that of blood. There are certain parts of animals which, though hardly solid in their own nature, are yet to be considered as solids, from their being fixed in their situation, and appropriated to local actions; some of them acting on the fluids (which are, to a certain degree, passive in all animals) and disposing of them for particular purposes in the animal œconomy, in the same manner as is done by those which are usually called the solids in animals; of this sort are the gelatinous parts in many of the inferior orders of sea animals, as the medusa, the vitrious humour of the eye, etc. There appears to be a sympathetic intercourse between the solid and the fluid parts of an animal, designed by nature for their mutual support. In disease, when the machine cannot be furnished in the common way, the solids of the body supply the defects, and the person becomes lean; and the fluids would appear from this, to be more an object of attention in the machine than even the solids.

This fluid part of an animal is called the blood, and in the animals with which we are most acquainted, it is of a red colour. The nature and appearances of the blood have been more attended to in diseases, especially of the inflammatory kind, than in full health, as it is more expressive of disease, when removed from the body, than any of the solids, and undergoes changes which the solids do not. Some of these changes are produced by the separation of parts from one another; but as the body is seldom in perfect health, we can hardly procure the blood in the same state twice from one person, although it may not be sensibly diseased. In a history of the blood these varieties must be mentioned, although they are often slighter appearances of what we find in disease; for disease certainly throws great light on the natural history of the blood, and the apparent changes which it undergoes must have unavoidably called medical men to consider it with attention.

The only knowledge, however, we have of any difference in the blood, arises from these varieties in its spontaneous changes when extravasated; nor do these differences appear always to affect the real nature of the blood, as the animals often continue in health while they are going on.

Blood is most probably as much alike in all animals, as the muscle of one animal is like that of another; only with this difference, that some animals have not that part which gives it the red colour; but the other parts, as the lymph and serum, are, as far as I yet know, the same in all.

Transfusion of the blood of one animal into the vessels of another, proves, to a certain degree, the uniform nature of the blood; for, as far as these experiments have been urged, no alteration has been observed.

Concerning natural objects, we usually acquire a gross knowledge, from the frequency with which they are observed, and it often requires little more than common attention to have a tolerable conception of their general principles. This is the case with the blood.

Blood is known to be of a red colour in a great number of animals, and to be altogether a fluid while circulating in the living body. It is known to separate into parts when out of the body, and a portion of it to become solid; it is likewise known, that, when deprived of a certain proportion of it, an animal dies; it has, therefore, been held in particular veneration, as constituting the life of the animal. Like other things which are discovered to be of great use, the blood has frequently attracted the attention of mankind, as an object of curiosity only, from which some have proceeded to a more critical enquiry into its nature and properties, and to more extensive elucidation of the subject at large. To this, practitioners in physic have a great deal contributed, from a conviction, that this knowledge would be of much use to them in their profession; and the teachers of the art have been still more industrious in their investigations; but the frequent recourse which is had to the lancet in diseases, has afforded the most ample opportunities of observation, almost sufficient to explain every principle in the blood, without the aid of further experiment.

In animals possessed of red blood, two modes of investigation may be adopted. One of these respects the blood while it is circulating, when the colour makes its motion visible, and gives an idea of the circulation in the smaller vessels. Accidents, operations, and anatomical knowledge of the vessels in which the blood is contained, have at the same time assisted us to form more perfect ideas of its motion in the larger vessels. The other mode, which is that of examining the blood when out of the body, enables us to observe whatever relates to its spontaneous changes and separation, together with the apparent properties of each component part. Its chemical properties become known likewise by this second mode, though without throwing much light on the nature of the fluid itself.

The blood is called a fluid because it is always found in a fluid state in the vessels of a living animal, while under the influence of the circulation: yet it is not, under all circumstances, naturally so; for of one part of it, when not circulating, solidity is a necessary and essential property; fluidity being only necessary at the time of circulation for its motion, distribution, and the easy separation of its parts.

Without being fluid, it could not be propelled through flexible tubes, and distributed to all parts of the body. It could not be divided into portions, as the vessels branch off; it could not pass through the smaller vessels, nor admit of the various separations of its parts, which are to produce the increase and repairs of the whole body; neither could it be adapted for furnishing the various secretions; nor could it be brought back to the heart*.

The red colour of the blood is produced merely by some red matter diffused through it, but not common to all animals. The blood exhibits a greater variety of changes, and admits of more experiments to determine its nature and properties than the solids. This, in some degree, arises from its fluidity, in which form it has not yet attained its ultimate state, and is only the substance that furnishes materials, out of which the solids are produced or augmented.

The heat in the animal body, principally in those which are called warm animals, has been commonly considered as depending principally on the blood, or at least as being connected with it, as much as with any other portion of the body†: as I shall have occasion to take notice of the increased heat of inflamed parts, it might be expected, that I ſhould endeavour to explain this principle in the history of the blood. I profess, however, not thoroughly to understand it, and the theories hitherto brought forward, do not in the least satisfy me; as I think that none of them accord perfectly with every circumstance observable in these cases.

I. OF THE MASS OF BLOOD, AS COMPOSED OF DIFFERENT PARTS.

THE blood, while circulating in the vessels, appears to the eye to be a homogeneous mass; but when it is passing in vessels so small as almost to separate its visible parts, and is viewed in a microscope, there is no appearance but that of globules moving in the vessels.

* The distribution of water from the sea, is similar to the arterial system; and the rivers returning to it have an analogy to the veins; but their effects are different, because the globe works entirely upon its own materials. The waters are continually carrying away the land from one situation, and depositing it in another; taking down continents, and leaving the ocean in their place; while at the same time they are raising continents out of the sea. But animals work upon foreign matter, introduced from time to time into the system.

† From whence the expression, warm blooded, or cold blooded animals; but the expression should rather be, the animals of a permanent heat in all atmospheres, and animals of a heat variable with every atmosphere.

In such a situation the other parts called the coagulable lymph, and the serum, are not distinguishable, on account of their being transparent, and the globules do not, strictly speaking, constitute a part of the fluid, but are only diffused through it. These globules being red, give this colour to the blood, and are called the red part, but are not always of the same redness when collected in a mass; this is probably owing to each globule being changed in its tint of colouring. The blood of some animals has no such globules, but is perfectly transparent, indeed more so than the most transparent parts of the red blood, to which it is analogeous. A red colour is therefore not essential to constitute true blood; and I believe the slight tinge of colour there is in the blood, independent of the globules, arises from the solution of various substances in the serum. The blood has a peculiar taste, being saltish, but of a peculiar flavor: we can always distinguish by the taste when there is blood in the mouth.

These are the principal observations we can make on the blood when circulating, or in its fluid state; but as one part of it under certain circumstances changes into a solid, or as it is commonly termed, coagulates, more of its parts are thus exposed; in this process the blood separates into two distinct substances, a coagulating part, and another which separates from it and remains fluid; but the coagulum entangles the red part, and this alone shews the blood to be formed of these component parts. The parts of the blood so separated, have been named according to their apparent properties; the one, the coagulable lymph; the other, the serum; and the red part has been called, the red globules; but upon a more intimate knowledge of the different parts of this fluid, we shall find that those terms are not expressive of all their properties.

The term *coagulable* lymph, is not expressive of this property, as one which is inherent in the lymph itself; for many substances are capable of being coagulated, though not spontaneously, yet by chemical means. For instance; heat coagulates the farinaceous part of vegetables, and thus forms paste; and also mucus. Spirits of wine coagulates many animal substances; acid coagulates milk, etc. the term, therefore, to be used respecting this property of the blood, should be such as expresses its inherent power of self-coagulation: perhaps *coagulating* might be better applied to what is called *coagulable* lymph; and the epithet coagulable might be reserved for those fluids which require a chemical process to produce that effect. Of this kind is the serum, for I have discovered this fluid to be composed of two parts, which is ascertained by means of the different causes of coagulation. To discover all the various properties and uses of the component parts of the blood in the machine, may be impossible; and to determine whether they will act, or are employed conjunctively to produce the effect, is not easy: but there are some properties discoverable which would incline us to believe, that particular parts of the blood are employed to compose particular solid parts, which are found to possess properties similar to different parts of the blood.

II. OF COAGULATION, AND ITS EFFECTS.

As coagulation is the first change which the blood undergoes, when out of the vessels, and as it even coagulates while in them, under certain circumstances, we shall consider this process first. Though fluidity is necessary to enable the blood to circulate, yet coagulation is no less necessary, when it is to be disposed of out of the circulation, even within the body, and therefore deserves to be considered with no less attention. There is, I think, more to be learned of the use of blood in the animal œconomy, from its coagulation, than from its fluidity. The coagulation of the blood, when out of the circulation, would seem to be unconnected with life, yet life could not go on without it; for as all the solid parts of the body are formed from the blood, this could not take place, if there did not exist in it the power of coagulating. Many diseases exhibit the blood coagulated in the living body, even in the vessels themselves, but more frequently when extravasated. Coagulation does not belong to the whole maſs of circulating blood; but only to the part I have called coagulating lymph, which during this action commonly detaches itself from the other part, called the serum.

Whether the whole mass of the serum be a distinct part of the blood when circulating, is not easily determined, as we have no mode of separating it from the coagulating lymph, while both are fluid. The serum making a part of the whole mass in the fluid state, the first stage in the coagulation is a species of decomposition, forming a separation of the serum. But, on the other hand, there are reasons for considering the coagulating lymph as distinct from the serum, even when both are fluid; since the serum can be separated from the lymph, without coagulating, by many actions of the vessels, both natural, preternatural, or diseased. Thus the liquor of the amnios, and that of dropsies, are formed; and therefore we may conclude, that the separation of the serum, when the lymph is coagulated, is not an act necessary to the coagulation, but an effect of it.

The circumstances attending the coagulation of the lymph are subject to great varieties. These depend upon or correspond with the state of the body at the time, of which we can best judge by the readiness or difficulty with which the blood coagulates, and by the firmness or loosness of the coagulum. The whole mass of the blood being a compound, of which the parts are in some degree separated: the appearances upon coagulation are attended with still more variety than the lymph alone could exhibit, or than could occur in those animals which are not possessed of red blood, as the red part brings to view many of the changes in the lymph, by the difference of its colour, as well as of its specific gravity.

The three substances which become visibly distinct when the lymph coagulates, differ as to gravity; the serum is the lightest, and remaining fluid swims upon the top; the red globules which undergo no change, are the heaviest, and sink more or less in the lymph; but being entangled in it, add to its weight so as to make it sink deeper in the serum.

Blood when extravasated coagulates sooner or later, according to the quickness or slowness of its extravasation, and the quantity extravasated: it coagulates late when drawn into a bason rapidly, and in considerable quantity; soon, when allowed to flow slowly, and in small quantities. This will be better understood when I treat of the principles of coagulation.

When blood is received into a cup, and is thereby exposed, it certainly coagulates more readily than when extravasated in the cellular membrane, or in the vessels; and on the exposed surface it coagulates more readily than any where else, except round the edges of the dish in which it is contained. It has been observed, that the upper surface of the blood coagulates first, forming a thin pellicle, as milk does, when near boiling; while underneath it still remains fluid; but the whole gradually becoming thicker, and losing its transparency, coagulates in about fifteen or twenty minutes into a substance of pretty thick consistence. The time required will vary according to the quantity of blood in one mass, and the disposition of the blood at the time.

We may observe the following appearances when the blood is coagulated. The coagulum is generally, but not always, swimming in a fluid; for it sometimes happens that the lymph does not squeeze out the serum in the act of coagulation, in which there is an act of contraction. The top of the coagulum is toughest, or firmest; and it becomes less and less so towards the bottom, because there is less of the coagulating lymph at the bottom, in proportion as the red globules subside in the lymph before it coagulates. The coagulating lymph has a degree of toughness in proportion as it is free from serum; for while the serum is mixed within it, though there may be red globules, it is not very tough; but when pressed between the finger and thumb, so as to squeeze out the serum, it becomes nearly as tough, and elastic, as the coats of an artery, to appearance, becoming fibrous and even, forming lamina; and indeed appears to be very much the same kind of substance with an artery, which gives us a clear idea how a membrane may be formed, and probably can be varied according to the impression made on it by the surrounding parts. This is one reason why the lymph, which has the strongest disposition for coagulation, is the toughest, as it parts with more of its serum. The lymph is transparent, but whether tinged as the serum is found to be, we can hardly say, as it is seldom possible to catch it in a fluid state free from red globules, and never from serum, which has itself a tinge. When out of the body in a dish, where it is long in coagulating, and the red globules sink fast, we find it transparent; but, during coagulation, it becomes more muddy, till at last it is opaque, but with a tinge of colour. On being steeped in water it is often rendered very white, which would not probably be the case if it had a tinge of its own, independent of the serum.

Blood usually requires a considerable time for its complete coagulation, or rather contraction; for, if allowed to stand some days, the coagulated part becomes less and less, as more and more of the serum is squeezed out, which cannot arise from the serum being lighter, and issuing out spontaneously; for without some expelling force it would be retained mechanically by the capillary attraction, as in a sponge. The blood which is longest in coagulating, coagulates most strongly, and produces the most complete separation of its parts. In such instances as the coagulating lymph continues longer fluid, it allows the red globules more time to subside, and the serum to be more squeezed out from the crassimentum. When the coagulation is slow, and of that kind which will be firm when completed, we may skim off the fluid coagulating lymph, free from the red globules; and the part so taken will coagulate immediately ,while that in the cup remains fluid some time longer.

Many causes have been assigned for the coagulation of the lymph, which appear to me to be ill-founded. It frequently happens that when changes take place in matter of which the immediate causes are unknown, the mind refers them to some circumstances which accompany these changes; although, perhaps, they may have had no concern whatever in producing them, and may be only attendants. This will always be the case where those changes arise out of the nature of the part itself. A seed put into moist ground grows; but the moist ground is only a neceſſary attendant, and not the immediate cause. The life of the seed, stimulated to action by the moisture, is the immediate cause of its growth, and it continues to grow because its action is always excited. All the water in the world would not make a dead seed grow. The same mode of distinction is applicable to the coagulation of the lymph.

The first observations on the blood were most probably made on that of the more perfect animals, whose heat is commonly greater than the heat of the atmosphere. Such blood when extravasated, was found to coagulate on cooling; it was therefore natural to suppose that the coagulation of the lymph arose from its becoming colder, as happens in jelly*; but cold, simply, has certainly no effect upon the coagulating lymph.

If we take a fish out of the sea, the heat of its body, perhaps about 60°, and bring it into an atmosphere of 70°, the blood, on being let out of the vessels, will immediately coagulate. This was ascertained on board of a ship lying off Bellisle, in the summer 1761; for immediately upon a fish being caught, I ascertained its heat, and letting out part of its blood, it immediately coagulated, although the blood discharged was become warmer than that remaining in the vessels of the fish; which, however, still continued fluid.

Indeed common experience and observation shews us, that cold alone has no power to coagulate the blood. It often happens that particular parts of an animal, such as the fingers, face, nose, ears, &c. are cooled nearly to the freezing point, and frequently are in that state for a considerable time; yet the blood retains its fluidity in those parts, as I have experienced in my own fingers; and indeed in those parts of an animal where the blood has been frozen, and again thawed, the blood appears as fluid as before, and circulates as usual. Heat has the power of exciting action in an animal; and we find that heat even increases the action of coagulation; for, if blood be heated to about 120°, it will coagulate five minutes sooner than when kept at its natural heat, and even sooner than the blood of the same animal, taken at the same time and cooled to 50°† Mr. Hewson has laboured this point, endeavouring to shew it is not cold that makes the blood coagulate; and he has laboured no less to shew the real cause of such a change.

He took fresh blood and froze it quickly; on being thawed, it was

* This term has been applied to the coagulation of the blood, but I think improperly; for I should only call that jelly, which became solid by cold, and fluid again by heat; coagulation is totally different, for it is a new species of combination. The freezing of blood may be called, congelation.

† These experiments were made on the jugular veins of dogs, by taking a section of the veins on each side filled with blood, and immersing them in water, either warmer, or colder, or of the natural heat, and observing the comparative difference.

again fluid, but soon afterwards coagulated; this he conceived to be a sufficient proof, that it was not cold which made the blood coagulate*.

From the above observations, and experiments, it must appear that cold, simply, has no influence whatever upon the coagulation of the blood.

And in most of the cases in which the blood is observed to coagulate, the air is commonly in contact with it; this was next presumed to be the cause of its coagulation†; but the air has really no more effect than any other extraneous body, in contact with the blood, that is capable of making an impression upon it; for the blood coagulates more readily in a vacuum than in the open air; nor will either of these supposed causes assist in explaining why it is not found coagulated after many kinds of death, nor in the menstrual discharge. Neither will they account for the very speedy coagulation of the blood which usually takes place in all the vessels after death, or when it has been extravasated into cavities, or cellular membranes, where no air has ever been admitted.

Rest is another cause upon which the coagulation of the blood has been said to depend: and although this opinion be not true in the full extent in which it has been taken, I think that rest has greater influence in the change than any other circumstance whatever. But though rest seems greatly to dispose the blood to coagulation, it is the operation of rest alone, without exposure, which we are to confider; as otherwise we shall be apt to confound it with the two foregoing causes, viz. cold, and the contact of air.

Since therefore the blood may coagulate in the veffels, either of a living, or a dead body, and fince it coagulates when extravasated into different parts of a living body, rest, like cold, or air, might be supposed to be the sole cause of the coagulation of the blood: yet it is not rest, considered simply, but rest, under certain circumstances, which appears to possess such a power; for motion given to the blood, out of the vessels, will not of itself prevent its coagulation; nor will it even in the vessels themselves, if all the purposes of motion are not answered by it. Motion seems to re-

* Hewson on the Blood, page 21. † Ibid, page 23.

tard coagulation*; yet we know for certain that blood will in time coagulate, even in the vessels themselves, and under certain circumstances sooner, perhaps, than any where else; as for instance, when there is a disposition to mortification. In this case we find the blood coagulated even in the larger vessels.

I have seen a mortification come on the foot, and leg, and when it had advanced only to a certain degree, the person died. On examining the parts above the mortified part, I found the crural, and iliac arteries, filled completely with strong coagulated blood; we may thence infer, that the tendency to mortification in the vessels produced this disposition in the blood. If the coagulation ſhould be supposed to have arisen from the blood being stopped in the large vessels, at the mortified part, let us reflect, that this cannot account for it; the same thing ought then to happen in an amputation, or in any case where the larger vessels are tied up.

In a priapism the blood does not coagulate, except it threatens mortification.

The separation of the blood, either from itself, that is, when divided into small portions, or separated from the living body, becomes one of the immediate causes of the coagulation of the lymph; therefore, the contact of blood with blood, or with living vessels, in some degree retards coagulation: this is the reason why blood which comes from the vessels slowly, or falls from some height, or runs someway on the surface of a dish, coagulates sooner than when the contrary circumstances happen; and upon this principle it is, that blood, when shaken in a phial, will coagulate the sooner, even if shaken in a vacuum. A deep mass of blood is also from the same cause, longer in coagulating than a shallow one.

From the above observations it must appear evident, that neither cold, nor air, nor rest alone, have any influence on the coagulating power of the blood; there must, therefore, be some other principle on which this pro-

* This is motion given to it in a vessel, without any empty space, and having beads put into it, which are shaken.

-cess depends; and, as it retains its fluid state while circulating, and even for a long time when at rest in the living vessels, and coagulates when the vessels or the body dies, it might naturally be supposed that it was the life of the body or vessels which kept it fluid; we know, however, that life in the body or vessels does not hinder the blood from coagulating under certain circumstances, but often rather excites coagulation; nor does death, in the body or vessels, in all cases become a cause of coagulation; for we find that in many who die suddenly, from a strong impression of the mind, the blood does not coagulate; there is, therefore, something more than the mere situation of the blood, surrounded with dead parts, that allows of coagulation; and that must be a something in the blood itself.

From these observations it must be evident, that the fluid state of the blood is connected with the living vessels, which is its natural ſituation, and with motion; and that where there is a full power of life, the vessels are capable of keeping the blood in a fluid state: I believe, however, very little motion is required to keep up this fluidity when the other is present. A total stagnation of the blood, while the body is alive, as in a trance, or where the circulation has been stopt for several hours, as in the case of persons apparently drowned, does not make it coagulate; yet where there are no actions going on, in a part, if the blood stagnates for a much shorter time than in a trance, it will be found coagulated, as in mortifications; but then this coagulation is to answer a good purpose, and arises from necessity*, which appears to act as a stimulus in disposing the blood to coagulate.

As a proof that blood will not coagulate in living vessels, in a perfect and natural state, and ready to act when powers were restored to it, I found that the blood of a fish, which had the actions of life stopped for three days, and was supposed to be dead, did not coagulate in the vessels; but, upon being exposed, or extravasated, soon coagulated.

* By action taking place from necessity, effects are meant which arise in consequence of some unusual, or unnatural change, going on in the parts, and become a stimulus to action. The stimuli from this cause, may vary exceedingly among themselves; but as we are unable to investigate them, I have included them under this general term, stimulus of necessity.

The blood of a lamprey-eel, which had been dead to appearance some days, was found fluid in the vessels, because the animal was not really dead; there had, however, been no motion in the blood, as the heart had ceased acting; but upon its being exposed, and extravasated into water, it soon coagulated*: yet under certain circumstances in life, it had been observed, that the blood will in a small degree coagulate: this is in the state of torpor. It is asserted by some author, whom I now do not recollect, that the blood of a batt coagulates when in that state; and Mr. Cornish, surgeon, at Totness, Denvonshire, to whom I applied for some batts in the torpid state, sent me them, but in the carriage they always died; however, he took opportunities of examining them, and he found that the blood was in a certain degree coagulated; but it soon recovered its fluidity on motion and heat.

From these remarks I should conclude, that rest does not of itself in the least assist the coagulation of the blood; but that this effect arises from the blood being separated from the living vessels, and being deprived of motion; and that it happens sooner, or later, according to other circumstances. It might be supposed that these are rather negative causes of coagulation, than positive ones; but it is to be considered, that in a living body, the cessation of a natural action, the absence of an usual impression becomes a cause of action, of which innumerable instances may be given.

I have now considered the circumstances under which the blood coagulates, and shewn that none of them alone, nor all them combined, induce the blood to coagulate. My opinion is, that it coagulates from an impression: that is, its fluidity under such circumstances, being improper, or no longer necessary, it coagulates to answer now the necessary purpose of solidity. This power seems to be influenced in a way, in some degree

* There are some circumstances which hinder the coagulation of blood in living bodies although extravasated. Two leeches had been applied, and had sucked till full. Thefe were preserved for ten weeks, and then had contained considerable quantity of blood, which appeared like that recently drawn from a vein, and coagulated when exposed. I have known, in tapping a hydrocele, that a small vessel has been wounded, and the blood, as it extravasated, got into the sack, and when tapped sixty-five days after, the blood has come out thickish; but when extracted it coagulated, and separated into different parts.

similar to muscular action, though probably not entirely of that kind; for I have reason to believe, that blood has the power of action within itself, according to the stimulus of necessity; which necessity arises out of its situation.

I shall now consider the simple act of coagulation, abstracted from causes.

Coagulation I conceive to be an operation of life; and I imagine it to proceed exactly upon the same principle as the union by the first intention; it is particle uniting with particle, by the attraction of cohesion, which, in the blood, forms a solid; and it is this coagulum, uniting with the surrounding parts, which forms the union by the first intention: for union by the first intention, is no more than the living parts when separated, whether naturally, or by art, forming a reciprocal attraction of cohesion with the intermediate coagulum, which immediately admits of mutual intercourse, and as it were, one interest.

To produce coagulation of the blood, however, something more is required than merely the reverse of the causes abovementioned, as having the power to keep it fluid; for the blood becomes in many cases instantaneously incapable of coagulation, either in or out of the vessels, even when nothing has been added, or taken away, and must be therefore under the influence of some other cause. This, I believe, must be sought in some property inherent in the blood itself: besides, some natural operations destroy this principle in the blood, when extravasated.

In many modes of destroying life the blood is deprived of its power of coagulation, as happens in sudden death produced by many kinds of fits; by anger, electricity, or lightning; or by a blow on the stomach, etc. In these cases we find the blood, after death, not only in as fluid a state as in the living vessels, but it does not even coagulate when taken out of them. As in the bodies of such persons no action of life takes place, the muscles do not contract. There are partial influences, likewise, which destroy the power of coagulation, as a blow on a part producing a considerable extravasation. This forms an ecchymosis, in which we shall often find the blood not in the least coagulated. In healthy menstruation, the blood which is discharged does not coagulate; in the irregular or unhealthy it does. The healthy menses, therefore, ſhew a peculiar action of the constitution; and it is most probably in this action that its salubrious purposes consist; for if twice the usual quantity is evacuated with the power of coagulation, even from the same vessels, the same benefit is not produced; much less when taken from another part by art.

Many substances, when mixed with the blood, prevent coagulation; bile has this effect out of the body; but we cannot suppose that in a living body it can be taken into the blood in such quantity as to produce this effect; for we find in a very severe jaundice, that the blood is still capable of coagulating strongly.

That probably every inanimate fluid in nature, which is capable of being rendered solid, produces heat, during that change; and in the contrary change cold is commonly known; it is on that principle Dr. Black has established his very ingenious theory of latent heat. Thus in the freezing of water, heat is produced.

To see how far the coagulation of the blood was ſimilar in this respect to the same change in other substances, I first coagulated the white of an egg, by applying to it rectified spirits of wine: the heat of both was the same before their union; but I found upon uniting them, that the white of the egg was immediately coagulated, and that the heat of the mixture was increased four, sometimes five degrees, according as it coagulated, slowly, or quickly.

As the blood in the animals upon which we most commonly make our experiments is warm, it becomes a difficult matter to ascertain whether it produces heat upon coagulation. In holding the ball of the thermometer in the stream of blood coming from the arm, I found the heat raised to ninety-two degrees: I then took a cup of human blood, allowed it to coagulate, and put it up to the brim in water warmed to ninety-two degrees, till the whole mass was heated to this point. I bled afterwards another person to the same quantity, in a similar cup, which was put into the same water. Having two well regulated thermometers, one in each cup of blood, I observed which cooled first, for I did not expect so much heat to be produced as to make it warmer; but conceived, if any heat was formed, it would retard the cooling of the freſh blood; but it rather cooled faster, which I imputed to the coagulated blood parting with its heat slower than the fluid blood. These experiments I have repeated several times, with nearly the same effect. I then conceived the experiment would be more conclusive if I could get blood in a fluid state, which was naturally of the heat of the atmosphere, for which purpose I took the blood of turtles.

A healthy turtle was kept in a room all night, the floor of which was about 64°, and the atmosphere 65°. In the morning the heat was nearly the same. The thermometer was introduced into the anus, and the heat of that part was 64°. The animal being suspended by the hind legs, the head was cut off at once, and the blood caught in a bason; the blood while flowing, was 65° and when collected, was 66°, but fell to 65° while coagulating, which it did very slowly: it remained at 65°, and when coagulated, was still 65°. These experiments had been made several times, but not with that nice accuracy which was obtained by causing all the heats to correspond exactly; yet as they were all known, and marked down, if any heat had been produced upon coagulation, its exact quantity would have been ascertained in each; and, indeed, in some, it seemed to cool, but in none it became warmer. From these experiments I should say, that in the coagulation of the blood, no heat is formed.

Coagulated blood, is an inorganized animal substance. When the blood is thinly spread before coagulation, or oozes out on surfaces, in which act it immediately coagulates, and coagulates in that form, it may then be said to form an inorganized membrane, of which there are many; and organization is seemingly so simple in many (which we know to be constituent parts of the body) that these coagula, more especially the thin ones, cannot easily by their appearances be distinguished from them.

The coagulating lymph of the blood being common, probably to all animals, while the red particles are not, we must suppose it from this alone, to be the most essential part; and as we find it capable of undergoing, in certain circumstances, spontaneous changes, which are necessary to the growth, continuance, and preservation of the animal; while to the other parts we cannot assign any such uses, we have still more reason to suppose it the most essential part of the blood in every animal.

Besides a disposition for coagulation under certain circumstances, as before described, the blood has also a disposition for the separation of the red globules, and probably of all its parts; for I think I have reason to believe that a disposition for coagulation, and a disposition for a separation of the red part, are not the same thing, but arise from two different principles. Indeed, a disposition to coagulation would counteract the effect, and hinder the separation of the red particles from taking place. Thus we see that rest, or slow motion of the blood in the vessels, gives a disposition towards the separation of the red part, as well as when it is extravasated; since the blood in the veins of an animal acquires a disposition to separate its red parts, more than in the arteries, especially if it be retarded in the veins; the nearer, therefore, to the heart in the veins the greater will the disposition for separation be; though it does not seem to retard coagulation. This is always observable in bleeding; for if we tie up an arm, and do not bleed immediately, the first blood that flows from the orifice, or that which has stagnated for some time in the veins, will soonest separate into its three constituent parts: this circumstance exposes more of the coagulating lymph, at the top, which is supposed by the ignorant to indicate more inflammation, while the next quantity taken suspends its red parts in the lymph, and gives the idea that the first small quantity had been of such service at the time of its flowing, as to have altered for the better the whole mass of blood. Rest, therefore, may be regarded as one of the immediate causes of the separation.

III. OF THE SERUM.

The serum is the second part of which the whole mass of blood appears to be composed; or is one of those substances into which the blood spontaneously separates itself. So far it appears as a simple fluid, in which light I shall first consider it; though we shall find hereafter that it is composed of two substances, which, in many of our experiments, separate.

Serum, I believe, is common to the blood of all animals; but there is more of it, I think, in those animals which have red blood: perhaps it may bear some proportion to the quantity of red particles in the blood, and may be of use to dilute it.

The serum is lighter than the other parts of the blood, and therefore swims above them when separated. It is commonly separated from the coagulating lymph when that fluid coagulates; and is, therefore, almost always found when the blood is taken out of the blood vessels, and kept together in a considerable mass. When the lymph coagulates strongly, we commonly find more serum, because it is then squeezed out more forcibly than when the coagulation is formed loosely; it is not, however, necessary for the lymph to coagulate, in order to separate the serum, for we find that it separates in disease, as in the dropsy. It is separated also from the mass of blood in uterine-gestation, being the fluid in which the fœtus is immersed or swims.

I have seen it separate from the remaining mass before the coagulation of the lymph. I observed once in the blood of a lady, that a separation between the two fluids almost immediately took place, the serous part swimming on the top, while the lymph remained still fluid. From this appearance I had pronounced that there would be a great deal of buff, supposing that the transparent fluid at the top was coagulating lymph; but I was mistaken, for when the lymph was coagulated, there was no buff, and the transparent fluid remaining at top, proved to be the serum.

In this there could be no deception, as there was no buff, or size; for if there had been size at the top of the coagulum, it might have been supposed that this fluid, which appeared so soon after bleeding, had been the coagulating lymph, and that the serum had been separated in the act of coagulation as usual. The serum is commonly of a yellowish colour, sometimes more so than at others; and this I should conceive arises from the substances dissolved in it*, by means of the water it contains; for it probably suspends every salt soluble in water, many of which are dissolved in

* The red globules are suspended without being dissolved in the serum, in which they are commonly examined.

it. If serum be not coagulable in itself, though it contains a large quantity of coagulable matter, yet I conceive it to be in a more fluid state when circulating. As it is separated from a compound mass, it appears in this respect to be somewhat similar to the whey of milk, though not exactly. This fluid undergoes no spontaneous changes but what may arise from its separation, from the coagulating lymph, except putrifaction. Though not coagulable in itself, yet one of its properties out of the body, is to coagulate upon the application of certain substances. This is the principal change it undergoes, and during the process, it more or less separates into two parts; one of which is not coagulable by such means.

The coagulable part, which I now mean to describe, seems to be in some degree the same with that in the white of an egg, synovia, etc. and many other secretions, but not exactly; for those secretions contain, as I conceive, a quantity of the coagulating lymph united to them, which makes them in part, coagulate after secretion; and the further coagulation of those secretions afterwards, by mixture with other substances, is owing to this part of the serum. Though the serum is coagulable under certain circumstances, and with certain mixtures, yet this power, or effect, may be prevented by other mixtures. Heat, to a certain degree, coagulates this part; and probably this is the only test necessary to know whether a fluid found any where in the body, not coagulable in itself, is this part of the serum; but as many substances do also coagulate it, I ſhall mention a few of them, although to me their effects do not seem to throw any light on the subject. Heat coagulates the serum at 160°, or 165°; it stood at 150°, for some time perfectly fluid. There is a great deal of air contained in the serum, which is let loose by heat; but not from its coagulation, for when it is coagulated by other means, no air is separated. The serum, which was a little whitish, coagulated in that degree of heat necessary for separating its air, which was extricated in very large quantities. This coagulum becomes first like the synovia, and then thicker. Many substances which do not coagulate this part of the serum, do not, however, hinder its coagulation by heat; such as vinegar, acid of lemon, salt of wormwood, nitre, sea-salt.

Serum coagulates with spirits of wine, in about equal quantities, into a sort of curd and whey; which, upon heating, becomes something like a jelly, but the spirit seems to evaporate.

It coagulates with volatile spirits, into a milky fluid, which becomes like a jelly upon heating; it requires a greater proportion of the spirit than the serum; and the spirit seems chiefly to evaporate.

When mixed with salt of hartshorn, it does not coagulate with heat, but makes a large effervescence, till the whole is formed into froth. This again becomes a fluid, by the froth subsiding, but at last it forms a sort of coagulum, which is not tough. Being mixed with water, and let to stand for twelve hours, it coagulates like pure serum upon heating. If this be mixed with sal. cernu cervi, as above, it rather becomes more fluid, and continues so for a long time, with a strong effervescence; but it forms at length into a jelly, or paste, although not a solid one.

Here I suspect that the salt is evaporated, and likewise the water in the paste, so that it is not a true coagulation.

When mixed with common water, it is coagulated by heat; but the water separates with the other substance, and does not unite with the coagulum.

Upon the coagulation of the serum, by heat, I have observed that it separates a fluid, which is not coagulable by heat; and, I have reason to believe, by none of the other means, viz. spirits of wine, etc. though this is not so easily ascertained; for the other coagulating substances, as spirits of wine, etc. are applied in a fluid form, and therefore, a fluid may remain after the coagulation of the serum, which might be supposed to be the fluid separated; but from other experiments, it is proved that those substances coagulate the coagulating part, and unite with the other. It is also observable in meat, either roasted, or boiled, that when cut, there flows from it a fluid, more or less tinged with the red part, commonly called gravy. I conceived that this must be different from the coagulating part of the serum, believing that the heat had been sufficient to coagulate it; but I chose to try it further, and therefore gave it such heat, as would have produced the effect if it had been coagulable by heat; but I found it did not coagulate. The fluid separated from the coagulable part of the serum, I conceived to be the same with this. Thus then I saw there was in the serum a matter coagulable by heat; and a fluid which was not so.

Pursuing the above observations on dreſſed meat, I observed that the older the animal had been, the more of this fluid was contained in the meat. In lamb we have hardly any of it: in young mutton of a year old, but little; but in mutton of three, four, five, or six years old, it is in large quantity: in veal also we have but little; while we have it in great quantity in beef; but perhaps we know less in general of the age of our beef, than of our mutton*.

Poultry is commonly killed young in this country, therefore we have not the comparative trials; but in wild fowl, and what is commonly called game, we find the above observations hold good. I likewise observe that animals who have not had exercise, such as house-lamb, veal, etc. have less of this fluid, than those of the same class which have been allowed to go at large: nothing can be drier than the English veal, though kept to a greater age than any where else; while it is juicy in every other country, though killed much younger.

In many of the trials respecting the coagulation of the serum, I observed, that it had in some cases much more coagulum than in others; and of course a less proportion of the fluid part that separated, and vice versâ: from the above observations too, I conceived that a deficiency of this fluid-part bespoke a greater quantity of coagulating matter in the serum; and to ascertain this, I took the serum of persons of different ages. This fluid, like the serum itself when united with the coagulating lymph, appears only to be mixed with the serum; for it is separated in the living body for many purposes of the œconomy; it is not therefore serum in another form; but a distinct fluid, which, before the coagulation, is mingled with the serum, and seems to make a part of it.

The following experiments are, perhaps, not perfectly conclusive; for

* It may be observed here, that this is very different from the jelly formed in boiling, or roasting meat; that which forms the jelly, is part of the meat itself, dissolved down in this very fluid, and the water in which it is boiled; and we find that this effect is just the reverse of the above, for in young meat there is the most of this jelly.

many were obliged to be made on blood taken from those who were not perfectly in health: peculiar dispositions in the body may make a material difference in the serum. It is probable, however, that disease may not have any great effect upon the serum; for I found, from experiment, that the serum of blood taken from a person labouring under an inflammatory complaint, and the serum of blood in a case not at all inflammatory, were nearly the same respecting coagulation, and the quantity of matter not coagulable by heat.

The serum of a man fifty-six years of age, who had met with a slight accident, and was of a healthy constitution, coagulated by heat, almost wholly into a pretty firm coagulum, separating only a small portion of that fluid which is not coagulable by such means.

The serum of the blood of a man seventy-two years of age, of a healthy constitution, hardly coagulated by heat, became only a little thicker, and formed a small coagulum, adhering to the bottom of the veſſel. With spirits, it formed but a very small quantity of coagulable matter.

On putting about three-fourths of water to the blood of the person aged fifty-six, and heating it as above, it coagulated much in the same way with the serum of seventy-two.

The serum of a boy fifteen years of age, coagulated wholly; there was hardly any of the fluid part that could be squeezed out; at the same time I coagulated the serum of a man sixty-three years of age, in which there was but a small quantity of the fluid part.

Conceiving that the whey of milk, made with runnet, was the serum of the blood, I made experiments on it, analogous to the above. I heated some of the whey, and found it formed a coagulable matter, which floated in flakes in a fluid, which did not coagulate by this means.

As this less coagulable fluid is a substance hitherto not taken notice of, and makes perhaps as interesting a part as any of the whole mass of blood, it will be necessary to be more descriptive in giving an account of it than of the other parts. As urine does not coagulate by heat; but I had found that it coagulated with the extract of Goulard*; and as I also knew that

* What led me to the above knowledge, was, mixing this extract of Goulard with ſolutions of gum arabic in water, for injections; when I found that the whole always became a

this extract coagulated the whole mass of the serum, I conceived that the fluid in question might be similar to urine, and that the coagulation of the serum might be owing to the coagulation of this part; I therefore put the fluid to this test, and found that it was coagulated by the extract, which led to a series of experiments.

As several fluids, apparently different from each other, appear to be thrown out from the blood on many occasions, I wiſhed to see how far they consisted of the common serum, viz. of a pretty equal quantity of matter coagulable by heat, or principally of that coagulable by Goulards extract; I therefore collected the several kinds, not only those which may be called natural, but also those proceeding from disease, which appear more like serum than the others. Of the natural, I took the aqueous humor of the eye, and first heated it in a spoon, to see what quantity of coagulable matter by heat was in it, and I found it became gently wheyish; therefore it had a small portion of matter coagulable by heat; but, upon adding the extract to it, it coagulated immediately. The same exactly happened with the water in the ventricles of the brain; and also with the tears.

Water was taken from the leg of a dropsical boy, who was extremely reduced by a compound fracture of the opposite thigh-bone; which water was much clearer than any serum. Upon heating it in a spoon over a candle, it became a little wheyish, and had a few flakes of coagulum floating in it.

The water from the abdomen of a lady, which was a little wheyish, coagulated before it gave out its air; but the coagulum was not one half of its quantity.

In another case of ascites, the water coagulated wholly, although not to a firm coagulum.

Water drawn from the abdomen of a gentleman, which was pretty clear, when held over a lamp to coagulate, became at first wheyish.

ſolid mass; while injections with sachrum saturni, had not that effect. I then tried it upon many other vegetable juices, and found it coagulated every one of them. In some of these experiments, I put ſome of the compounds into a vessel where there was some urine, and I found that when the extract had been in too large a quantity, that the urine was also coagulated.

The liquor amnii has but very little coagulable matter in it.

In coagulating all the above kinds of serum by heat, and taking the incoagulable parts, and putting extract of Goulard to them, they coagulated immediately.

Whether this fluid is of the same specific gravity with the other, I do not know; for though when part of it is coagulated by the extract of lead it is the heaviest; yet as it is united with the lead, it may acquire its additional weight from this union.

The use of the serum is probably to keep suspended, and undissolved, the red globules; for we find it in largest quantity when these globules are most abundant. It is also intended to suspend, and dissolve any foreign substances in the blood, whether they are of use to the body, or otherwise, acting upon them as a common solvent.

Thus we see in a jaundiced person, the serum is yellower than common. When a person has taken rheubarb, the same thing happens. It is probably the solvent of all our secretions.

I conceive it to be unnecessary to say how much water enters into the composition of the blood. In order to constitute a perfect body or compound, it is necessary that all its parts should be in due proportion; but as the blood in many animals is made up of four distinct parts, viz. the coagulating lymph; serum, which we find is composed of two parts; and the red globules, each must have its due quantity of water when in a perfect state; and I think it is probable that the lymph, and red part, cannot have more water than a certain quantity, but that the serum may be diluted with any proportion of it; yet as serum, it can have a certain proportion only; and indeed this was in some degree proved by the experiment of mixing some water with serum, and then coagulating the whole with heat: the water separated and did not make part of the coagulum.

Some of the juices of a living animal, whether circulating, or out of circulation, as those which lubricate surfaces, are in a volatile state while the animal is alive; for when the scarfskin is taken off, the part soon dries; and if the skin is removed from a new killed animal, it immediately dries; or if a cavity is opened, the surface of the cavity dries quickly; this shews that some part of the juices must have evaporated from the surface: but let the animal cool, before it is skined, or the cavity is opened, and then give it the same degree of heat that it had when alive, you will find, on taking off the skin, no immediate sensible evaporation; but the parts so exposed will remain moist. This volatility I conceive therefore to be connected with life, and not with the circulation; for that is stopped in both cases before the experiment. Whether it is this volatile part that gives the smell that most recent killed animals have upon being skined, or opened, I do not know; but it may be observed that it follows the same rules; for if the animal is allowed to cool, it looses this smell, although warmed to the same degree of heat as when alive.

The serum of the blood is sometimes wheyish, and then upon settling, it often throws up a white scum like cream: this was most probably first observed in the human blood; but is not peculiar to it; although these appearances pretty often happen, yet few instances fall under the observation of one man in the common course of bleeding. When they have occurred to myself, I have made inquiry after the state of health of the patient, as well as examined the nature of this change; and whether there was any variety in it. So far as I have been able to observe, it can hardly be said to have any leading cause; having found it, however, more frequently in the blood of breeding women, I conceived it might have some connection with that state; but I have seen it in others, and sometimes in men: yet it is possible that the state of pregnancy may adapt the constitution for forming such appearances, as well as for producing other symptoms in the blood like those of inflammation; for we often find the same effect, or disease, arising from various causes, which have no immediate connection with each other. There have been many opinions formed about the nature and cause of this appearance of the serum.

It has been supposed to be occasioned by chyle not yet assimilated; but it does not occur frequently enough to be attributed to this fluid. Mr. Hewson supposed it to be absorbed fat, or oil; which certainly is not the case; for it is not the same in all cases.

The globules forming this wheyiſh appearance are not of the same specific gravity in every case; for though they always, I believe, swim on the serum, and often on water, yet they sometimes sink in water. The white cream that swims on the top of the serum, I believe to be formed after the serum is separated from the mass; for, if it existed as such, prior to this, it would be retained in the coagulum, as the red globules are, which is not the fact; and therefore it does not exist in the blood while circulating.

I bled a little woman who seemed half an idiot, and was big with child: this happened in the afternoon, about three or four hours after her having eat some veal-cutlets: the day following I went to see the blood, and found the serum of a milky white, with a white pellicle swimming at the top like cream.

I bled a lady in the arm, who was six months, gone with child. It was about two o'clock in the forenoon: she had only eaten a dry toast, and drank a cup of chocolate for breakfast, about ten o'clock, which was four hours before she was bled. On seeing the blood the next day, I found it inflamed rather more than is common in women who are pregnant; and I also found a thin white scum on the the top of the serum; this scum I examined in the microscope, and found it to be globular: I diluted it with water, and found the globules did not dissolve, as the red globules do. I put some of them in water, and found that they rose to the top, but not so fast as in the serum.

About six days after, I bled the same lady again, after she had eaten the same kind of breakfast, and about the same interval of time from it. The blood was still sizy, but the serum had no white appearance at the top.

I examined the wheyish serum taken from the blood of a man at St. George's Hospital, who had received a severe blow on the head, which had stunned him, but had produced no bad symptoms. In this serum, when viewed in the microscope, I could not observe any thing like globules, or flakes, although the magnifier was a deep one. The red globules when mixed with it were the same as in common serum. It dried uniformly like size.

Blood was taken away from the arm, being of no particular quality, except in having a wheyiſh serum, and was allowed to stand quiet in order to see the spontaneous changes of this serum. The white part came to the top like cream, being therefore lighter than the serum, and was very white when collected. When viewed in a microscope, it was plainly globular, but the globules were smaller than those of red blood. They did not seem to be dissolved, when mixed with water, as red globules are.

Thomas Skelton, a publican, forty-seven years of age, being rather lusty, subject to frequent colds, attended with coughs, hoarsness, and a discharge of matter from the lungs or throat, but otherwise enjoying a good state of health, was attacked with a violent cold, together with a difficulty of breathing, and applied to Mr. Wilson, apothecary, who took twelve ounces of blood from his arm, which relieved him greatly. He had taken some bread and butter, with some tea, without milk, about four hours before he was bled. The blood coagulated firmly, and the serum which separated, was of a white colour, with a yellowish tinge, appearing like the colour of cream; upon the top of this floated a whiter scum, like another cream.

On viewing this cream in a microscope, it had a flakey appearance. It did not coagulate sooner than common serum.

In spirits of wine, a white mixture was produced, which, on standing, fell to the bottom of the glass; this most probably arose from the serum, with which it was mixed, coagulating.

The globules of the white serum, differ from the red globules in colour; specific gravity, size, and in not dissolving in water.

To see how far this is chyle, it would be proper to try the chyle in the same way in serum, etc.

After dipping a bit of blotting paper into the cream, and absorbing all of it, and also dipping a piece of the same paper into the serum, and drying them, I burnt them both, to see if one burnt more briskly than the other; but there appeared to be no difference.

The white part of the white serum sunk in water.

IV. OF THE RED GLOBULES.

The red part of the blood I choose to consider last, although it has been more the object of attention than the other two, because I believe it to be the least important; for it is not an universal ingredient in the blood of animals, like the coagulating lymph, and the serum; neither is it to be found in every part of those animals who have it* in the general mass of their blood.

The blood, as I have already observed, in those animals we are most acquainted with, appears to the naked eye to be a red mass of fluid, having a part which coagulates upon being extravasated. The red part, however, may be washed out of this coagulum, so as to leave it white; and this shews that the blood is not wholly red, but only has a red matter diffused through its other component parts.

Any further information we receive concerning the red part of the blood, is by means of magnifying glasses, which appear to give a good deal of information.

They ſhew us, that the red part is composed of bodies of a globular form, swimming in the lymph, and serum of the blood: this circumstance, of the red part having form, probably led anatomists to pay more attention to it than it deserves; as if they could thence explain any essential principle in the blood, or animal œconomy.

This knowledge is of late date; for such examinations of minute bodies could only have taken place since the invention and application of magnifying glasses.

Malpighi was probably the first who employed the microscope for this purpose, and he, in 1668, wrote a description of the appearance of the globules in the blood-vessels of the omentum, which he mistook, however, for globules of fat. Microscopical observations were pursued with

* The blood of the insect-tribe of every kind is free from any red parts, as is probably that of most animals below them; yet it has been asserted, and supposed, that their blood contains globules, although not red. I have examined the blood of the silk-worm, lobster, etc. and with considerable magnifying powers; but never could discover any thing, but an uniform transparent mass.

great ardour by Antonius Van Leeuwenhoeck, who saw the red globules, August the 15th, 1673*. These early observers probably imagined more than they saw.

When an old opinion is partly exploded, and a new one brought forward, it becomes only necessary to see how far the new one is just; because, if it be not proved, we must revert to the old opinion again or to some other.

Mr. Hewson has been at great pains to examine the blood in the microscope, and has given us figures of the different shapes of those globules; but there is reason to think he may have been deceived in the manner I have just mentioned.

The red globules are always nearly of the same size in the same animal, and when in the serum do not run into one another as oil does when divided into small globules in water. This form, therefore, does not arise simply from their not uniting with the serum; but they have really a determined ſhape and size. This is similar to what is observed of the globules in milk; for milk being oily, its globules are not soluble in water; neither do they consist of such pure oil as to run into each other; nor will they dissolve in oil. I suspect, therefore, that they are regular bodies, so that two of them could not unite and form one†.

What this property in the red part is, I do not know, for it has something like the nature of a solid body, yet the particles seem not to have the properties of a solid; for to the touch they yield no feeling of solidity; when circulating in the vessels they may be seen to assume eliptical forms, adapting themselves to the size of the vessels; they must, therefore, be a fluid, with an attraction to themselves while in the serum, which forms them into round globules, yet without the power of uniting with one another, which may arise from their central attraction extending no farther than their own circumference: if they are found, however, of an oval figure in some animals, as authors have described, that circumstance would rather oppose the idea of their being a fluid, having

* Haller's Physiology, vol. ii. lib. v. Sangui. ſect xi. page 51.

† Milk appears to be oil united with a proportion of mucus.

a central attraction; but this is probably an optical deception. Whatever their shape is, I should suppose it to be always the same, in the same animals, and indeed in all animals, as it must depend upon a fixed principle in the globule itself.

Hence, the less credit is to be given to those who have described the globules as being of an oval figure in some animals; for they have also described them as being of different and strange shapes, even in the same animal*.

* I am led to believe that we may be deceived by the appearances viewed through a magnifying glass; for although objects, large enough to be seen by the naked eye, are the same when viewed through a magnifying glass which can only magnify in a small degree, yet as the naked eye, when viewing an object rather too small for it, is not to be trusted, it is much less to be depended upon, when viewing an object infinitely smaller, brought to the same magnitude by a glass. In such a situation, respecting our eye, all the relative objects, by which the eye, from habit, judges with more nicety of the object itself, are cut off; the eye has likewise a power of varying its forms, adapting it to the different distances of the parts of an object within its compass, making the object always a whole; but a magnifying glass has no such power: for instance, in viewing a spherical body, a magnifying glass must be made to vary its position, and bring in succession the different parts of the hemisphere into so many focal points; every part separate, not having the same relative effect on our organ of vision as when they are all seen at the same time; and the eye, under such circumstances, being unable to vary itself sufficiently to alter the focal distance of the glass, is the reason why rounded bodies appear of different shapes, giving the shape only of the part that is within the focus of the glass, placed upon an undefined plane; and if it should have more focal points than one, then there is an increase of parts; and this will vary according to the opacity or transparency of the body. It may also be remarked, that from habit our minds are informed by the necessary actions of our body; therefore the eye taking on the necessary actions (as it were instinctively) adapting itself at once to the circumstances of the object, gives an intelligence to the mind, independent of the real impression of the object, so that both the impression and the consequent action give information; but this cannot be effected by glasses, for the different focal distances of the hemisphere do not accord with those to which we vary our eyes in adapting them to the distances of the different parts of a rounded body; we are, therefore, left to the impression alone, which is new, and consequently imperfect, the centre being too near for the circumference to be seen at one distance, and the circumference, when seen, bringing the centre within the focus, so as to obscure it: for an eye with a given focus which can vary it in a certain degree when viewing objects alone, yet when looking through a magnifying glass of any power, must now vary the distance of the object, according to the magnifying power in the glass, the eye not being able to vary the focal distance of both; and this, probably, in an inverse degree, to the magnifying power of the glass. This may be observed to take place

The globules of the blood are endowed with a number of properties. They are the only part of the blood which has form or colour; two properties which are ready to catch the eye, and render the mass more visible. In the living body, by making it an object of sight, they give some idea of the motion of the blood in the smaller vessels where it is much divided; being there viewed with microscopes, the red globules are seen moving with different velocities in different parts, and taking retrograde, or lateral motions, according as mechanical obstructions, or those arising from contractions in the vessels, may happen to retard or change their motion.

They are heavier than the coagulating lymph, and of course heavier than the serum, which is known by their falling to the bottom of the cup when blood is taken out of a blood-vessel. This allows the coagulating lymph to be seen more or less at the top, and produces on the surface various hues, according as the red globules subside: when they subside much, the buff is then of a yellowiſh colour; when the buff is thin at the top, then we have the red globules shining through it, of various colours, such as

in very short-sighted people, for in them the eye has the least variation respecting distance. A rounded body may be just of such a size as ſhall have either of its parts out of the focal distance of the eye, and must be moved to and fro, alternately, before the centre and circumference can be seen; and indeed, it is only having a spherical body, of a size proportional to the length of focus, to produce the same effect in every eye.

The appearance in a transparent body, when viewed through a magnifying glass, are still more falacious than of an opaque one; for an opaque body gives only the reflected light, which, however, will vary according as the rays come on the object. The moon, an opaque body, gives us various shapes, and therefore ſhews only the light and shade arising from the irregularity of the surface; but a semi-transparent body, like a red globule, gives both the reflection of the light from the surface and also the refraction of other rays of lights, which vary according to the direction of the light thrown upon the object respecting our eye.

In some transparent bodies we have still a greater variety, for we have both the reflex and refracted light, and these varying according to the distance of the object from the eye, or the distance of the light.

If the transparent body is not perfectly round, or is by any circumstance broken in the uniformity of structure on which transparency depends, which, I conceive happens to the red globules when diluted in the serum, then the different reflections and refractions will give to the eye the impression of so many shapes.

blue, purple*, etc. according to the reflection or refraction, which is according to the depths.

In healthy blood, however, the coagulum is commonly formed before the red part has time to subside; but we may always observe, that the lower part of the mass contains more red globules than the top, and will sink more quickly in water. The red globules do not retain their globular form in every fluid, but are dissolved and diffused through the whole, and this probably happens sooner in water than in any other fluid, though the red globules are not soluble in the serum of the blood, yet it is not the only fluid in which they are insoluble; the urine does not dissolve them; but urine might be supposed to be principally serum. Water itself, however, ceases to dissolve them when saturated with many of the neutral salts, or with some of the acids. The red globules are not soluble in water mixed with common sea-salt, sal. armoniac, Epsom-salt, nitre, Glauber-salt, soluble tartar, Lymington-tartar; nor in the fixed vegetable alkalies, when saturated with fixed air. As they do not dissolve in the serum or urine, it might be imagined to arise from the neutral salts which they contain; but I should believe that neither of these fluids have a quantity sufficient for that purpose.

The vitriolic acid does not dissolve the red globules when diluted so low as to have less pungency of taste than common vinegar.

The red globules are soluble in common vinegar, but take a longer time to dissolve than in water; and they also dissolve much sooner when the vinegar is diluted with water.

In muriatic acid, diluted so as to be more pungent to the tongue, and three times stronger than the vinegar, the red globules are not dissolved, but lose their red colour: by adding more water to the red globules they dissolve; lemon juice dissolves the red globules: all this, however, throws but little light on this part of the blood.

When the globules are put into water they dissolve, which destroys their globular form: it is therefore the serum, and probably the coagulating lymph also, when circulating, which confines them to this form;

* The blood in the veins, when near the skin, gives the same hues.

but when the serum is diluted with water, they dissolve in it; and this appears to take place at once; as quick as water unites with water. I could not observe that it was like the solution of a solid body, as a salt for instance: a drop of blood requires about two drops of water added to it to dissolve its globules: if urine also be diluted with water, the globules dissolve in it. However, after standing some days, the globules dissolve both in serum and urine; but I think later in the last. When the globules are not dissolved in any fluid, the whole looks muddy, not transparent; but when dissolved in water the whole is a fine clear red. What are the properties of the serum, and those other substances that preserve the red part of the blood in a regular form, I do not know.

The red globules, when dried in the serum, and moistened in the same, do not again resume their regular form; nor do they dissolve in it, as they do in water, but form rather a sort of flakes. As the serum and solutions of many kind of salts do not dissolve the red globules, I conceived that it might be possible for them to resume their globular figure (after having been dissolved in water) by adding such a quantity of serum as to make the proportion of water very little; but I could not produce this effect, although the menstruum was such as not to dissolve fresh globules.

The red globules not dissolving in the serum, nor in the coagulating lymph, become separable from those parts, when circulating, and therefore may be prevented from going where the coagulating lymph passes in a natural state; which they certainly do not*; and which also is the reason why they are so perfectly retained in the coagulum when extravasated. The globules, besides being heavier than the serum, or the coagulating lymph, appear to have more substance, for they do not lose so much upon drying, and when dried with serum, they give a kind of roughness to the surface, which serum has not by itself. They appear not to be a natural part of the blood; but as it were, composed out of it, or composed in it, and not with it; for they seem to be formed later in

* This will be more fully explained, when on the colour of parts from the blood.

life than either of the other two; thus we see, while the chick is in the egg, the heart beating, and it then contains a transparent fluid before any red globules are formed, which we may suppose to be the serum, and the lymph. The globules do not appear to be formed in those parts of the blood already produced, but rather to rise up in the surrounding parts*. It would also seem to be formed with more difficulty, than either of the other two parts. When an animal has lost a considerable quantity of its blood, the other parts seem to be sooner made up than the red globules; the animal looks long pale; but this is only conjecture, for we have no method of knowing the quantity of the other parts.

From the above account it appears, that whatever may be their utility in the machine, the red globules certainly are not of such universal use as the coagulating lymph, since they are not to be found in all animals, nor so early in those that have them, nor are they pushed into the extreme arteries, where we must suppose the coagulating lymph reaches; neither do they appear to be so readily formed. This being the case, we must conclude them not to be the important part of the blood, in contributing to growth, repair, etc. Their use would seem to be connected with strength; for the ſtronger the animal the more it has of the red globules; and the strength acquired by exercise increases their proportion; not only in the whole body, but, as we shall find, occasions them to be carried into parts where in either a quiet or debelitated state of the animal they were not allowed to go; the use, therefore, of a part, and the quantity of red globules passing through it, are probably pretty well proportioned to each other. This effect is so well known to feeders of young animals, for the table of the epicure, that bleeding, to lessen the quantity, is immediately practised; as also debarring the creature from exercise, in order to prevent their increasing, and being carried so far from the heart, as they otherwise would be.

* Thus, on some of the first appearances of the chick we find a zone surrounding it, composed of dots, which contain red globules, but not in veſſels, and which zone becomes vascular afterwards. Vide plate i.

These three substances are of different specific gravities: the serum or fluid part is the lightest; the solid part or lymph is the next in order; and the red globules are the heavieſt. This is seen in such blood as separates readily into its constituent parts. The serum swims upon the top, and the red globules fall to the bottom, while the lymph would be suspended between the two, if the red part were not retained in the lymph, from its coagulation; but this constant effect is no absolute proof of the difference in the specific gravities of the serum, and coagulating lymph; for we still do not know but that the red globules, which are evidently the heavieſt, make the coagulating lymph to ſink in the serum. To ascertain this circumstance, I made the following experiment: I took some blood, which separated easily into its constituent parts; I then suspended in a portion of serum apiece of coagulating lymph, which was free from red globules, and it sunk to the bottom, but not very quickly; this proves that the lymph, when coagulated, is somewhat heavier than the serum.

I then took as much of the bottom of the coagulum, containing the red globules, and put it into the serum along with the lymph, to see which of them sunk the fastest, and found that the piece with the red globules sunk much more quickly than the other; I should think three times as faſt. The serum itself is much heavier than common water, for when the parts beforementioned were put into common water, in the same manner as into the serum, they both sunk much faster, and there was not that disproportion between the times of their falling, as in the serum. But if the blood has a strong disposition to coagulate, and is not in large quantity, it will coagulate soon, and involve the red globules; yet there will then be fewest at top, and they will be more and more crowded towards the bottom; though there would appear in such blood to be no coagulating lymph at top free from the red globules, yet in most of it a thin pellicle may be found, which can be pulled off.

I have already observed that the whole mass of blood, taken together in a great variety of classes of animals, appears of a red colour; and I ſhall now further remark, that it is of a much deeper colour in some classes of animals than in others, which I believe arises from a greater number of red globules being contained in a given quantity of lymph and serum. This, I think, evidently appears to be the case when we examine a portion of the blood itself, belonging to different classes of animals. In the class called quadruped, I believe it has the deepest body of colour; I am not, however, certain that it is not nearly as deep in some birds; and even in the same class of animals it appears to have a much greater body of colour in some species than in others. Thus it appears to be deeper in the hare than the rabbit.

It is the red part itself which makes the difference in depth of colour in different parts of the same animal; and the common mode of judging is by the colour of the parts in different classes of animals that have red blood; on these we generally form our opinion, for though in some animals, which have white muscles, the liver, kidney, and heart, may be nearly as red as in others whose muscles are universally as red; yet, as the muscles are white, there must be a deficiency in the red globules on the whole; for if these parts which are red in animals, having white muscles, as the heart, liver, etc. have no more than their due proportion with other animals that are universally red, there must be in such animals a deficiency of red globules on the whole. This idea may be gradually carried on, from the animal which has fewest red muscles, to those whose muscles are universally red, and of a high colour; even in the same species the colour of all the muscles is not equally high. What are called different temperaments have their muscles redder, or paler; the darker the colour of the skin, hair, etc. of any one species, I believe the blood is in proportion redder. When a part, of whatever kind, is red, it takes place in consequence of its vessels being large enough to carry red blood; and therefore, when we find a muscle red, we know it arises from the same cause. When a part, on the contrary, is white, as a tendon, it is because its vessels are small, and have little or none of the red blood passing along them; although it may probably be as vascular as the muscle to which it belongs*; and those animals that have no red blood, have white flesh

* Conceiving that the amnion of a calf might have but few vessels, I injected a piece of it with quick-silver, first drying its edges all round, on the edge of a dish, while the middle

universally*, and this, probably, no less vascular than the flesh which receives red blood.

The blood in the same animals is not equally deep coloured in every part; that is, every part of the body has not its blood equally loaded with red globules, or, at least, it is not equally red, even in parts of the same construction and use, such as muscles; this arises from the red globules not being carried into those parts in equal proportion; these are the white parts of animals; such muscles, in animals used for food, are called white meat. In animals, which have these muscles, there is commonly not so much red blood, as in others where thefe parts are more universally red; and perhaps the red part of the blood is not pushed so far in them as in those which have it in a larger proportion: there are some animals, however, which have a larger quantity of red globules in the blood, yet have some of their muscles of a lighter colour than others: even in the human subject, all the muscles are not equally red; the muscular part of the intestines, for instance, is not equal in redness to the heart, and many other muscles. To what is this owing? Does it arise from mechanical causes? Do the vessels become suddenly so small beyond a certain limit as not to allow the red blood to pass? or are the other parts of the blood less tenacious? Is the red part in such not allowed to go so far? or is it a separating principle in the vessels themselves? Many circumstances in life either increase the quantity of the red globules, or make them more universal in the muscles of the same animal: thus exercise increases the quantity of the red globules, and the red colour of muscles, while there is the same quantity on the whole, or perhaps we should rather say, that indolence decreases the quantity; this is particularly

of it lay in the dish in water; but the whole became one mass of vessels. The intention of this experiment was to see, if possible, the communication between the arteries and the veins; but the mass of vessels prevented every view of this kind.

* The redness of the blood is of great use towards the knowledge of diseases; many inflammations are known by it, when on the skin, and even the kind of inflammation is distinguished by the kind of redness: also putrid diseases are distinguished when the blood is extravasated. The quantity in the face is a sign of health or disease.

remarkable in woman; and probably the whiteness of the muscles of young animals may arise from the same cause; I suspect, however, something more; I conceive it arises from the principle of life, influenced by accidental or mechanical causes; for the muscles of young animals are increasing in colour till they arrive at the age of maturity, and not afterwards, although they continue to use exercise. Diseases lessen the quantity of the red globules, and often render their distribution unequal.

From the above account we may reason upon the whole, that the animals which are reddest, or have the greatest number of red parts, have their blood furnished with the greatest proportion of red globules.

One would naturally suppose that the red globules were of the same colour every where in the same animal; this last is perhaps the case, but now we find that these globules are of different hues in the different systems of vessels in the same animal. In the more perfect animals, where there are two systems of vessels, carrying the blood, viz. arteries and veins, the blood is not of the same species of red in both of them in the same animal; one red is the scarlet, which takes place in the arteries of the body, the other is the modena which takes place in the veins; and as every part of the body possesses such systems of vessels, the parts which are visited by red blood must have a mixture of both. As there are two circulations in every animal above the insect, one in the lungs in those that breathe air, or in the gills in fish who breathe water, and the other the general circulation to the body in both, we find the two colours of the globules not corresponding to the same system of vessels in each. The scarlet is the venal blood in the lungs, and afterwards becomes the arterial in the body, where it is commonly seen; and hence it is called the arterial blood; the modena is the venal blood of the body, and is the blood also of the pulmonary artery; but, as it is commonly seen in the veins only of the body, it is called the venal blood; the scarlet colour, therefore, is acquired in the lungs, and the modena in the body. There are so many proofs of this, that it hardly requires any illustration; yet, many circumstances and experiments may be brought in direct proof of it. I bled a man in the temporal artery, and in the vein of the arm at the same time, each into a phial. The blood of the artery was of a florid red, and the venal was dark. The arterial kept its colour, and did not separate its serum; but this was singular, for in others it does separate its serum and coagulum; the venal separated into its constituent parts as usual.

Although this, however, is a general rule, yet there are many exceptions; for we find in many cases the scarlet colour of the blood in the arteries not changed in the veins, and under some circumstances the modena taking place in the arteries, as well as where blood is extravasated in the body.

It becomes a question, how the change is produced in each?

More attention has been paid to the mode in which it gets the scarlet colour, than the modena, (though both probably are of equal importance) because it was believed that life, in some degree, depended on this colour. Many substances change the colour of the blood from the modena to the scarlet: respirable air has this effect, and many of the neutral salts, more especially nitre, which occasions the florid colour in meat that has been salted, also with sea-salt. But, as the air produces this effect in the living body, and as we find that without air the animal dies, great stress has been laid on this change of colour, whereas, it should only be considered as a sign that the blood has been in contact with the air, but not that it must be fit for the purpose of circulation. This effect takes place readily under many circumstances; it takes place out of the circulation as readily as when in it; as readily when blood is coagulated as before: it takes place in blood whose coagulating principle has been destroyed, as by lightning, sudden death, etc. it does not, therefore, depend upon life. It is the cause only of this change in the colour by respirable air, which becomes an object of consideration; for if we suppose the change of colour in the red globules to be all that respiration is to perform, we shall make the red globules the most essential part of the blood, whereas they are the least so. Most probably, the effect of air upon the blood is greatest on the coagulating lymph; and this conjecture is rendered more likely, when we consider, that in animals which have no red globules of any kind, respiration is as essential to their existence as in any other; and we find, that the blood may lose this effect, and yet retain its salutary effects in the constitution. Thus in the tying up a large artery, when the parts beyond must be supplied with blood that shall have lost its florid colour; and in the chick in the egg, the blood in the arterial system is dark, while in the veins of the temporary lungs it is florid. We are led, by daily experience, to observe, that the dark blood taken from a vein becomes red on that surface which is exposed to the common atmosphere; and, that if it be shaken in a phial with air, the whole becomes red*. If blood also be allowed to stand exposed to the air, and coagulate, its upper surface will become of the scarlet red, while the bottom remains dark, or even of a darker colour than common venal blood, because it contains a greater quantity of red globules. If the coagulated blood be inverted, and the bottom exposed to the air, this part will also assume the scarlet red, and become even redder than that exposed before, because it contains a greater number of red globules, which undergo this change. The red colour will even penetrate to some depth, which ſhews that the effect can be produced through a thick substance. We often find the vessels of the lungs full of blood, and the whole substance of the lungs of a dark colour; but, if we inflate the lungs, the cells will become of a florid red, the small vessels on those cells, both arteries and veins, having the colour of their blood changed by the air in the cells affecting it through their coats: we find the same thing on the surface of flesh, or muscles, liver, etc. We may observe in the gills of fish, that they retain their florid colour as long as the fish is fresh, from being exposed to the air, for they naturally have the air applied externally in the act of breathing. It is from these facts we reason, respecting the scarlet colour which the blood acquires in the lungs, but loses in the body, and therefore is found of the modena colour in the veins, and of course in the right side of the heart, and larger trunks of the pulmonary artery. As the blood is florid in the pulmonary veins, as far as we can trace them, we reasonably suppose that it acquires this appearance in the small vessels of the lungs, and as

* This does not arise from motion, for fill the phial with blood without air, and put into it glass-beads, and shake them, so as to give it motion, the colour will not be altered.

the lungs constantly take in fresh air, we conceive that by exposure to the air (perhaps both in arteries and veins) it acquired the scarlet colour; for we shall see that the air, or the influence of the air, is capable of passing through animal substance.

In the living body when the breathing is imperfect, we can plainly see the change taking place in the colour of the blood, in proportion as the breathing becomes more perfect, of which the following experiments are proofs:

They were made with a view to observe the motion of the heart, by producing an artificial breathing, and exhibited a vast variety of satisfactory phenomena, of which the change in the colour of the blood in the lungs was one.

I invented a pair of double bellows, each of which had two openings, but their actions were reversed; two of the openings were inclosed in one pipe or nozzle, and the other two were on the sides. The lower chamber had its valve placed exactly similar to that of the common bellows; but it had also a valve at the nozzle, which did not allow any air to enter there. The upper half had a valve placed at the nozzle, which allowed the air to enter, but not to escape, and the opening on the upper side, allowed the air to escape, but not to enter; so that on dilating the bellows, the upper side, or chamber, drew in the air, by the nozzle only, and at the same time, the under chamber drew in its air by the side only: on closing the bellows, or expelling this air, the air drawn in by the nozzle passed out at the opening on the upper side, and the air that was drawn in by the under side, passed out by the nozzle. By this means I could, by fixing the nozzle into the trachea, draw the air out of the lungs into the upper chamber of the bellows, and at the same time draw fresh air into the lower chamber; on emptying these cavities of their air, the pure air in the lower chamber passed into the lungs, and that which had been just taken from the lungs into the upper chamber passed into the open air alternately. The action of these bellows, though double, is exactly as simple as breathing itself; and they appear to me to be superior to any invention made since for the same purpose. I fixed the nozzle of these bellows into the trachea of a dog, and immediately began the artificial breathing; I then removed the sternum and cartilages, and opened the pericardium. While I continued the artificial breathing, I observed that the blood in the pulmonary veins, coming from the lungs, the left auricle, the aorta, etc. was florid or dark, just as I threw in air or not, into the lungs.

I cut off a piece of the lungs, and found that the colour of the blood which came from the wound corresponded with the above effects: when I threw air into the lungs, so as to render the blood florid in the pulmonary veins, two kinds of blood issued from the wound; and when I left off blowing, the whole blood which passed out by the wound was of the dark colour. If the air is confined in the lungs of a quadruped, it soon loses its power over the blood, which remains dark, or has the appearance of becoming dark, because dark coloured blood is thrown in, and it undergoes no change; but if the same experiment is made on an amphibious animal, it is a considerable time before the whole blood becomes dark, because in such animals, the lungs are a reservoir of air, which of course continues its influence over the blood the longer.

This experiment I have repeated upon several animals, and commonly for half an hour at a time, which was sufficient to allow me to make my observations with coolness and accuracy: in this part of the experiment it was curious to see the coronary arteries turn darker and darker, becoming like the veins which run on each side of them; and on blowing again, resume gradually a brighter colour, till they become of a florid red. As respiration was generally prevented in the first part of the experiment, the blood was found at firſt wholly of a dark colour, and the heart large, and hardly acting; but on throwing into the lungs fresh air, the heart began to act, upon which both auricles and ventricles became gradually smaller; then by stopping the respiration, they again became larger and larger.

The diminution of the heart's motion upon stopping respiration, does not depend upon the immediate impression of improper blood on the left auricle and ventricle, as a sedative, but upon the sympathetic connection between the heart and lungs; one action ceasing, the other also ceases; which sympathy is established, because, if the heart were to continue acting, it would send improper blood into the body, by which it can be supported only a little while. The right auricle and ventricle also cease acting, although not so early, and for the same reason; because, on the cessation in the lungs the blood cannot receive any benefit in passing through them.

These actions and cessations of actions are all dependant on life, and the connection of one action with another. It is upon the same principle that the first effect of recovery is the act of breathing.

The following cases illustrate this still further:

I bled a gentleman in the temporal artery, while in a fit of apoplexy; he breathed seemingly with great difficulty; the blood flowed very freely, and he continued to bleed longer than we commonly find, from the same wound, which made me suspect that the artery had lost some of its contracting power. The blood was as dark as venal blood; he became somewhat relieved, and his breathing more free; about two hours afterwards we opened the same orifice, which still bled freely, but now the blood was become florid as usual.

Mrs. ———, in Norris-street, Haymarket, fell into an apoplectic fit, in which she was insensible, respecting ideas: her breathing was very imperfect, attended with a rattling in her throat, and a snort; the pulse was very steady, but rather slow. I opened the temporal artery, which bled very freely; but I observed that when she breathed freely, the blood from the artery became red; and when her breathing was difficult, or when she hardly breathed at all, the blood became dark, and this alternately several times in the course of bleeding; yet all this made but little alteration in the pulse.

In many disseases of the heart, as well as of the lungs, we may often observe the same appearance. In many diseases of the heart, producing what is called angina pectoris, (the symptoms of which arise from a vast variety of causes, palpitations being commonly one) we shall see that upon any exertion, the heart acts with great violence, and the breathing is very laborious, or rather imperfect, not corresponding with the violence of the motion of the blood; the face will become of a dark purple colour, the patients will be nearly expiring, and nothing but rest relieves them: of this the following case is a strong instance.

A. B. when a boy, could never use the same exercise that other boys did; he could not run up ſtairs, nor ascend a hill without being out of breath, and had almost through his whole life, an irregular pulse; more especially when he used more exercise than he could well bear. Upon the least increase of motion, he had a palpitation at the heart, which was often so strong, as to be heard by those that were near to him; and his becoming soon fatigued, was by his acquaintance supposed to be owing to a want of spirit or courage.

With all this he grew to be a well formed and common sized man, but ſtill he retained those defects, which, indeed, rather increased as he extended his views, and with them extended his actions. About the age of thirty, he took to violent exercise, such as hunting, and often in the chase would be seized so ill with palpitations, and almoſt a total suffocation, that he was obliged to ſtop his horse, and be held upon the saddle. At such times he became black in the face, and continued so as long as the fit lasted. It was often several days before he perfectly recovered his usual health; and frequently he could not lie down in his bed, but was obliged to sit up for breath: all these symptoms gradually increased upon him, and at times, without any violence of exercise or action, he would feel as if dying, and used so to express himself: but as the cause of these feelings did not appear to his friends, they rather treated them slightly.

At last mere anxiety of mind would bring on these feelings, palpitations, and suffocations in some degree.

In the winter 1780, and 1781, he hunted very violently and also caught cold, which together brought on the abovementioned complaints with greater violence than ever.

He consulted two gentlemen of the profession: the palpitation, the difficulty of breathing, the great oppression, with the blackness in the face (I suppose) they thought either arose from spasms, or was nervous, for they ordered cordials, such as spirit of lavender, wine, etc.

I was sent for, to give a name to the disease. Upon enquiring into all the symptoms, my opinion was, that there was something very wrong about the construction of the heart, viz. about the source of the circulation; that the blood did not flow at any time freely through the lungs, so as to have the proper influence of the air, but much less so when he was hurried; that a stagnation of the blood in any one part about the heart would produce in some degree suffocation; and want of due influence of the air upon the blood, being the same thing, which was the cause of the darkness of the face at those times: that the means to be practised were in some degree contrary to what had been advised, namely, reft, gentle bleeding, care to eat moderately, keep the body open, and the mind easy; and as he had got the better of former attacks, (although those were not so violent) I saw no absolute reason why he should not get the better of the present. Eight ounces of blood were taken from him that day, which relieved him. The ſymptoms still continuing, though not so violently, I saw him once more; he lost about four or five ounces more blood, which also relieved him, but still he did not get materially better: at last, as an addition to the above symptoms, he became yellow, his legs began to swell with water, and all his other complaints gradually increased, which made me suspect that a deposit of water was begun in the chest. He was now attended by a physician; was blistered on his legs, which threatened a mortification, and a caustic was applied to the pit of his stomach, (I suppose for a pain there): nature was at last worn out, and he died. I solicited to open him, and was allowed.

On opening the belly there was found in the abdomen a very small quantity of bloody yellowish serum. Every viscus appeared to be sound; the gall-bladder was pretty full of bile, which was thick, but not ropy, as if the thinner parts had been strained off; the ducts were clear both to and from the gall-bladder.

Upon opening the chest the lungs did not collapse, being a good deal œdematous, but otherwise appearing sound.

There was also a little bloody serum in both sides of the chest. These I conceive were the consequences of the last attack.

The heart was very large, and very full of blood.

Upon opening the right side of the heart, I found nothing uncommon, either in the heart or the pulmonary artery.

Upon opening the left side, I found the valves of the aorta thicker, and harder than usual, having at the same time the appearance of being very much shrivelled. This diseased structure of the valves accounts for every one of what may be called his original symptoms, and was such as to render them of very little use; the blood, therefore, must have fallen back into the cavity of the ventricle again at every systole of the artery.

Whether this shrivelled state of the valves of the aorta was a natural formation, or a disease, is not easily ascertained; but if it was a disease, it muſt have begun much earlier in life than such diseases commonly do, as the symptoms appeared when he was young*. From this conſtruction of valve, we must see that it required the greateſt quiet to allow the motions of the blood from the left side of the heart to go on sufficiently, and that whatever interrupted this, produced a stagnation, or an accumulation of the blood almost in every part of the body; first in the left ventricle, then the left auricle; pulmonary veins, pulmonary arteries; right ventricle, right auricle, and all the veins in the body; however a smaller quantity than usual could get to the veins of the body through the arteries, so that a kind of circulation went on.

If we consider the effect arising from this construction of valves, simply on mechanical principles, we cannot account for the darkness of the arterial blood, which must have passed through the lungs, when there was no mechanical obstruction to respiration; but since it happens that when the heart either ceases to act, or cannot get rid of its blood, (which must have been the case in the present instance) respiration ceases, or is performed so imperfectly as to have nearly the same effect†; the person is in reality in a state of suffocation. Suffocation is no more than imperfect respiration, which is the cause of imperfect blood passing to and from the

* I have seen it at a very early period.

† In such inspirations I conceive that so little air is taken in as hardly to reach the cells of the lungs, so as to be able to influence the blood circulating on those cells.

left side of the heart; and it is therefore immaterial, as to consequences, whether a stoppage to respiration is the first cause, or is an effect, for in either way it is the cause of imperfect blood being introduced into the arterial system.

It may be difficult to account for the increased size of the heart, whether it was a mechanical effect, as the blood would be thrown back into it at every systole of the aorta and diastole of the heart, or whether it arose from a particular affection of that viscus. The first idea is the more natural; but it is not neceſſary that the cause should be of this kind; for we see every day enlarged hearts, where the symptoms have been somewhat similar, and yet no viſible mechanical cause existed; and indeed it is a common effect where there is an impeded circulation.

It is easy to be conceived, first, that the circulation could not, in the case of this patient, be carried on regularly and perfectly: secondly, that a stoppage to the blood's motion in either arteries or veins, but much more a retrograde motion in the blood in any part must produce a stagnation, which will be more or less extensive, according to the quantity of blood passing that way: thirdly, that if it was only in a branch of an artery, or vein, the stagnation would probably be only partial; but when in an artery, or the veins of the whole body, as the aorta, or vena cava, it must then be pretty universal; and as the retrogade motion in the blood began in the aorta, we can easily trace its effects. We also find in imperfect constructions of the heart, etc. where there is a communication between the right and left side, kept up after birth, that the same circumstances and appearances take place; cases of this kind frequently occur, of which the following is a strong inſtance:

I was several times consulted about the state of a young gentleman's health, and though it could not be said anatomically, with precision, what the real confirmation of the heart was, yet it was imagined that the symptoms arose from some imperfection in that organ. From his infancy, every considerable exertion produced a seeming tendency to suffocation; and as suffocation always arises from a want of the due effect of air on the blood, while the circulation is going on, the whole body must change from the scarlet tinge to the modena or purple; and in those parts where the blood gives its colour most, there will this effect be greatest, which is commonly in the face, and particular parts of the face, at the finger-ends, etc. While very young, nothing but crying brought on those fits, but when he was grown so as to take bodily exercise, as running, etc. then they became more frequent and more violent; and it is to be observed, that the older he grew, the worse he was likely to be; for with years approaching to maturity, his actions were likely to increase: great care, however, was taken to suppress such actions as were found, from experience, to bring on the fits. No medical advice could be of the least service, further than to inform him what experience had already taught, unless to recommend occasionally, when his friends found that the fits of suffocation were more easily excited than usual, that he should lose a little blood, so as to lessen the necessary action of breathing; putting, in this way, the quantity and motion of the blood more upon a par, and at the same time, not to indulge too much his appetite; but all these precautions hardly kept him tolerably well. The heart, in proportion to the difficulty, acted with more violence, and one could rather have wished the contrary to have taken place. As he could hardly use any exercise of his own, motion was given him, such as riding slowly on horseback, in carriages, etc. He lived to the age of between thirteen and fourteen; and though the disorder did not destroy him, yet it is most probable that he could not have lived long, as he was every day arriving more and more at an age of action, but not in the same proportion acquiring prudence. When he died he was opened by Dr. Poultney, who transmitted an account of the appearance of the parts to the College of Physicians of London, which is published in the third volume of their Medical Transactions: such parts as are immediately connected with my subject, I shall transcribe.

" Both lobes of the lungs were remarkably small, and some parts of them flacid to such a degree, as to suggest an idea of their having been incapable of performing their functions *. The liquor pericardii was in due quantity, and the heart was firm in texture, and of the natural

* Although I have transcribed this, yet I do not lay much stress upon it.

size*. On examining the ventricles, and the beginning of the aorta, a canal, or passage, was found communicating with both ventricles, situated in an oblique direction near the basis of the heart, so large as to admit the end of the finger from the aorta, with equal facility into either ventricle; the septum of the ventricle appearing to terminate with this canal. On examining the entrance of the pulmonary artery within the ventricle, it was judged that this entrance was much smaller, and more firm than common." It is difficult here to say what would be the exact effect of this communication on the motion of the two bloods; that is, whether the blood of the right side was received into the left, or vice versâ; if the oblique direction of this passage had been further described, it might have explained this doubt; for if the passage was direct, the blood would most probably pass from the left to the right, as the left ventricle acquires the greatest strength; the word oblique, however, and the expression, that the finger, from the aorta, passed with equal facility into either ventricle, would make us suppose that the obliquity led out of the right ventricle into the aorta; but even with this obliquity, I should not think it probable that the blood would pass from the right to the left, because the left acts with so much more force: the description leaves us to account for the defect in respiration another way. If the blood passed from the right to the left, then it would have had the same effect as the canalis arteriosus, and probably was the only one in the fœtus. In this case too little blood would pass through the lungs; but I do not conceive that this circumstance would affect respiration, because no stagnation would take place in the lungs; but if the blood got from the left to the right, then too much blood would be sent to the lungs, as it would be found to take its course twice. On the other hand, if the lungs be not capable of allowing a full distention equal to the actions of the heart, though naturally framed, the same thing takes place. In natural deaths, the pulsation of the heart commonly stops before breathing ceases; but in deaths arising from a stoppage of breath, such as hanging or drowning, the reverse must take place; and in such we shall always find dark blood

* This shews there was no disease.

in the left side, which plainly took place in the experiment abovementioned.

It may be supposed that in the lungs the blood cannot come in contact with the air, but the circumstances above related, that the florid colour will extend some depths into the blood, shews that the effect of air can, and does pervade animal-matter. Not attending to this fact at firſt, I covered the mouths of vessels filled with venal blood with goldbeaters' ſkin, touching the surface of the blood, and the blood conſtantly became of a florid red on the surface, and even for some depth.

I put some dark venal blood into a phial, till it was about half full, and shook the blood which mixed with the air in this motion, and it became immediately of a florid red*.

As the globules are the coarsest part of the blood, and they appear to be fully affected by the air in the lungs, we may suppose that the vessels of that viscus do not run into extreme minuteness, by which, apparently, no other purpose would be answered.

The blood of the menses, when it comes down to the mouth of the vagina, is as dark as venal blood; and as it does not coagulate, it has exactly the appearance of the blood in those where the blood continues fluid. Whether this arises from its being venal blood, or from its acquiring that colour after extravasation, by its slow motion, it is not easily determined; but upon being exposed it becomes florid: it is naturally of a dark colour, but rather muddy, not having that transparency which pure blood has. Whether this arises from its mixing with the mucus of the vagina, or from the cessation of life in it, I will not pretend to say. The red globules, however, are not dissolved, they retain their figure.

Does air in the cellular membrane of an emphysematous person produce, or continue the floridness of the blood or not†?

The surface of the blood becoming of a scarlet red, whether exposed immediately to the air, or when only covered by membranes, through

* These experiments I made in the summer 1755, when I was house-surgeon at St. George's Hospital, and Dr. Hunter taught them ever after at his lectures.

† Vide Chester on Cases. Case first, the venal florid. St. George's, a man emphysematous; blood very dark.

which we may suppose its influence to pass, is a circumstance which leads us to suppose, that it is the pure air which has this effect, and not simply an exposed surface*. To ascertain this, I made the following experiment:

I took a phial, and fixed a stop cock to its mouth, and then applying an air-pump to the cock, exhausted the whole air: in this state keeping it stopped, I immersed its mouth in fresh blood flowing from a vein, and then turning the cock, allowed the blood to be pressed up into the phial. When it was about half full, I turned the cock back, and now shook the phial with the blood, but its colour did not alter, as in the former experiments; and when I allowed the blood to stand in this vacuum, its exposed surface was not in the least changed.

The vast number of cells into which the lungs are divided, the whole arterial and venal system ramifying on the surface of those cells and of course the whole of the blood passing through them in every circulation, together with the loss of life upon the missing three or four breathings in the most perfect animals, shew the great nicety that is required in preserving the due properties of the blood for the purposes of animal life: the time that we can live without air, or breathing, is shorter than that in which we die from a defect in any other natural operation; breathing, therefore, seems to render life to the blood, and the blood continues it in every part of the body. This nicety is not nearly so great in many of the more imperfect animals.

The amphibia have not this division of lungs, nor does the whole of the blood pass through the lungs in them, and they can live a considerable time without breathing. This, at present I only mention as a fact, not meaning to give my opinion of the mode of preserving life, either in the blood, or body, by the application of air to it; though, I will say, that mere life in both is supported by the air, and probably few of the other properties connected with the blood depend so much upon air, as its life. But we may observe, that it was not necessary for the blood to undergo this change, to render it fit for every purpose in the animal œconomy;

* I may here observe, that fixed air, as also inflammable airs, have contrary effects.

for we find that venal blood answers some purposes: thus the blood from the intestines, spleen, etc. going to the liver, as we suppose, for the secretion of the bile, ſhews that venal blood will do for some secretions, though propably not absolutely necessary. This application of venal blood, is a saving of blood; and it is not necessary for the formation of bile, that the venous blood should proceed from the parts abovementioned; for in birds, amphibia, etc. other veins, besides those, enter the liver.

I have shewn that several substances mixed with dark coloured blood, have the property of rendering it of a florid red; and it must have appeared, that by circulating through the body, its dark colour is restored. As it is capable of being rendered florid, by several substances, so it may be rendered dark by several when florid: vital air has the power of rendering it florid; but the other vapours, or gasses, which have the name of airs, such as fixed air, inflammable air, etc. render it dark. This change is peculiar to the living body; for if arterial blood is taken away, it retains its florid colour, although not in the least exposed to the air. As it is found dark in the veins, and as it performs some offices in the course of the circulation, which perhaps render it unfit for the purposes of life, we may conceive, that the loss of colour, and this unfitness, are effects of the same cause: but, upon further observations on this fluid, it will be found, that it may be rendered unfit for the purposes of life, without losing its colour, and may lose its colour without being rendered unfit for life: slowness of motion in the blood of the veins, is one circumstance that causes the alteration; but this alone will not produce the effect; for I have observed above, that arterial blood put into a phial, and allowed to stand quiet, does not become dark; but rest, or slowness of motion in living parts, would appear, from many observations, to be a cause of this change in its colour: we know that the blood begins to move more and more slowly in the arteries: we know its motion in the veins is slow, in comparison to what it is in the arteries; we should, therefore, naturally suppose, (considering this alone) that it was the slowness of the motion that was the immediate cause. Rest, or slowness of motion, in living, and probably healthy parts, certainly allows the blood to change its colour: thus we never see extravasations of blood, but it is continually dark. I never saw a person die of an apoplexy, from extravasation in the brain, but the extravasated blood was dark; even in aneurism it becomes dark in the aneurismal sac, also when the blood escapes out of the artery and coagulates in the cellular membrane, we find the same appearance.

These observations respecting apoplexy, struck me much. I conceived at first, that the extravasations there must consist of venal blood; but, from reasoning, I could hardly allow myself to think so; for whatever might be the beginning of the disease, it was impossible it could continue afterwards wholly venal; especially when the blood was found in a considerable quantity; because, in many cases, great mischief was done to both systems of vessels, and the arteries once ruptured would give the greatest quantity of blood; but to afcertain this with more certainty, I made the following experiment:

I wounded the femoral artery of a puppy obliquely; the opening in the skin was made at some distance from the artery, by a couching needle; the blood that came from the small orifice in the skin was florid. The cellular membrane swelled up very much; about five minutes afterwards, I punctured the tumour, and the blood was fluid. In ten minutes I punctured it again; the blood was thinner, and more serous, but still florid. In fifteen minutes I punctured it again: at firft only serum issued; upon squeezing, a little blood came, but still florid: the mass now seemed to be principally coagulated, which prevented further trials. Some days after, when I cut into the swelled part, I found the blood as dark as common venal blood; so that here the change had taken place after coagulation.

When I had plaster of Paris applied to my face to make a mould, in the taking it off, it produced a kind of suction on the fore part of the nose, which I felt; and when the plaster was removed, on observing the part, it was red, as if the cells of the skin were loaded with extravasated blood; this was then of a florid red, but it soon became of a dark purple, which shewed that it was arterial blood, and that by stagnating in the cells of the body it became of the colour of venal blood.

Blood may even be rendered dark in the larger arteries, by a short stagnation. I laid bare the caroted artery of a dog, for about two inches in length; I then tied a thread round it at each end, leaving a space of two inches in length between each ligature, filled with blood; the external wound was stitched loosly up: several hours after, I opened the stitches, and observed in this vessel that the blood was coagulated, and of a dark colour, the same as in the vein. Thus I have also seen when a tourniquet has been applied round the thigh, and the artery divided, that when it was slackened the first blood came out of a dark colour, but what followed was florid.

This I have seen in amputations, when a tourniquet had been applied for a considerable time; and, it is commonly observed in performing the operation for the anuerism.

July, 1779, Mr. Bromfield had a patient in St. George's Hospital, with an anuerism in the crural artery, about the middle of the thigh: the artery had been dilated about three inches in length. The operation was performed, in which the artery was tied up above the dilatation, three or more inches, for security. When this was done, the tourniquet was slackened, and a pretty considerable bleeding was observed, seemingly at the lower orifice, leading from the dilated part, which, at first, was supposed, from its colour, to be the venous blood that had stagnated in the veins, by means of the tourniquet; but this it could not be; and it was found to flow from the lower orifice of the artery, which was immediately tied: we must suppose, that the motion of the blood, in making this retrograde course, was very slow, for it had first to pass off into small collateral branches, above where it was tied, then to anastomose with similar small ones, from the trunk below, and then to enter that trunk; all of which must very much retard its motion; and indeed, the manner of its oozing out of the vessels shewed such a retardation. This motion of the blood, though in the arterial system, was in some respects similar to the motion of the blood in both systems of vessels.

This last circumstance plainly indicates a communication of the arteries above the anuerism with those below, by means of the anastomozing branches.

The blood from the lower orifice flowed without any pulsation; which must have been owing to its coming into the large artery below by a vast number of smaller ones at different distances, and of course, at different times; but probably, the chief cause of this want of pulsation in the great artery was, that the power of the heart was lost in the two systems of smaller arteries above, and below; for the second system, or those from below, became in a considerable degree similar to veins; and the great artery in the leg below the anuerism was like a considerable vein.

A young man, servant to Henry Drummond, Esq. having had a knife run into his thigh, which wounded the crural artery, a considerable tumour came on the part, consisting chiefly of blood extravasated, and lodged in the cellular membrane. This in some degree stopped the flowing of the blood from the cut artery, and on dilating the wound so as to get to the artery, I observed that the extravasated blood in the cellular membrane was of the venal colour. On exposing the artery, which was first secured from bleeding by a tourniquet above, and then slightly slackening that instrument, the first blood which flowed from above, was dark; and even was taken for venous blood by the operator; but he was soon convinced that it was arterial, by the florid colour of that which almost immediately ensued. I observed that the colour of the blood was as dark as that of any venous blood I ever saw.

From these experiments, and observation, we must conclude that the colour of the blood is altered, either by rest, or slow motion, in living parts, and even in the arteries; this circumstance takes place in the vessels as the motion of the blood decreases.

Another observation occurs, viz. that the whole of the limbs below the ligature, where the crural artery has been taken up, must be entirely supplied with such altered blood; and as this leg kept its life, its warmth, and the action of the muscles, it is evident that the colour of the blood is of little service to any of those properties. It is probably from this cause, that granulations on the lower part of the lower extremity look dark when the person stands erect; as well as in very indolent sores, however situated.

Another observation strongly in favor of the supposition, that rest is a cause of the change of blood from the scarlet colour to the dark, or modena, is taken from the common operation of bleeding; for we generally find the blood of a dark colour at its first coming out, but it becomes lighter and lighter towards the last. Some reasons may be given for this: first, it has stagnated in the veins, while the vein was filling, and the orifice making, which occupies some time, and may render it darker than it otherwise might have been in the same vein: secondly, when there is a free orifice, the blood may pass more readily into the veins from the arteries, and therefore may be somewhat in the state of arterial blood, which may occasion the last blood to be rather lighter. What amounts almost to a proof of this, is, that although a ligature is tied so as to stop the passage of the blood to the heart, and therefore it might be supposed not to have so free a passage from the arteries as in common, yet from the following observations, it appears that it certainly has a much freer; for if the orifice be large in a full sized vein, the arm beyond the orifice will be much paler than the natural colour, and the blood will become more florid; but if on the contrary the vein be small and little blood passes, it will retain its dark colour; this, however, would appear not always to be the case.

I bled a lady whose blood, at first was of a dark colour; but she fainted, and while she continued in the fit, the colour of the blood that came from the vein, was a fine scarlet.

The circulation was then very languid.

We may observe that venal blood in the most healthy, is commonly, if not always, the darkest; and when the body is the least out of order, it is then not so much changed from the florid to the very dark purple. This I have often observed, and particularly recollect a stricking instance of it in a gentleman who had a slight fever; his venal blood was quite florid, like arterial blood. This could not arise from the increase of the blood's motion, or from being kept up in the veins by the fever, for it was slight*.

The blood will change its colour from the scarlet to the modena in different situations, according to the mode of circulation. In animals who

* I believe the blood does not become dark by standing in an inflamed part. I have seen cases of apoplexy, where the person died some days after the attack. I have found the pia-mater inflamed in several places, even to the length of inflammatory transfusion; forming dots, all of which were of a florid red colour, while the other parts of the same membrane, the blood in the larger vessels, and also the extravasated blood, were of the usual dark colour.

have lungs, and a complete double circulation, the darkest blood will be where it *comes* (if I may be allowed the expression) to get anew its bright colour; for instance, in the arteries of the lungs, and of course the brighteſt in the veins of the same part, which will be continued more or less into the arteries of the other circulation, where again it will begin to change, except in one stage of life of some animals who do not use their lungs, such as fœtuses; but in such fœtuses as convert animal-matter into nourishment, therefore, most probably, must have it influenced by the air, such as the chick in the egg, although not by means of the lungs of the chick, we find the blood in the veins of their temporary lungs of a florid colour while it is dark in the arteries; therefore has become of a dark colour, in its passage to and from the heart; but in the more perfect animals the blood, I believe, becomes darker and darker, as it proceeds from the heart, till it returns to the heart again; but this change is very little in the arterial system, more especially in vessels near the heart, as the coronary arteries. The change of colour is more rapid in the veins, but it is not equally made through the whole venous system; for it will be produced more quickly in the lower parts of the lower extremities, than in the veins near the heart: it begins, most probably, where the motion first has a tendency to become languid; and this usually takes place in the very small arteries; for in bleeding in the foot, or on the back of the hand, I have observed, in general, that the blood is of a more florid red than in the bend of the arm.

V. OF THE QUANTITY OF BLOOD, AND COURSE OF ITS CIRCULATION.

It appears to me impossible to acsertain the quantity of blood in the body; and the knowledge of it would probably give very little assistance towards better understanding the œconomy of the animal. The quantity of blood is probably as permanent a circumstance as any, and not depending on immediate action: we have not one hour less and another hour more; nothing but accident or disease can lessen the quantity; the first, probably, immediately, the other slowly; but even then, although under par, it is so slowly made up as not to constitute sudden variations; yet when we come to consider the varieties in the pulse, we should imagine there would be great varieties in the quantity of blood. The quantity I think must be considerable, when we reflect on the use of this fluid; the quantity of supply, or food, necessary to keep it up; that it supports the body and life, every where; and, that it forms the pabulum of many secretions. All these cannot depend on a very small quantity of this fluid, without conceiving at the same time an extremely quick change. There seems to be two modes of judging, both of which are evidently liable to objections in point of accuracy, and they differ so much, as to shew that neither can be right. One is to calculate how much may be in an animal from the quantity it will loſe in a short time. I have seen several quarts thrown up from the stomach in a few hours, even by a very thin, puny person: and, on the other hand, if we had not this proof, we should suppose there could be but very little, when a few ounces will make a person faint: I have an idea, however, that people can bear to lose more by the stomach, than in any other way. Besides, it becomes a matter almost of surprise, how little is commonly found in the dead body: but I believe in disease it in some degree diminishes with the body; for more is to be found in those who die suddenly, or of acute diseases; and even in some who die of lingering diseases, as a dropsy, we have a considerable quantity of blood. The only way of accounting for this is, that in a common lingering illness there is less blood; and in a dropsy, it coagulates less; for the strong coagulation squeezes out the serum, which, I imagine, transudes after death, and is not observable.

It would appear upon the whole, that the quantity of blood in an animal is proportioned to the uses of that blood in the machine, which, probably, may be reckoned three in number: the first is simply the support of the whole, which includes the growth, or increase of parts, the keeping the parts already formed to their necessary standard, and also the supply of waste in the parts. The second is the support of action, such as the action of the brain, and muscles, in which is produced uncommon waste; and thirdly, secretion; all of which will fluctuate except the simple support; but more particularly the support of action. I have already observed that the anastomosing of vessels gives greater space for blood. Probably, a paralytic limb would give the necessary quantity for simple support.

There is nothing in the veins particular, so as to give an idea that they were intended to increase the quantity of blood; they hold, however, more than the arteries, which certainly adds to the quantity: but the increase of size lessens the velocity. They form plexuses, and what are called certain bodies, as the plexus retiformis in the female; the corpora cavernosa, and spongiosa in the male. We see how little blood supports a part in an aneurism; and, probably, slowness of motion is suitable to little blood.

It must have appeared in the account of the different colours, of the different parts of the body, arising from the proportion of red blood, that some parts must have much more blood than others, and we have now to mention, that some parts have much larger vessels going to them, than others. This idea is confirmed, by the blood being the moving material of life, and taking a part in every action of it: its quantity is to be found in proportion to those actions; and since the body is a compound of parts, or rather of actions, whose uses are known to vary considerably, we find blood directed to those parts in proportion to their actions; and this we judge of by the size of the vessels, and redness of the part, in those animals which have red blood, and we may suppose the same in those which have not this part of the blood. The brain has considerable vessels, etc. going to it, yet its substance is white, which is in some degree owing to its opacity. The tongue is vascular. The thyroid gland is vascular. The lungs allow of the passage of the whole blood in most animals, and therefore have always a current of blood through them equal to the whole.

The liver is extremely vascular, which is known from its proportion of vessels, as well as its colour; and as there is in this viscus a peculiar circulation, the very great quantity of blood passing through it, adds to the quantity in the whole body.

The spleen is extremely vascular, as are likewise the kidnies. The stomach, and intestines, have considerable vessels going to them, and the muscles in general, more especially those of labouring people; for labour increases the quantity of blood in the whole, beyond simple nourishment in the full grown, or beyond the mere growth in the young.

In tracing the course of this nourishment in animals, which consists ultimately in the blood; from the most simple to the most complicated, there is a pretty regular series; but this regularity is interrupted whenever there is a variety in the circumstances which are to be taken into the account; but the whole of this forms too extensive a subject for our present consideration.

If I were to begin at the formation of the blood, I should first treat of digestion in those animals which have stomachs; but this is a distinct subject: we may, however, begin with its immediate consequences, as it produces the first, and most essential change, viz. the conversion of the blood into a fluid called chyle. The chyle is the immediate effect, or product of digestion, and is the seed, which, as it were, grows into blood, or may be said to be the blood, not yet made perfect. The chyle, to appearance, varies in different animals. In the quadruped, and in the crocodile, it is white; but in moſt other animals it is transparent: where it is white its parts are more conspicuous than where it is transparent. In this respect it is similar to the red blood, and is found to consist of a coagulating matter, a serum, and white globules, which render it of a white colour, and in some degree resembles milk. These globules are smaller than the red globules of the blood, and about the size of those in the pancreatic juice; they retain their figure in water, and therefore are not similar to the red globules: they retain, also, their round form in the serum.

They are specifically heavier than their own lymph, and serum.

One would naturally suppose from observing the chyle to have globular particles, in certain animals, that they formed the red globules in the blood; but when we consider that the chyle in fowls, has no globules, and yet that they have red blood, we must conclude that they do not answer this purpose.

The first motion of the nourishment in most animals is by the absorption of this fluid from the appendages of the stomach; and in many, this alone appears to be the whole, as they have no such organ, or viscus, as a heart, to which it may be carried; and in such, it may be supposed to be in its mode of distinction somewhat similar to the mesenteric veins and vena-portarum: the parts, therefore, assimilate, and dispose of it themselves; but this structure belongs only to the most simple, or the first class of animals. In those which are more perfect, where parts are formed for each particular purpose, the chyle is brought to one organ, called the heart, having first joined the venous blood, which now requires a similar process, and both are sent to the lungs, where, most probably, the chyle receives its finishing process, and from thence it comes back to the heart again, to be sent to every part of the body*.

In those animals that have hearts, we are to take into the account a number of particulars: first, the blood's motion in consequence of that organ: secondly, the first intention of that motion, viz. to be prepared in the lungs, which introduces breathing: thirdly, the variety in the kinds of lungs: fourthly, the different kinds of substance animals are obliged to breathe for the purpose of matter, employed in the preparation of this fluid.

In this investigation we shall find there is not an exact, or regular correspondence in all the parts so employed.

This irregularity arises from animals breathing different substances; such as some breathing the common atmosphere, in which is included the respirable air; others water, in which air is included, as fish.

Some breathe both air and water; while there are others which breathe air in their perfect state, but water in their first periods, or imperfect state of life†.

If we were to take a view of all these systems, each should be considered apart, with all its peculiarities or connections; together with the

* The circulation in fish is an exception to this.

† In this account I do not include animals in embryo, and some others, which do not breathe at all.

different systems, as they gradually creep into one another, some being perfectly distinct, while others partake more or less of both.

The complete system is always to be considered as the most perfect, although it may belong, in other respects, to a more imperfect order of animals.

It has been supposed by physiologists, that as the blood is found to consist of different parts, or rather properties, that certain parts, or properties, were determined to certain parts of the body, for particular purposes; but from the frequent anastomosis of arteries, the great variety in their number, origin, and the different courses which they take in different bodies, it is very evident, that there can be no particular blood sent to any part of the body, where the whole blood can circulate. Many unnatural situations of parts shew this. For instance, the kidneys sometimes have one artery only on one side, and two, three, or four on the other. On one side they arise from the aorta as high as near the superior mesenteric, on the other as low almost as the division into the two iliacs: and in some cases a kidney has been formed in the pelvis, and the artery has arisen from the iliac; the spermatic arteries too, sometimes, arise on one side from the aorta, and on the other from the emulgents or the arteria capsulæ renalis. If there was a particular blood sent to every gland, we should expect to find urine secreted in the testicle, when its artery arose from the emulgent: but as the blood visibly consists of different parts in those animals we are most acquainted with, and whose physiology is probably best known to us, and as one part of the blood can be traced in the vessels, we can determine with sufficient accuracy the proportions of blood sent, as well as the different kinds. Thus, the red part of the blood informs us, how far it is carried; and we find that our coloured injections nearly correspond with this information. I may here first remind the reader, that the red globules are the grosser part of the blood, and therefore, whenever they are most in quantity, we have the blood with all its parts in due proportion and unseparated; but the construction in many parts of an animal is such, that the red blood is excluded, and this also excludes every coloured powder we can inject; the vascularity, therefore, of such parts is not known, as has been mentioned.

Through them the coagulating lymph only can pass, and probably the serum, for the simple nouriſhment of the parts. Of this nature are tendons, or tendinous parts, ligaments, elastic ligaments, cartilages, especially those of joints, the cornia, etc. Even the brain, and nerves, have not the red blood pushed so far into their substance as many other parts have; we see, therefore, that the whole blood is not conveyed to all parts alike, and this we must suppose to answer some good purpose; yet, upon a more particular view of this subject, we may find it difficult to assign causes for this selection of the blood; for in many animals we find parts similar in construction and use, such as muscles, which are furnished, some with the whole blood, others with the coagulating lymph only, with all the gradations; some animals having both red, and white muscles; others having them wholly red, and others wholly white, as will be more fully explained. Even venous blood can be rendered useful, when it is not to answer the purpose of nourishment; for we find the blood of the intestine, and spleen, going to the liver, we may presume, for the secretion of the bile, as has been already observed.

The idea of particular kinds of blood being sent to parts having particular uses, more especially where the part is employed solely in disposing of this fluid, such as glands, is now, I believe, pretty well exploded; and, it is supposed, therefore, that the whole mass of blood is such as to be fitted for all the purposes of the machine. This idea gives to the parts themselves, full power over the blood so composed, and makes us consider the circulation, or motion of the blood simply.

As the blood is composed of different parts, it might be supposed, that if any particular part had been expended in any process, the remainder, as returned by the veins, would shew this, by its different appearance or qualities. The only visible difference that I could conceive to take place, was in the appearance, or the quantity of coagulating lymph. To ascertain this, however, I made the following experiments:

I opened the right side of the thorax in a living dog, and tied a ligature round the vena-cava inferior, above the diaphragm. I then applied my hand upon the opening, which allowed him to breathe, that the circulation might go on and fill the larger veins. When the inferior vena-cava became turgid, I killed him. On the day following I examined the blood in the different veins, and found a coagulum in the emulgent, mesenteric, vena-cava inferior, splenic, and in the venæ-cavæ hepaticæ, of sizes proportional to the sizes of the vessels; nor was there any difference in any other way.

Experiment the second. Some blood was taken from the mesenteric vein of a living dog, and similar quantities from the splenic vein, the emulgent vein, and the vena-cava inferior, below the openings of the emulgents.

These four quantities were taken in four separate cups.

They all soon coagulated: if there was any one later of coagulating than another, it was that from the mesenteric veins. On standing twenty-four hours the coagula were all of the same firmness.

VI. OF THE LIVING PRINCIPLE OF THE BLOOD.

So far I have considered the blood, and in the common way; but all this will explain nothing in the animal œconomy, unless we can refer it to some principle which may shew the nature of its connection with the living solids in which it moves, and which it both forms and supports. If we should find this principle to be similar to life in the solids, then we shall see the harmony that is supported between the two, and we shall call it, the living principle of the blood. Without some such principle, all we have been examining is like dissecting a dead body without having any reference to the living, or even knowing it ever had been alive. But, from the account I have given of the blood, it must have appeared, that I have still in reserve a property not hitherto explained; for in treating of the coagulation of the coagulating lymph, I have not been so full in my account as I might have been. As many phœnomena, respecting the coagulating or not coaguluting of the blood, develope this principle, I have chosen in part to reserve it for this place; nor shall I be so full upon the present occasion, as I should otherwise be, were I writing on this subject expressly. My intention being rather to explain many appearances in the animal œconomy, and particularly the diseases I am to treat of, than to discuss this single principle. I reserve the illustration of my doctrine for such parts of the treatise as shall be employed on these subjects; the explanations, and illustrations, therefore, will be interspersed through the work, by which means they will come more forcibly on the mind: from many circumstances attending this fluid, it would seem to be the most simple body we know of, endowed with the principle of life. That the blood has life, is an opinion I have started for above thirty years, and have taught it, for near twenty of that time, in my lectures; it does not, therefore, come out at present as a new doctrine; but has had time to meet with considerable opposition, and also acquire its advocates. To conceive that blood is endowed with life, while circulating, is perhaps carrying the imagination as far as it well can go; but the difficulty arises merely from its being fluid, the mind not being accustomed to the idea of a living fluid*. It may therefore be obscure at first, and it will be the more necessary that I should be pretty full in my account of it; yet the illustration of it in my account of inflammation, will, perhaps, do more to produce conviction, than any other attempt, although strongly supported by facts. It is to me somewhat astoniſhing, that this idea did not early strike the medical enquirers, considering the stress which they have laid on the appearances of this fluid in diseases; since it is probably more expressive of disease than any other part of the animal œconomy: and yet all this, according to them, must have arisen from, what shall I call it? a dead ani-

* It is just as difficult for a man born in the West-Indies, to conceive water becoming a solid. I recollect a gentleman from Barbadoes, walking out with me, one frosty morning, when there was ice on the gutters, and I, without having any thing else in my mind than just common observation, said, "it has been a frost in the night." He immediately caught at the word frost, and asked me, "How I knew that?" Without thinking particularly of the cause of his question, I said, "because I see the ice on the gutters." He immediately said, "where?" and I answered, "there." Having been told that ice was a solid, he put his fingers down upon it, but with such caution as bespoke a mind that did not know what it was to meet; and upon feeling the resistance it gave, he gently pulled his hand back, and looked at the ice, and then became more bold; broke it, and examined it.

mal fluid, on which a disease in the solids must have had such an effect. This, I think, is giving too much to the solids, and too little to the fluids. When all the circumstances attending this fluid are fully considered, the idea, that it has life within itself, may not appear so difficult to comprehend; and indeed, when once conceived, I do not see how it is possible we should think it to be otherwise; when we consider, that every part is formed from the blood, that we grow out of it, and if it has not life previous to this operation, it must then acquire it in the act of forming; for we all give our assent to the existence of life in the parts, when once formed. Our ideas of life have been so much connected with organic bodies, and principally those endowed with visible action, that it requires a new bend to the mind, to make it conceive that these circumstances are not inseparable. It is within these fifty years only, that the callus of bones has been allowed to be alive*; but, I shall endeavour to show, that organization, and life, do not depend in the least on each other; that organization may arise out of living parts, and produce action, but that life can never rise out of, or depend on organization. An organ is a peculiar conformation of matter, (let that matter be what it may) to answer some purpose, the operation of which is mechanical; but, mere organization can do nothing, even in mechanics, it must still have something corresponding to a living principle; namely, some power. I had long suspected that the principle of life was not wholly confined to animals, or animal substances endowed with visible organization and spontaneous motion: I conceived that the same principle existed in animal substances devoid of apparent organization and motion, where there existed simply the power of preservation.

I was led to this notion about the years 55, or 56, when I was making drawings of the growth of the chick, in the process of incubation. I then observed, that whenever an egg was hatched, the yolk, (which is not diminished in the time of incubation) was always perfectly sweet to the very last; and that part of the albumen, which is not expended on the growth

* Dr. Hunter was the first who showed callus to be endowed with the principle of life, as much as bone.

of the animal, some days before hatching, was also sweet, although both were kept in a heat of 103° in the hen's egg for three weeks, and in the ducks for four. I observed, however, that if an egg did not hatch, it became putrid in nearly the same time with any other dead animal matter; an egg, therefore, must have the power of self-preservation, or in other words, the simple principle of life. To determine how far eggs would stand other tests, to prove a living principle, I made the following experiments* :

Having put a new laid egg into a cold about 0, which froze it, I then allowed it to thaw; from this process I imagined that the preserving powers of the egg might be destroyed.†

I next put this egg into the cold mixture, and with it one newly laid; the difference in freezing was seven minutes and a half; the fresh egg taking so much longer time in freezing.

A new laid egg was put into a cold atmosphere, fluctuating between 17° and 15°; it took above half an hour to freeze; but when thawed, and put into an atmosphere at 25°, viz. nine degrees warmer, it froze in half the time: this experiment was repeated several times with nearly the same result.

To determine the comparative heat between a living and a dead egg, and also to determine whether a living egg be subject to the same laws with the more imperfect animals, I made the following experiments: A fresh egg, and one which had been frozen, and thawed, were put into the cold mixture at 15°; the thawed one soon came down to 32° and began to swell and congeal; the fresh one sunk first to 29° and a half, and in twenty-five minutes after the dead one, it rose to 32°, and began to swell, and freeze. The result of this experiment upon the fresh egg was similar to what was observed in the like experiments upon frogs, eels, snails, &c. where life allowed the heat to be diminished two or three degrees below

* Philos. Transact. vol. 48, part i, page 28, 9; as also Observations on certain Parts of the Animal Œconomy, page 106, first edition.

† However, this was at first not so certain; but the result of the experiment proved it was so. To be more certain of killing a part by freezing it, I believe it should be froze very slowly, for simple freezing does not kill.

the freezing point, and then resisted all further decrease; but in both, the powers of life were expended by this exertion, and then the parts froze like any other dead animal matter.

This is not a principle peculiar to life, but is common in many other cases: it has been observed that water could be so circumstanced as to be brought below the freezing point, without freezing; but just as it began to freeze, it rose to 32°. In my experiments on the heat of vegetables, I observed that the sap of a tree would freeze at 32°, when taken out of the vessels of the tree; but I found the trees often so low as 15°, and the sap not frozen.

From these experiments, it appears that a fresh egg has the power of resisting heat, cold, and putrefaction, in a degree equal to many of the more imperfect animals, which exhibit exactly the same phœnomena under the same experiments; and it is more than probable that this power arises from the same principle in both. Similar experiments have been made on the blood: after a portion of blood had been frozen, and then thawed, it has again been frozen with a similar quantity of fresh blood, drawn from the same person, and that which had undergone this process froze again much faster than the fresh blood*.

As all the experiments I had made upon the freezing of animals, with a view to see whether it was possible to restore the actions of life, when they were again thawed, were made upon whole animals; and as I never saw life return by thawing, I wished to ascertain how far parts were, in this respect, similar to the whole; especially since it was asserted, and with some authority, that parts of a man may be frozen, and may afterwards recover; for this purpose I made the following experiments upon an animal of the same order with ourselves.

In January 1777, I mixed salt and ice, till the cold was about 0; and on the side of the vessel containing them was a hole, through which I introduced the ear of a rabbit. To carry off the heat as fast as possible, the ear was held between two flat pieces of iron, that sunk further into the mixture than the ear; the ear remained in the mixture nearly an hour,

* Vide Corrie on the Vitality of the Blood, page 45.

in which time the part projecting into the vessel became stiff; when taken out, and cut into, did not bleed; and a part being cut off by a pair of scissars, flew from between the blades like a hard chip. It soon after thawed, and began to bleed, and became very flaccid, so as to double upon itself, having lost its natural elasticity. When it had been out of the mixture nearly an hour, it became warm, and this warmth increased to a considerable degree; it also began to thicken, in consequence of inflammation; while the other ear continued of its usual temperature. On the day following, the frozen ear was still warm, and it retained its heat, and thickness, for many days after. About a week after this, the mixture in the vessel, being the same as in the former experiment, I introduced both ears of the same rabbit through the hole, and froze them both; the sound one however froze first, probably from its being considerably colder at the beginning, and probably too, from its powers not being so easily excited as those of the other: when withdrawn, they both soon thawed, and became warm; and the fresh ear thickened as the other had done before. These changes in the parts, do not always so quickly take place; for on repeating these experiments on the ear of another rabbit, till it became as hard as a board, it was longer in thawing, than in the former experiment; and much longer before it became warm; in about two hours, however, it became a little warm, and the following day it was very warm, and thickened. In the spring, 1776, I observed, that the cocks I had in the country had their combs smooth with an even edge, and not so broad as formerly, appearing as if nearly one half of them had been cut off. Having inquired into the cause of this, my servant told me, that it had been common in that winter, during the hard frost. He observed, that the combs had become in part dead, and, at last, had dropt off; and, that the comb of one cock, had dropped off entirely; this I did not see, as the cock by accident had burnt himself to death. I naturally imputed this effect to the combs having been frozen in the time of the severe frost, and having, consequently, lost their life by this operation. I endeavoured to try the solidity of this reasoning by experiment. I attempted to freeze the comb of a very large young cock, (being of a considerable breadth) but could only freeze the serrated edges, (which processes were fully half an inch long); for the comb itself being very thick and warm, resisted the cold. The frozen parts became white and hard; and when I cut off a little bit, it did not bleed, neither did the animal show any signs of pain. I next introduced into the cold mixture, one of the cock's wattles, which was very broad and thin; it froze very readily; and, upon thawing both the frozen parts of the comb and wattle, they became warm, but were of a purple colour, having lost the transparency which remained in the other parts of the comb, and in the other wattle: the wound in the comb now bled freely: both comb and wattle, recovered perfectly in about a month: the natural colour returned first, next to the sound parts, and increased gradually till the whole had acquired a healthy appearance. Finding that freezing both the solids, and the blood, did not destroy the life in either; nor the future actions depending on organization; and, that it also did not prevent the blood from recovering its fluidity, I conceived the life of every part of the body to be similar: what will affect, therefore, the life of any one part, will affect, also, that of another, though probably not in an equal degree; for in these experiments, the blood was under the same circumstances with the solids, and it retained its life; that is to say, when the solids and blood were frozen, and afterwards thawed, they were both capable of carrying on their functions.

The following experiments were made in the same manner, on living muscles, to see how far the contractions of living muscles, after having been frozen, correspond with the coagulation of the blood.

A muscle was removed from a frog's leg, with a portion of its tendon, was immediately placed between two pieces of lead, and exposed to a cold about ten degrees below 0. In five minutes it was taken out, when it was quite hard and white; on being gradually thawed, it became shorter, and thicker, than while frozen; but on being irritated, did not contract; yet if at all elongated by force, it contracted again, and the tendinous expansion covering the muscle was thrown into wrinkles: when the stimulus of death took place, it became still shorter.

From a straight muscle in a bullock's neck, a portion, three inches in length, was taken out immediately after the animal had been knocked down, and was exposed between two pieces of lead, to a cold below o, for fourteen minutes; at the end of this time it was found to be frozen exceedingly hard, was become white, and was now only two inches long: it was thawed gradually, and in about fix hours after thawing, it contracted so as only to measure one inch in length; but irritation did not produce any sensible motion in the fibres. Here then were the juices of muscles frozen, so as to prevent all power of contraction in their fibres, without destroying their life; for when thawed, they showed the same life which they had before: this is exactly similar to the freezing of blood too fast for its coagulation; which, when thawed, does afterwards coagulate, as it depends in each on the life of the part not being destroyed. I took notice in the history of the coagulation of the lymph, that heat of 120° excited this action in that fluid: to see how far muscular contraction was similar in this respect, I made the following experiment*.

As soon as the skin could be removed from a sheep that was newly killed, a square piece of muscle was cut off, which was afterwards divided into three pieces, in the direction of the fibres: each piece was put into a bason of water; the water in each bason being of different temperatures, viz. one 125°, about 27 degrees warmer than the animal; another 98°, the heat of the animal; and the third 55°, about 43 degrees colder than the animal. The muscle in the water heated to 125°, contracted directly, so as to be half an inch shorter than the other two, and was hard and stiff. The muscle in the water heated to 98°; after six minutes, began to contract and grow stiff: at the end of 20 minutes it was nearly, though not quite, as short and hard as the above. The muscle in the water heated to 55°; after 15 minutes, began to shorten, and grow hard: after 20 minutes, it was nearly as short, and as hard, as that in the water heated to 98°. At the end of 24 hours, they were all found to be of the same length and stiffness.

Here is also a similarity in the excitements of coagulation in the blood, and of contraction in muscles, both apparently depending on the same principle, namely, life†.

* Vide Philos. Trans. vol. 66, page 412. Paper on Drowning; alfo, Observations on certain Parts of the Animal Œconomy.

† The application of this principle in disease, I shall not at present take notice of.

If it should still be difficult to conceive how a body in a fluid state, whose parts are in constant motion upon one another, always shifting their situation with respect to themselves and the body; and which may lose a portion without affecting itself or the body, can possibly be alive, let us see if it is also difficult to conceive that a body may be so compounded, as to make a perfect whole of itself, having no parts dissimilar, and having the same properties in a small quantity, as in a great. Under those circumstances, the removing a portion is not taking away a constituent part, upon which the whole depends, or by which it is made a whole, but is only taking away a portion of the whole; the remaining portion being equal in quality to the whole, and in this respect is similar to the reducing a whole of any thing. This might be perfectly illustrated without straining the imagination, by considering the operation of union by the first intention. Union, by the first intention, is an immediate sympathetic harmony between divided parts, when brought simply into contact, which I call, contiguous sympathy. In this case, it is not necessary that the very same parts should oppose each other, else harmony, and consequently union, could never take place; it is simply necessary that the two parts be alive, and they might be shifted from one sort of a living creature to another for ever, without any injury to either, or without exciting irritation; and the whole would still be as perfect as ever. Neither can the motion of one living part upon another, affect the body, because all its parts are similar, and in harmony with each other. It is exactly the same with the blood, for neither its motion on itself, nor its motion on the body, can either affect it, or the body, since all the parts are similar among themselves. This is the case with all matter, where the property does not depend upon structure, or configuration, but upon the compound; for water, is still water, whether its parts are moving on each other, or at rest: and a small portion has the same property with the whole, and is in fact, a smaller whole. One of the great proofs that the blood possesses life, depends on the circumstances affecting its coagulation; and, at present, we are only to explain the principles upon which these are founded, which it will be in some degree necessary to recapitulate; but, perhaps, the strongest conviction on the mind will arise from the application of this principle to diseases, especially inflammation. While the blood is circulating, it is subject to certain laws to which it is not subject when not circulating. It has the power of preserving its fluidity, which was taken notice of when treating of its coagulation; or, in other words, the living principle in the body has the power of preserving it in this state. This is not produced by motion alone, for in the colder animals, when almost in a state of death during the winter, when their blood is moving with extreme slowness, and would appear to preserve simply animal life through the whole body, and keep up that dependence which exists between the blood, and the body already formed, the blood does not coagulate to accomplish these purposes. If the blood had not the living principle, it would be, in respect of the body, as an extraneous substance. Blood is not only alive itself, but is the support of life in every part of the body; for mortification immediately follows, when the circulation is cut off from any part, which is no more than death taking place in the part, from the want of the successive changes of fresh blood. This shows, that no part of the body is to be considered as a complete living substance, producing and continuing mere life, without the blood: so that blood makes one part of the compound; without which life would neither begin nor be continued. This circumstance, on its first appearance, would seem a little extraordinary, when we consider that a part, or the whole, are completely formed in themselves, and have their nerves going to them, which are supposed to give animal life; yet that perfect living part, or whole, shall die in a little time, by simply preventing the blood from moving through the vessels: under this idea, it is not clear to me, whether the blood dies sooner without the body, or the body without the blood. Life, then is preserved by the compound of the two, and an animal is not perfect without the blood: but this alone is not sufficient, for the blood itself must be kept alive; because, while it is supporting life in the solids, it is either losing its own, or is rendered incapable of supporting that of the body. To accomplish all this it must have motion, and that in a circle, as it is a continuance of the same blood which circulates, in which circle it is in one vieu supersaturated, as it were, with living powers, and in another is deficient, having parted with them while it visited the different parts of the body. Life is in some degree, in proportion to this motion, either stronger, or weaker; so that the motion of the blood may be reckoned, in some degree, a first moving power; and not only is the blood alive in itself, but seems to carry life every where; however, it is not simply the motion, but it is that which arises out of, or in consequence of the motion. Here then would appear to be three parts, viz. body, blood, and motion; which latter preserves the living union between the other two, or the life in both. These three make up a complete body, out of which arises a principle of self-motion; a motion totally spent upon the machine, or which may be said to move in a circle, for the support of the whole: for the body dies without the motion of the blood upon it; and the blood dies without the motion of the body upon it; perhaps, pretty nearly in equal times.

So far, I have considered the blood when compounded with the body and motion, in which we find it preserves its fluidity, and continues life in the body; but fluidity is only necessary for its motion to convey life, and the continuance of life is, probably, owing to its being coagulated, and becoming a solid; or at least, the support of the body is owing to this cause. For this, however, it requires rest, either by extravasation, or by being retained in the vessels till the utility of circulating is lost; or till it can answer some good purpose by its coagulation, as in mortification. Under any of these circumstances it becomes a solid body; for the moment it is at rest, it begins to form itself into a solid, and changes into this or that particular kind of substance, according to the stimulus of the surrounding parts which excites this coagulum into action, and makes it form within itself, blood, vessels, nerves, etc.

The coagulation is the first step towards its utility in the constitution, and this arises from its living principle; for if that principle be destroyed it does not coagulate at all, that is naturally; for I do not here speak of any chemical coagulation.

I shall now endeavour to prove that the coagulation of the coagulating lymph bears some analogy to the actions of muscles, which we know to depend upon life; and which affords one of the strongest proofs of the existence of this principle: and though the action of coagulation itself be not similar to the actions of muscles; yet, if we can show that they are governed by the same laws, we may reasonably conclude, that the first principle is the same in both. When I was treating of the coagulation of the lymph, I took notice that cold did not cause it, and supported the opinion by several experiments; at the same time I mentioned an experiment of Mr. Hewson, to prove the same thing, and which he conceived to be conclusive, but which does not appear to me in any way to affect his hypothesis. This experiment I had often made, but with another view, viz. to illustrate the living principle of the blood, which to me, it in some measure does, more especially when compared with similar experiments on living muscles.

As the coagulation of the blood is a natural process, and as all natural processes have their time of action, unless influenced by some exciting causes, and since cold is not a cause of the blood's coagulation, even when removed out of the circulation, the blood may be frozen much more quickly than it can coagulate, by which change its coagulating power is suspended. To prove this by experiment, I took a thin leaden vessel, with a flat bottom, of some width, and put it into a cold mixture below 0, and allowed as much blood to run from a vein into it, as covered its bottom. The blood froze immediately, and when thawed, became fluid, and coagulated, I believe, as soon as it would have done had it been frozen.

As the coagulation of the blood appears to be that process which may be compared with the action of life in the solids, we shall examine this property a little further, and see if this power of coagulation can be destroyed; if it can, we shall next inquire, if by the same means life is destroyed in the solids; and if the phænomena are nearly the same in both. The prevention of coagulation may be effected by electricity, and often is by lightning: it takes place in some deaths, and is produced in some of the natural operations of the body; all of which I shall now consider.

Animals killed by lightning, and also by electricity, have not their muscles contracted: this arises from death being instantaneously produced in the muscles, which therefore cannot be affected by any stimulus, nor consequently by the stimulus of death. In such cases the blood does not coagulate. Animals who are run very hard, and killed in such a state, or what produces still a greater effect, are run to death, have neither their muscles contracted, nor their blood coagulated; and in both respects the effect is in proportion to the cause*.

I had two deer run, till they dropped down and died; in neither did I find the muscles contracted, nor the blood coagulated.

In many kinds of death, we find that the muscles neither contract, nor the blood coagulate. In some cases the muscles will contract while the blood continues fluid, in some the contrary happens; and in others the blood will only coagulate to the consistence of cream.

Blows on the stomach kill immediately, and the muscles do not contract, nor does the blood coagulate. Such deaths as prevent the contraction of the muscles, or the coagulation of the blood, are, I believe, always sudden. Death from sudden gusts of passion, is of this kind; and in all these cases the body soon putrifies after death. In many diseases, if accurately attended to, we find this correspondence between muscles and blood; for where there is strong action going on, the muscles contract strongly after death, and the blood coagulates strongly.

It is unnecessary, I imagine, to relate particular instances of the effects of each of those causes: I need only mention that I have seen them all. In a natural evacuation of blood, viz. menstruation, it is neither similar to blood taken from a vein of the same person, nor to that which is extravasated by an accident in any other part of the body; but is a species of blood, changed, separated, or thrown off from the common mass, by an action of the vessels of the uterus, similar to that of secretion; by which action the blood loses the principle of coagulation, and I suppose life.

The natural deduction from all these facts, and observations, I think is perfectly easy; it is impossible to miss it.

This living principle in the blood, which I have endeavoured to show to be similar in its effects to the living principle in the solids, owes its existence to the same matter which belongs to the other, and is the materia

* This is the reason why hunted animals are commonly more tender than those that are shot.

vitæ diffusa, of which every part of an animal has its portion*: it is, as it were, diffused through the whole solids and fluids, making a necessary constituent part of them, and forming with them a perfect whole; giving to both the power of preservation, the susceptibility of impression; and, from their construction, giving them consequent reciprocal action. This is the matter which principally composes the brain; and where there is a brain, their must necessarily be parts to connect it with the rest of the body, which are the nerves; and as the use of the nerves is to continue, and therefore convey the impression or action of the one to the other, these parts of communication must necessarily be of the same matter; for any other matter could not continue the same action.

From this it may be underſtood, that nothing material is conveyed from the brain, by the nerves; nor vice versa, from the body to the brain: for if that was exactly the case, it would not be necessary for the nerves to be of the same materials with the brain; but as we find the nerves of the same materials, it is a presumptive proof, that they only continue the same action which they receive at either end.

The blood has as much the materia vitæ as the solids, which keeps up that harmony between them; and as every part endued with this principle has a sympathetic affection upon simple contact, so as to affect each other, (which I have called contiguous sympathy) so the blood, and the body, are capable of affecting, and being affected, by each other; which accounts for that reciprocal influence which each has on the other. The blood being evidently composed of the same materials with the body, being endued with the same living powers, but from its unsettled state, having no communication with the brain, is one of the strongest proofs of the materia vitæ making part of the composition of the body, independent of the nerves; and is similar, in this respect, to those inferior order of animals that have no nerves, where every other principle of the animal is diffused through the whole. This opinion cannot be proved by experiment; but I

* I consider that something similar to the materials of the brain is diffused through the body, and even contained in the blood; between this and the brain a communication is kept up by the nerves; I have, therefore, adopted terms explanatory of this theory; calling the brain, the materia vitæ coascervata; the nerves, the chordæ internunciæ; and that diffused through the body, the materia visæ diffusa.

think daily experience shows us, that the living principle in the body acts exactly upon the same principle with the brain. Every part of the body is susceptible of impression; and the materia vitæ, of every part, is thrown into action; which, if continued to the brain, produces sensation; but it may only be such as to throw the part of impression into such actions as it is capable of, according to the kind of impression; so does the brain or mind. The body loses impression by habit; so does the brain; it continues action from habit; so does the brain. The body, or parts of the body, have a recollection of former impressions, when impressed anew; so has the brain; but they have not spontaneous memory as the brain has, because the brain is a complete whole of itself, and therefore its actions are complete in themselves. The materia vitæ of the body being diffused, makes part of the body in which it exists and acts for this part, probably for this part alone. The whole, taken together, hardly makes a whole, so as to constitute what might be called an organ; the action of which is always for some other purpose than itself: but this is not the case with the brain. The brain is a mass of this matter, not diffused through any thing, for the purpose of that thing, but constituting an organ in itself, the actions of which are for other purposes, viz. receiving, by means of the nerves, the vast variety of actions in the diffused materia vitæ, which arise from impression, and habit, combining these and distinguishing from what part they come. The whole of these actions form the mind; and, according to the result, impress more or less of the materia vitæ of the body in return, producing in such parts consequent actions. The brain then depends upon the body for its impression, which is sensation; and the consequent action is that of the mind: and the body depends upon the consequence of this intelligence, or effect of this mind, called the will, to impress it to action; but such are not spent upon itself, but are for other purposes, and are called voluntary.

But mere composition of matter does not give life; for the dead body has all the composition it ever had: life is a property we do not understand: we can only see the necessary leading steps towards it.

If nerves, either of themselves, or from their connection with the brain, gave vitality to our solids, how should a solid continue life, after a nerve is destroyed? or still more, when paralytic? for the part continues to be nourished, although not to the full health of voluntary action; and this nourishment is the blood; for deprive it of the blood, and it mortifies.

The uterus, in the time of pregnancy, increases in substance and size, probably fifty times beyond what it naturally is, and this increase is made up of living animal matter, which is capable of action within itself. I think we may suppose its action more than double; for the action of every individual part of this viscus, at this period, is much increased, even beyond its increase of size; and yet we find that the nerves of this part, are not in the smallest degree increased. This shews that the nerves, and brain, have nothing to do with the actions of a part: while the vessels, whose uses are evident, increase in proportion to the increased size: if the same had taken place with the nerves, we should have reasoned from analogy. It is probably impossible to say where the living principle first begins in the blood: whether in the chyle itself, or not till that fluid mixes with the other blood, and receives its influence from the lungs. I am, however, rather inclined to think, that the chyle is itself alive; for we find it coagulates when extravasated; it has the same powers of separation with the blood; and it acquires its power of action in the lungs as the venal blood does. I conceive this to be similar to the influence of the male and female on an egg, which requires air, and a due warmth, to produce the principle of action in it; and is somewhat similar to the venal blood coming to the lungs to receive new powers, which it communicates to the body. To endeavour to prove whether the chyle had the power of action in it, similar to the blood, I made the following experiment:

I opened the abdomen of a dog, and punctured one of the largest lacteals at the root of the mesentery, out of which flowed a good deal of chyle: I then allowed this part to come in contact with another part of the mesentery, to see if they would unite, as extravasated blood does; but they did not; however, this experiment, though performed twice, is not conclusive; for similar experiments with blood might not have succeeded.

From what has been said with regard to the blood, that it becomes a solid, when extravasated in the body, we must suppose that some material purpose is answered by it; for if the blood could only have been of use in a fluid state, its solidity would not have been so much an object with nature. It appears to me to be evident that its fluidity is only intended for its motion; and its motion is only to convey life, and living materials, to every part of the body. These materials when carried, become solid; so that solidity is the ultimate end of the blood, as blood.

The blood when it naturally increases the body, or repairs a part, may be said to be extravasated, although not commonly so considered; what is usually understood to be extravasation, is when it arises from accident of some kind, or disease in the vessel, and of course is obvious to the sight; but even this extravasation is of use by the blood coagulating, although too often it is in too large a quantity. Accident does not calculate the size of the vessel ruptured, to be just equal to the effect wanted by the rupture: but nature has made a wise provision for this overplus.

As extravasation arises from a rupture of a vessel, it is of service in the reunion of that vessel: if there are more solids ruptured than a vessel, as in a fracture of a bone, it becomes a bond of union to those parts; and this may be called, union by the first intention: but the union is not that of the two parts to each other, but the union of the broken parts to the intermediate extravasated blood; so that it is the blood and parts uniting, which constitutes the union by the first intention.

This blood, so extravasated, forms either vessels in itself, or vessels shoot out from the original surface of contact into it, forming an elongation of themselves, as we have reason to suppose they do in granulations. I have reason, however, to believe that the coagulum has the power, under necessary circumstances, to form vessels in, and of itself; for I have already observed, that coagulation, although not organic, is still of a peculiar form, structure, or arrangement, so as to take on necessary action, which I should suppose is somewhat similar to muscular action. I think I have been able to inject what I suspected to be the beginning of a vascular formation in a coagulum, when it could not derive any vessels from the surrounding parts. By injecting the crural artery of a stump, above the knee, where there was a small piramidal coagulum, I have filled this coagulum with my injection, as if it had been cellular; but there was no regular structure of vessels. When I compare this appearance, with that of many violent inflammations on surfaces where the red blood is extravasated, forming as it were specks of extravasation like stars; and which, when injected, produce the same appearance with what I have described in the injection of the coagulum: when I compare these again with the progress of vascularity in the membranes of the chick, one can perceive where a zone of specks beyond the surface of regular vessels close to the chick, similar to the above extravasation, and which in a few hours become vascular, I conceive that these parts have a power of forming vessels within themselves, all of them acting upon the same principle. But where this coagulum can form an immediate union with the surrounding parts, it either receives vessels at this surface, or forms vessels first at this union, which communicate with those of the surrounding surface; and they either shoot deeper, and deeper, or form vessels deeper, and deeper, in the coagulum, till the whole meets in its centre: if it is by the first mode, viz. the shooting of vessels from the surrounding surfaces into the coagulum, then it may be the ruptured vessels in cases of accident, which shoot into the coagulum, and where a coagulum, or extravasation of coagulable lymph is thrown in between two surfaces only contiguous, there it may be the exhaling vessels of those surfaces which now become the vessels of the part. In whatever way they meet in the centre, they instantly embrace, unite, or inosculate: now this is all perfectly, and easily conceived, among living parts, but not otherwise.

As the coagulum, whether wholly blood, or coagulating lymph alone, has the materia vitæ in its composition, which is the cause of all the above actions, it soon opens a communication with the mind, forming within itself, nerves. Nerves have not the power of forming themselves into longer chords, as we conceive vessels to have; for we know, that in the union of a cut nerve, where a piece has been taken out, it is by means of the blood forming a union of coagulum; and, that the coagulum gradually becomes more and more of the texture, and has, of course, more and more the use of a nerve, somewhat similar to the gradual change of blood into a bone, in fractures.

It would appear then, that the blood is subservient to two purposes in an animal: the one is the support of the matter of the body when formed; the other is the support of the different actions of the body.

VII. SOME UNCONNECTED EXPERIMENTS RESPECTING THE BLOOD.

The following experiments have rather been imagined than fully executed, and the subject is rather broached and touched upon than prosecuted; but as I have not time, at present, to go through with the experiments, so as to arrive at some general result, I thought it better to bring forward, what, in my opinion, should be done, than to omit the subject altogether*.

I wished to see if blood that coagulated with an inflammatory crust putrified later than that which coagulated without it; for I conceived that the strength of coagulation was something similar to the strength of contraction in a muscle, resisting putrifaction. For this purpose I ordered the following experiments to be made:

Experiment I. Four ounces of blood were taken from the arm, which, after coagulation, had the inflammatory crust upon its surface, and was also cupped.

Experiment II. On the same day, four ounces of blood were taken from another person's arm, which, on coagulating, shewed no inflammatory crust on its surface. Both these quantities of blood were kept, in order to see which would resist putrifaction longeſt.

By the fourth day, that without buff was putrified; but the blood with the inflammatory crust did not putrify till the seventh day.

In these two experiments it would appear that the inflammatory blood preserved its sweetness longest; but, from a repetition of these experiments, it did not appear upon the whole that there was much difference.

To see whether the blood in a young person or an old one become soonest putrid, I desired that the following trials should be made:

June 24th. Some blood was taken from a woman twenty years of

* Many of these experiments were repeated, by my desire, by Dr. Physic, now of Philadelphia, when he acted as house-surgeon at St. George's Hospital, whose accuracy I could depend upon.

age, and its surface, after coagulation, was covered with an inflammatory cruſt.

On the same day, some blood was taken from a woman, aged sixty, when the crassamentum was also covered with an inflammatory crust.

These quantities of blood were set by.

The blood from the old woman putrified in two days. That from the young woman kept quite sweet till the fifth day, when it began to smell disagreeably; in this state it continued two days more, and then emitted the common odour of putrid blood.

Several experiments were made in the course of the summer, of a similar nature with the last, in all which it appeared that the blood from young people, kept longer sweet than that which was taken from the old.

Experiment III. In October, 1790, when the weather was cold, some blood was taken from two men, one of whom was seventy-five years of age, and the other eighty-three, about six ounces from each. The blood in each kept sweet till the fifth day; but, on the sixth, both quantities smelt equally putrid, which uniformity accords with the above experiment.

To see if recent blood or coagulated blood loſt their heat soonest.

Experiment IV. Four ounces of blood, after coagulation, was heated till it raised the mercury of a thermometer, placed in the middle of the coagulum to the 98th degree. The thermometer was put into a similar quantity of blood, immediately after it was taken from the vein, and the mercury ſtood at 90°. These were placed by each other, and the thermometer put alternately into each, to observe how they parted with their heat.

Coagulated blood.................98°	Recent blood..................................90°
Ditto, after two minutes.........97°	Ditto, after two minutes.................89°
Ditto, after four minutes more 93°	Ditto, after four minutes more..........88°
Ditto, after two ditto more....92°	Ditto, after two ditto more coagulated 87°
Ditto, after two ditto more....91°	Ditto, after two ditto more...............86°

This experiment was not accurately made, for the two bloods should have been of the same temperature, because the warmer any body is, the faſter it will lose its heat to any neighbouring colder body; yet I believe that the coagulated blood loſt its heat faſter than the fluid blood.

To see whether a stimulus can be applied to the blood, so as to make it coagulate faster than it does naturally, I deſired the following experiment to be made:

Three ounces of blood were taken from a boy about ten years of age, and immediately after, the cup was put into water heated to 150°. A similar quantity was taken in another cup from the same boy, at the same time, which was put into water heated only to 48°. The first coagulated completely in five minutes, but the latter remained quite fluid for twenty minutes, and then began to coagulate, but was not completely coagulated for five minutes more. When looking at each portion of blood an hour afterwards, it appeared that the blood which coagulated in the warmest water, had the greatest proportion of serum, and the leaſt of crassamentum; but by next morning, the serum in each was equal in quantity, and the crassamentum of equal size.

This experiment shews that heat above the natural standard, acts as a stimulus upon the blood, and makes it coagulate considerably sooner than cold does, though not more firmly. This heat did not aċt as heat upon the blood, but only as the stimulus; for heat acting as heat would also have coagulated the serum, which was not the case.

This experiment, or a similar one, is brought forwards as one of the proofs of the living principles of the blood, where it is contrasted with a similar experiment on living muſcles.

To see whether blood, when mixed with different substances in strong solution, and which appeared to prevent coagulation, would, when diluted with water, admit of coagulation.

In December, half an ounce of blood, immediately after it was taken from the arm, was mixed with one pound of water. This was intended as a standard to judge of the others.

More blood was taken from the same person at the same time, to which a strong solution of Glauber's salts was added; this altered its colour to a florid red, and was found to prevent it from coagulating. A strong solution of Glauber's salts, therefore, has the power of preventing the coagulation of the blood. Ten minutes after this mixture, half an ounce of it was mixed with one pound of water; half an hour after, another half ounce was mixed with one pound of water; at the end of an hour, the same was done, and also after two hours; all these were allowed to stand twenty-four hours, when the pure blood and water had deposited a considerable dark coloured sediment, and a light coloured blood was suspended, which had begun to subside, leaving the fluid above perfectly transparent, and of a beautiful red colour. The different portions of blood which had been first mixed with the salt, and afterwards with water, had the cloud exactly like that of the pure blood, but there was no sediment whatever at the bottom of the vessel: this cloud gradually subsided, and left the fluid above of a beautiful red colour, and also quite transparent. At this time, (viz. twenty-four hours after the mixture of the salt with the blood) another half ounce was mixed with one pound of water, and next day the appearances were exactly similar to what have been already described.

The sediment in the pure blood was most probably the coagulating lymph; and as there was none in the others, it is most likely that the lymph in them did not now coagulate.

As medicines, when taken into the circulation, whether by the stomach or by the skin, produce considerable effects on the constitution, I wished to know what effect such substances would have upon the blood, with regard to the act and power of its coagulation.

Two ounces of blood were received from the arm into a vessel, as a standard of natural coagulation.

Two ounces more were taken in another vessel, to which one ounce of water was added. The intention of this addition was to put this blood in the same circumstances with blood in other comparative trials, respecting water, so that the difference, if there was any, must belong to the substance mixed with the blood, independent of the water.

Two ounces more blood were received in another vessel, to which was added one ounce of the decoction of bark.

These different quantities were taken from one person, one after the other in the same order in which they are here set down. After six minutes, the blood mixed with water was quite coagulated: after nine minutes, that mixed with the decoction of Peruvian-bark formed a loose coagulum: after twelve minutes, the blood firſt drawn coagulated: the coagula of the firſt and second drawn blood were equally firm; the water in the second having been squeesed out along with the serum; but that mixed with the decoction of bark was much less so. It appears from these experiments, that water rather hastened coagulation, but made it neither firmer nor looser in the texture.

In the following experiments, the blood was firſt all received into one vessel, and stirred before it was mixed with the different substances.

The intention of this was, that the three portions of blood might all be exactly under the same circumstances.

Two ounce were poured into a vessel as a standard of natural coagulation.

Two ounces more of blood were poured into another vessel, to which was added two ounces of water, as in the former experiment. Two ounces more were mixed with two ounces of the decoction of bark: after twelve minutes the two first were coagulated, and the coagula were equally firm: after fourteen minutes, that with the decoction of bark coagulated, but the coagulum was very loose. Upon comparing the three coagula next day, that which had the decoction of bark mixed with it, was by much the least firm.

This experiment was repeated, and the result was nearly the same; and it shews, that even putting equal parts of water and blood together, did not alter the time, or the firmness of coagulation; but that the decoction of bark evidently did.

Some blood was taken from the arm into a bason, stirred, and then mixed with different infusions, as follows:

Two ounces were mixed with the same quantity of the infusion of columba-root.

Two ounces, with the same quantity of the infusion of gentian; two more, with two ounces of the watery solution of opium; and two ounces were kept in a vessel by themselves.

The blood which had been mixed with the bitter infusions, and the simple blood, all coagulated at the same time, viz. in six minutes; but that which had been mixed with the infusion of gentian was firmer than with the infusion of columba-root, but was not more firm than the coagulum of the simple blood. The blood which had been mixed with the solution of opium did not coagulate for twelve minutes, and then the coagulum was very loose.

This experiment, with the opium, was repeated, and the result was exactly the same.

Of extraneous matter in the blood.

Whatever is dissolved in the blood must be only diffused through it, not chemically combined with it, otherwise the nature of the blood itself would be altered, and the effect of medicine destroyed. The blood can receive and retain extraneous matter, capable of destroying the solids, by stimulating to action so as to destroy them.

Extraneous matter in the blood is capable of altering the chemical properties of the solids in those who work in lead, as is evident in the following case:

Morgan, a house-painter, who had been paralytic in his hands and legs for a considerable time, was thrown down, and had his thigh-bone broken just below the little trochanter. The upper end of the inferior portion had passed over the outside of the other, and moved with the knee, so that the end of the lower bone was taken for the great trochanter; but I discovered the fracture, by extending the leg, and got the portions of bone in their places, and bound up the limb with a wroller. It went on well for near a fortnight, only his hands swelling at times, which gave way to fomentations; in the third week he grew very ill, became low, had a kind of lethargy, a great deal of blood came out of his mouth, he sunk still lower, and died about three weeks after the accident.

On examining the body after death, the muscles, particularly those of the arms, had lost their natural colour; but instead of being ligamentous and semitransparent, as happens in common paralysis, they were opaque, resembling exactly, in appearance, parts steeped in a solution of Goulard's extract. From this case it appears the lead had been evidently carried along with the blood, even into the muscles themselves.

CHAPTER II.

OF THE VASCULAR SYSTEM.

I. GENERAL OBSERVATIONS ON MUSCULAR CONTRACTION AND ELASTICITY.

It is not my present intention to explain all the circumstances connected with muscular contraction and relaxation, nor that other power of action introduced into an animal body, called elasticity. I propose only to state a few of the facts which throw some light upon the vascular system, by shewing that there is in vessels a power of muscular action; and that the co-operation of elasticity is also necessary to their function; these may likewise assist in explaining the manner in which the two powers are combined; I may, however, occasionally be led to mention causes and effects, which cannot be immediately considered as applicable to the vessels themselves, though they will render many of the phenomena in the vascular systemmore easy to be understood.

The common action of a muscle, from which its immediate use is derived, is its contraction; and the effect produced by it, is that of bringing the origin and insertion, or the parts which it is fitted, to move nearer each other*; which is universally the case whether the muscle is straight, hollow, or circular. It is likewise necessary that a muscle should relax, or be capable of relaxation; a condition which allows it to be stretched, by permitting the parts acted upon to recede from each other. Muscles, in common, probably, with every other part of the body, have a power of adapting themselves to the necessary distance between origin and insertion, in case an alteration has taken place in the natural distance; and I have reason to

* I do not here consider the circumflex tendons; for, by the origin and insection, I mean the muscular ends of the fibres.

believe, that under certain circumstances, they have a power of becoming longer, almost immediately, than they are in the natural relaxed, or even the natural elongated state of their fibres. This opinion will be best illuftrated in inflammation.

Muscular contraction has been generally supposed to arise from some impression, which is commonly called, a stimulus; I doubt, however, of an impression being always necessary; and I believe that in many cases the cessation of an accustomed impulse may become the cause of contraction in a muscle. The sphincter iridis of the eye contracts when there is too much light; but the radii contract when there is little or no light. I can even conceive that a cessation of action requires its stimulus to produce it, which may be called, the stimulus of cessation; for relaxation is not the state into which a muscle will naturally fall upon the removal of a continued stimulus; a muscle remaining contracted after absolute death, when the stimulus of relaxation cannot be applied; so that a muscle can as little relax after death, as it can contract. If a stone is raised, and the raising power removed, it falls; but it would not fall if not acted upon. When it has fallen it lies at rest, but so it would have done, when raised, if gravitation would have allowed it. The stone is passive and must be acted upon. Whatever becomes a stimulus to one set of muscles, becomes a cause of relaxation to those which act in a contrary direction*; and whatever becomes a stimulus to one part of a muscular canal, where a succession of actions is to take place, becomes also a cause of relaxation in the part beyond it, as in an intestine.

Muscular contraction, in some of the involuntary muscles, does not constantly arise from immediate stimuli, as in the sphincters; for the sphincter ani contracts whenever the stimulus of relaxation is removed, which may be said to produce the stimulus for contraction.

Muscular actions have been divided into the voluntary, involuntary, and mixed, which is only dividing them according to the different natural modes of stimuli, or causes of their action: to these a fourth might be

* This might be called a sympathetic stimulus, and is that which regulates the actions of the whole machine; and which I have called, in another place, the stimulus of necessity.

added, where the actions are in consequence of accidental stimuli or impressions, to which both the voluntary and involuntary muscles are subject, viz. such as arise from affections of the mind*, or are the immediate effects of violence.

The involuntary contraction should be first considered, as the more necessary operations of the machine are carried on by it; for the machine could even exist independent of any voluntary contraction; but it could not go on if left wholly to the voluntary contraction of the muscles, unless we were endued with innate ideas capable of producing a will. This involuntary contraction is very extensive in the system, and is employed in carrying on a number of operations, of which the circulation is one; and which may be said to be, in a great measure, the œconomy of the animal within itself.

The mixed kind of contraction is most to our present purpose, and is of two kinds, though it has been in general supposed to be of one kind only, and that belonging solely to the muscles of respiration, as being in them the most conspicuous. But in fact, we find another mode of involuntary actions in other muscles of the body where it answers very useful purposes. In these the involuntary contraction may be reckoned the natural state; and it is a kind of permanent contraction, these muscles only relaxing occasionally; by which means parts are sustained or supported; the voluntary contraction of such muscles is also only occasional. All sphincter muscles in some degree partake of this power, and therefore should be called, muscles with power of occasional relaxation. For although many circular muscles may not have these mixed contractions, as the orbicularis palpebrarum; yet that muscle has a disposition to contract peculiar to itself. Its relaxation is to be reckoned of the active kind, which may be called, the relaxation of watchfulness, and it is when tired of this species of action that it contracts; which, on the contrary, may be called, the contraction of ſleep: or it may be considered as an elongator muscle to the levator palpebræ, with a disposition to remain relaxed while that muscle is contracted; but contracting when the elevator is tired. The natural contraction of the orbicularis muscle is involuntary; the relaxation, both natural and occasi-

* Mind and will are often blended together, but will has nothing to do here.

onal is involuntary; but it has likewise a voluntary contraction and relaxation, which can be made to exceed the involuntary, resembling what is inherent in all the sphincters.

Sphincter muscles, as those of the anus and urethra, and probably the expulsatores, seminis, and crura of the diaphragm, have both a voluntary and involuntary contraction. In the two sphincters of the anus and urethra this is evident; and the involuntary contraction in these muscles I have called, sphintoric. The sphincter ani possesses it to a degree just sufficient to resist the pressure of the air and fœces, while the parts above are inactive, preventing the escape of these, till they give the stimulus for expulsion, and then an involuntary relaxation naturally takes place, similar to what happens in muscular canals.

The sphinctoric contraction resembles, in its effects, that produced by elastic ligaments in other parts of the body, which action may be called, contractile elasticity, as bringing back the parts to a certain necessary state, and retaining them there. But elasticity would not here have answered all the purposes, since, as it has no relaxing power, more force would have been required to overcome its resistance in the expulsion of the fœces than the gut above could have been able to exert. But the sustaining power being muscular contraction, a relaxation or cessation of that contraction during the time of expulsion, leaves nothing for the fœces to do; but, by means of the action above, simply to dilate the relaxed parts. There is, likewise, in these muscles, a still further power of contraction, which is produced by the will, and for the purpose of giving on particular occasions greater force than what is commonly necessary. The voluntary action of these muscles is, therefore, we find more powerful than the involuntary; but upon the whole I think we have reason to suppose, that the involuntary muscles are much stronger than the voluntary. Can we believe that so thin a muscle as the colon of a horse could squeeze out its contents, consisting of a column of dung about eight inches diameter, if those involuntary muscles had no more strength than the muscles of an extremity? When we see the bladder of urine throwing out its contents through a large tube, to a distance perhaps two yards beyond its extreme end, we must suppose a much greater force exerted than could belong to any such quantity of voluntary muscle. For I believe that by grasping the bladder with both hands we could not make the water flow out to an equal distance. It may be here observed, that the power of involuntary contraction commonly remains longer than that of the voluntary, though I believe not in all instances; which difference produces a greater variety in the former, than in the latter. Thus the muscular action of the arteries is longer retained than that of the heart.

Elasticity is a property of matter (whether animal or not) which renders it capable of restoring itself to its natural position, after having been acted upon by some mechanical power, but having no power of action arising out of itself; this is exactly the reverse of muscular contraction. Muscles, as has been already observed, have the power of contraction and of cessation, which last is called, relaxation; but not the power of elongation, which would be an act of restoration, such as exists in elasticity. A muscle, therefore, has the power of action within itself, by which it produces its effects, but is obliged to other powers for its restoration, so as to be able to act again; whereas elasticity is obliged to other powers to alter the position of the parts, so as to require recovery or restoration; but this it is capable of doing itself, and by this power it produces its effects, becoming a cause of motion in other bodies. A body possessed of this property, when brought from the state of rest, is always endeavouring to arrive at this state, which it also endeavours to preserve; and it is capable of supporting itself in this state in proportion to the degree of elasticity which may belong to it.

The action of elasticity is continual, and its immediate effects are produced whenever the resistance is removed; by which it may be distinguished from other powers. Elastic matter can either be extended beyond its state of rest, or brought within it. Thus a spring being bent, its cancave side is brought within this state, and the convex side is carried beyond it: when under these circumstances it is left to itself, both sides endeavour to restore themselves. The power of an elastic body is permanent, always acting with a force proportioned to the power applied, and therefore reacts as the body is elongated, bent, or compressed; but this is very different from the action of a muscle, as this last may act with its full force, or only part, or not at all, according to circumstances. Elasticity*, which has the power of resisting the action of other parts, as well as of restoring the substance endowed with it, when forcibly removed from a state of rest, is introduced into an animal body, in order to co-operate in many respects with the muscles, and so to act as to restore or fit them for a new action, becoming in many cases antagonists to the muscles, which will be described when we speak of the combination of the two.

II. GENERAL OBSERVATIONS ON THE ELONGATION OF RELAXED MUSCLES.

Every thing in nature that has the power of action has two kinds of motion exerted alternately, and a state of rest. Of the former the one may be called, the active; the other, the state of recovery. In a muscle the active is the state of contraction; the other, the state of relaxation: the state of rest is merely the state of inaction. The contractile state of a muscle, as well as the relaxed, arises from a power inherent in itself; but the recovery, or elongation, must depend on some other power.

Simple relaxation of a contracted muscle is not sufficient to enable it to produce another requisite effect; it is, therefore, necessary that there should be an elongater equal to the quantity of contraction intended to be produced: and as no muscle has the power of extending itself into what I shall call, the state of recovery, an elongater of some kind or other is required, to enable every muscle to produce its effect, by a renewal of contraction. This, although in some respects similar to the winding up of a clock, in others differs materially from it. For the muscle being

* It is to be observed, that elasticity in animals does not, like muscular contraction, depend on life; an elastic body possessing that quality as perfectly after death as before. Elasticity admits of two actions, a contraction, when the substance is extended beyond the natural state, and an extension, when it is compressed within it; both these is possessed by the elastic parts which compose the vascular system; whereas, muscles have but one action, or at least, but one which can produce an immediate effect, and that is contraction.

capable of relaxing itself, there is no resistance to overcome, except the vis inertiæ and friction of the matter to be removed: whereas in the clock, the power that winds it up must be greater than the spring or weight, to be capable of overcoming the gravity of the weight, or the elasticity of the spring, together with the vis inertiæ.

The elongation of muscles is not the immediate cause of their relaxation, but the effect of a contrary and necessary motion of the elongaters, by which they are recovered so as to be enabled to renew their action with effect.

The elongaters, or powers which enable muscles to recover themselves, are not always muscular; for when simple elongation is required, it is effected by other means, as elasticity, which is the case, in part, in the blood-vessels; and sometimes by motion in matter foreign to the body, yet propelled either by muscles or elasticity, as is also the case in blood-vessels. The elongaters may be divided into three kinds, with their compounds.

The first kind is muscular, and these may either act immediately, or they may act on some other substance, by which action that substance becomes the immediate cause of the elongation. Those which act immediately, and become elongators to other muscles by their contraction are in turn elongated by the contraction of these very muscles, to which they served as elongaters; the two sets thus becoming reciprocally elongaters to each other. This is the case with the greater part of the muscles in the body, and in some muscles, as the occipito, frontalis, two different portions are reciprocally elongators; yet these may strictly be considered as two muscles; for although there is no interruption, in the tendon they move the same part in two opposite directions, like distinct antagonist muscles.

These reciprocal elongaters, by their mutual action on each other, bring out a middle state between the extremes of contraction and elongation, which is the state of ease, or tone, in both. This appears not to be so much required for the ease of the relaxed muscle, as for that of the part moved; either extreme of motion leaving the muscle in an uneasy state. We find, therefore, that as soon as any set of muscles cease to act, the elongaters which were stretched during their action, are stimulated either by this cessation, or by the uneasy state into which the parts moved have been put, they act to bring these parts into a state the furthest removed from the extremes which were uneasy, and by which the stimulus arising from both is equally balanced.

This, however, can only happen in such parts of the body as are furnished with muscular elongaters; where these are wanting, the muscles of the part having but one office, their state of ease is that of simple relaxation, as they can have no middle state from the action of antagonists, but such are commonly muscular parts, or so constructed as not to be thrown into an uneasy position by the action of their muscles. I suppose, however, that an elongated state in a muscle is an uneasy state; a muscle, therefore, that is stretched, although in a relaxed state, is uneasy and will contract a certain length, to what is probably the middle state.

It is still necessary that such parts as are simply muscular, and having no antagonist muscles appropriated immediately for such purposes should have their muscles elongated; this is still performed by muscles, but in a secondary way; for instance, by a succession of actions in different parts, each performing the same effect, the last action becoming an antagonist to the succeeding.

This second mode of elongation takes place in all the muscles which assist in forming canals. In them the muscles, if once contracted, cannot be elongated, or the part dilated again; but by the contraction of some other part of the canal, propelling its contents into the relaxed part, and by that means serving as an elongater. This, in some instances, goes on in regular succession, as we know the dilatation of the fauces to be occasioned by the action of the mouth and tongue; that of the œsophagus, by the contraction of the fauces; of the stomach, by that of the œsophagus; the upper part of the intestines by the stomach, and so on; the successive contractions of the last dilated parts pushing on the contents, and in that manner becoming elongaters of the muscles next in succession of action. A first propelling power, such as a heart, could in these instances have had but little effect, and would even have been unnecessary; for as there must be a succession of contractions and dilatations, its power would soon have been lost. This mode of propelling substances through canals, as stated above, would probably have been too slow for the circulation in many animals; but I believe is very much the case in others.

The elongation of the muscles of the bladder, from the distention of urine, becomes the means by which they are excited to recover themselves so as to renew their action, and may be referred to the same general head.

The third kind is by means of elastic substances, which render the combined actions produced by muscular contraction and elasticity more complicated. Elasticity we find to be introduced both as an assistant to the contraction of the mussels, and as an antagonist or elongater; the natural position being that which is produced by the elasticity. Thus we see elasticity combined with muscular action assisting in the contraction of muscles on one side, and likewise performing the office of elongaters or antagonists on the opposite, by bringing parts, which have been moved by muscles, back into their natural position. Such parts too as have yielded to the action of some other power, as gravitation, are brought back into what may be called, a natural state, and are retained there by elasticity, till that power is again overcome by another, as in the necks of some animals. We may hence see that the application of those powers is twofold; one, where the muscles and elastic substances assist each other; the second, where they are antagonists, the elastic being neither assisted by the muscular parts, nor the muscular by the elastic: for many parts of the body are so constructed, as to admit of but one kind of muscular action, the other action arising from elasticity alone; it being necessary that such parts should have a determined or middle state, though not intended as a state of ease.

Of this kind are the blood-vessels, trachea, bronchia, the ears of animals, etc. in which therefore elasticity is introduced to procure that determined state, and is chiefly employed where the middle state is much limited. For it is to be observed, that the middle state, when produced by muscular action, has not commonly a determined point of rest, but admits of considerable latitude between the two extremes; except in the sphincters. Where it is produced by elasticity, it is always more determined, provided the elasticity has sufficient power to overcome the natural or accidental resistance; and where that is the case, we must suppose that a state in some degree determined was necessary to such parts. But where the elastic power is not sufficient to overcome the natural, or accidental resistance, then it is assisted by the muscular, which forms one of the compounds of the three modes of elongation; instances of which we have in many joints.

The relaxed state of a muscle would appear in general to be the most natural; but to this there are exceptions; a degree of contraction appearing natural to some muscles.

The face, for instance, is a part where the action of the muscles on one side influences the position of the parts on the other side; a circumstance, perhaps, peculiar to the face; here, therefore, the muscles bring and keep the skin in one position, till altered by an increased action in some other muscle; and when this increased action ceases, the constant and natural contraction of the whole (similar to that of the sphincter) immediately takes place*.

Sphincter muscles are the most remarkable instances of this, being always above three parts contracted†.

The constant and regular degree of contraction in those sphincter muscles, serves the purposes of elasticity, and may have superior advantages; as we know that they have a power of relaxing when their elongaters act, which no elastic substance can have. Hence, we see, that where a continued action only is wanted, there is elasticity: where an alternate action and relaxation, there is the action of muscles; where only an occasional relaxing power is required, there are muscles under certain restrictions; and where a constant power of contraction is necessary, but which is occasionally to be overcome by muscles, there are introduced both elasticity and muscular powers co-operating with each other in their actions.

Where constant action is not necessary, muscles alone are employed, as

* As a proof that this is muscular contraction, and not elasticity, we find that the face in a dead body does not keep its natural form, nor resume it when lost.

† The parts supp'ied with sphincters, do not contract after being dilated in the dead body, which they certainly would do if the contraction in the living body had arisen from elasticity.

in the greater number of moving parts in most animals; and where any position is required to be constant, and the motion only occasional, from being seldom wanted, there elasticity alone is employed for the purpose of constant position, and muscles for the occasional action*.

When a position is to be pretty constant, yet elastic substances are not employed, we have muscles endowed with the power of constant contraction to a certain degree, but capable of either relaxation, or greater contraction, as in the sphincters.

We find, therefore, that in many parts of an animal body fitted for motion, a tolerably constant position is necessary, at the same time that an occasional self-moving power is also wanted, to serve as a sort of auxiliary to the performance of the necessary action. For such occasional actions, muscles, assisted by elastic substances, are employed; the elastic power easing the muscles in the fixed position, and the muscular giving the increased occasional action; and in other parts of the body, where a more constant action was wanted, and could not be completely obtained by elasticity, there are to be found muscles endowed with the property of both permanent and occasional contraction.

The elastic power is very remarkable in such parts of an animal body as require a constant effort to support them; elasticity being introduced to act against the power of gravitation, as in the necks of animals whose heads are held horizontally, or beyond the centre of gravity. This is effected by an elastic ligament, and is strikingly illustrated in the camel, whose neck is long. Between the vertebræ of the neck and backs of fowls, are placed elastic ligaments for the same purpose; the wings of birds and bats are also furnished with them, by which means they are retained close to the body when not used in flying. On the abdomen of most quadrupeds are likewise to be found elastic ligaments, especially on that of the elephant, which is a constant support to the parts in their horizontal position, and even the

* Some bivalves (as the oyster) have a strong muscle passing between the shells for closing them occasionally; but for opening them no muscles are made use of, as this is performed by an elastic ligament in the joint of the two shells, which is squeezed, when shut, by the contraction of the muscle; and when the muscle ceases to contract, the elasticity of the ligament expands it, so that the shell is opened.

cellular membrane of the elephant has a degree of elasticity much above what is generally met with in cellular membranes. Hence there is less expence of muscular contraction in such parts. The trachea and its branches are instances of these two powers; being composed of cartilages, muscles, and membranes, the proportion of muscular substance, however, is small, the muscles which act principally upon this part being those of respiration; but the tendency of the action of the proper muscles of the trachea is to compress and alter the size of the trachea; this is counteracted by the elasticity of the cartilages, and membranes, exerting a constant and regular endeavour to keep it of one certain size.

The external ears of many animals furnish us with another instance of the joint application of these two powers; for being chiefly composed of elastic cartilage, they retain a general uniformity of shape, although that is capable of being altered occasionally by the action of muscles.

It is however to be observed, that in all cases where these two powers are joined, the muscular, as it can always act in opposition to the elastic, must be the strongest and capable of being carried further than the other; it therefore must always be proportionably stronger than it otherwise need to have been.

Parts in which these two powers are employed, are capable of being in either of three states, the natural, the stretched, and the contracted; but in some parts the natural state may coincide either with the stretched, or contracted, and consequently such parts are only capable of being in two states. The natural state is produced by the elastic power simply, the contracted is the effect of the muscular power alone, and the stretched is produced either by some foreign force or body protruded, which may be effected by a muscular power.

III OF THE STRUCTURE OF ARTERIES.

The arteries in an animal, as far as we can examine them, are endowed with the property of elasticity, the use of which we perceive in the action of those parts; and this power is at all times demonstrable, while the muscular has been by some overlooked, by others denied, and has only been asserted by others as appearing necessary by reasoning from analogy.

The quantity of elasticity in any artery, on which an experiment can be made, is easily ascertained, as it only requires the application of an opposing force, to prove both its power and extent. But it will appear from experiment, that the power varies according to the diftance from the heart, being greateft at the heart; while probably the extent may be the same in every artery.

To endeavour to ascertain the elasticity of arteries, I made comparative experiments on the aorta and pulmonary artery. Having cut off a portion of about an inch in length from the ascending aorta, at half an inch above the valves, and having slit it up, it measured, transversly, two inches and three quarters, but when stretched to its full length, three inches and three quarters, having gained rather more than one third, and having required a force equal to the weight of one pound ten ounces to produce this effect. A similar section was made of the pulmonary artery in the same subject, which measured two inches one half, transversly; and when subjected to trial in the same manner, was stretched to three inches and a half, being rather more in proportion than the aorta; so that the pulmonary artery appears to have rather more elasticity than the aorta. It is not impossible that this difference might arise from the aorta having lost some of its elasticity by use; for although I chose for my experiment the arteries of a young man, where I conceived them to be perfectly sound, yet if there could have been any diminution of the elasticity from use, it would be most considerable in the aorta.

These experiments were made on different arteries with nearly the same result, and seemed to prove that there was almost the same extent of elasticity, though not the same powers.

An artery being composed of an elastic and inelastic substance, its elasticity is not altogether similar to that of a body which is wholly elastic. There is an effect produced from stretching it that is expressive of the nature of both these substances, till it gives way or breaks; for an artery has a check to its yielding to so great a degree, and is ſtopt at once, when stretched to a certain point*, which check is occasioned propably by the muscular, together with the internal inelastic coat.

To prove the muscularity of an artery, it is only necessary to compare its action with that of elastic substances.

Action in an elastic body can only be produced by a mechanical power; but muscles acting upon another principle, can act quickly or slowly, much or little, according to the stimulus applied; though all muscles do not act alike in this respect.

If an artery is cut through or laid bare, it will be found that it contracts by degrees till the whole cavity is closed; but if it be allowed to remain in this contracted state till after the death of the animal, and be then dilated beyond the state of rest of elastic substances, it will only contract to the degree of that state; this it will do immediately, but the contraction will not be equal to that of which it was capable while alive.

The posterior tibial artery of a dog being laid bare, and its size attended to, it was observed to be so much contracted in a short time as almoſt to prevent the blood from passing through it, and when divided, the blood only oozed out from the orifice.

On laying bare the carotid and crural arteries, and observing what took place in them while the animal was allowed to bleed to death, these arteries very evidently became smaller and smaller.

When the various uses of arteries is considered, ſuch as their forming different parts of the body out of the blood, their performing the different secretions, their allowing at one time the blood to pass readily into the

* This gives a determined size to an artery.

smaller branches, as in blushing, and at another preventing it altogether, as in paleness from fear; and if to these we add the power of producing a diseased increase of any or every part of the body, we cannot but conclude that they are possessed of muscular powers.

The influence of the heart in the body, like that of the sun in the planetary system, we know extends to every part; all the parts of the vascular system being supplied according to the necessity it has, though every part is not equally endowed with power, or disposition to make use of that power.

The arteries, upon the whole, may be said to possess considerable living powers, and to retain them for a long time. This is evident when we observe what must happen in transplanting a living part of one body with an intention that it should unite with another body and become a part of it: the part transplanted must retain life till it can unite so as to receive its nourishment from that into which it has been inserted. It is however to be supposed, that in such situations, life can be retained longer than in others, although it is well known that it is preserved in the vascular system, even when there is no colateral assistance. I found in the uterus of a cow, which had been separated from the animal above twenty-four hours, that after its having been injected and allowed to stand another day, the larger vessels were become much more turgid than when I first injected them, and that the smaller arteries had contracted so as to force the injection back into the larger. This contraction was so obvious that it could not but be observed at the time, which was forty-eight hours after the separation from the body of the animal.

This shews too the muscular power of the smaller arteries to be superior to that of the larger, and that it is probably continued longer after the separation from the body; a property which the involuntary muscles possess to a degree greater than the voluntary, in the former of which classes the muscular structure of the arteries is to be considered.

To ascertain how long the living power existed in an artery after separation from the body, or perhaps, to speak more properly, after that communication with the body was cut off, by which we have reason to suppose life to be continued in a part, I made the following experiments, for which I chose the umbilical arteries, because I could confine the blood in them, and keep them distended for any length of time. In a woman delivered on the Thursday afternoon, the naval string was separated from the fœtus; it was first tied in two places and cut between, so that the blood contained in the chord and placenta was confined in them.

The placenta came away full of blood; and on Friday morning, the day after, I tied a string round the chord about an inch below the other ligature, that the blood might still be confined in the placenta and remaining chord. Having cut off this piece, the blood immediately gushed out, and by examining the cut ends of the chord, I attentively observed to what degree the ends of the arteries were open; and the blood having now all escaped from this portion, the vessels were left to contract with the whole of their elastic power, the effect of which is immediate.

Saturday morning, the day after this last part of the experiment, having examined the mouths of the arteries, I found them closed up, so that the muscular coat had contracted in the twenty-four hours to such a degree as to close entirely the area of the artery. That same morning I repeated the experiment of Friday, and on Sunday morning observed the result of this second experiment to be similar to that of the former.

On this morning, Sunday, I repeated this experiment the third time, and on Monday observed that the result had not been the same as before, the mouths of the arteries remaining open; which shewed that the artery was become dead.

There was but little alteration perceived in the orifices of the veins in all the experiments.

These experiments shew that the vessels of the chord have the power of contraction above two days after separation from the body.

Having given a general idea of muscular action, including muscular relaxation, together with the union of the muscular and elastic power in an animal, I shall now apply them to the arteries.

There are three states in which an artery is found, viz. the natural pervious state, the stretched, and the contracted state which may or may not be pervious.

The natural pervious state is that to which the elastic power naturally brings a vessel which has been stretched beyond or contracted within the extent which it held in a state of rest.

The stretched is that state produced by the impulse of the blood in consequence of the contraction of the heart; from which it is again brought back to the natural state by the elastic power, perhaps assisted by the muscular.

The contracted state of an artery arises from the action of the muscular power, and is again restored to the natural state by the elastic. It has been shewn that certain muscles have both a voluntary and involuntary contraction, and that in some of these the involuntary action having brought the part to a necessary position, supports it in that state till it be either necessary for the muscle to relax, or for the voluntary action to take place; instances of which I have given in the sphincter muscles.

I shall now endeavour to shew that the arteries have a middle state; but that in them the power of bringing the coats into a certain position and sustaining them in it, is not the effect of a muscular but of an elastic power; and that the muscular action, both in contraction and relaxation, is involuntary.

In parts endowed with considerable elastic powers, although not apparently muscular, as many arteries, but which we yet know from other modes of information to be possessed of muscular power, elasticity is so combined as to produce a middle or natural state, by acting to a certain degree only as an elongator of the muscular part in some of its actions*.

These two powers, muscular and elastic, are probably introduced into the vascular system of all animals, the parts themselves being composed of substances of this description, together with a fine inner membrane, which I believe to be but little elastic, and this membrane is more apparent in the larger than in the smaller ramifications; although when we consider the construction and use of the arteries, we must at once see the necessity of their having these two powers; yet in the greatest number it

* We can hardly suppose that the muscular coat of the artery assists the elastic in bringing it to the middle state when already contracted within it.

is impossible to give clear ocular demonstration of the existence of distinct muscular fibres. But still, as arteries are evidently composed of two distinst substances, one of which is demonstrably elastic, and we know them likewise to be certainly endowed with the power of contraction peculiar to a muscle, it is reasonable to suppose the other substance to be muscular; I shall endeavour also to prove its existence in such vessels, from their having a power of contraction in the action of death.

As the human body is always alluded to in this account, I shall found my experiments and observations on such animals only as have a similar structure, as in other animals, as the turtle, alligator, &c. we can plainly discern muscular fibres, the insides of the arteries and veins being evidently fasciculated with them.

Every part of the vascular system is not equally furnished with muscular fibres; some parts being almoſt wholly composed of the elastic substance, such as the larger vessels, especially the arteries, in which, were they equally muscular with the smaller vessels, the existence of muscular fibres might be more easily proved. Neither does the elastic substance equally prevail in every part, for many, especially the smaller arteries, or what have been called, the capillary vessels, appear to be almost entirely muscular; at least I am led to think so by my observations and experiments on that subject. From these I have discovered that the larger arteries possess little muscular powers, but that as they recede from the heart towards the extremities, the muscular power is gradually increased, and the elastic diminished. Hence I imagine there may exist a size of vessels totally void of elasticity; but this I should conceive to be in the very extremities only. For it is to be observed that every portion of an artery, of a considerable length, is capable of assuming the middle state, which state must be referred to the elastic power.

The greatest part of the arterial system evidently appears to be composed of two substances, which structure is most remarkable in the middle sized arteries, where the two subſtances are more equally divided, and where the size admits of a visible distinction of parts. The best method to see this is to cut the vessels either across or longitudinally, and to look upon the edges that have been cut.

If the aorta be treated in this way, we shall find that though it appears to be composed of one substance, yet towards the inner surface it is darker in colour, and of a structure which differs, although but in a small degree, from that of the outer surface.

If we proceed by this mode of investigation, following the course of the circulation, we shall find that the internal and external parts become evidently more distinguishable from each other: the internal part which is darker, but with a degree of transparency, begins almost insensibly in the larger vessels, and increases proportionably in thickness, as the arteries divide, and of course become smaller, while the external, being of a white colour, is gradually diminishing, but in a greater degree, according to the diminution of size in the artery, and of the increased thickness of the other coat, so that the two do not bear the same proportion to each other in the small arteries, as in the larger.

The disproportion, however, between them appears greater than it really is, some deception arising from the greater muscular power, possessed by the smaller arteries, in consequence of which the inner coat will be more contracted, and therefore seem thicker. This circumstance alone makes the difference of thickness between the whole coats of a large artery, and those of a small one, appear less than it really is; accordingly we find the coats of the humeral artery in the horse apparently thicker than the coats of the axillary, the coats of the radial as thick as those of the humeral, and the artery near the hoof as thick in its coats as any of the others. There is yet another circumstance which also deserves attention in comparing the two coats, namely, that in many places, but especially at the surfaces of contact in the elastic and muscular substances of the middle sized arteries, the fibres of the muscular and elastic are very much blended or intermixed. I mention this, because otherwise we might be led to draw false conclusions, with regard to the comparative quantity of each substance; and, because it explains by what means both these coats are made elastic.

The external coat, however, is more so than the internal, being composed almost entirely of elastic substance, while the internal has a mixture of muscular with its elastic fribres. As there is, therefore, a difference in the elastic power of the two coats, there must be a difference in their powers of contraction after death; for instance, the external coat contracting more than the internal, and also, as there is a difference between the muscular and elastic powers of contraction, the muscular having the greatest, there must have been a difference between the contracting powers of these two coats during life, but contrary to that which takes place after death.

In those arteries, which are evidently composed of two distinct substances, especially in the smaller, we may observe two very opposite appearances, according as the elastic or muscular coats have contracted most. In the one, when we make a transverse section, and look upon the cut end, we may observe that the inner surface has been thrown into rugæ, so as to fill up the whole cavity; and if such an artery be slit up longitudinally, so as to expose its inner surface, we shall find that inner surface forming wrinkles, which are principally longitudinal. If the finger is passed over that surface, it feels hard, while the external is soft; but if the artery be stretched, and allowed to recover itself by its elasticity, which is the only power it now has, it will be felt equally soft on both surfaces, and its coats will be found to have become thinner than before. On the contrary, I have observed in many of the smaller arteries, when the muscular contraction has been considerable, the external or elastic coat to be thrown into longitudinal inequalities, from not having an equal power of contraction with the muscular, an artery under such circumstances being to the touch as hard as a cord. But if the muscular contraction be destroyed by stretching, or passing something through the artery, then it becomes very soft and pliant, and the muscular coat having once been stretched, without having the power of contracting again, is thrown into irregularities by the action of the elastic.

The elastic coat of an artery is fibrous, and the direction of its fibres is principally transverse or circular; but where a branch is going off, or at the division of an artery into two, the direction of the fibres is very irregular. I cannot say that I have found any fibres which are to a great degree oblique or longitudinal, a circumstance that shews their simple elasticity to be equal to the intention or use, a transverse or circular direction of fibres not being the most advantageous for producing the greatest effect*. They are also elastic laterally, from the direction of their fibres, which property shortens the artery when elongated by the blood; and I believe the muscles have little share in this action; the whole of which tends to shew that the elastic power is equal to the task of producing, and really does produce the natural state of the artery. What the direction of the muscular fibres may be, I never could discover, but should suppose them oblique, because the degree of contraction appears greater than a straight muscle could produce, in which light a circular muscle is to be considered, as its effects are in the direction of its fibres; for either the diameter or the circumference of the artery will decrease in the same proportion, but not the area, which will decrease in proportion to the square of the diameter.

We should naturally suppose that where the action of the heart is strong, elasticity is the best property to sustain its force; and that where the force and elasticity are well proportioned, no mischief can ensue. Where the force, therefore, of the heart is greatest there is a degree of elasticity, which yields with reluctance, and constantly endeavours to oppose and counteract that force.

From these active powers of an artery, together with a foreign power, viz. the blood acting upon them in a manner somewhat similar to the common action of fluids in canals, protruding their contents, we may perceive that there are three actions which take place, all of them, operating in concert with each other, and producing one ultimate effect.

As the filling of the cavity of an artery produces an extension of its coats in every direction, the arteries are endowed with the elastic power, which, by contracting in all directions, may bring the vessels back again to their natural state.

The action of the muscular power being principally in a transverse direction, tends, when the artery is extended, to lessen its diameter, and

* This is a principle in mechanics so well known, that it need not here be explained; we find it happily introduced in the disposition of muscles in various parts of the body.

assist the elastic power; but as its quantity of contraction is superior to that of the elastic power, it does or may contract the artery within what the latter could effect. When the muscular action ceases, elasticity will be exerted to dilate the vessel and restore it to a middle state again, becoming the elongater or antagonist of the muscular coat, and by that means fitting it for a new action as described in other parts of the body. This will be most evident in the middle sized vessels; for in the smaller, the proportion of elastic substance is not so considerable, and therefore it will contribute less to the dilatation of the vessel, when the muscular coat relaxes. Yet we must suppose that no vessel, even to its very extremity, is ever entirely collapsed; but that it possesses an elastic power sufficient to give it a middle state. Although these differences do not in all cases bear the same proportion to the size of artery, yet we must conclude there is in the arteries themselves a certain regular proportion preserved; and I am inclined to believe, that this is in some degree in an inverse proportion to the decrease of size, presuming at the same time that the muscular power increases in the same proportion. A vessel is stretched beyond its natural state, first by the force of the heart, and in succession by the first order of vessels; then it is that the elastic power is exerted to contract the vessel, and restore it to the natural size; and in the performance of this it will be more or less assisted by the muscular power, according to the size of the vessels; least in the larger, and most in the smaller vessels, as was observed above.

There appears to be no muscular power capable of contracting an artery in its length, the whole of that contraction being produced by the elasticity. For in a transverse section of an artery, made when the muscles of the vessel are in a contracted state, it may always be observed, that the external or elastic coat, immediately contracts longitudinally, and leaves the internal or muscular projecting; which would not be the case if there was a longitudinal muscular contraction, equal to the elastic; and were not the quantity of muscular contraction greater than the elastic there would be no occasion for muscles.

Another proof of this is, that if a piece of contracted artery be stretched transversly, or have its area increased and be allowed to recover itself, it loses a part of its length. To understand this it will be necessary to know that muscular fibres, by contraction, become thicker, and in proportion corresponding with the degree of contraction in the muscle.

The thickening in the muscle of a horse was found to be an increase of one fourth part of thickness to one third of a contraction*; from which it follows, that the more the muscular fibres of any vessel contract, the more the vessel is lengthened; but destroy the muscular contraction by dilating the artery, and the elastic power, which acts in all directions, will immediately take place and restore the vessel to its proper size; which is a proof that the effect of the lateral swell, produced by the muscular contraction, is greater than that of the longitudinal elasticity of the artery.

If we examine how much the vessel has lost of its length in this trial, we shall find it will amount to about one twelfth of the whole; a proof that the internal coat does not contract so much longitudinally by its muscular power, as the external does by its elasticity. By multiplying such experiments we have further proofs that the power of muscular contraction acts chiefly in a circular direction; for in a longitudinal section of an artery in its contracted state, the internal coat does not project as in a transverse section, both coats remaining equal, or rather indeed the elastic coat projects beyond the other, from the intermal muscular coat having contracted most. But if this section be stretched transversly, the external coat then contracts and leaves the internal most projecting; because the internal or muscular has now no power of contraction. If the transverse extension be repeated, and to a greater degree, the artery, when allowed to recover itself, will have its inside turned outwards, as well as bent longitudinally, having the inside of the artery on the outside of the curve, and often bringing the two ends together; but this is easily accounted for, as by the transverse extension of the artery its muscular contraction is destroyed, it becomes pliant, and the only resis-

* This calculation is not accurate; for in the experiments made to discover if the muscle lost of its size in the whole when contracted, I found it hardly did; therefore what it lost in length, it must have acquired in thickness.

tance to the elastic power on this side being removed, it is allowed to exert itself to its utmost extent. In doing this it bends the section in a longitudinal direction, which also inclines us to believe, that the external part of the elastic coat, is the most elastic.

These experiments not only prove that the muscular power of an artery, acts chiefly in a transverse direction; but also, that the elastic power exists almost entirely in the external coat, and therefore that the internal coat must be the seat of the muscular power.

EXPERIMENTS on the arteries of a horse bled to death.

To ascertain the muscular power of contraction in the arteries, and determine the proportions which it bears to their elasticity, I made the following experiments upon the aorta, iliac, axillary, carotid, crural, humeral, and radial arteries of a horse.

In this animal the muscles were all allowed equally to contract, and therefore we might reasonably presume that the vessels (at least such of them as were furnished with muscles) would also be contracted, the stimulus of death acting equally upon muscles in every form, and every situation. The animal had also been bled to death, so that the vessels had an additional stimulus to produce contraction in them; as we know that all vessels in animals endeavour as much as possible to adapt themselves to the quantity of fluid circulating through them.

As I supposed the larger arteries had less of this power than the smaller, and that perhaps in an inverse proportion to their size, in order to ascertain that fact, and also to contrast the two powers, I made my first experiments upon the aorta and its nearest branches; continuing them on the other branches as these became smaller and smaller.

The arteries were taken out of the body with great care, so as not in the least to alter their texture, or state of contraction.

The experiments were made in the following manner: I took short sections of the different arteries, slit them up in a longitudinal direction, and in that state measured the breadth of each, by which means as I conceived, I could ascertain their muscular contraction; then taking the same sections and stretching them transversly, I measured them in that state, which gave me the greatest elongation their muscular, and elastic powers were capable of. As by this extension I had entirely destroyed their muscular contraction; whatever degree of contraction they exerted afterwards must, I believe, have been owing to elasticity. Having allowed them to contract, I again measured them a third time in that state, and thus ascertained three different states of vessels, between which I could compare the difference either in the same or different sections, so as from the result to deduce with some degree of certainty the extent of these powers in every size of vessel. I say only with some degree of certainty; for I do not pretend to affirm that these experiments will always be exact; circumstances often happening in the body which prevent the stimulus of death from taking place with equal effect in every part. I have accordingly seen in the same artery some parts wider than others, even when the more contracted parts were nearest the heart, and this merely from a difference of action in the muscular power; for when that was destroyed by stretching, the parts contracted equally in both.

Experiment I. A circular section of the aorta ascendens when slit up and opened into a plane, measured five inches and a half; on being stretched, it lengthened to ten inches and a half; the stretching power being removed, it contracted again to six inches, which we must suppose to be the middle state of the vessel. Hence the vessel appeared to have gained by stretching half an inch in width or rather circumference, which may be attributed to the relaxation of its muscular fibres, whose contraction must have been equal to one-eleventh part; six inches being the natural size, or most contracted state of the elastic power.

Experiment II. A circular section of the aorta at the origin of the first intercostal artery, measuring four inches one-fourth, extended by stretching to seven inches and one-half; it contracted again to four inches and one half, and therefore gained one-seventeenth part.

Experiment III. A circular section of the aorta at the lower part of the thorax, on being stretched, and being allowed to contract again, gained one-tenth part.

Experiment IV. A circular section of the iliac artery, measuring two inches, when stretched and allowed to contract again, measured two inches and four-twelfths, and therefore gained one-sixth.

Experiment V. A circular section of the axillary artery, measuring one inch, when stretched and contracted again, measured an inch and one-eighth, therefore gained one-eighth.

Experiment VI. A circular section of the carotid artery, measuring six-twelfths of an inch, when stretched, measured sixteen-twelfths and one-half; and when contracted again, ten-twelfths; therefore had gained two-thirds.

Experiment VII. A circular section of the crural artery, measuring ten-twelfths, when contracted after being stretched, measured one inch and two-twelfths, therefore gained one-third.

Experiment VIII. The humeral artery, near the joint of the elbow, in a contracted state, was thicker in its coats than the axillary; the circumference of the artery in that state being seven-twelfths and one-half; after being stretched and contracted again, it measured nine-twelfths, therefore gained one-seventh and one-half.

Experiment IX. A circular section of the radial artery being taken, was found so contracted as hardly to be at all pervious; and the coats, especially the inner, much thicker than even the humeral: when slit up it scarcely measured three-twelfths of an inch; when stretched, and allowed to contract again, six-twelfths; therefore gained three-twelfths of an inch, which was about the whole contraction of the artery.

To see how far this power of recovery in the same artery took place at different distances from the source of the circulation, I made the following experiments on the spermatic artery of a bull; and likewise on the artery of the fore-leg and penis. The spermatic artery, near the aorta, when stretched longitudinally, recovered perfectly the former length; when stretched transversly, it likewise recovered perfectly. About the middle, when stretched transversly, it gained one-twelfth. Upon the testicle a portion separated; when stretched transversly gained one-fourth, which was its muscular power.

The humeral portion of the artery of the fore-leg, when stretched transversly, and also longitudinally, recovered entirely.

The artery of one hoof, or rather finger, when stretched transversly, gained one-twentieth, when stretched longitudinally it recovered perfectly; which one-twentieth was the muscular power.

The artery of the penis, when stretched longitudinally, or transversly, recovered itself perfectly. This artery is considerably more elastic longitudinally than the others, but not more transversly. This increased elasticity in the longitudinal direction may be intended to allow of the difference in the length of the penis at different times.

From these experiments we see that the power of recovery in a vessel is greater in proportion as it is nearer to the heart; but as it becomes more distant it lessens; which shews the decrease of the elastic, and the increase of the muscular power.

	Inches.		Inches.		Inches.	
Aorta ascendens	$5\frac{6}{12}$	stretched to	$10\frac{6}{12}$	Recovered to	6	Had contracted by death $\frac{1}{11}$ part.
Aorta descendens at first intercostal	$4\frac{1}{4}$	....	$7\frac{6}{12}$	....	$4\frac{6}{12}$	.... $\frac{1}{17}$
Aorta descendens at the lowest part		....		....		.... $\frac{1}{10}$
Iliac artery........	2	....		....	$2\frac{4}{12}$	.... $\frac{1}{6}$
Axillary........	1	....		....	$1\frac{1}{8}$	.... $\frac{1}{8}$
Carotid........	$\frac{6}{12}$	....	$1\frac{4}{12}$ $\frac{1}{2}$	....	$\frac{10}{12}$	.... $\frac{2}{3}$
Crural........	$\frac{10}{12}$	....		....	$1\frac{2}{12}$	.... $\frac{1}{3}$
Humeral........	$\frac{7}{12}$ $\frac{1}{2}$	....		....	$\frac{9}{12}$	.... $\frac{1}{7}$ $\frac{1}{2}$
Radial........	$\frac{3}{12}$	....		....	$\frac{6}{12}$	.... equal to the whole.

EXPERIMENTS on the power of arteries to contract longitudinally.

To prove that arteries do not produce the same power of muscular contraction in a longitudinal, which they do in a transverse direction, the following experiments were made:

Experiment I. A longitudinal section of the aorta ascendens, measuring two inches, when stretched and allowed again to contract, measured the same length.

Experiment II. A longitudinal section of the aorta descendens at the lower part of the thorax, of a given length, after having been stretched, contracted exactly the same length.

Experiment III. Two inches of the same carotid artery used in the sixth experiment, when stretched longitudinally, recovered itself, so as not to be longer than before the experiment.

Experiment IV. A portion of that humeral artery used in the eighth of the former experiments was not altered in its original length, when it recovered itself after being stretched.

These experiments appear to be decisive, and prove that the muscular power acts chiefly in a transverse direction; yet it is to be observed that the elastic power of arteries is greater in a longitudinal than in a transverse direction. This appears to be intended to counteract the lengthening effect of the heart, as well as that arising from the action of the muscular coat; for the transverse contraction of that coat lengthens the artery, therefore stretches the elastic, which again contracts upon the diastole of the artery.

From the account we have given of those substances which compose an artery, we may perceive it has two powers, the one elastic and the other muscular. We see also that the larger arteries are principally endowed with the elastic power, and the smaller with the muscular, that the elastic is always gradually diminishing in the smaller, and the muscular increasing, till, at last, probably, the action of an artery is almost wholly muscular; yet I think it is not to be supposed but that some degree of elasticity is continued to the extremity of an artery; for the middle state cannot be procured without it; and I conceive the middle state to be essential to every part of an artery. Let us now apply those two powers of action; or, to speak more properly, of re-action, with their different proportions in the different parts of the arterial system. From these we must suppose the elastic to be best fitted for sustaining a force applied to it, such as the motion of the blood given by the heart, and propelling it along the vessel; the muscular power, most probably, is required to assist in continuing that motion, the force of the heart being partly spent; but certainly was intended to dispose of the blood when arrived at its place of destination; for elasticity can neither assist in the one nor the other; it is still, however, of use through the whole to preserve the middle state. Elasticity is better adapted to sustain a force than muscular power; for an elastic body recovers itself again, whenever the stretching cause suspends its action; while muscles endeavour to adapt themselves to circumstances as they arise. This is verified by different sorts of engines whose pipes are made of different metals. A pipe made of lead will, for instance, in time dilate and become useless*; whereas a pipe of iron will re-act on the fluid, if the force of the fluid be in proportion to the elastic power of the iron; but the lead having little or no elasticity whenever it is stretched, it will remain so, and every new force will stretch it more and more. We are therefore to suppose that the force of the heart is not capable of stretching the artery so much as to destroy its elasticity; or in other words, the force of the heart is not able to dilate the artery beyond the contracting power. As the motion of the blood is mechanical, elasticity is best adapted to take off the immediate force of the heart; and, as we go from the heart, this property becomes less necessary; because in this course, the influence of the heart is gradually lessened, by which means a more equal motion of the blood is immediately produced, and even in the first artery a continued stream is at all times obtained; although it is considerably increased by each contraction of the heart. Without this power the motion of the blood in the aorta would have been similar to what it is in its passage out of the heart, and would have been nearly the same in every part of the arterial system.

For though the motion of the blood out of the heart be by interrupted jerks, yet the whole arterial tube being more or less elastic, the motion of the blood becomes gradually more uniform from this cause. Elasticity in arteries acts like a pair of double bellows; although their motion be alternate, the stream of air is continued; and if it were to pass through a long elastic pipe, resembling an artery, the current of air would be still

* This accounts for the size of ancurisms in arteries whose coats must have lost their elasticity before they could be dilated.

more uniform. The advantage arising from elasticity in the arterial system, will be more complete in the young subject than in the old; for in the latter, the elasticity of the arteries being very considerably diminished, more especially in the larger trunks, where the force of the heart ought to be broken, the blood will be thrown into the second and third order of vessels with increased velocity. In the young, the current is slower, from the re-action of the elastic power during the relaxed state of the heart; whereas at the heart, the motion is equal to the contraction of the heart; and as the heart is probably twice the time in relaxing that it is in contracting, from this cause alone we may suppose the whole is two-thirds less in the smaller vessels. As elastic bodies, I have already observed, have a middle state, or state of rest, to which they return after having been dilated or contracted by any other power, and as they must always be acted upon before they can re-act, the use of elasticity in the arterial system will be very evident. It is by this means that the vessels are adapted to the different motions of the body, flexion and extension; so that one side of an artery contracts while the other is elongated; and the canal is always open for the reception of blood in the curved, stretched, or relaxed state.

The muscular power of an artery renders a smaller force of the heart sufficient for the purposes of circulation; for the heart need only act with such force as to carry the blood through the larger arteries, and then the muscular power of the arteries takes it up, and, as it were, removes the load of blood while the heart is dilating. In confirmation of this remark, it is observable in animals whose arteries are very muscular, that the heart is proportionably weaker, so that the muscular portion of the vessels becomes a second part to the heart, acting where the power of the heart begins to fail, and increasing in strength as that decreases in power Besides this, it disposes of such part of the blood as is necessary for the animal œconomy, principally in growth, repair, and secretions. At the extreme ends of the arteries, therefore, we must suppose that their actions are varied from that of simply conveying blood, except those arteries which are continued into veins.

IV. OF THE VASA ARTERIARUM.

The arteries are furnished with both arteries and veins, although it cannot be said that they are to appearance very vascular. Their arteries come from neighbouring vessels, and not from the artery itself which they supply.

This we see in dissection; and I found by filling an artery, such as the carotid, with fine injection, that still the arteries of the artery were not injected. On laying the coats of arteries bare in the living body we can discern their vessels more evidently some little time after the exposure, for then they become vessels conveying red blood, as in a beginning inflammation, growing turgid, when the arteries may be easily discerned from the veins by the difference of colour of the blood in each: these observations will also generally apply to the corresponding veins.

Perhaps arteries afford the most striking instance of animal substance furnished with two powers existing in the same part, one to resist mechanical impulse, the other to produce action. The first of these powers is greatest where there is the most impulse to resist; therefore we find it particulary in the arteries nearest to the heart, the better to support the force of that organ; but in those parts where gravitation is gradually increasing, the diminution of power in the artery is not in proportion to the diminution of the force of the heart.

In the veins, the allotment of strength is commonly the reverse; for as they have nothing mechanical to resist, but the effect of gravitation, their principal strength is at the extremities.

We are to suppose that the power of the heart, and the mechanical strength of the arteries, bear a just proportion to each other; and therefore by ascertaining the last we may give a tolerable good guess with respect to the other.

In this view, to determine the strength of the ventricles, so far as I was able, I made comparative trials of the strength of the aorta and pulmonary arteries in a healthy young man. I separated a circular section of each, and on being slit, they measured three inches and three-eights, their breadths being also equal. On trial I found the aorta, being stretched to near five inches, broke with a weight of eight pounds. The pulmonary artery stretched to near five inches and a half, and then broke with four pounds, twelve ounces.

This experiment I have repeated, but with very different results; for in one experiment, although the aorta took one pound ten ounces to stretch it, while the pulmonary artery took only six ounces; yet to break this pulmonary artery required eleven pounds, three ounces, while the aorta broke with ten pounds, four ounces; but this difference I impute to the aorta having lost its elasticity, which is very apt to happen in that vessel.

There is nearly the same proportion of elasticity in both arteries; but the strength of the aorta in the first experiment appeared to be nearly double that of the pulmonary artery; while in the second it was less: yet we must suppose the result of the first experiment nearer the truth; for we seldom find the pulmonary artery diseased, while the aorta is seldom otherwise.

The mechanical strength of arteries is much greater in the trunk than in the branches; which is evident from accidents and from injections in dead bodies. For when we inject arteries with too much force, the first extravasation takes place in the smaller vessels. This can only be proved by subtile injections, which do not become solid by cold; such injections keeping up an equal pressure throughout the arterial system; and the smaller arteries being found to give way first, viz. those of the muscles, pia-mater, and the cellular membrane; which contradicts Haller's theory of the relative strength of the coats of the vessels.

I am however inclined to suppose that they are even weaker in proportion to their size, viz. in proportion to the diminished force of the heart, or motion of the blood; but how far this is the case I will not venture to determine, as mechanical strength is not so much wanted in the smaller arteries, as muscular; for the mechanical strength of muscles appear to be less than the power of their own contraction; experiments, therefore, made in the dead body upon parts whose uses arise from an action within themselves when active are not conclusive. The flexor policis longus, being one of the most detached muscles in the body respecting structure and use, has been selected for experiments on this subject, and is found to raise by its action a greater weight than it can sustain after death. This however is liable to fallacy, as the two experiments are made on different muscles, one certainly healthy, the other most probably weakened by the disease preceding death.

The coats of arteries are not equally strong on all sides of the same artery; at the bending of a joint they are strongest on the convex side through the whole length of the curve; this is most evident in the permanent curves, such as in the great curvature of the aorta. Arteries are likewise strongest at the sharp angles made by a trunk and its branch, and at an angle formed by a trunk divided into two.

These parts have the blood as it were dashing against them. Those likewise are the parts which first lose their elasticity and soonest ossify, being generally more stretched than the other parts of an artery, and making a kind of bag. These circumstances are chiefly observable in the curvature of the aorta, that of the internal carotids, and the division of the aorta into the two iliacs.

V. OF THE HEART.

The heart is an organ which is the great agent in the motion of the blood, but it is not essential to animals of every class, nor for the motion of the blood in every part where it is perfect; it is less so than the nerves, and many even possess the organs of generation, that have no heart. Its actions in health are regular and characteristic of that state; and in disease its actions are in some degree characteristic of the disease; but although there is that connection between the body and the heart, yet there seems not to be such a connection between the heart and the body; for the heart may be in some degree disordered in its action, yet the body but little affected; it is therefore only to be considered as a local agent very little affecting the constitution sympathetically, except by means of the failure in its duty. The heart in the more perfect animals is double, answerable to the two circulations, the one through the lungs, the other over the body; but many that have only single hearts have what is analagous to a double circulation; and this is performed in very different ways in different animals, so that one of the circulations in these is performed without a heart.

A large class of animals, well known and pretty perfect in their construction, namely, all the class of fish, have no heart for the motion of the blood in the great circulation, or that over the whole body, having only a heart for the lungs or branchea, while the snail has only a heart for the great circulation, and none for the lungs; as also in the liver of the most perfect animals, the motion of the blood, in the vana portarum, and vena cava hypatica, is carried on without a heart. The absorbing system in every animal has no immediate propelling power; therefore this propelling power is not universally necessary. The heart varies in its structure in different orders of animals, principally with respect to the number of cavities and their communications with each other, yet in all nearly the same purpose is answered. I shall here observe, that in the bird and quadruped there is a double circulation, which requires a double heart, namely, a heart for each circulation, each heart consisting of an auricle and ventricle, called the right and the left; and from their forming but one body among them, they are all included in one heart; the right side, or heart, may be called the pulmonary, and the left may be called the corporeal. In many classes of animals there is to be found only one of those hearts; and according to the class, it is either the pulmonary or corporeal. In the fish, as was observed, the heart is the pulmonary; and in the snail, the heart is the corporeal; so that the corporeal motion of the blood in the fish is carried on without a heart; and in the snail the pulmonary motion is carried on without a heart; and in the winged insects which have but one heart, as also but one circulation, there is this heart, answering both purposes; and in all these varieties, breathing is the principal object.

The heart in most animals is composed principally of a strong muscle thrown into the form of a cavity or cavities; but it is not wholly muscular, being in part tendinous or ligamentous, which last parts have neither action nor re-action within themselves, but are only acted upon; they are therefore made inelastic and rigid to support the force of the acting parts in this action, without varying in themselves.

The heart is in all animals which have red blood, the reddest muscle in the body. Thus in the bird whose muscles are mostly white, the heart is red; we find it the same in the white fish.

As it differs in the different orders of animals respecting the number of cavities, it may admit of dispute what are to be reckoned truly hearts, and what only appendages; for some of its cavities may only be considered as reservoirs peculiar to some hearts.

The most simple form of heart is composed of one cavity only, and the most complicated has no more than two; it would seem indeed to increase progressively in the number of cavities from one to four, which includes the mixed; yet two of these belonging to the heart with four cavities, ought not to be called parts of the heart although they belong to it. The single cavity of the heart in the most simple class, or the two in the most complicated, are called ventricles. The other cavities belonging to it are called auricles, many of those which have one ventricle only have no auricle, such as insects; but there are others which have both a ventricle and auricle, such as fish, the snail, many shell fish; some of the last class have indeed two auricles with only one ventricle; which shows that the number of auricles is not fixed under the same mode of circulation; those animals which have two distinct ventricles, constituting four cavities, are what are called quadrupedes, or mammalia, and birds. If the auricles are considered as parts of the heart, we might class animals which have hearts according to the number of their cavities, viz. monocoilia, dicoilia, tricoilia, tetracoilia; the tricoilia is a mixture of the dicoilia and tetracoilia. This is the case in distinct classes of animals; but it takes place in other classes at different stages of life; for the fœtus of the class possessing four cavities may be classed with the mixed, having but one auricle, by the communication between the two and also one ventricle, by means of the union between the two arteries which produces an union of blood although not in the same way. Those passages however are shut up almost immediately after birth, or at least the canalis arteriosus*, which immediately prevents the foramen ovale from producing its former effects; therefore it is not so necessary it should be shut up in the adult. I have seen it, to common appearance, as much open as in a fœtus.

The heart may be considered as a truly mechanical engine; for although muscles are the powers in an animal, yet these powers are themselves often converted into a machine, of which the heart is a strong instance; for from the disposition of its muscular fibres, tendons, ligaments, and valves, it is adapted to mechanical purposes; which make it a complete organ or machine in itself. It is most probable that by means of this viscus a quicker supply of blood is furnished than otherwise could be effected.

In birds and quadrupedes the heart by its action first throws out the blood, both that which is fit for the purposes of life, and that which requires to be prepaired; the last having lost those salutary powers in the growth, repairs, secretion, etc. in the machine.

It may be said to give the first impulse to the blood, producing a greater velocity where the blood is simply conveyed to the parts for whose use it is destined. This velocity is alternately greater and less, and from the construction of the arteries alone is gradually diminished, becoming more uniform where slowness and eveness in motion is necessary. This velocity of the blood in those parts where it is to be considered as passing only, allows a much larger quantity to flow through the part to which it is destined than otherwise could be transmitted

The heart is placed in the vascular system, to be ready to receive the blood from the body, and to propel it back on the body again, although not in the centre of the whole; but it is reasonable to suppose that its situation is such as to be best suited to the various parts of the body; some parts requiring a brisk, others a more languid circulation. Some also require a greater supply of blood than others.

* There have been instances of the canalis arteriosus being open in the adult.

We may suppose that the parts near the heart will receive more blood than those at a greater distance, because the resistance will be less if the vessels are of equal size in proportion to the size of the part. The situation of the heart in the body varies in different animals. One would imagine when the animal was divided into its several portions appropriated for the different purposes, that the situation of the heart would be nearly the same in all; but we find this not to be the case; its situation depends upon the organs of respiration, more than any other part. It is placed in what is called the chest in the quadruped, bird, amphibia, in fish, and in the aquatic and terrestial insect; but not in what may be called the chest in the flying insect. The chest in the above named animals seems best suited to contain the lungs and branchia, and therefore the heart is placed there; but as the lungs of the flying insect are placed through the whole body, the heart is more diffused, extending through the whole length of the animal. The situation, therefore, of the heart is chiefly connected with that of the lungs; and when it is united with the body at large, it is because the lungs are also so disposed. We must suppose that these two have a relation to each other.

A heart is composed of an auricle and ventricle; and it is the ventricle which sends the blood through its course in the circulation; and from what has been said, it must appear that the ventricle is the true heart, the other parts having only secondary uses; and as the ventricle is the part which propels the blood to the different parts of the body, its muscular power must be adequate to that purpose, and therefore it has a very strong muscular coat. Much more pains than were necessary have been taken to dissect and describe the course and arrangement of the muscular fibres of the heart, as if the knowledge of the course of its fibres could in the least account for its action. But as the heart can, in its contracted state, almost throw out its whole contents, to produce this effect, its fibres must pass obliquely.

Its red colour arises probably from its being at the fountain head of the circulation: for those animals that have but little red blood have it only in those parts near the heart; and the heart being nearest to its own powers, receives the blood before the vessels can so act as to dispose of the red blood, or allow of a kind of separation by distance; its constant action too renders it more red, as happens in other muscles.

The ventricles in the quadruped, bird, and amphibia, are called right and left, and this accords very well with the situation in such animals; but where there is only one ventricle, and that in some acting the part of right, as in fish, and in others acting the part of the left, as in the snail, we ought to have some term expressive of their immediate use, and such as would apply to all animals that have such a viscus.

The auricles of the heart are to be considered only as reservoirs for the blood to be ready to supply the ventricles; for an auricle is not to be found in all the animals which have a ventricle; nor does the number of auricles always correspond to that of the ventricles. Where the veins entering into the heart are small, in comparison to the quantity of blood which is wanted in the ventricles, there we have an auricle; but where the veins near to the heart are large, there is no auricle; as in the lobster, and generally in insects. In the snail, where the veins in common are large, yet as they are small where they enter the heart, there is an auricle; and as its office is somewhat similar to a large vein, it has some of its properties, viz. being in some degree both elastic and muscular.

The name sinus venosus is a very proper one; and as a proof that it is only such in the circulation, there are no valves placed between it and the veins.

As the heart is an engine formed to keep up the motion of the blood, and as it is necessary that this motion should be determined in a particular direction, it is adapted, as are also the other parts of the vascular system, to this purpose.

The heart is formed into a cavity through which the blood must pass, receiving at once a considerable quantity of this fluid, upon which it immediately acts with equal force, although not progressively, as an intestine; and that this motion of the blood may be regulated, and a retrograde motion prevented, we find the valves constructed.

A valve, I believe, is in general understood to be a part in every machine, calculated to allow whatever is to pass to move in one direction only; and the valves in the vascular system are intended for this purpose. They are of two kinds, having two modes of attachment, which is suited to the action of the part to which they are attached, and making a very essential difference in their formation.

They are thin inelastic membranes, having no action within themselves, with one edge fixed, the other loose in some, but not entirely so in others; they are either attached in a circular form, or in an oblique one. The circular attachment belongs to those of the ventricles, and the oblique to those of the arteries and veins. The circular are the most complex, requiring an additional apparatus to make them answer the intended purpose; it is necessary that their loose floating edges should be restrained from inverting themselves into the auricle upon the contraction of the ventricles: this is done by tendons, which are fixed at one extremity along the edge of the valves, and at the other to some part upon the inside of the ventricle.

The tendons which are longest are inserted into columns of muscle, the intention of which is very evident; for if they had gone the whole length in form of a tendon, they would have been too long when the heart contracted, and the valves in such a case would have allowed of being pushed into the auricles, so far as to admit of the blood escaping back again into the cavity; but the carniæ columnæ keep the valves within the ventricle, in the contracted state of the ventricles; and the dilatation of the ventricles counteracts them and places the valves in their proper situation in that state.

If the valves in this cavity had been placed obliquely along the inner sides of the ventricle, as in the beginning of the arteries, and in the veins, the attachment then would not have been permanent; for it would have varied according to the relaxed or contracted state of the heart; it would have been short in the contracted state, and longer in the relaxed; therefore to have a fixed base, it was necessary for them to be attached all round the mouth of the ventricles.

I have reason to believe, that the valves in the right side of the heart do not so perfectly do their duty as those of the left, therefore we may suppose it was not so necessary.

The vessels of the heart are called coronary arteries and veins. In quadrupeds and birds, there are two coronary arteries, which arise from the aorta just at its beginning, behind two of the valves of the artery; from this circumstance a theory respecting the action of the heart was raised; but in the amphibia they arise at some distance, and not always from the same artery in the same species, often from the subclavian, and often from the anterior surface of the ascending aorta, which is reflected back. In the fish they arise from the artery as they are coming from the gills.

The veins pass into the right auricle.

In all animals, which have an auricle and ventricle, so far as I know, there is a bag (unattached) in which they are placed, called a pericardium,* but the insect tribe, whether aerial, aquatic, or terrestial have none, their heart being attached to the surrounding parts by the cellular membrane, or some other mode of attachment. In those animals which have this bag, it is not a smooth termination of the cellular membrane, as the peritonæum may be supposed to be; but a distinct bag, as in man, and in all quadrupeds.

The use of this bag is probably that the heart may move with more ease and facility; the two parts, to wit, the contained and containing, acting as a kind of joint with a capsular ligament, and like such joints it contains a fluid, but not a synovia, as the two surfaces are not hard like cartilage; besides, the heart is kept very much in its place, which we must suppose is of use. I have conceived it also to be possible, as it is a pretty strong membrane, that it might in some degree preserve the heart from too great distention; for I have observed by injections, that a little force will distend it beyond its natural size, if a part of the pericardium

* There have been instances where the pericardium has been wanting in the human subject: a case of this kind is published by Dr. Baillie, in a periodical work, entitled "Transactions of a Society instituted for promoting medical and chirurgical Knowledge."

be taken off; but in the heart mentioned by Dr. Baillie there was no particular increase of bulk.

This bag has, like most others, a fluid which moistens the two surfaces. In every other cavity of the body the fluid is no more in quantity than what is simply sufficient to moisten the parts. In this bag, however, it is more, from whence it has acquired the name of liquor pericardii. There may be about a tea spoon-full in the whole. This fluid appears to be serum, and is commonly a little tinged with blood, which arises from the transudation of the red blood after death.

That this cavity has more water in it than most other cavities of the body, may arise from there being a greater action of those parts on one another than takes place in others; it may also fill up the interstices formed between two round bodies, so that when the pulmonary artery and aorta are filled, they may more easily assume a round figure.

The size of a heart we should naturally suppose is proportioned to the size of the animal, and the natural quantity of blood; which last is, we might conceive, ever in proportion to the size of the animal; but I believe these modes of calculation will not be found to be just; for certainly some animals have much more blood in proportion to their size than others; and I believe the heart is not in size proportioned to the size of the animal, but bears a compound proportion or ratio to the quantity of blood to be moved, and the frequency of the stroke it has to make; for when it is decreased in the one respect it must be increased in the other; and as a proof of this we find when an animal loses a considerable quantity of blood, the heart increases in its frequency of strokes, as also in its violence. That it principally bears proportion to the quantity of blood is evident; for the right ventricle is equal in size to the left, if not larger, which sends its blood to the lungs only, which are infinitely small when compared to the body; and the hearts of those animals which have but one ventricle, as fish for instance, which is similar in use to our right, are perhaps made as large in proportion to the size of the body as both ventricles in the quadruped.

The strength of a heart is commonly, if not always, in proportion to the size of the parts to which the blood is carried with the velocity with which the blood is propelled, which becomes a collateral proof that it is an universal agent in the circulation. In the complete heart this is not equal in every part of the same heart; the right ventricle being much weaker than the left, but still in the above proportions. The proportion between the two will be best known by ascertaining the difference in the strength of the two arteries, and this again will differ according to the whole parts the blood is sent to by the heart. In the fish, for instance, it is only necessary it should bear the proportion in strength to the whole fish, that our right ventricle bears to our lungs, which is not in the least equal to that of the left ventricle; or in other words, its strength should commensurate with the size of the lungs; however, it is most probable that the right ventricle in the quadruped is stronger than in this proportion, because it is obliged to move a larger quantity of blood than is contained in any other part of the body of the same size, and with greater velocity; in the double heart, therefore, such as the human, the two cavities are not of equal strength, each being nearly in proportion to the size of the parts, or rather to the distance the blood is to go; the right ventricle only throwing it into the lungs, the left into the body. As a proof of this doctrine, we find that in the fœtal state of this class of animals, the two ventricles and the two large arteries, are equal in strength. Indeed, from reasoning, we should expect this, and even that the right ventricle should rather be the strongest; for at this period it sends the blood to the lower extremities; but since both the arteries unite into one canal we must suppose it to be necessary that the velocities of the blood in both should be equal; upon examination we find the two ventricles to be nearly equal in thickness in this young state of the animal.

The mixt kind of heart, as that of the turtle, etc. is under the same predicament. The two ventricles are to be considered as joint agents in the circulation; and as the pulmonary artery and aorta are equally strong, it becomes a proof that the strength of the heart must be equal every where.

If we were to estimate the strength of the ventricles in those possessed of four cavities, by the strength of the aorta and pulmonary arteries, either by their absolute strength or elasticity, we might come pretty near the truth.

Dr. Hales made an experiment on a horse, to ascertain the strength of the arteries, which gives us the power of the left ventricle; but all this explains nothing, for its power is equal to the use wanted.

The power of contraction of the ventricle must be within the strength of the artery; but it is hardly possible to ascertain what is the strength of an artery, nor, if we could, would it ascertain the strength of the ventricle, for the force of the heart is in part immediately lost by the blood being allowed to pass on, although not so freely as if the artery was open at the other end; in proportion, therefore, to the retardment, the artery is affected. We can ascertain the elastic power of a given section of an artery, and also its absolute strength, but we are not acquainted with the size of a section that will give the strength of the artery to which it belonged when the whole was in a perfect state or form.

Experiment I. A section of a sound aorta, close to the valves, three quarters of an inch long, was stretched transversly to its greatest extent, which state was ascertained by measuring it with a pair of compasses, and the artery was allowed to contract. The weight required to stretch it again to the same degree was one pound ten ounces. To break the artery required ten pounds and a quarter.

Experiment II. A section of the pulmonary artery, similar to the former in length and situation, required six ounces two drachms to stretch it to its full extent. To break it required eleven pounds three quarters.

The use of this viscus is in general very well known; however, its use has been frequently supposed to be more universal than it really is. It gives to the blood its motion in most animals, and in all it sends the blood to the organs of respiration: in the flying insect it sends the blood both to those organs and to the body at large; but in fish to those organs only, the body at large in them having no heart. In the amphibia there is an attempt towards a heart both for the lungs and body, but not two distinct hearts. In the bird and quadruped there is a distinct heart for each. We may say, therefore, that there is one heart for respiration, and another for the life, nourishment, etc. of the animal; these constitute the two ventricles.

As the extent of these two circulations is different, the two hearts, or in other words, the two ventricles, are suited in their strength to the different extents of each circulation, as was observed above in treating of the strength of the heart.

How far the heart is alone capable of carrying on the circulation is not to be ascertained; for although the circulation is carried on in paralytic cases, yet this does not exclude the involuntary nervous influence of the part; this, however, varies very much in different classes of animals; for I have already observed concerning the structure of the arteries, that their muscularity assisted in the circulation, and that in proportion as the vessels in general were endowed with this power the heart was weaker. I believe that the quadruped has the strongest heart of any class of animals; and I believe that their vessels have the least muscular power, more especially near the heart.

The immediate use of the heart in an animal, would seem to be generally subject to as little variety as that of any other viscus; but perhaps the heart is subject to more variety than any other part in its construction. I have observed that it is either single, double, or mixed, that it is single without an auricle, single with one auricle, single with two auricles, double with a union of the two, making the mixed, and double with two auricles. With respect to its use, it is, in the most simple kind of single heart, to propel the blood through the body, immediately from the veins, which blood is to receive its purification in this passage, when the lungs are disposed throughout the body, as in the flying insect. In another single heart it is intended to mix both the purified and the adulterated blood, and of course to throw it out to the body and lungs equally in this mixed state, as in the lobster. In the single heart, with an auricle, its use is, in one class, to throw the blood throughout the body, after being purified, as in the snail; and in another single kind, with an auricle, it is to receive the blood from the body, and send it to the lungs only, as in all fish. In the single heart with two auricles, it is formed to receive the blood both purified and unpurified, and dispose of it to both body and lungs in that state, as was observed in the lobster: the same thing happens, in some degree, in the turtle, snake, fœtus, etc. In the double heart with two auricles, it acts like an union of the heart of the snail with that of the fish, one heart receiving the blood purified from the lungs, and sending it over the body, as in the snail; and the other receiving the blood from the body, and sending it into the lungs to be purified, as in the fish. From the above account we must see that the immediate use arising from the heart in one class of animals will not agree with its immediate use in another; but still in all, it is the engine employed to throw the blood to those parts into which the arteries conduct it.

It is impossible to say what the quantity of blood is that is thrown out of the heart at each contraction. The size of a relaxed heart, in the dead body of any animal, gives us the size of the cavity, or what it is capable of holding; but muscles seldom or ever are obliged to relax themselves to their full extent in common actions, although they often are when extensive effects are to be produced. The heart, like every part constructed for action, has its times of action beyond, and also within its natural limit of action; but it is its natural action which should be ascertained.

If we compare the actions of the heart with those of the body, we may suppose that the common quantity of motion in the heart is about half what it can perform, that is, it relaxes three-fourths and contracts one-half; therefore a ventricle which contains four ounces, will, in common, only dilate so as to contain three, and will only contract so as to throw out two.

The question is, when the heart acts with more frequency, as from exercise, Does it, or does it not also dilate and contract more fully, and also act with greater velocity in its contraction? I believe that all these circumstances take place; for in exercise, the pulse not only becomes more frequent, but fuller, as if more was thrown out of the heart; and the heart is found to make a greater emotion in the chest, striking with its apex against the inside of the chest with greater force*, which can only arise from a greater quantity being thrown out, and with greater velocity. The breathing corresponds with the quantity of blood and the velocity; for if a larger quantity passes through the lungs in a given time, the breathing must be in the same proportion increased; if with a greater velocity, the same thing must necessarily take place; and if a greater quantity is thrown out, and with a greater velocity, then the arteries must relax in proportion, since the different parts must correspond with each other; we must suppose, therefore, that in health, whenever there is any exertion greater than common, (which always increases the pulse) the heart dilates more, contracts more, and does both with greater velocity; this I conceive arises from a necessity, which begins first in the veins; for when the body is in action, the blood in the veins is obliged to move with greater velocity than when at rest: how far there may be other reasons for this, I will not pretend to determine.

Another question naturally arises; as we find that the times of repetition of the pulse or the actions of the heart increase in many diseases, Does the same thing happen, that is above supposed to arise, from exercise in health? viz. Does the heart dilate more, contract more, and also contract with more velocity? I believe this case does not in the least correspond with our former position. The pulse in such circumstances, altho' frequent, is small and hard, showing the arteries to be too much contracted by their muscular power, and therefore unfit to receive a large quantity of blood from the heart in any given time. The breathing does not correspond with the frequency of the pulsations, as in the former instance; yet it is possible that nearly the same quantity of blood may

* The reason why the apex of the heart strikes against the chest in its actions, was, I believe, first accounted for by the late Dr. William Hunter, in his lectures, as far back as the year 1746. The systole and diastole of the heart, simply, could not produce such an effect; nor could it have been produced, if it had thrown the blood into a straight tube, in the direction of the axis in the left ventricle, as is the case with the ventricles of fish, and some other classes of animals; but by its throwing the blood into a curved tube, viz. the aorta, that artery at its curve endeavours to throw itself into a straight line to increase its capacity; but the aorta being the fixed point against the back, and the heart in some degree loose or pendelous, the influence of its own action is thrown upon itself, and it is tilted forwards against the inside of the chest.

pass as when in health, the velocity in the contracted state of heart and vessels making up for the quantity in the enlarged. That it moves faster in such state of vessels, is, I think probable; for in bleeding, the blood in the veins during such a state of vessels, is commonly more florid.

Observations upon the heart's motion, while under the influence of artificial breathing.

I. I observed that the auricles contracted but very little, so that they did not nearly empty themselves.

II. That the ventricles were not turgid at the time of their diastole; for I could feel them soft, and could easily compress them.

III. That the ventricles became hard at the time of their systole.

IV. That the heart, when it ceased to act, became nearly twice as large as when acting, and that it recovered its small size again whenever it began to act.

Observations on the above appearances.

From the first observation it would appear, that the auricles are only reservoirs, capable of holding a much larger quantity than is necessary for filling the ventricles at any one time, in order that the ventricles may always have blood ready to fill them.

From observation the fourth, it would appear, that any idea we form of the size of a heart from those in dead bodies, must be far from the truth; for the blood coming from every part of the body to the heart, in some measure distends it while it is in a relaxed state, so that when the heart begins to contract (as muscles do some time after death) it is kept dilated by the contained blood. However, it may be observed that the increased size of the heart would be less in the present case, than natural; for the very quick motion of this viscus, under this irritation, hindered a full diastole; but when I left off blowing, and the heart ceased acting, it became large; and on resuming my artificial breathing, it again became small; which I did three times in the course of this experiment. But I think I have observed in general that the heart is not so much affected by the stimulus of death as the other muscles of the body. We seldom see a dead body that is not stiff; but we very often find the heart large and flabby, not in the least contracted: and I am not certain but this may be the case also with some of the other vital parts, as the stomach and intestines.

It is to be set down as a principle, that the action of every muscle is alternate contraction and relaxation; and it cannot be otherwise; but as there is a necessity for a more constant and regular motion in the heart, than probably in any of the other muscles, more disputes have arisen about the cause of its regular alternate motion. Some have accounted for it from the position of the mouths of the coronary arteries respecting the valves of the aorta, supposing, erroneously, that the heart has its blood in the time of its relaxation*; but the circulation, whether existing or not, has not such immediate effect upon a muscle; nor would it account for the action of the auricle in the same animal, nor would it account for the action of the heart in a fish; but from what we shall observe on the valves of the aorta, we shall find that this opinion immediately falls to the ground. An easy experiment may put this beyond a doubt; for, if the heart of a dog be laid open and the coronary artery wounded, it will be found to jet out its blood as the aorta distends. Others have accounted for the alternate motion of the heart, from the course of its nerves passing between the two great arteries, so as to be compressed when the arteries are dilated; but this could only produce relaxation. We know too that such immediate compression on a nerve has no such immediate effect upon a muscle; and it would most probably make it contract; for when the nerves of the heart are cut, it does not stop its motion, but rather makes it contract for the instant. The heart's motion does not arise from an immediate impulse from the brain, as it does in the voluntary muscles, and as it is only in the quadruped and bird that the nerves can be influenced in their passage to it; it does not account for this alternate motion in other classes of animals. The flowing

* This will be readily understood when I come to explain the mode of action in the valves of the arteries.

of the blood into the heart has been assigned as a cause of its contraction; but even that will not account for it; although it will for many of its phenomena, yet not for all; for a local stimulus merely is too mechanical to produce all the variety attending the action of this viscus; it would not be attended with that regularity which it has in health, nor that irregularity which we find in disease; neither could it ever stop, unless when absolute death took place; nor resume its action if it ever did stop. We find that those parts which have occasion for the immediate stimulus to produce action, have that action very irregular; as for instance, the bladder of urine and intestines. The bladder is taking up its action as simply for itself, and not secondarily, however beneficial that might be for the whole in a secondary degree; but the heart's actions arise from its being so much part of the whole, as the whole immediately to depend upon it; therefore we must look out for another cause of this regular alternate action of the heart, than that arising from mechanism or mechanical impression; something more immediately connected with the general laws of the animal œconomy.

The alternate contraction and relaxation of the heart constitutes a part of the circulation; and the whole takes place in consequence of a necessity, the constitution demanding it, and becoming the stimulus, it is rather therefore the want of repletion which makes a negative impression on the constitution, which becomes the stimulus, than the immediate impression of something applied to the heart.

This we see to be the case, wherever a constant supply, or some kind of aid, is wanted in consequence of some action; we have as regularly the stimulus for respiration, the moment one is finished an immediate demand taking place; and if prevented, as this action is under the influence of the will, the stimulus of want is increased. We have the stimulus of want of food, which takes place regularly in health, and so it is with the circulation. The heart, we find, cannot rest one stroke, but the constitution feels it; even the mind and the heart is thereby stimulated to action. The constant want in the constitution of this action in the heart, is as much as the constant action of the spring of a clock is to its pendulum, all hanging or depending on each other.

The nearest dependence of the heart is upon the lungs, and probably they have the same upon the heart; the two together become in their immediate use interwoven with the whole; for a stoppage of respiration produces a stoppage of circulation, and a restoration of respiration produces a restoration of the circulation or heart's motion. Thus, in my experiments on artificial breathing, the heart soon ceased acting whenever I left off acting with my bellows; and upon renewing my artificial breathing, it, in a very short time, renewed its action, first by slow degrees; but became quicker and quicker till it came to its full action.

I believe this experiment cannot be reversed; we cannot make an artificial circulation, so as to know, that if we stopped the heart's motion, we should so readily stop respiration; and on producing the heart's motion, respiration would again take place; but if we could do this, I doubt very much its being attended with equal success, because I believe that in all deaths, respiration stops first; however it must be supposed, that if the heart stopped for any length of time, respiration would also stop; and if I were to take the following case as proof, it would appear that respiration would not go on without the heart's motion.

A gentleman was attacked with a pain in the situation of the pylorus. The pains were such as indicated its seat to be in the nerves of the stomach and its connections. It was such as he could hardly bear. The other attending symptom was a total stoppage in the actions of the heart; and of course the face was pale and ghastly. Not the least signs of motion in the heart could be felt. In this state he was about three quarters of an hour. He was attended by Drs. Hunter, Sir George Baker, Sir William Fordyce and Dr. Huck Saunders. As he was perfectly sensible at the time, and could perform every voluntary action, he observed, that he was not breathing, which astonished him; and at first conceiving he must die if he did not breathe, he performed the act of breathing voluntarily. This shews that breathing depends on the actions of the heart; and it also shews, that under certain circumstances the actions of both may be suspended, and yet death not be the consequence. As he spoke while in this fit, without attending to his breathing, it shews that the breathing which produces sound, is voluntary; and if we had only the power of involuntary breathing, then probably we could not speak; for it is probable we could not regulate the action of the glottis and tongue, which are voluntary, to so regular an action of the lungs; for in speaking, it is the one acting so as to correspond with the other, both becoming voluntary. A gentleman who had a singular asthmatic affection, his breathing gradually stopt, and again gradually recovered, but became violent, and this constantly and alternately held two or three minutes; and when the breathing ceased yet he spoke, although but faintly.

In those animals which have two ventricles, it has been asserted by some, that their actions are alternate; but observation and experiment shews us, that the two auricles contract together, and that the two ventricles also contract together. This can be observed simply by looking on the heart in its actions; and if we in that state make a puncture into the pulmonary artery and the aorta, we shall find the jet in both at the same instant, corresponding with the contractions of the ventricles. Indeed the circulation in the fœtus is a proof of it; for in the child there would otherwise be two pulsations instead of one.

This alternate motion of the heart is quicker in some classes of animals than others; in some being extremely quick, in others very slow. In all the more inferior orders of animals, I believe it is the slowest; and this may probably be in some degree in proportion to their imperfection. It is also slower, probably, in each class in proportion to the size; and we know it is slower in each species, in some degree in proportion to the size, although not nearly exactly so. The pulse is also found to be quicker in the young than in the old of each species, in greater proportion than what we find arising from size only. Thus the motion of the heart of a caterpillar is extremely slow, and also of a snail. The motion of the heart in fish is not frequent; and we know it is extremely slow in the amphibia. But in those possessed of two ventricles, as in birds and quadrupeds, the motion of this viscus is much quicker. In them too it differs very much in proportion to their size, although not nearly in the same proportion. Thus, a horse's pulse is about thirty-six in a minute; while a man's is about seventy. In the same species it is nearly of equal quickness; for in a man three feet high, the pulse was eighty, while a man above eight feet high, had a pulse about seventy.

VI. GENERAL OBSERVATIONS ON BLOOD-VESSELS.

By the vessels in an animal, are commonly understood those canals which carry the juices of the body, called the blood of the animal, to and from the heart, for the immediate purposes of the animal œconomy; and in those animals where no heart is to be found, yet vessels are found, though their uses are not so demonstrable; and in some of a still more inferior order, where no vessels can be demonstrated, yet, from analogy, canals may be supposed to exist; and those should still be called vessels*.

The vascular system in an animal, is, in some degree, to be considered as the efficient part of the whole animal respecting itself; every other part of the body being more or less subservient to it, and depending upon it, for existence and support; and therefore the greatest attention should be paid to every circumstance that can possibly explain the various uses of the vessels; for there is no operation respecting the internal œconomy of the animal, but is performed by them; insomuch, that for the convenience of the vessels in performing those peculiar actions, they seem to constitute various combinations, which are called organs†. And al-

* Of this, I am not certain. I have an idea, that some animals absorb their nourishment, even without action, somewhat similar to a sponge; but dispose of it immediately by converting it into its own increase.

† Perhaps it may be difficult to give a difinition of an organ that will meet every one's ideas; or will distinguish those bodies, accurately, from what may be said, not to be an organ. A muscle may be called an organ; but I would only consider it among the materials of which an organ is composed. I have the same idea of elastic substances, cellular membrane, bone, cartilage, etc.

I would, at present, define an organ to be a part of a particular construction, composed of a variety of substances, which are combined together to answer some particular purpose, which is the result of the actions of the whole.

though many parts have actions, independent of the vessels, yet these are not for the purposes of growth, support, etc. So that the vessels are constructed for the immediate use of the machine, and may be called labourers in the machine. This naturally implies something that is not vessel, or vessels; a something that constitutes the different parts of the body, and is only more or less vascular. They are probably the very first active parts in the system; for we find them in action before they have formed themselves into a heart; and in such a state of parts we find them the only part that has any strength; the other parts only preparing for action: this is so remarkable that we can dissect the vessels of a chicken in the egg without injection, the other parts easily giving way. These parts are formed of living animal matter, so composed as to constitute the different structures fitted for their different uses in the machine; yet some parts are so vascular as to appear almost to consist wholly of vessels; as if vessels were formed into such structures; but this, we cannot conceive, for then they must lose the action of vessels.

In those animals where the vascular system is connected with a heart, which may be called the termination, as well as origin of the vessels, we find that viscus to make so material a part of this system, as to require particular attention.

In many of these animals, we find two systems of vessels, the arteries, and veins; and most probably they exist in all of them: there is also a third, which consists of the absorbents. The heart is the source of the arteries, and the termination of the veins and absorbents. The two first depending on each other, form the circulation; and the third, is essential to both, bringing the materials which are to circulate*.

The arteries are to be considered as the acting part of the vascular system, since they perform a variety of actions, the uses of which are very important in the animal œconomy. They may be called universal, or constitutional, for their actions are immediately productive of health, or disease, in the constitution; and if they could be diseased as a system,

* This system is too extensive to be described, in the present work, although it will be necessary to describe one use not hitherto attributed to it, as it explains one part of my system of disease.

X

that disease would, of course, be universal; as their actions are expressive of health, or disease, they become also one means of discovering either.

There is no internal operation in the machine respecting growth, natural repair, and secretion, that is not performed by them: no new part is formed, nor additional alteration made in the structure of natural parts, nor repair for the loss of natural substances, either by disease or accident, but is made by the arteries, although of all operations we know nothing, but from the effect produced. These operations are performed by the termination of the arteries, which may be supposed to be of three kinds: one may be called arterial, conveying debelitated blood into the veins, and through their whole length, may be called arteries: another kind consists of the separaters from the blood, performing the different secretions: and the third contains the formers and supporters of the body: the two latter kinds I should not call arteries, they are the workers, or labourers.

The absorbing system also takes a very active part in the animal œconomy, whether natural or diseased, and seems in many actions to be the antagonist of the arteries; while the veins are much more passive, being principally employed in returning the blood to the heart.

It is probable, that every part of the body is equally vascular, although they may not all have equal quantities of blood passing through them, which must arise from the smallness of the vessels, and not from their being fewer in number. When we say that a part is very vascular, we can only mean that it is visibly so, by having a large vessel, or vessels, going to it, and ramifying in it; from which circumstance it contains a certain proportion of red blood, rendering the vessels visible; which may also easily be made conspicuous by injections. Where the vessels are smaller this is not the case. When we say, therefore, that a part is not vascular, we mean it is not visibly so; but still we must suppose such parts to be equally vascular, so far as respects their œconomy within themselves; but in such parts I conceive the blood to be more languid in its motion. Many parts appear to be much more vascular than they really are, from their vessels dividing, and anastomising, and taking a winding course before they terminate*; for it is by the number of terminations of an artery in a given space, that a part is made vascular, or not vascular: muscles appear to be more vascular than they really are. When parts have another use, in which blood furnishes the materials to be disposed of, as in secretion, and respiration, where vessels fitted for such purposes are superadded, then parts become proportionably more vascular. When blood does not seem to be the matter to be disposed of, yet if there are other operations continually carried on in a part, besides its simple support, as in a muscle, which has both the power of contraction, and considerable sensation, etc. then the vessels are larger, and of course appear in great numbers: this is evident in the living body, for if a muscle is hardly allowed to act, its vessels become small, and it becomes pale; but if thrown into more violent action, for a continuance it becomes red: we cannot here suppose an increase of vessels, but only an increase of size. Thus we have parts vascular in proportion to the quantity of action they are capable of, or under the necessity of performing: and this particularly in parts whose uses may be called double, as the organs of secretion in general, brain, and muscles; even in inflammation, and in proportion as these parts are employed in their peculiar actions, they become to appearance more vascular. Some animals have naturally red muscles, without its being the effect of considerable action: this is very remarkable in the hare; but the redness in the muscles of this animal may be intended to adapt its muscles naturally for violent exertions at all times. Muscles are of different colours, respecting red and white, in the same animal; but that I believe is also in proportion to the quantity of action the parts are put to.

This effect the epicure is well acquainted with; he knows that the wing of a partridge is whiter than the leg: and that the leg of a woodcock is whiter than the wing. The veal of this country is a remarkable instance of this; for the calf is hardly allowed to stir, and the muscles are white; but when the calf is allowed to follow its mother, the muscles are of a reddish colour: it may be, however, remarked, that white

* By simply cutting into the spermatic artery of a bull it appears to be extremely vascular, though, according to our idea of vascularity, it is as little so as any part.

meat is commonly the least juicy; and we find it remarkably so in those animals which are fed for this purpose, because, they require nothing but their simple support, and having little or no action within themselves, they have but little waste. Such change of appearance we find carried to a considerable extent in the uterus, at the time of the menses; but much more particularly at the time of uterine-gestation, where the vessels increase both in size and length, in proportion to the actions required. But parts whose use in the machine may be said to be passive, as tendon, cellular membrane, ligaments, investing membrane, bone, and cartilage, which last is probably the most passive, have all small vessels, and of course but few that are visible. As bone, however, is composed of two parts, viz. animal substance, and earth, it is probable there may be more action required to form the latter than either tendon or cartilage, and therefore there will be more vessels.

As a further proof that this is a general principle, we find that all growing parts are much more vascular than those that are come to their full growth; because growth is an operation beyond the simple support of the part: this is the reason why young animals are more vascular, than those that are full grown. This is not peculiar to the natural operation of growth, but applies also to disease, and restoration. Parts become vascular in inflammation; the callus, granulations, and new formed cutis, are much more vascular in the growing state, or when just formed, than afterwards; for we see them crowded with blood-vessels when growing, but when full grown, they begin to lose their visible vessels, and become not even so vascular as in the other neighbouring original parts, only retaining a sufficient number of vessels to carry on the simple œconomy of the part; which would now seem to be less than in an original part. This is known by injections, when parts are in the growing state, or are just grown, and for some time after. We may observe, when the small-pox is cured, that the remains of the pustules are red, and continue so for some time; which is owing to those parts being visibly more vascular than common: and those who have had the small-pox severely, are, in general, afterwards more pale than others, when those parts have arrived at their permanent state. If we cut into a part that has had a wound, or sore, upon it, which has been healed for a considerable time, we shall find that the cicatrix, and the new formed parts, are not nearly so vascular as the original, which corresponds with what has been advanced; for we know that those parts are not equal in power to original parts. In short, whenever nature has considerable operations going on, and those are rapid, then we find the vascular system in a proportionable degree enlarged.

The number of vessels in a part, and also the circulation of the blood through them, appears to keep pace with its sensibility; for first we find that most probably all parts endowed with vessels are sensible; and all sensible parts are, to appearance, very vascular. Where any increased action is going on, requiring increased sensibility, there is also an increased circulation through those vessels, as in the parts of generation, during the time of coition, more especially in the female; and this increase of vessels, circulation, and sensibility in a part, takes place in disease, as is well illustrated in inflammation, where the whole seems to be increased in the same proportion, especially the two last, viz. circulation, and sensibility.

These observations can only be made in animals which have red blood; and best in those which have the most red blood; but it is not possible to ascertain, with accuracy, the proportion that one blood-vessel bears to another, so as to know the exact quantity of blood each part may possess; which would better ascertain the action of the part; for they may be said not to be measurable with any degree of accuracy; and therefore such investigation must be taken in the gross.

Vessels have a power of increase within themselves, both in diameter and in length; which is according to the necessity, whether natural, or diseased. The necessity appears to arise from an increase of the part to which the artery is going, the formation of a new part, or an irritation. The first may be reckoned the natural increase of the body: the second, the occasional increase of parts, as of the uterus, in uterine-gestation, where the vessels are increased in width, in proportion to the whole solid contents, including the young: besides this, they are considerably increased in length before they reach the uterus, which obliges the spermatic artery, in particular, to be thrown into a serpentine form: this is more remarkable in some animals than in the human species.

Instances of new-formed parts, where the vessels are increased, are to be found in the stag, or all those of the deer kind which cast their horns; such animals having the arteries considerably increased at the time the young horn is growing, so that the carotid arteries, which before had only to supply the head, and the external carotid, which before had only to supply the sides of the head, now become larger, and are continued into the horn, which is extremely vascular.

After the separation of the fœtus, or the full growth of the horn, the vessels naturally lesson, to adapt themselves to the diminished size of the parts.

It is curious to observe how vessels become enlarged upon any irritation; not only the arteries, but the veins; and not only the smaller branches, but the larger trunks. This was evident in the following case: I applied a caustic to the ball of the great toe of a patient every other day, for more than a month, and after each application the surrounding parts put on a blush; and all the veins on the top of the foot, as well as up the leg, immediately began to swell, and became large and full. This was so remarkable, that the patient watched for this effect, on the days on which the caustic was applied, from its happening only on those days.

In diseases where there is an increased size of the part, as in tumors, etc. the increase of vessels is no less conspicuous; and they have the power of dilatation, and increase of strength, in proportion to the size of the vessels; which are now endowed with new dispositions, and actions, different from those they had before.

The arteries often perform diseased operations in the body, which become symptoms both of local and constitutional actions, as in inflammation, fever, etc. for they are not only active in local disease, but their action often becomes a symptom of a constitutional disease, whether original, or arising from a local cause; but these symptoms become mostly sensible to us in those arteries whose actions we can feel; because they have a peculiar action in their diastole, as well as in their systole, which is sensible to the touch; from which sensation, we, in many cases, judge of the state of the body at the time; as also the state of the cause, when it is local, and out of sight. The heart, the source of the circulation, is also affected from the same cause; so that its motion, and the motions of the arteries, commonly, if not always, correspond.

VII. VALVES OF ARTERIES.

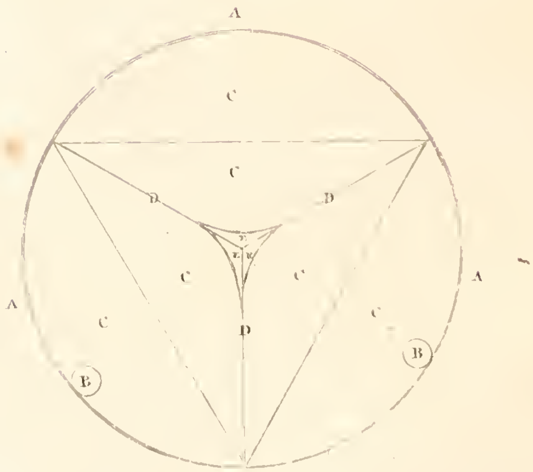
The arteries arising from the heart, I believe in all animals, have valves, which are so many flood-gates, to hinder a return of the blood into the cavities: and as there are two main arteries in the human body, so there are two sets of valves, viz. one belonging to each artery. These are situated at the beginning of the artery, and from their shape, are called semilunar. Veins have similar valves, almost through their whole course. The valves are inelastic, being similar to the inner coat of an artery; but the difference in the properties of the valves, and the arteries themselves, which are elastic, will be further considered in treating of the use, and mode of action of the valves. Each of these sets is made up of three valves*; but in veins, there are commonly only two. This difference in the valves of the arteries, and veins, is perhaps to bring the artery into a more rounded figure, than could have taken place by two valves only: each of these valves is of a semilunar form, having one convex edge, and the other nearly straight. These valves are attached to the insides of the artery, at its very beginning, by their semicircular edge, which is oblique; the points, as it were, running a little way into the artery. These terminations in each valve come close to one another; but the loose edges, which constitute the diameter, are not cut straight off, but rounded. There is, besides, a small body on each, attached to, or near, the edge, between the two points, called corpora-

* I have found in the human subject, only two valves to the aorta; but this is very rare.

sesamoidea. These bodies are not placed exactly on the edge, but rather on that side next to the artery, leaving the edge of the valve loose: this situation is best adapted to their intended use; the reason of the loose edge being a little rounded, and of the bodies called corpora-sesamoidea being placed there, arises from there being three valves to each artery. Each of these valves, with its artery, forms a pouch, whose mouth, or cavity, opens towards the artery; and the convexity of each of the valves, when the artery is dilated, makes nearly the third of a circle, which is turned inwards, towards the centre of the artery, as well as towards the heart. It is from this oblique direction in the attachment that the valves perform their office, simply from the action of the heart upon the blood; and the blood upon the artery. This is entirely mechanical; depending on mechanical principles alone, as much as the action of a joint.

I have above observed, that the area described by the valves is the same with the artery, when that vessel is in its systole, their outer surface lining the inner surface of the artery; but the artery being elastic, its diameter becomes larger when the blood flows into it; and the valves being inelastic, their loose margins, or edges, are brought more into straight lines across the area of the mouth of the artery, and nearer to each other; so as to make an equilateral triangle. Thus they are fitted to catch the returning blood; and the artery re-acting with considerable force on the blood, presses on the valves, so as to push them inwards: these having no pressure on the side next the heart become convex on this side, shutting up entirely the mouth of the artery. Here then is an effect arising naturally out of a variety of causes, viz. the oblique direction of the valves; their want of elasticity; the elasticity of the artery; and the dilatation of the artery; so that the return of the blood does not open the mouths of the valves, and in that way, shut up the mouths of the artery. To demonstrate this, let us suppose the extreme length of each of these valves to be an inch; then the circumference of the artery, when in its systole, will be three inches: in that case the valves lie close to the sides of the artery, and describe a circle of three inches circumference, (as in figure I.); but if you dilate this artery, as far as the valves will allow, which will be rather more than one fifth, the valves will

Fig. 2.



run nearly into straight lines, and make an equilateral triangle, (as in figure II.) whose sides are a little curved inwards. As the artery is filled from the contraction of the heart, it is distended: and as it is distended, the valves do more and more their duty, till at length, by the full distension of the artery, they are made to bulge inwards, and the loose edges, with the corpora-sesamoidea, are pushed further towards one another; by all of which positions the area of the artery is entirely shut up.

Figure I. shews the artery in its systole, with the three valves, nearly close to its sides. The two black dots are designed to represent the mouths of the coronary arteries, now covered by the valves.

a a a.....The circular section of the aorta.
b b.......The mouths of the coronary arteries almost covered by the valves.
c c c.....The hollow pouch of the valves.
d.........The area within the valves.

Figure II. shews the artery in its diastole, where the three valves run nearly into straight lines, making an equilateral triangle of the area of the aorta, d d d. But as their edges are rounded, and the bodies of the valves make a curve inwards, they by these means fill up in part this triangular space, as is seen at f; and the corpora-sesamoidea, fill up the other part at e. In this way the whole of the area of the artery is filled up.

a a a.....The circular section of the aorta, in its state of diastole; being now larger about one-fifth.
b b.......The mouths of the coronary, now quite exposed.
cccccc. The hollow pouch of the valves, now enlarged.
d d d.....The circular edges which fill up more of the area of the artery than if they were straight.
e e e.....The corpora-sesamoidea.

The foregoing account is proved by injections against the valves; but it is still more clearly proved that the diastole of the arteries makes the valves do their duty, when it is injected with the current of blood: for in proportion as the artery is distended, the valves recede from the sides of the artery: and if the artery is fully distended, the communication is entirely cut off between the two pieces of injection, viz. that which is within the heart, and that which is within the artery. It may be objected here, that it will require a certain quantity of blood to make these valves do their office: and when there is not that quantity, it must be done by regurgitation. To this it may be answered, that nature always keeps a due proportion; and all the parts depend on one another: so that the quantity of blood, that is just sufficient to keep the animal alive, is sufficient to distend the artery so as to shut the valves*. The valves of the pulmonary artery do not do their duty so completely as those of the aorta; for in them we do not find the corpora-sesamoidea; and if we inject a pulmonary artery, towards the right ventricle, it does not so completely hinder the injection passing into that cavity: nor are the two portions of injection completely separated when the artery is injected from the ventricle, as in the left side. So far as respects injections, the same observations are applicable to the valvulæ tricuspides; therefore I believe the valves of the right side of the heart, are not so perfect as those of the left: from hence we may suppose that the universal circulation requires to be more perfect than that through the lungs. We must see from this account of the action of the valves, that the mouths of the coronary arteries are opened by the action of the heart; for as the arteries dilate, they become more and more exposed.

* As people advance in life, especially men, we find the aorta losing its elasticity: and as it is acted upon with great force by the impetus of the blood, it loses that elasticity in the state of its diastole; which throws the valves continually across the area of the vessels; and as the valves in those cases commonly become thicker, are often very irregular, and bony, we find that they neither recede from the sides of the aorta, during the contraction of the heart, nor towards it during the systole of the artery: so that more blood is allowed to regurgitate into the ventricle, than in a regular circulation.

VIII. OF THE DIVISION, OR BRANCHING, OF ARTERIES.

As all the arteries in animals possessed of a heart arise from, or begin at that heart, by one, or two trunks only, they are obliged to divide into, or send off branches, or smaller trunks, which again divide into still smaller, till at last the whole body is supplied by the ultimate divisions. This is called the branching, or ramification of arteries; and is somewhat similar to the branching of a tree.

This branching of an artery does not depend on the artery itself, or on the powers propelling the blood, as in a tree, but is governed by the formation of the body; that is, according as a greater, or less quantity of blood, or a greater, or less velocity is necessary to different parts.

Various modes of branching are made use of to answer the above purposes.

In general the most favourable mode for the free passage of the blood is adopted, viz. branching with acute angles; more especially those which are to carry the blood some considerable way; and still more so in those which are at a great distance from the propelling impulse of the heart; which I shall now more particularly consider.

As the force of the blood in the artery is stronger, the nearer it is to the heart, the difference in the velocity of the blood, near, and at a distance from the heart, if there was nothing to retard it, would be too great for the difference in parts; the near and the distant parts being in many instances of the same kind. To keep up a velocity sufficient for the parts, and no more, nature has varied the angle of the origin of arteries, at different distances, from the source of the circulation. Thus we find that near the heart the arteries arise by obtuse angles; some of them being reflected, and the angles become less and less, till at length they are very sharp. The most remarkable instance of this is in the intercostal and lumbar arteries; because since they are a set of branches in the body, whose length and uses are so much the same, if there be any difference in the angles, at the origin of the arteries, at equal distances from the heart, it must be made with regard to their length, from the origin to the part supplied. We find a difference even in the arteries which arise from the intercostals; for they are much more obtuse at the beginning of the intercostals, than at their termination. The reason why this is not so evident, in all the arteries of the body, is, that there are so few arteries on the same side of the body, which take the same course, go to the same distance, and have the same office: for some parts require a greater velocity than others, which will make a difference in the origin of the two arteries, supposing they should go the same length, and take the same course. We see the same thing in the secondary arteries, such as the subclavian; for it sends off its branches near its origin, at much more obtuse angles than it does further on. Haller, in his Physiology, says, That the arteries arise at an angle of forty-five degrees; which is the greatest angle in projection: but he did not consider, that in projection there are two powers, viz. gravitation, and the force applied; while the blood in the arteries has only one. It may be asked, Whether the blood in an artery of a given size, arising from a large one, is sent in with the same force as if the artery had arisen from a much smaller trunk; or from an artery of the same size with itself, whose blood passed with the same velocity as in the large one? We find small arteries coming off at once from large ones, instead of being a third, fourth, or fifth, from the large one. Arteries send off their branches at a longer, or shorter distance, according to circumstances; or, in other words, they divide, and subdivide, more quickly in some places than in others. I believe this quick division is more peculiar to glands, than most other parts, though it does not take place in all, as in the testicle. They divide also quickly in the substance of the brain. In the kidney, this is also remarkable; they would seem in that gland to be hurrying to their termination. The same happens as soon as the arteries enter the substance of the brain. Other parts appear to have the arteries elongated before they enter the part, as the spermatic artery; more especially in some animals, as the bull, boar, etc. and in the female, in the time of uterine-gestation, where we should expect the quickest circulation, we find the arteries elongated very considerably, which throws them into a serpentine course; all of which must retard the blood's motion in the part. We also find arteries playing in the parts, ramifying and anastomosing, which diminishes the velocity of the blood; such as those of muscles, membranes, etc. We may suppose from the foregoing instances, that in some, a quick supply of blood was necessary in such parts: in the one for the drain; in an other, for the support of the living powers: while in others, a more regular, slow, and even motion, answered the purpose better.

Arteries, in common, pass in as direct lines from their origin to their destination, as possible; but this is not universally the case, for in many parts they run in a serpentine manner; so much so in some as to form a body of themselves. Thus the spermatic artery in the male of many animals, more especially the bull, is so convoluted, as to form a body. In the female also, the spermatic artery increases its serpentine course in the state of uterine-gestation. The internal carotid artery in man, and many other animals, as the horse, where it passes through the skull, runs in a serpentine direction; and in the lion, bull, etc. it forms a plexus. This would appear to answer two purposes; one to lessen the impulse of the blood, as in the vertebral, and internal carotid, the spermatic artery, etc. the other to allow of the stretching of the parts, upon which the artery passes, as the mouth, or lips, the uterus, and other parts of the body, which admit of being stretched, or relaxed, as the bladder, stomach, intestines, etc. independent of their elasticity.

We find not only the different systems of vessels communicating with each other, as the arteries with the veins, the veins with the heart, to be continued into the artery again, and the absorbents with the veins, to communicate, in the end, with the whole, but also the branches of each system communicating with one another, which is called anastomosis.

Anastomosing of vessels, is the opening of one vessel into another; so that if one of them be prevented from carrying its contents, the office can be performed by the other. The most common mode of anastomosing is, when two vessels run into one, or are continued into each other; or one vessel opens into another, from which others arise; but there is a peculiar communication between the two carotids, as well as between them and the vertebral, where a canal of communication passes directly between them; and this mode of communication takes place between the two descending aortas of some of the amphibia.

This anastomosing is much more frequent in the smaller than the larger arteries. We seldom find trunks anastomose with one another. One reason for this is, the great disproportion in number between the larger and smaller arteries; but the anastomosis is much more frequent in the smaller, in proportion to their number. The use of this is to give freedom to the circulation, as the chance of a stop being put to it is greatest in the smaller arteries; the circulation in them not being so strong; and passing through parts liable to be pressed upon: this is readily seen in the transparent parts of the living body, when viewed through a microscope. In some parts of the body we find anastomosis in pretty large trunks; but these are in parts essential to life, very liable to be compressed; or both.

The mesenteric artery anastomoses by large trunks; the mysentery being a part essential to life, and very liable to compression, from indurated fœces compressing the artery. In this case, if they only anastomosed by the small branches, on the intestines, the circulation might not be kept up sufficiently to preserve the gut. We observe the same thing in the brain; for there the arteries anastomose by large trunks, before they are distributed to the brain. The use of this is, that all parts of the brain might have an equal quantity of blood at all times, even where accident had put a stop to the circulation in any one vessel; for the small anastomosis on the pia-mater, would not be sufficient to keep up a due circulation; every where in the brain as I believe the arteries do not anastomose in the substance of the brain itself. There are large anastomoses in the hand, and foot, for the same reason, as in the intestines. All the uses arising from the anastomosing of the vessels are, perhaps, not yet perfectly understood: general reasons can, I think, be assigned for them; but these will not apply to all cases; there is something, therefore, more than we are yet acquainted with. The absorbents, and the veins, upon the whole, anastomose more frequently than the arteries; yet that circumstance is reversed respecting the veins in some places; and in the instances the uses of these systems of vessels are also in some measure reversed. Where all the three systems of vessels have nearly the same mode of action, we find that their manner of anastomosing is somewhat similar; and probably the differences might be easily accounted for.

Wherever they appear to be simply carriers, then their mode of anastomosing is somewhat similar: however, the absorbents anastomose more frequently than the veins; and the veins more than the arteries; and, probably, the absorbents anastomose every where. This is not so much the case with the veins; and not in the least so in some parts with the arteries. Let us see if we can assign reasons for all this variety in the different systems of vessels. The absorbents, from the office of absorbing, are to be considered only as carriers; and as they have no propelling force applied to their contents, and their coats are not strong, it is very probable, that a free communication between vessel, and vessel, should take place; upon the same general principle, the veins also anastomose; although perhaps not so frequently; and this difference may be, because they have, in some degree, a propelling power applied to their contents; namely, the action of the heart. The arteries having a very strong propelling power applied to their contents, it was in them not necessary as a general principle; but where they are placed in similar circumstances, we find them similar in this respect.

Although the anastomosing of vessels is upon a general principle very proper, yet in many cases it would appear in the following parts to be very improper. The arteries do not anastomose in the kidnies. This cannot arise simply from there being no occasion for it, on account of there being no lateral, mechanical obstruction; since from the same mode of reasoning, the veins should not anastomose; which they do, very freely: this want of anastomosis in the arteries, therefore, answers some purpose in the œconomy of the part. In the liver, the branches of the vena-porta do not anastomose although the arteries do in their smaller branches; we may, therefore, suppose some particular purpose answered, besides free communication; and I believe the arteries do not anastomose in the substance of the brain; which makes the brain appear less vascular than it really is. We may observe, perhaps, as a general principle, that arteries near to their destination, where they are to perform their particular functions, do not anastomose. Thus the artery of the kidnies, the vena-porta*; the arteries in the substance of the brain, do not anastomose; nor do the arteries on the villous coat of the intestines.

If it be questioned, whether anastomoses are a means of retarding, or accelerating the circulation, I should answer, that they appear to me, to retard the blood's motion; although we find vessels anastomosing as freely with one another, at the greatest distance from the heart, as near to it; but at the same time we may observe, that where we should suppose it was necessary for the circulation to be brisk, we find no anastomoses in the arteries, as in the lungs, the kidnies; and I believe hardly in the liver, except on the peritoneal coat, whose arteries are continuations of the hypatic artery.

I believe that the anastomosing of vessels increases their volume on the whole, and therefore allows a greater quantity of blood to be in them, than if they did not: that kind of net work too, which they make, increases the magnitude of the vascular system; for to answer this purpose, they take lateral and circular courses; which give them greater length, than if they had simply passed between origin, and destination, in straight lines.

The better to ascertain the velocity of the blood in the arteries, at the different distances from the heart, it will be necessary to know, whether an artery be a cylinder, or a cone; and when it divides into any number of branches, whether the whole of these, taken together, be less, equal, or greater, than the vessel, or vessels, from which they arose; and, therefore, whether they hold less, the same, or more blood. It may be

* This vessel should be considered as an artery.

observed, that arteries keep a pretty exact proportion with each other; the branches, with the trunk, etc. through the whole system; and therefore, whatever may be their shape, they preserve it pretty regular, viz. if they are cylindrical, they are so regularly; if conical, the same. I should suspect, however, that the anastomosing of the arteries, in some degree, interferes with this regularity; but it is probable that the ultimate branches may come back again, and correspond with the original trunk. To ascertain this, it is necessary to make choice of arteries, which for some length either send off no branches, or at least such as are very small, when compared with the trunk: for it is impossible to measure with any degree of accuracy the size of branches, and then calculate their different capacity, in comparison with that of the trunk, from whence they are derived: and I think it is reasonable to suppose, that whether an artery divides or not, the size must be the same in both; for it is necessary that the ultimate effect should be the same.

The arteries which are best adapted for this experiment, are those of the placenta, and of the testicles; particularly in the bull. The carotid arteries in some animals are tolerably well formed for experiments of this kind; for though these do not give us the exact proportions which the one end bears to another, yet they plainly demonstrate which end is the largest.

The arteries of the placenta evidently increase in size, the nearer they approach to the placenta; and this so very considerably as to require no experiment, unless it be intended to ascertain the difference correctly. In the spermatic artery of the bull, it is equally evident; but as these arteries are much longer than the distance between their origin, and the parts which they are to supply, it may be supposed that this increase is peculiar to them, in order to answer some particular purpose: but the carotid arteries in some animals afford sufficient proof that the arteries in common become larger as they pass on and ramify; for the carotids may be reckoned ramifying arteries, as they send off branches.

The carotid artery of the camel, among quadrupeds, and of the swan, among birds, are very proper arteries for such experiments.

To be as accurate as possible, I injected the arteries of two camels, and the arteries of a swan; and that one end might not be more distended than the other, the artery was well warmed, and placed in a perfectly horizontal position: the pipe was fixed into the lower end*, and the injection made so warm, as to keep fluid some time after having been injected: in this position it was allowed to cool. I made sections from each end; and, that they might be perfectly equal, I took a hard piece of wood, an inch thich, and bored a hole through it of the size of the artery, so as to contain a section exactly of that length, having a moveable button fixed at one end, which could be turned upon the hole, or off, at discretion. The artery being introduced through the hole, a projecting part was cut through, by a thin knife, in order that the artery might be divided at right angels to itself. After doing this, the artery was withdrawn, and the button was then turned upon the hole, so as to stop that end; and the cut end of the artery introduced to the bottom, or button: this piece, so enclosed, was separated in the same manner.

Having taken a piece of the carotid artery from each end, which were of course exactly of equal lengths, I weighed them, and found that the section of the upper end was one grain and a half heavier than that of the lower.

The carotid artery of another camel, measuring three feet and a half in length, was found to send off forty-four small branches, about the size of the human intercostal arteries; with one as large as the ulnar. Of this artery, a transverse section, of one inch in length, being taken from each end, and weighed; that from the lower end was found to weigh two scruples, sixteen grains and a half: while that from the upper end, weighed only two scruples, fourteen grains and a half.

In similar sections of the opposite carotid, which sent off forty-seven branches, the difference in weight, between the upper and lower section, was five grains.

Similar sections from carotid arteries of a swan being weighed, the lower sections were found to be three grains and a half heavier than the upper; the lower section weighing thirteen grains and a half.

* The fixing the pipe into the lower end was rather in favour of increasing the size of this end.

Had the lateral branches been preserved an inch long, being the length of the sections of the trunk, I believe each might have weighed above a grain; and in that case, the forty-four would have been nearly equal in weight to the trunk: should this be true, the arteries increase very considerably, not only in their ramifications, but in their trunks. I imagine if the carotid artery, in the camel, did not send off any branch in it's course, it would increase in size, nearly in the same proportion with the umbilical artery, or the spermatic, in the bull.

It is to be observed, that as arteries divide they increase in size, much faster than if they did not: for instance, if a section of an artery, two inches long, is equally divided into two, the section that is the further from the heart shall be heavier than the other, perhaps, by one grain; but if the most distant section had divided into two branches, the two, taken together, would have been a grain and a half heavier; if three branches, two grains heavier, etc.

The increase of size in the arteries as they ramify, is an effect of the numerous ramifications.

From what has been already said, it must appear that arteries form a cone, whose apex is at the heart: and if this be the case, in the adult, we shall find that it must be more so in the young subject; and will every day become less, as the child increases in growth.

The capillary arteries in the fœtus are probably as numerous as in an adult, perhaps more so; for we know that there is the same number of principal arteries in each. As far as we can trace them, they seem to send off the same number of smaller branches; and in many parts we find a great many more small vessels in the fœtus than in the adult.

In the eye, the membrane of the ear, etc. in all growing parts, such as callus, granulations, etc. we find a great many more vessels, than in similar grown parts; or in the same parts, when completely formed; not in proportion to the size of the part, but more in number.

These are strong proofs that many arteries are obliterated in the adult. How much more vascular, therefore, must a child be, than an adult, in proportion to its size, when in a much smaller compass a greater number of arteries are accumulated!

From this it would appear, that the only great change in the vascular system, is elongation of the vessels. As we find very little difference between the blood of a fœtus, and of an adult, it is natural to infer, that the smallest vessels are nearly of the same size in both; for the termination of the arteries, or what may be called the operative part of the arterial system, being intended to perform the same functions in the fœtus, as in the adult, it is reasonable to suppose, that the increase is in the length of the whole vascular system; and that the increase in the size of the trunks is in an uniform gradation, from the capillaries, towards the heart; but never becoming equal to the capillaries.

If the preceding account be true, or nearly so, we see that there must be a great proportional difference between the size of the two extremes of the arteries, in the young subject, and the adult. We may venture to say, that the aorta in the child is not one-fourth of the size of that vessel in the adult; and that the capillaries are rather larger than those in the adult, which would of itself make the whole capillaries in the fœtus more than four times the size of the aorta in the same; and as these arteries are very short, the cone, of course, increases very fast.

In the fœtus in utero, we are to consider that the aorta, at the beginning from the ventricle, is larger than in the adult, in proportion to the quantity of blood that passes through the foramen ovale: and beyond the entrance of the canalis arteriosus the aorta is increased in proportion to the size of the canalis arteriosus; and it is at this part its size is to be estimated: this probably makes the aorta, beyond the entrance of the canalis anteriosus, twice as large as in the adult, in proportion to their size; but the drawback upon this, from the body, is the placenta; for the placenta is to be considered as part of the body, disposing of the blood that afterwards circulates through the lungs: however, when it is separated, it may take away with it nearly its own proportion of blood; although I rather suspect it does not. But I do not suppose it is equal to the quantity passing through the foramen ovale, and canalis arteriosus; and if so, then the body has the overplus.

The aorta of a fœtus is, therefore, not only larger than that of an adult, but larger than in that proportion which the size of the fœtus bears to the size of the placenta : or it may be put in this view, that besides the difference in the size of the aorta, in a young subject, (as before observed) and in an adult, the size of the aorta, in the fœtus, is still larger, viz. more than in that proportion which the circulation in the lungs of the adult, bears to the circulation in the lungs of the fœtus; which is probably much more than that of the placenta.

Experiment on the arteries of a child.

I injected the descending aorta of a fœtus, just above the diaphragm, in the same manner as I did the carotids in the camel, and swan, by which means I injected the mysenteric artery, the subject of experiment.

This artery has a trunk, which at first does not put off branches, and then sends off several; which may be all called, so many trunks. These again do not immediately give off branches, and are therefore measurable with the trunk, from which they arise.

I first made a section of the trunk of the mesenteric artery, near its root, before it sends off any considerable branches, one-third of an inch in length ; and then another section of the same artery, having the same length, close to the origin of the first branch : all the branches arising from it being preserved of the same length with the trunk itself. When they were weighed in opposition to each other, the trunk without the branches was found to weigh thirteen grains and a half; while that with the branches weighed eighteen grains ; four grains more than the trunk. A section of the aorta, near half an inch long, being made just above the origin of the inferior mesenteric artery, was weighed against a section of the same length, including the inferior mesenteric, likewise of the same length; the last section weighing one grain more than the other. The highest amounting to six grains, the lowest to seven. A section of the lower end of the aorta, including a portion of the two iliacs, was weighed against a section of the two iliacs, which was equal in length, and these were found to weigh rather heavier.

By the above is confirmed what I formerly asserted; that an artery, not giving off branches, does not increase so fast as another which does, if we include all the branches.

From all that has been said, it appears that there must be a much greater quantity of blood in a fœtus, than an adult, in proportion to their difference of size; and that the heart must be larger and stronger, in proportion, to move this blood; which will probably still circulate in the smaller vessels with less velocity.

The whole of these differences, between the fœtus and the adult, must be intended for the purposes of growth; and indeed we may discern the necessity of it: for if a child was not more vascular in proportion to its size, than the adult, its growth, we might conceive, would only be in proportion to the number of its vessels; which would be twelve times less than they are; for a new born child is only one-twelfth in size to that of an adult. A child would, therefore, grow faster and faster every year; for instance, in proportion to its size, as the vessels would become numerous in that proportion.

But this is not really the case, for children grow less and less, every year, in proportion to the size; only adding its first year's growth to itself every succeeding year; though, perhaps, not quite so much, as the vessels rather decrease in number.

That this is the case may be proved by taking the eye for an example, which grows more the first year after conception, than it does any year after; so that the disproportion between the vessels of this part, in those two states, is particularly great.

Thegrowth of an animal is, therefore, in proportion to the number of its capillary vessels: as the body grows, the vessels elongate to keep pace with that growth: the capillary vessels at last come to a stand; and the arterial system is daily losing ground.

The heart grows in proportion to the increased length of arteries, that it may be able to throw the blood through the whole, but not in proportion to the size of the whole body; because the vessels do not increase in number, or size, in proportion to the size of the body. But as the heart increases only in proportion to the size of the whole vascular system; while the body increases faster, and more, the heart cannot be in proportion to the size of the whole body; hence its action must in time lose the power of elongating the body, and become merely sufficient to nourish what is already formed. Perhaps it does not even continue to do so much; for it is not impossible, that the body may begin to decline from the moment it ceases to grow; the heart having pushed the growth of the body, even beyond its own powers, to preserve it in that state.

IX. OF THE ACTION OF THE ARTERIES, AND THE VELOCITY OF THE BLOOD'S MOTION.

ARTERIES during their diastole, which arises from an increased quantity of blood being thrown into them, increase much more in length than width, being thrown into a serpentine course; therefore, instead of the term diastole, it should rather be called, the elongated state. It is, however, the increased diameter that becomes sensible to the touch. This, probably, arises from the muscular coat opposing the dilatation of the arteries, while it cannot the lengthening. The dilatation of the artery producing the stroke, is either felt by the finger, or may be seen when superficial; but were we to judge of the real increase of the artery by this, we should deceive ourselves; for when covered by the integuments, the apparent effect is much greater than it really is in the artery itself; for in laying such an artery bare, the nearer we come to it, the less visible is its pulsation; and when laid bare, its motion is hardly to be either felt, or seen.

The more an artery is covered, especially with solid bodies, the more is the pulsation to be felt, or seen: thus tumors over large arteries have a considerable motion given to them; and have often been supposed to be aneurisms.

The knowledge of this fact arising more from experiment than common observation in the living body, may be a sufficient reason for keeping to the old expression, dilatation.

This circumstance, which has been but little taken notice of, produces an effect, which has also been unobserved. If the arteries had been dilated by the force of the blood's motion, as has been supposed, its motion should be much less retarded than it is; for even supposing that the increased area of the artery is the same when elongated, as if dilated, and therefore holds an equal quantity to a dilated one, it must appear evident, that the blood will not arrive so quickly at the opposite end.

The continual repetition of the cause of this serpentine course obliges the arteries in many places to retain this state, especially in parts that do not yield readily, as the scull, upon which the temporal artery is placed; and this retention of the serpentine course, is still more obvious in those arteries which have lost a good deal of their elasticity. However, this increase of the artery is so manifest, as to be felt, or seen; and produces what is called the pulse; which must gradually diminish in proportion as the arteries divide into smaller branches; a small artery having a proportional pulse, and the arterial system increasing as it goes along; both of which causes diminish the velocity of the blood, render the diastole less, and its motions more uniform.

From the description I have given of the heart, with its action, and the parts of which an artery is composed, it must appear that an artery is at all times full of blood, which is moving on with more or less velocity; because it receives it from the heart, at interrupted periods; and when a given quantity is thrown in at one end, this will make a considerable difference between this part and the other; which part will of course be more upon the stretch; for although the artery dilates, yet as it is from the impulse of the blood, the blood must move much faster on in the diastole of the artery, than its systole. This part of the artery will contract, and throw the blood into the remaining part; but not with the same force it was received; but still the artery beyond will receive it faster, than it will give it. By these means, all the parts of the artery are brought to a more equal state; for this additional quantity of blood, that was at first in one part only, is in some degree equally diffused through the whole arterial system; by which means too, it is becoming proportionably slower in its motion: but all these circumstances will vary according as the arterial system consists of cylinders, or cones; and if of cones, then according to the extremity, which is the base; all of which may be conjectured, but cannot be exactly estimated. Yet that the force of the heart might not be lost, the elasticity of the great artery, over the smaller, is happily applied; because it propels the blood more forcibly on, between the strokes of the heart: for although we are to suppose that the heart, which was capable of distending a part, so as to make it react, and send the blood through any given length, was also capable of sending it through that length at once; yet we must see, that by an elastic power being applied at one end, while this is gradually lost towards the other, the elastic part acts with a superior force over the other, in the proportion as the other has less elasticity. This other being also less upon the stretch, is overcome by that which is more so; which is always the end next to the heart: for the muscular part relaxes, requiring hardly any force to distend it; and indeed, as the muscular power has contracted the artery, within its middle, or stationary state; and this more and more, as we get into smaller vessels, the muscular coat is at first stretched by the recovery of the elastic power; so that the blood passes into the smaller branches with much less resistance than it would have done if the vessels had been elastic in proportion to their size. These proportions, however, in the blood's motion, arising from the elastic power of the arteries, will not be the same in the fœtus, and adult; and will be still more different in the aged subject; for in this last the elastic power of the artery is diminishing, as well as the muscular, the coats becoming more rigid: besides which, the vessels vary from a conical shape, (whose apex is at the heart, and basis at their extremities) towards a cylinder; and this change is also increased by the loss of many of the smaller vessels; so that as we grow up, the base of the cone is gradually diminished from two causes.

The elastic power will allow of a quantity of blood in the animal, beyond the natural state of the artery; and the muscular power will allow of a smaller, without the animal being affected, although the muscular alone would have answered both these purposes. Arteries then are the conducters, and disposers of the blood: as conducters, they are in every animal above fish, both passive, and active; passive, in admitting of the propelling power of the heart; and active, in continuing that power to the extreme part.

Besides these reasons for a difference in the velocities of the blood, at different distances from the heart, I conceive there is a material difference between the velocities of the blood, in those vessels which carry red blood, and those which carry only the coagulable lymph, and the serum; for where the red blood goes, there is a quicker return, than where there is only the coagulable lymph, and serum. For this, there are two reasons, viz. that where the red blood passes, it is commonly nearer to the heart, while the other parts go to a greater distance: but, besides this, the vessels which carry the red blood, are larger, and I believe ramify more quickly; the velocity therefore of the blood, is greater in them. Where the lymph and serum pass only, the velocity of the blood is languid, and it appears merely to carry nourishment, such as in tendons, ligaments, etc.

So far we are to consider the above as a general principle arising out of the construction of a blood-vessel; but there are secondary, or collateral circumstances, acting so as to accelerate, or retard, the blood's motion.

Since the solids and fluids have a mutual dependence on each other, and since the solids answer various purposes, for which, quantity, velocity, etc. are peculiarly necessary, we find that this intercourse between the two is with great exactness kept up. I have already observed that the angles, by which branches of an artery arise, either retard or allow of a freer motion in the blood; but Nature appears to have taken still more care in retarding the blood's motion, where velocity might do mischief. She seems also to have taken more care about the blood's motion in some parts than in others: as for example, in the brain; a part which probably cannot bear the same irregularity in quantity, or velocity, of the blood, as many other parts of the body. I should suppose, that by sending four arteries to the brain, instead of one, or which would have been more regular, two, the force of the motion of the blood is broken, as well as by the winding course of the internal carotid arteries. The verterbræ, likewise, are intended, we may suppose, to prevent a too great velocity of the blood; both because the artery is longer than it need be, and the blood is hindered from moving in a straight line: but besides the serpentine course of the arteries of the head, they pass through a bone; but principally the carotids, where the bony canal is closely applied to the coats of the artery; so that there can be no pulsation here, but a greater velocity of the blood in those parts, and probably less in the brain. This I should suppose retards also the motion of the blood in the brain; because the blood passing through a smaller place than common, must meet with a greater resistance, and therefore a small quantity must pass through this part in a given time, so that the pulsation of the arteries in the brain should be less than any where else: for we may suppose, that the motion is considerably lost by the blood coming into an elastic canal of the same diameter, with that through which it passed, before it came into the bony canal. If then this motion is lost, and the quantity of blood is really lessened in a given time, its motion must be more regular, and the pulsation less.

In some animals, the carotid artery is found to divide and subdivide, forming a plexus, and the branches unite again before it goes to the brain. This is called, rete mirabile; and in animals, which have it, will certainly break the force of the blood's motion: but since it is not universal, some peculiar purpose must be answered by it. It is not in the horse, and ass, for instance; but it is in the lion. Where the vessels anastomose, there is also a considerable retardation to the blood's motion; and they are found to anastomose a good deal on the pia-mater, before they enter the brain; but I believe not within its substance.

X. OF VEINS.

The vessels* carrying the blood from any part of the body towards the heart, are called the veins: they are more passive than the arteries; and seem to be from their beginning, to their termination in the heart, little more than conducters of the blood to the heart, that it may receive its salutary influence from the lungs. However, this is not universally the case, for the vena portarum would seem to assume the office of an artery in the liver, and therefore becomes an active part; and we have many veins formed into plexuses, so as to answer some purpose, not at all subservient to the circulation; but still in this respect, they are not to be reckoned active. They differ from the arteries in many of their properties, although in some they are very similar.

They do not compose so uniform, or regular a system of vessels, as the arteries, either in their form, or use, being subject to considerable variety in their uses, which are, however, passive, not active; and often answering, from their construction, collateral purposes.

The coats of the veins, upon the whole, are not so thick as those of the arteries; but differ materially in different situations of the body. Thus they become thinner, and thinner, in proportion to their size, the nearer to the heart: however, this is not equally so through the whole venal system, but principally in the depending veins, as those of the extremities, more especially the lower in the human, and still more so, the nearer to the extreme parts. In such parts it is often difficult to distinguish the vein from the artery: yet this is not to be remarked in the veins of ascending parts, or those coming from the head, or such as are horizontal, especially in the human subject; and in animals who have a large portion of their body horizontal, there is little difference in the coats of such veins at different distances from the heart. I suspect the muscular powers are much greater in what may be called ascending veins, than either descending, or horizontal: and I believe, in general, it is very

* A vein is commonly a canal, especially that which carries red blood; but in many animals it is entirely cellular; yet I use the word as a general term, when applied to the blood.

considerable; for if we look at the back of our hand, and compare their size in a warm day, or before a fire; and in a cold day, they hardly appear to be the same veins. They are not so strong in their coats as the arteries, and their strength is in an inverse proportion to their size in the extremities; and the reason is very obvious. They are more dense in their coats than the arteries, yet in the dead body they seem to admit the transudation of the blood; for when there is the least degree of putrefaction, we can trace the veins with the eye, on the skin, as if very large, the cellular membrane and the skin being tinged for some way on each side of the vein. In the liver, we find injections escaping the vena cava hepatica, and getting into its substance in a peculiar manner. They have nearly the same elasticity with the arteries.

They are similar to the arteries in their structure, being composed of an elastic, and muscular substance; the elastic in some degree preserving a middle state, although not so perfectly as in the arteries. The muscular power adapts the veins to the various circumstances which require the area to be within the middle state, and assists the blood in its motion towards the heart.

The coats of the veins themselves are vascular; although not very much so. The arteries arise from the nearest small ramifying arteries; and the corresponding veins do not terminate in the cavity of the vein to which they belong, but pass off from the body of the vein, and join some others from different parts; and at last terminate in the common trunk, some way higher.

On laying open the jugular vein of a dog, and closing up the wound for some hours, and then opening it, I observed the vessels of this part very distinctly. They were becoming inflamed, therefore turgid; and I could easily distinguish between the arteries and veins, by the colour of the blood in them.

Veins have interruptions in their cavities, called valves. They are thin inelastic membranes, of an exact semilunar form; their unattached edge being cut off straight, not curved, as in those of the arteries; and this is, because there are only two of them, whose semicircumference adheres to the sides of the vein. They are not placed in a transverse direction, so as to cut the axis of the vein perpendicularly; but obliquely, as the valves at the beginning of the arteries, making a pouch, whose mouth is turned towards the heart. They are attached in pairs, the two making two pouches, whose edges come in contact. In the larger veins of many animals, as the jugular veins of a horse, etc. there are often three valves, as at the beginning of the aorta, but not so completely formed: these valves as it were, cut the veins into two at this part. These two valves are not always of equal ſize. At this part there are always two swellings in this form; but I believe more in the adult, than in the young subject. They are not formed from a doubling of the internal coat, as has been imagined; for the internal coat is elastic; but the valves are rather of a tendinous nature; from this circumſtance, together with their ſhape, and their mode of attachment to the sides of the vein, they always do their office whenever the vein is full, in the same manner as the valves of the arteries. The valves of the veins are chiefly in the extremities, jugular veins, and the veins on the exterior parts of the head; but never in the veins of the brain, heart, lungs, intestines, liver, spleen, nor kidnies.

Where a smaller vein opens into a larger, there is often a valvular structure at the acute angles; but this is not constant.

The veins, taken altogether, are much larger than the arteries; but in the extremities, the veins that attend an artery, are sometimes less. Nevertheless, there are commonly two of them; but besides these, there are superficial ones, which are much larger than those deeply seated. The best way, however, of judging, is by comparing them with the corresponding arteries, where there are no supernumerary veins, as in the intestines, kidnies, lungs, brain, etc. we find that they are larger than the arteries; and this too, where a conſiderable waste has taken place of the arterial blood in the different secretions.

From this circumstance the blood's motion in them is slower; and they allow a greater quantity to be in the body at all times.

There is a greater number of trunks of veins in the body, than of arteries, at least visible veins; for wherever there is an artery, in common there is a vein; and in many places two, one on each side, which sometimes make a kind of plexus round it; besides, there are many veins where there are no corresponding arteries, as on the surface of the body; for in the extremities many of the larger veins pass superficially; but those become fewer and fewer towards the trunk of the body. They are numerous also in the neck of the human subject; but in some of the viscera, as the intestines, the veins and arteries correspond in number very exactly. Dr. Hales, however, in his Staticks says, that he has seen a number of arteries throw their blood into one vein, which, if true, shews that there are more small arteries than veins.

Although veins generally attend the arteries, there are some exceptions, even in corresponding veins, as in the piamater; but they cannot all attend the arteries, there being more superficial veins on the extremities, and neck; but the large trunks do. The supernumerary veins are not so regular as those that attend the arteries, being hardly alike in two people

The veins may be said, upon the whole, to accompany the arteries; and it is most reasonable that this should be the case, since both perform the same office of conducting the blood, the same course muſt answer equally in both: this, however, is not universally the case, some veins being intended for particular purposes, as the vena portarum; some forming bodies, as the penis, plexus reteformis, and others varying their course for convenience, as in the brain; the veins of this viscus taking in general a very different course from the arteries, but this is principally in the larger veins of the brain; for the smaller, which are in the substance, accompany the arteries. The intention of this seems to be, that the largest veins, called the sinuses, should be so formed as not to be compressible; probably that there should be as little chance as possible of any stoppage to the circulation of the blood in this part. But in some parts of animals they vary their course from the arteries, where we do not so well see the intention, because it is not the case in others. Thus the veins in the kidnies of the cat kind and hyæna have the veins, in part, passing along the surface in the external membrane, like the sinuses in the brain. Veins seldom or ever take a serpentine course, because a retardment in the blood's motion in them answers no particular purpose in the œconomy of the parts; and the more readily the blood gets to the heart the better. However, the plexuses, although not intended to retard the motion of the blood, answer other purposes not immediately connected with the circulation.

Veins, upon the whole, anastomose more frequently than the arteries, especially by their larger trunks, and more particularly in the extremities; for we often see a canal of communication going between two trunks, and one trunk shall divide into two, and then unite again. Where the veins and the arteries correspond, their anastomoses are nearly the same. I believe they do not anastomose in the lungs or liver; however, the veins corresponding to the arteries, do not always follow this rule; for the veins in the spleen and kidnies anastomose in very large trunks, while the arteries do not at all. This of the larger veins anastomosing more frequently, is because a vein is easily compressed, and the blood has a ready passage into another; besides, the valves render it more necessary, for when the blood has got past a valve, it cannot take a retrograde course, but may take a lateral: and indeed it is principally in those veins which have valves that we find those large anastomosing branches; by this means the blood gets freely to the heart.

As the area of all the veins is larger than that of the arteries, the blood will move more slowly through them; and this is evident from every observation that can be made. It may be observed in the large superficial veins in the extremities of the living body, and the difference of velocity in the blood flowing from a vein and artery in an operation is very great. The blood, however, moves with a good deal of velocity in a vein: for if we stop the circulation in the beginning of any of the superficial veins of an extremity, and empty the vein above, immediately upon removing the finger the blood will move along the vein faster than the eye can follow it; yet its motion is so slow as to allow the blood to lose its scarlet colour, and acquire the modena red; and this more so as it passes on to the heart.

The blood moves more slowly in the veins than in the arteries, that it may come into the right auricle more slowly; for if the two venæ cavæ were of the same size with the aorta, the blood would have the same velocity in them which the auricle, as it is now constructed, could not have borne: but it may be probable, that the blood is assisted in its passage into the auricle by a kind of vacuum being produced by the decrease of the size of the ventricles in their contraction.

From the number of anastomosing branches, especially by larger trunks, from the blood being liable to temporary obstructions in many places, and and also moving with little force, its course becomes often very irregular, and undetermined; much more so than in the arteries.

The first cause of the blood's motion in a vein of a quadruped, is the force of the heart; for I think we must suppose that the heart can, and does carry on simple circulation; because in paralytic limbs, where voluntary muscular action is totally lost, and where, I conceive, the involuntary is very weak, the circulation is continued, although, I believe, with much less velocity than in perfect and sound parts: besides, we have observed, that the arteries continue the motion of the blood in them where the heart either fails to do it, or where an increased motion may be wanted. The arteries, therefore, will assist the heart in propelling the blood through the veins; however, it is assisted by collateral causes. The second cause, is their muscular contraction; which most probably is in the direction of the blood's motion, assisted by lateral pressure of all kinds; because the valves will favour this course wherever they are. However, as the valves are not universal, the motion of the blood in some veins must be carried on without them, and therefore they are not absolutely necessary.

Since we see the veins assuming the office of arteries in the liver of quadrupeds, birds, amphibia, and fish, and much more so in many of the inferior orders of animals, the motion of whose blood is first derived from the heart, we must suppose that veins have considerable power in carrying on the circulation; but the resistance being continually removed at their termination into the heart, will direct and assist the blood's motion in that direction, more especially when influenced by the action of the vessels themselves, or any lateral pressure. In those veins which are accompanied by the arteries, the pulsation of the artery assists in propelling the blood towards the heart; more especially where there are two or more attending an artery.

When treating of the motion of the blood, in the arteries, I observed that its motion was not in an uniform stream, but interrupted, which arose from the heart's action; but as it receded from that viscus, that its motion gradually became more uniform, till at last it was nearly a continued stream. However, it is not certain, but an alternate accelerated motion is continued into the veins, immediately from the heart, although it may not be an easy undertaking to ascertain this: for fimply observing an accelerated motion in the blood of the veins, more especially the small ones, does not prove that this was an alternate increase immediately from the arteries.

Every artery has a pulsation in itself, immediately from the heart; but a secondary vein, or one that is a third or fourth in order of size cannot, because it has more than one cause acting upon it: for such vein is receiving the impulse of the heart at very different times, owing to the larger trunk receiving blood by a number of smaller veins that come from a variety of parts: so that if the trunk was to receive it by starts from the smaller veins, it would only be a tremor, or confused motion. This is a reason why this cause could produce none in the secondary veins. The fact is, however, that there is a pulsation in the veins; for when we bleed a patient in the hand, or foot, we evidently see a strong jet, much more in some than in others; and much more here than in the bend of the arm. The query is, Does this arise from the immediate stroke of the heart; or is it by the lateral preffure, occasoned by the swell of the arteries? To ascertain this the better, it is necessary to observe several things: we may remark that the pulsation in the veins is more in some parts than in others: thus I should suppose it was more in the veins of the kidney, spleen, lungs and brain, especially the last, than in many other parts: but this from the lateral swell of the arteries cannot, from the above observations, affect all parts alike; for the veins on the back of the hand being superficial, and not surrounded with vascular parts, could not be affected by arteries: but still it may arise from the lateral swell of the smaller arteries; and this acceleration, given to the blood's motion in the smaller veins, is carried to those on the back of the hand. But I think I have seen the difference in the projection so great, that it hardly could arise from that cause alone: and, indeed, if this was the only cause, we should have it in some degree in every vein; for every vein is so far surrounded as to be in some measure affected from the swell of the arteries of the part: but we certainly do not perceive it in so great a degree in the bend of the arm. The larger veins, near to the heart, have a pulsation which arises from the contraction of the heart preventing the entrance of the blood at that time, and producing a stagnation. This I saw very evidently in a dog whose chest I opened, and produced artificial breathing: but I could not say whether this arose from the contraction of the auricles, ventricles, or both: but the vena cava superior has a contraction in itself, in both dog and cat, and, probably, in the human subject. Even breathing produces a stagnation near the thorax; for during inspiration the veins readily empty themselves; but in expiration there is a degree of stagnation. Coughing, sneezing, or straining, in any way where the thoracic and abdominal muscles are concerned, produces this effect.

I think it is probable, that where there is an universal action of the vascular system, the action of the arteries and veins is alternate. That when the arteries contract, as in many fevers, the veins rather dilate, more especially the larger.

PART II.

CHAPTER I.

UNION BY THE FIRST INTENTION.

I MAY observe, that all alterations in the natural dispositions of a body are the result either of injury or disease; and, that all deviations from its natural actions arise from a new disposition being formed.

Injury is commonly simple; disease more complicated.

The dispositions arising from these are of three kinds; the firſt, is the disposition of restoration in consequence of some immediate mischief, and is the most simple.

The second is the disposition arising from necessity; as for instance, that which produces the action of thickning parts, of ulceration, etc.

This is a little more complicated than the former, as it may arise both from accident and disease, and therefore becomes a compound of the two.

The third is the disposition in consequence of disease; which is more complicated than either, as diseases are infinite. Yet many local diseases although complex in their natures, are so simple in their extent, as to allow the removal of the diseased part, becoming when that is done, similar to many accidents.

As disease is a wrong action of the living parts, the restoration to health muſt first consist in stopping the diseased dispostions and actions, and then in a retrograde motion towards health.

In treating systematically of such complaints as are the object of surgery, we should always begin with the most simple, and advance gradually to the more complicated, by which means we shall be more clearly understood.

There are many complaints requiring the attention of the surgeon, which cannot be called disease, because having been produced by something foreign to the body, as in accidents, they are to be considered as a violence committed upon it, altering in some degree the structure of parts, and consequently interrupting the natural operations already described.

The parts so hurt not being able to pursue their original or natural mode of action, are obliged to deviate from it; and this deviation will vary according to the nature of the violence, the nature of the part, and the state of the constitution at the time.

An alteration in structure requires a new mode of action for its restoration; as the act of restoration cannot be the same with what was natural to the parts before any alteration had taken place.

The alteration of structure by violence, requires only the most simple change in the natural action of the part to restore it; and of course the most simple method of treatment by art, if it be such as to require any assistance at all; for there are many accidents where none is necessary.

It will be proper to observe here, that there is a circumstance attending accidental injury which does not belong to disease, viz. that the injury done, has in all cases a tendency to produce both the disposition and the means of cure.

The operations of restoration arise naturally out of the accident itself; for when there is only a mechanical alteration in the structure, the stimulus of imperfection taking place, immediately calls forth the action of restoration; but this is contrary to what happens in disease; for disease is a disposition producing a wrong action, and it must continue this wrong action till the disposition is stopped, or wears itself out; when this salutary effect, however, has once taken place, the state of the body becomes similar to that in a simple accident, viz. a consciousness of imperfection is excited, which produces the action of restoration.

In injuries arising from accident, we have hitherto supposed that the parts have no tendency to any diseased action, independent of the accident; for if they have, it is probable that such a tendency may be stronger than the disposition for restoration, and in that case they will fall into the peculiar diseased action, as was explained when treating of susceptibility. Let us take the scrophula and the cancer as examples, and we shall find, that if a part be hurt, which has a strong tendency to scrophula, it will, most probably run into the scrophulous mode of action, in preference to that of restoration; and therefore, we have many joints, when injured, assuming the scrophulous action, called white swelling; or if a woman, beyond thirty years of age, receives a blow on the breast, it is more likely to acquire the cancerous mode of action, than that of restoration; which should be well distinguished from what is immediately consequent, viz. the inflammation; for on this depends a knowledge of diseases.

Although accident may be said to produce an effect on a part (whatever that effect may be) which has a tendency to its own cure, yet there are often not only immediate consequences arising from that effect, as inflammation; and again, the consequences of this inflammation, as suppuration; but the basis of diseases are also frequently laid by it, not by producing them immediately or naturally, but by exciting some susceptibility of the constitution, or of a part, into a disposition for a disease, which may be latent for a considerable time, and then come into action.

Thus scrophula, cancer, etc. often arise from accident, even where the parts in consequence of the injury have gone through the immediate and the secondary stages of a cure.

Those effects of accident which arise from the nature of the parts hurt, may be divided into such as take place in sound parts, and such as affect parts already diseased. The first is what I shall at present treat of, the second, being connected with disease, is not to our present purpose.

The injuries done to sound parts, I shall divide into two sorts, according to the effects of the accident.

The first kind consists of those in which the injured parts do not communicate externally, as concussions of the whole body, or of particular parts, strains, bruises, and simple fractures, either of bone or of tendon, which form a large division. The second consists of those which have an external communication, comprehending wounds of all kinds, and compound fractures.

Bruises which have destroyed the life of the part, may be considered as a third division, partaking, at the beginning, of the nature of the first, but finally terminating like the second.

I. OF INJURIES, IN WHICH THERE IS NO EXTERNAL COMMUNICATION.

THE injuries of the first division in which the parts do not communicate externally, seldom inflame; while those of the second commonly both inflame and suppurate. The same operations, however, very often take place in both, though the order in which they happen is reversed; the first becoming like the second, by inflaming and suppurating; and the second being in many cases, when properly treated, brought back to a resemblance of the first, and united by the first intention; by which inflammation and suppuration are prevented. But when the life of a part has been destroyed by the accident, it must necessarily suppurate; and therefore these injuries will be rendered similar, in this respect, to those of parts which communicate immediately, and have not been united by the first intention.

That injury which in its nature is the most simple, and yet calls forth the actions of the part to recover from it, is a degree of concussion*, where the only effect produced is a debility of the actions or functions of the whole or part, similar to that occasioned by a bruise, in which the continuity of the substance is not interrupted; in such a state the parts have little to do, but to expand, and reinstate themselves in their natural position, actions, and feelings; and this is what happens in concussion of the brain.

The rupture of a small blood-vessel is, perhaps, the next in order of simplicity; where the continuity of the part is broken, extravasation takes place, and the blood is diffused into the common cellular membrane, into the interstices of some part, or into a circumscribed cavity. But should the vessel be either very large, or essential to life, such as are

* Here I mean concussion as a general term, not confining it to the brain.

femoral, bracheal, or coronary arteries; or should the rupture take place in a vital part, as the brain, or in interstices or cavities belonging to a vital part, as in the cavities of the brain, or pericardium, in all such cases the injury may kill from the extravasation alone, however inconsiderable may be the original mischief.

The operation of restoration in this case, when the vital parts are not concerned or disturbed, consists first in the coagulation of the extravasated blood between the ruptured parts, laying, as it were, the foundation of union, next in closing the ruptured vessel, or in promoting its inosculation, and sometime after in bringing about an absorption of the superfluous extravasated blood. If the vessel close, that effect is produced by the muscular contraction of its coats; but in what way it inosculates, whether by the two orifices when opposed having a mutual attraction, and instead of contracting the two portions of the ruptured vessel elongating, so as to approach each other reciprocally and unite*; or whether a new piece of vessel is formed in the intermediate coagulable lymph, is not easily determined.

Inosculation, however, can only take place where the extent of the parts divided is not great, and the opposite surfaces remain near each other; but even then it is most probable that we must in part ascribe to another mode of union the communication of vessels which takes place between the two divided surfaces; for where inosculation does not, or cannot take place, the union of the ruptured vessels is produced by the coagulation of the extravasated blood of this part, which becomes vascular.

* Inosculation is a term commonly used by writers, but whether it was derived from theory or observation is not material. The very few instances where it can be obſerved, together with the want of accuracy in thoſe who first introduced the term, would incline me to think that it aroſe from theory, or opinion only. I never could get an opportunity of observing it in all my experiments, and observations on inflammation, except in the coats of the eye. In many inflammations of that organ, we find an artery or arteries passing from the tunica conjunctiva to the cornea, and ramifying on that part. These have been often cut across to prevent the influx of blood; the two ends are seen to shrink, but in a little time they are again perceived to unite, and the circulation to be carried on as before. In this there can be no deception; and to perform, therefore, such an operation effectually, a part of the vessel should be removed.

That the blood becomes vascular, is clearly shewn in the case of the blood extravasated on the testicle.

The superfluous extravasated blood is taken up by the absorbents, by which means the whole is reinstated as much as it is in the power of the parts to do it. I may observe here, that the power of recovery in the arteries is greater nearly in proportion to the smallness of their size, which is combined with several causes, viz. their distance from the heart, their elasticity, their division into smaller branches, and their accumulated diameters becoming larger, which allows them to recover. Secondly, there is an increased power within the smaller artery itself abstracted from the above circumstances.

This includes a great variety of cases, and the most simple difference which can happen between them will be owing to the magnitude of the ruptured parts, or to a difference in the parts themselves; or to the magnitude of the injury; or to a difference in the effects. It will comprehend simple fractures of all kinds, broken tendons, as is often the case with the tendo-achilles; even many injuries of the brain producing extravasated blood, which is probably the only way in which the brain can be torn when there is no fracture.

Some of these will often require art to reinstate them in the natural position, out of which they may have been put by the accident, or by some peculiar circumstance attending the nature of the part, as we see in a fracture of the patella, or broken tendon, where the upper part being too far pulled up by the muscles, it must be reinstated by the hand of the surgeon, to bring the parts into a situation more favorable to their recovery.

But extravasations, even from the most simple accidents, are often so situated as to obstruct the actions of life; as for instance, in that affection of the brain, which is called apoplexy. The same thing happens in extravasations into the pericardium, or into any of the other vital parts, where little can be done, although much is wanted. In many other parts, where the actions of life cannot be affected, yet the extravasations are often too considerable to allow the parts to go through their proper modes of restoration. The quantity of exravasated blood being often so large as to distend the parts, and form a kind of tumor, called ecchymosis, of which I shall now treat.

The extravasated blood in such cases being the only visible complaint, to remove it is the cure, which may be effected by absorption; or, if necessary, by an operation.

An ecchymosis we may consider as of two kinds, one in which the blood coagulates when extravasated, the other where it remains fluid; but this distinction makes little difference in the disease itself, and of course little in the mode of treatment; it should be observed, however, that the first kind, for the most part, terminates well; while the second sometimes inflames and suppurates.

When these injuries get well by the absorption of the blood, the cure is gradual, and often takes a considerable time; but if the tumors become less and do not inflame, they should be allowed to go on to perform their own cure; and even where inflammation takes place, that should be permitted to advance to suppuration, and the tumors to threaten bursting before they are opened by art, or what I believe would be still better practice, they should be left to open of themselves.

In some instances, a blow the cause of the ecchymosis, may have injured the superficial parts or skin so much as to produce inflammation; and under such circumstances I should recommend the case to be treated as an inflammation arising from any other cause, without paying attention to the blood underneath. It often happens that the blow has deadened the skin over this blood, which deadened part, as is usual in such cases, must, in a certain time, afterwards separate from the living.

Where this has taken place, and the extravasated blood has coagulated, it has often been found to remain in the cavity, as a mere extraneous body, without acting, and without even allowing the stimulus of an exposed surface, or of an imperfect cavity to take place. The edges of the skin all round shewing the disposition to contract over this blood, as if it was a living part to be preserved, nothing has seemed to be wanting to finish the cure but the blood being alive with due powers of action.

In these cases the common practice has been to scoop out the blood and distend the internal surface with warm dressings to stimulate it to inflammation, etc. and a sore being the consequence of this method it goes on as sores commonly do. But in other cases where the opening leading to the coagulated blood has been very small, I have seen that without any other means being used the blood has been gradually squeezed out of the orifice by the contraction of the surrounding parts, till the whole cavity became so much contracted as to contain no more than what seemed to serve as a bond of union to the parts; and thus the cure has been completed without further trouble. The following case was treated in this way.

CASE.

Mrs. B---t fell backwards and pitched upon a pail which was behind her, and the left labium pudendi struck against its handle with the whole weight of her body.

Within five minutes after the accident, the bruised part swelled to as great degree as the skin would allow; from which sudden appearance of the swelling, and the feeling of fluctuation, I concluded that blood had been extravasated by the rupture of some small artery. I bled her, and desired a poultice to be applied to the part, in order to keep the skin as easy as possible under such distention.

Believing the tumor to arise from extravasated blood, I did not chuse to open it, that the bleeding might be sooner stopped by the preſſure of the extravasated blood against the sides of the cavity. Some hours after the accident the skin burst, and a good deal of blood came away. On examining the wound I found the opening of considerable size, leading into a cavity as large as the egg of a goose, and filled with coagulated blood, which I did not remove for the reason given above, that it might assist in stopping the vessels which were still bleeding. The poultice was continued, the bleeding gradually became less; and every time I examined the part, I found the cavity diminished, but still filled with coagulated blood, which continued to be pushed out of the wound, and after some time a slough came off from the bruised skin, which enlarged the size of the wound. About a fortnight after the accident the parts were all so much collapsed, as to have forced out the blood entirely, and there seemed only a superficial sore, not above an inch long and half an inch wide. What may it be supposed would have been the consequence, if I had enlarged the opening, scooped out the blood and dressed the part with lint, or any other application I might think proper?

The effect of such treatment would certainly have been a large sore, nearly of the same size with the cavity; and the sides of the cavity would have inflamed and suppurated. Is there not reason to believe that the coagulated blood, by remaining in the wound, prevented inflammation over the whole surface, and allowed the parts to contract to their natural position, so as to leave no other sore than that where the skin had burst and sloughed?

This practice should be generally followed in such cases of ecchymosis.

The second species of ecchymosis is that in which the blood has not coagulated but remains fluid. This case, although it also frequently occurs, does not always terminate so well as the former, nor allow of such a salutary termination, where an opening has been made, either by the accident, or by art; for then suppuration will be produced all over the cavity; more caution is, therefore, necessary to prevent an opening. It has often the appearance of an incysted tumor; but being an immediate consequence of some accident upon the part, its nature becomes readily understood, though sometimes from its situation it has the symptoms of an aneurism attending it; neither does the cause of it contradict this idea.

If formed over a large artery the tumor will be attended with a pulsation; but when from this cause it cannot be made to subside by pressure, yet it is not, therefore, to be supposed harmless, as in fact it requires to be treated with great caution.

If the pulsation should arise from the real influx of blood, this will soon be shewn by the increase of the tumor, and will lead to the proper treatment, viz. opening it and stopping the bleeding vessel. This seldom happens from contusion, the kind of accident destroying in some degree the free exit of the blood out of the artery; and if the tumor should not increase after a certain period, even if there be a pretty evident pulsation, we may then be certain that it assumes this symptom from some neighbouring artery or arteries. The ecchymosis which is produced on the head of a child during birth, has sometimes a pulsation, arising from that of the brain, as the sutures are still open ; and every tumor of the scalp, whether from a blow or any other cause, may be mistaken for aneurism, if it appears before the fontinelle be closed, and ſhould it be opened without proper examination, may disconcert the ignorant surgeon.

That the blood does not coagulate in this species of ecchymosis, muſt arise from some peculiar mode of action in the vessels, occasioned by the effects of the injury ; for I apprehend that in such cases, the blood dies in the act of extravasation, in the same manner as the blood of the menstrual discharge whenever it is effused.

The ecchymosis which we have mentioned, as happening very commonly to children in the birth, particularly under the scalp, requires nothing to be done ; as by waiting with patience, the whole will in general be absorbed.

Although this is commonly the event in new born infants, yet ecchymosis does not terminate alike favourably in other cases, the tumor often remaining for a confiderable time without undergoing any change, and after months, sometimes disappearing, but at other times inflaming and suppurating.

When an extravasation of blood takes place between the scalp and head, in consequence of a blow, which is very common, and continues fluid, we find a kind of ridge all round the bag, and by pressing all round the edge of the bag, the finger sinks, so as to give distinctly, (we conceive) the feel of a depressed bone ; but this feeling of a depression following the edge of the ecchymosis all round, is a proof that it cannot be depression of the bone ; because no depression could be so regular, nor would any depression be of the same extent with the ecchymosis. The edge of the scalp surrounding the ecchymosis seems to be raised, and I believe it is ; if so, then something similar to the adhesive inflammation must have taken place to set bounds to the extent of the bag, and to hinder the blood from getting into the cellular membrane.

It might perhaps be the best practice to make a small opening into such tumors with a lancet, and by letting out the blood get the sides of the cavity to heal by the first intention. When the parts inflame and suppurate, the case is to be treated as an abscess.

This sometimes disappears by resolution : but this being seldom permitted, the ecchymosis is reduced either to the state of a fresh wound, which is allowed to suppurate, or an abscess ; for surgeons are induced to open early, by seeing an inflammation, and feeling a fluctuation, two strong motives when every circumstance is not well attended to ; but in such cases I should wait till I observed evident signs of suppuration, viz. the thinning of the skin over the matter, and pointing of the contents, which are the only true marks of the formation of the matter, as well as of its coming near the skin.

If the blow should have deadened a part of the skin, then a separation of the slough will take place, and expose this cavity so as to produce suppuration. And this is to be considered as a step still farther removed from the most simple species of injury, than where the blood coagulates.

I am not able, under such circumstances, decidedly to say which is the best practice, whether to leave the slough to separate, or to make a small opening and allow the blood to escape slowly from the cavity.

In both kinds of ecchymosis, when inflammation has taken place in the skin from the violence, if it has not advanced to suppuration, the object of the surgeon should be to bring about the resolution of the tumor ; when he finds there is no further increase of the tumor, he may conclude that resolution is beginning to take place ; which being clearly ascertained, he is then to assit in exciting the absorbents to do their duty, in order to take up the extravasated blood. I believe the best exciting power is pressure, which if urged beyond the point of ease, sets the obsorbents of the part to work, for the purpose of removing the substance which presses, or the part that is pressed : but most commonly the body pressing, if it be subject to the laws (or powers) of absorption ; and in this case the extraneous substance pressing on the inner surface of the cavity, is the extavasated blood which we wish to have removed.

The following cases explain this.

A lady fell and struck her shin against a stone, a considerable ecchymosis came on almost immediately, and the skin over it inflamed to a considerable degree. The blood had not coagulated, there was therefore a perceptible fluctuation underneath, and her physician recommended an opening to be made. I was sent for, and on examining the part, was rather of opinion, from the surface being a regular curve, and no part pointing, that matter had no tformed; I therefore recommended patience; the subsiding of the inflammation, and the application of such pressure as she could bear without uneasiness, caused the whole tumor to be absorbed.

A man was brought into St. George's Hospital whose thigh had been run over by the wheel of a cart; a very large enchymosis was formed on its inside, and a considerable inflammation of the skin had taken place. The blood had not coagulated, therefore a fluctuation could easily be felt; but as there was no appearance of pointing, similar to that of matter coming to the skin, I was in hopes that suppuration was not coming on; and although the inflammation was considerable, I supposed that it might arise rather from the violence of the accident than from the extravasation: I waited therefore the event; saw the inflammation gradually go off, and as that subsided I observed the tumor decay, although it was very slow in its decrease: I then directed a slight compress to be applied, after which the tumor evidently diminised much faster than before, till the whole was absorbed.

The union by the first intention usually takes place so soon after the injury, that it may be said to be almost immediate; for when the blood has coagulated in such a situation as to adhere to both surfaces, and so as to keep them together, it may be said that the union is begun. It is not, however, immediately secure from mechanical violence, and the blood itself by losing its power of retaining life, may likewise be rendered unfit to preserve the communication with the adhesing surface, (by which it is connected with the body at large) and thus the union be of course prevented. If there be no such impediment, then the union of the parts may be very quick; but it will be in some degree according to the quantity of extravasated blood interposed; for if that be large, the whole blood will not become vascular, but the surface only which is in contact with surrounding parts, and the rest will be absorbed as in the enchymosis. Where the quantity is small, as in a slight wound without laceration, and where all the divided surfaces can be brought into almost absolute contact, their union will be firm in twenty-four hours, as happens in a hair-lip, or wounds of the scalp.

Although under such circumstances the blood seems to change into a solid form very quickly, yet when the situation of the wound particularly subjects the parts to mechanical violence, we should not trust to this union being completed in so short a time.

In the hair-lip, for instance, perhaps forty-eight hours may be required to make it perfectly secure, and except when the stitches by producing ulceration might make scars, there can be no harm in allowing such parts even a longer time for their union. But in wounds of the scalp, this caution is not necessary; and indeed in such cases it is scarcely required to make stitches at all.

In cases of accidental injury, whether they be in themselves slight or considerable, in whatever situation or part they may have happened, if the salutary processes, above described, go on readily, no other effect of injury, or irritation, or pain, in consequence of nature's operations is felt. No universal sympathy or fever takes place, except what arises from the mere injury done, but all is quiet as if nothing had happened. This is sometimes the case even in a simple fracture of the bones of the leg, in fissures of the scull, etc. However, the magnitude of the accident often produces effects which are alarming, and more particularly when they happen to parts essential to life. These effects are often the cause of much danger, the constitution becoming affected according to the nature and importance of the parts injured. Thus concussion and extravasation affecting the brain, must likewise affect the constitution, from its natural action and influence on the body being diminished, increased, or otherwise disturbed. The same thing happens from an injury done to any other vital part of the body, and the effects will be according to the use of such parts, or the influence which they have on the system.

However, these immediate and salutary operations do not always take place simply, for they are often altered by other circumstances; as the accident sometimes becomes the cause of irritation, and produces another operation of the parts, called inflammation, which is often of singular service, by increasing the power of union in the broken parts.

This inflammation will generally be in proportion to the degree of injury done, the nature of the parts injured, and the state of the constitution at the time, which in other words, is in proportion to what is requisite for the first powers of union. But it sometimes happens, that inflammation goes further than is required, and produces a variety of actions succeeding each other in regular progression. This may occasionally be observed in certain simple fractures, in which the extravasated blood acting as an extraneous body, becomes the cause of the suppurative inflammation; and the simple is in this way brought to a state resembling the compound fracture. The inflammation, however, does not extend over all the lacerated parts, as when they are exposed at the time of the injury, many of these having united by the first intention.

We may here observe, that accidents of the most simple kind may produce effects which do not allow the common operations of nature to take place, as when a large blood-vessel is broken, or when a fractured rib penetrates into the lungs, or a compression of the brain arises from a fracture of the scull. But none of these accidents admit of the modes of cure abovementioned, as they each require particular treatment, and therefore are not to our present purpose.

II. OF INJURIES WHERE THE WOUND COMMUNICATES EXTERNALLY.

The second division of injury arising from accident, is where the ruptured parts communicate externally, producing effects different from the former. These may be divided into two kinds, viz. wounds made by a sharp cutting instrument, and contusions producing death in the parts injured. Wounds are subject to as great a variety as any thing in surgery.

A wound is a breach made in the continuity of the solids of a part, beginning most commonly on the external surface, and proceeding inwards; although sometimes its direction is from the inside outwards, as in compound fractures. A gun-shot wound may be said to partake of both circumstances, as it passes through a part: wounds often admit of the same mode of cure with accidents which do not communicate externally, but then it requires the art of the surgeon to place them in the same situation, or under the same circumstances.

A wound is either simple or compound; the simple is what I have now to explain, and is of such a nature as to admit of union by the first intention. Of this description we may likewise consider wounds which are the consequence of certain surgical operations.

The form of the instrument by which wounds have been inflicted will also make a difference in their nature; for if it be sharp it will make a clean cut wound; if obtuse in its shape, a bruised one, and may also deaden a part, and the parts may likewise be torn after having been cut; all of which varieties will render a different treatment necessary towards effecting a cure.

In the most simple cases of wounds, a number of blood-vessels being divided, there is an effusion of blood, which escaping by the wound, the internal parts are left exposed, especially the cellular membrane; and these if not brought into contact with corresponding living parts immediately, or by means of the coagulated blood, will inflame and suppurate. Accidents of this kind differ from those of the first division by communicating externally, a circumſtance which makes them often require very different modes of treatment. In cases where parts have been forced out of their natural situation, they should be reduced, that when cured they may answer their natural purposes, as in fracture, dislocation, &c.

Wounds admit of three modes of treatment, arising from their size, situation, and the nature of the parts wounded. One mode is artificial, two are natural, in which last the constitution is allowed to perform the cure in its own way, which will be explained when we speak of scabbing.

These being different from the former, and from each other, it might be thought that I should have considered them first as being natural processes; but the first can be put into the same state with the two others, and therefore ought to precede them. For this purpose art must be employed by the surgeon to bring the separated surfaces in contact;

that by retaining them there till union shall have taken place, the injury may be removed from the state of an exposed wound.

This treatment of fresh wounds with a view to cure them by the first intention, is equally proper after many operations, as in accidental injuries. Instances of this often occur after dissecting out tumors, scalping when no fracture is found, and when trepanning has not been performed; and it has been put in practice even where the trepan has been applied. It has been employed also after amputations; in short, wherever a clean cut wound is made in sound parts, and when the surfaces can be brought into contact, or where there is sufficient skin to cover the part, this practice may, and should be followed.

In no case, however, of a breach of continuity, can we entirely prevent the parts from retaining the appearance of a wound, for the breach in the skin will more or less remain, and the blood will coagulate, become dry, and form a scab. But this operation of nature reduces the injury to the state of a mere superficial wound, and the blood which is continued from the scab to the more deeply seated parts, retaining its living principle, just as the natural parts do at the bottom of a superficial wound, the skin is formed under this scab in the one case as in the other; yet if the scab should either irritate, or a part underneath lose its uniting powers, then inflammation, and even sometimes suppuration, may be produced. It is often, however, only inflammation that is produced; the scab here preventing the further progress of mischief in the same manner as the scabbing of the pus on a sore prevents the process of suppuration, which becomes one of the uses of pus.

In many of the cases in which we mean to produce union by the first intention, it is not necessary to be very nice in spunging out the blood, with a view to make the two surfaces of the flesh come entirely into contact, the blood itself answering a similar purpose. In several cases, having brought the two portions of loose skin together, I have seen the two cut edges unite almost immediately, and though the cavity underneath was distended with blood yet it did well, the tumor gradually decreasing as the blood was absorbed; this is to be considered in the same light as an ecchymosis.

When the portion of skin is not sufficient to cover the whole wound, and the cut edges cannot be brought together, still the skin should be made to cover as much as it can, in order to diminish the size of the parts that must otherwise suppurate and form a sore; as in consequence of this mode of treatment, the living extravasated blood is confined in the wound, and coagulating there, unites the two surfaces together.

The mouths of the vessels are soon shut, either by inosculation, or their own power of contraction, and by the blood becoming vascular, as in the former stated case of union by the first intention; and if there should be any superfluous extravasated blood, we know that it will be afterwards absorbed.

The blood being alive, this uniting medium becomes immediately a part of ourselves, and the parts not being offended by it, no irritation is produced. The red particles are absorbed, and nothing but the coagulating lymph is retained, which being the true living bond of union, afterwards becomes vascular, nervous, etc.

This mode of treatment by art, though an imitation of the former, can seldom be supposed equally complete; perhaps we ought not to expect it to be so in any case, as there are circumstances often attending the artificial mode of treating wounds, which do not occur in the natural. The ligature used for tying a blood-vessel leaves an extraneous body in the wound*; a part deprived of life by the instrument, etc. will become an extraneous substance, and the surfaces cannot always be brought into contact, so as to allow a perfect union to take place. In such cases, union is prevented by the blood losing in part its living principle, especially in those parts next to the external surface; and perhaps the art employed by the surgeon himself may assist in changing the original state of the wound, as the passing of needles and ligatures must always produce suppuration through the whole passage.

These substances so circumstanced, most probably become the cause of irritation, and consequently of inflammation. But if the position of the

* If such a wound has a depending angle, and the vessels should even be tied nearer the upper angle than the lower, yet I would advise to bring the loose end of the thread out of the wound at the lower, for by that means the matter will flow much more easily.

parts be such as in any sort to allow of union, although not readily, the inflammation will go no further than the first stage, and will even give assistance to the first mode of union.

The possibility of effecting a cure by this method is probably limited to some certain distance of time after the wound has been received, though that space may admit of some latitude; perhaps the sooner it is done the better; but while the blood continues to be extravasated it certainly may be attempted upon our first principles of union.

Where the former bond of union is lost in a part, to produce a new one a secondary operation takes place, namely, inflammation; and if this is likewise lost, then a third mode of union will arise, which is by means of granulation.

If the divided parts are allowed to remain till the mouths of the divided vessels be entirely shut, inflammation will inevitably follow, and will furnish the same materials for union which are contained in extravasated blood, by throwing out the coagulated lymph; so that union may still take place, though some time later after the division of the parts. This inflammation I have called the adhesive; and the inflammation that precedes suppuration, I have called the suppurative inflammation. If the parts, however, continue too long asunder, suppuration must follow, and pus is unfriendly to union. We may here observe, that suppuration takes place on exposed surfaces, with a much less degree of inflammation and in much less time than on those which are not exposed, and from their not being opposed by living surfaces, which tend to bring on the adhesive state, they continue it much longer.

Whether this coagulating lymph issues from the half closed mouths of the vessels which were cut, or from the surface of the opened cells, is not easily determined; but most probably it is from the latter, as it comes on about the time that the swelling of the surrounding parts begins to appear. There is reason to suppose it to be the same kind of discharge with that which causes the swelling, and which is continued through the whole course of this stage of inflammation; for on examining the dressings of such wounds as are allowed to suppurate, several days after the wounds have been made, the lint is generally adhering to the surface by means of the coagulating lymph; the suppuration not having yet sufficiently taken place to loosen it.

When these operations are completed in due order, the simple operations of the animal are entirely confined to the part, neither the mind nor the constitution seeming in such cases to be at all affected, except that there is a feeling of tenderness in the part. But whatever these sensations may be, they arise entirely from the injury done, and not from the operation of union, unless when the suppurative inflammation comes on.

The inflammation often runs so high, even where the parts have been brought into contact, as to destroy, by its violence, that union which the extravasated juices were intended to produce, the consequence of which is suppuration at last.

Is it by this excess of inflammation that the extravasated juices lose their living principle, and become as it were extraneous bodies? or is it not possible, that in these cases the inflammation may be the effect rather than the cause of the loss of the living principle, by the blood first losing its living principle, and inflammation arising from it as a consequence?

The time requisite to complete this union will be nearly the same as that of the first intention; and probably sooner if there be no particular tendency to suppuration; but if there be, union may be suspended some time longer, for here the uniting medium will be thrown out in larger quantity, and where the union is most easily effected, there is less of this medium; when two surfaces unite by inflammation, they are commonly in contact, or else most probably union from this cause would not so readily take place. We shall find in the description of the adhesive inflammation, that the union of two sides of a circumscribed cavity is very soon effected, and soon becomes strong.

There is another mode of union, which, although upon the same principle, yet differs with regard to the parts which are to be united.

I have hitherto explained union as taking place only in the division of corresponding parts of the same living body, but it is equally possible to unite different parts of the same, or of different bodies, by bringing them into contact under certain circumstances. There is seldom occasion for such practice; but accident, or rather want of attention, has in some cases been the cause of union taking place between different parts of the body. The chin has been united to the breast, the tongue to the lips or cheek, etc. and when this happens it has commonly been through the medium of granulations. The attempt to unite parts of two different bodies, has only been recommended by Taliacotius. The most extraordinary of all the circumstances respecting union, is by removing a part of one body and afterwards uniting it to some part of another, where on one side there can be no assistance given to the union, as the divided or separated part is hardly able to do more than preserve its own living principle, and accept of the union.

The possibility of this species of union shews how strong the uniting power must be; by it the spurs of the young cock can be made to grow on his comb, or on that of another cock; and its testicles, after having been removed, may be made to unite to the inside of any cavity of an animal.

Teeth, after having been drawn and inserted into the sockets of another person, unite to the new socket, which is called transplanting. Ingrafting and the inoculating of trees succeed upon the same principle*.

* That the living principles in two bodies which have a perfect affinity to one another, should not only be a preservative, but a cause of union is evident; but even in bodies which appear foreign to one another, the stimulus of an extraneous body is not produced where union is not intended, and cannot take place, although we should at first suppose that the extraneous stimulus would be given, and suppuration succeed.

This is verified by the eggs of many insects, which are laid under the skin of different animals, producing only the adhesive inflammation in the surrounding parts; by which the skin is thickened and a nidus is formed for the eggs.

The Guinea worm, called vena medenensis, is also a striking instance of this; for while the animal is endowed with the living principle, it gives but little trouble, yet if killed, gives the stimulus of an extraneous body, which produces suppuration through its whole length.

Other instances of the same sort are:

The æstrum bovis, which lays its eggs in the backs of cattle.

The æstrum tarendi, which lays its eggs in the back of the rein deer.

The æstrum nasale, which lays its eggs in the noses of rein deer.

The æstrum hæmorrhoidale, which lays its eggs in the rectum of horses.

III. PRACTICAL OBSERVATIONS RESPECTING UNION BY THE FIRST INTENTION.

It is with a view to this principle of union, that it has been recommended to bring the sides (or lips) of wounds together; but as the natural elasticity of the parts makes them recede, it has been found necessary to employ art for that purpose. This necessity first suggested the practice of sewing wounds, and afterwards gave rise to various inventions in order to answer this end, such as bandages, sticking-plasters, and ligatures. Among these, the bandage commonly called the uniting bandage, is preferable to all the rest, where it can be employed; but its application is very confined, from being only adapted to parts where a roller can be used. A piece of sticking-plaster, which has been called the dry suture, is more general in its application than the uniting bandage, and is therefore preferable to it on many occasions.

I can hardly suppose a wound, in any situation, where it may not be applied, excepting penetrating wounds, where we wish the inner portion of the wound to be closed equally with the outer, as in the case of hair-lip. But even in such wounds, if the parts are thick, and the wound not large, the sides will seldom recede so far as to make any other means necessary. The dry suture has an advantage over stitches, by bringing a larger surface of the wound together, by not inflaming the parts to which it is applied, and by neither producing in them suppuration or ulceration, which stitches always do. When parts, therefore, can be brought together, and especially where some force is required for that purpose, from the skin not being in large quantity, the sticking-plaster is certainly the best application. This happens frequently to be the case after removal of tumors, in amputation, or where the sides of the wound are only to be brought together at one end, as in the hair-lip; and I think the difference

The æstrum ovis, which lays its eggs in the nose and frontal sinuses of ruminating animals, particularly sheep.

The little insect in Mexico, called migna, which lays its eggs under the skin; and lastly, the cheggars, which get in the feet of animals.

between Mr. Sharp's cross stitch, after amputation, as recommended in his Critical Enquiries, and Mr. Alison's practice, shews strongly the superiority of the sticking-plaster (or dry suture). In those parts of the body where the skin recedes more than in others, this treatment becomes most necessary; and as the scalp probably recedes as little as any, it is therefore seldom necessary to apply any thing in wounds of that part; the practice will certainly answer best in superficial wounds, because the bottom is in these more within its influence.

The sticking-plasters should be laid on in stripes, and these should be at small distances from each other, viz. about a quarter of an inch at most, if the part requires close confinement; but when it does not, they may be at greater distances. This precaution becomes more necessary if the bleeding is not quite stopped, there should be passages left for the exit of blood, as its accumulation might prevent the union, although this does not always happen. If any extraneous body, such as a ligature, should have been left in the wound, suppuration will take place, and the matter should be allowed to vent at some of those openings, or spaces, between the slips of plaster. I have known a very considerable abscess formed in consequence of this precaution being neglected, by which the whole of the recently united parts has been separated.

The interrupted suture, which has generally been recommended in large wounds, is still in use, but seldom proves equal to the intention. This we may reckon to be the only one that deserves the name of suture; it was formerly used, but is now in a great measure laid aside in practice, not from the impropriety of uniting parts by this process, but from the ineffectual mode of attempting it. In what manner better methods could be contrived, I have not been able to suggest. It is to be understood that the above methods of bringing wounded parts together, in order to unite, are only to be put in practice in such cases as will admit of it; for if there was a method known, which in all cases would bring the wounded surfaces into contact, it would in many instances be improper, as some wounds are attended with contusion, by which the parts have been more or less deadened; in such cases, as was formerly observed, union cannot take place according to our first principle, and therefore it is improper to attempt it.

In many wounds which are not attended with contusion, when we either know, or suspect, that extraneous bodies have been introduced into the wound, union by the first intention should not be attempted, but they should be allowed to suppurate, in order that the extraneous matter may be expelled. Wounds which are attended with laceration, although free from contusion, cannot always be united by the first intention, because it must frequently be impossible to bring the external parts, or skin, so much in contact, as to prevent that inflammation which is naturally produced by exposure. But even in cases of simple laceration, where the external influence is but slight, or can be prevented, (as we observed in treating of the compound simple fracture) we find that union by the first intention often takes place; the blood which fills up the interstices of the lacerated parts having prevented the stimulus of imperfection in them, and preventing suppuration, may afterwards be absorbed.

Many operations may be so performed as to admit of parts uniting by the first intention; but the practice should be adopted with great circumspection; the mode of operating with that view, should, in all cases, be a secondary, and not a first, consideration, which it has unluckily been too often among surgeons. In cases of cancer, it is a most dangerous attempt at refinement in surgery.

In the union of wounded parts by the first intention, it is hardly or never possible to bring them so close together at the exposed edges, as to unite them perfectly by these means; such edges are therefore obliged to take another method of healing. If kept moist, they will inflame as deep between the cut surfaces as the blood fails in the union, and there suppurate and granulate; but if the blood is allowed to dry and form a scab between, and along the cut edges, then inflammation and suppuration of those edges will be prevented, and this will complete the union, as will be described by and by.

As those effects of accidental injury, which can be cured by the first intention, call up none of the powers of the constitution to assist in the reparation, it is not the least affected or disturbed by them; the parts are united by the extravasated blood alone, which was thrown out by the injury, either from the divided vessels, or in consequence of inflammation, without a single action taking place, even in the part itself, except the closing, or inosculation of the vessels, for the flowing of the blood is to be considered as entirely mechanical. Even in cases where a small degree of inflammation comes on, it is merely a local action, and so inconsiderable, that the constitution is not affected by it; because it is an operation to which the powers belonging to the parts themselves are fully equal. The inflammation may produce a small degree of pain, but the operation of union gives no sensation of any kind whatever.

The first and great requisite for the restoration of injured parts, is rest, as it allows that action, which is necessary for repairing injured parts, to go on without interruption, and as injuries often excite more action than is required, rest becomes still more necessary. But rest may be thought to consist merely in abstaining from bodily exercise; this will in general be proper, as most parts of the body will be affected either immediately, as being engaged in the action itself, or intermediately by some connection with the injured parts. Thus, if the injury be in the limbs, and not such as to prevent walking altogether, still persons should not be allowed to walk; and we find from the want of this caution, complaints in those parts are commonly longer in recovering than in others; for by keeping the limbs at rest, the whole progressive motion is stopped, a thing more disagreeable to the mind than any prevention of motion in the body. If an arm be injured, it is not so, the want of its use is not so distressing to the patient, because he can enjoy locomotion, and may have no objection to keeping his hands quiet. Rest is often admitted from necessity, as in the fracture of a leg, but seldom where motion is only an inconvenience. But it must appear, that the rupture of a vessel requires union as well as the fracture of a bone, although the vessel having more powers of restoration within itself than the bone, and having less occasional disturbance from other powers, especially of fractures of the lower extremities, yet the rest should be proportioned to the mischief which would follow from the want of it; and this will vary according to the situation of parts. The same principle of rest should apply to every injury, although this is not often allowed to be the case. Thus where an injury produces inability to move a part, especially if in a joint, it is from fear of the loss of motion, not only allowed to be moved by its own muscles, which would be the most proper mode, if motion at all was necessary, but is moved by the surgeon, or by his direction, who, not satisfied with mechanical violence, has recourse to stimulants, as warm applications, in order to rouse up the internal action of the parts, and at the very time when every thing should be kept quiet till restoration of the injury has taken place. In many parts of the body this practice is not so injurious as in others, in which it may be attended with very serious consequences. Thus when a man has suffered a concussion of the brain, and perhaps a blood-vessel has given way, the mind is deranged, becoming either defective or too acute, and if these symptoms should continue but a little while, the medical assistant applies blisters to remove the effect, either forgetting, or not rightly judging the cause. This is even carried further, we hardly see a man taken with all the signs of an apoplexy, where a paralysis in some part takes place, or hemiplegia*, but that he is immediately attacked with cordials, stimulants, electricity, etc. Upon a supposition that it is nervous, debility, etc. the poor body is also tortured, because it cannot act, the brain not being in a condition to influence the voluntary muscles; we might with exactly the same propriety stimulate the fingers when their muscles were torn to pieces. I must own I never saw one of them which had not an extravasation of blood in the brain when opened, excepting one, who died of a gouty affection in the brain, with symptoms similar to apoplexy†. Such a case, most probably, would require a very different mode of treatment, therefore

* It may be observed here, that the only difference between an apoplexy and hemiplegia, is in degree, for they both arise from extravasations of blood.

† For many years I have been particularly attentive to those who have been attacked with a paralitic stroke, forming a hemiplegia. I have watched them while alive, that I might have an opportunity to open them when dead; and in all I found an injury done to the brain, in consequence of the extravasation of blood. I have examined them at all stages, when it was recent, some of weeks standing, others of months, and a few years, in which I saw the progress of reparation.

when it happens to a gouty man, blisters to the head, feet, etc. would probably be the best practice; but surely this would not be the proper practice in a rupture of a vessel; we ought to bleed at once very largely, especially from the temporal artery, till the patient begin to shew signs of recovery, and to continue it till he might begin to become faintish. We should give saline purges freely, to diminish impetus and promote absorption; then great quietness should be enjoined, and as little exercise of body as possible, and especially to avoid coughing and sneezing. Plain food should be directed, and but little of it; nor will such cases ever allow of being roused to action, when as much recovered in their texture as nature can accomplish, to the same degree that other parts will admit of or even require.

These observations lead us to consider the means of relief, for, besides rest, it often happens that the parts can be relieved from the secondary consequences of the injury, such as inflammations, etc. But this leads to constitutional and local treatment, and will be included in the history of inflammation.

I have already mentioned that when the salutary effects above described take place, the constitution is not in the least effected, yet it is proper in all cases where much mischief might arise from a failure, to pay a little attention to the constitution. The patient should eat plain food, drink weak liquors, and have the body kept open; this treatment with rest suitable to the case, will in many instances prevent evils that might otherwise occur and prove troublesome.

IV. OF SCABBING.

The operations which I have described prevent inflammation, especially that sort of it which produces suppuration; but even where the parts are not brought together, so as to admit of union by the first intention, nature is always endeavouring to produce the same effect. The blood which is thrown out in consequence of the accident, and which would have united surfaces brought into contact, is in part allowed to escape, but by its coagulation on the surface a portion is there retained, which drying and forming a scab*, becomes an obstacle to suppuration. The inflammation in this case may be greater than where union can be effected, but not nearly so great as when suppuration takes place.

The blood lying on the fresh surface, although not now alive, and therefore not fitted for union with the living parts underneath, yet precludes the necessity of any further discharge as a covering to the exposed surface, which is one of the uses of pus.

This might be considered as the first mode of healing a wound or sore, for it appears to be the natural one, requiring no art; and in the state of parts beforementioned, the complete union is in some degree indebted to this mode of healing, by uniting the edges that were not or could not be brought into close contact, by means of a scab; proper attention to this has, I believe, been too much neglected.

Many wounds ought to be allowed to scab, in which this process is now prevented; and this arises, I believe, from the conceit of surgeons, who think themselves possessed of powers superior to nature, and therefore have introduced the practice of making sores of all wounds: as a scab however must always be on a surface, it is only on superficial wounds, or on superficial parts of deeper wounds, that scabs can form.

How far this practice may be extended, I do not know, but there are cases in which it should be discouraged, as where deep seated extraneous bodies have been introduced, as in gun-shot wounds, or where deeper seated parts have been filled; but it will answer extremely well, where the superficies only is deprived of life.

Superficial hurts are very common, on parts opposite and near to some bone, as on the head, shin-bone, fingers, etc. but more especially on the shin. In all such cases it is better to let them scab, if they seem

* A scab may be defined first, dried blood on a wound, dried pus on a sore, a slough from whatever cause allowed to dry, mucus from an inflamed surface, as in the nose.

inclined, or will admit of it; and if that should not succeed, they can but suppurate at laſt, and no harm is done.

In many deep seated wounds, where all the parts have remained in contact, those underneath will unite much better if the surface be allowed to scab. Some compound fractures (more especially where the external wound is very small) should be allowed to heal in the same way; for by permitting the blood to scab upon the wound, either by itself, or when soaked into lint, the parts underneath will unite, the blood under the scab will become vascular, and the union will be complete, even where the parts are not in contact.

How far this practice may be extended is not yet ascertained. A small wound doing well under this treatment is a common case, and some examples of large wounds are mentioned, though these do not so generally succeed; but I do not know that there is any danger in the attempt. In many cases, therefore, which seem doubtful, where the external contusion is not very great, or not continued of the same size as in the deeper seated parts, it may be tried.

In some of those cases which have been allowed to scab, the parts injured have appeared ready to go into inflammation; a red circle has been seen all round, produced by the irritation of the scab. Suppuration takes place underneath the scab, and the pus makes its escape from under its edges: but even in such cases, I should be cautious of treating it as a suppurating sore: I should allow it to go on, and occasionally press the scab in order to squeeze out the pus; for it very often happens that the red circle surrounding the scab becomes of a dusky brown, which is the best sign of resolution, the suppuration diminishes, and the whole does well. But if inflammation should proceed farther and seem to be increased by the mode of treatment, it must not be urged further; the scab should be poulticed in order to soften it, that it may come off easily, and it should afterwards be treated according to the nature of the sore.

This practice succeeds wonderfully well in cases where we find applications of all kinds disagree with the skin. A person shall get a blow on the shin, which shall probably deaden a part, a poultice is then often applied, that poultice brings out pimples on the surrounding skin, these pimples increase and become sores of some breadth, the poultice is increased in breadth to cover them, new pimples arise, and so on, that I have seen a whole leg full of those sores.

In such, I always allow the wound to scab, and to accomplish this, the best way is to take off the dressings in the morning, and put on trowsers, without stockings, and by the evening the parts are scabbed; or we may powder them with lapis calam: or chalk finely powdered, and desire the patient to go to bed, for the first night, with the trowsers on; where the sore has been only one, I have made a circular pad, and bound that on till the scab was formed.

The mode of assisting the cure of wounds by permitting a scab to form is likewise applicable, in some cases, to that species of accident where the parts have not only been lacerated, but deprived of life. If the deadened surface is not allowed to dry or scab, it must separate from the living parts, by which means these will be exposed, and suppuration brought on; but if the whole can be made to dry, the parts underneath the slough will cicatrize, and the dried slough will at last drop off. I have seen this take place after the application of a caustic, and many other sloughs. Where this can be effected, it is the best practice, as it will preclude inflammation and suppuration, which, in most cases should be avoided if possible.

I have treated many cases in this way, and the living parts underneath have formed a skin as the slough separated. This will more readily take place where the cutis is not deprived of life through its whole substance; for it has a much stronger disposition and powers to restore itself than the cellular membrane has to form a new cutis; indeed the skin formed upon entire new flesh is very different from the original cutis; therefore as the skin is the part most liable to these accidents, we have the best chance of succeeding in this way when the cutis alone is injured.

This practice is the very best for burns or scalds, after the inflammation has either been considerably prevented, or subdued, by proper applications or by time, for which there probably are more remedies than for an inflammation arising from any other cause, as if there was something specific in such causes. Whatever will abate an inflammation arising from accident, will have the same effect upon a scald or a burn; and from the diversities of applications, we have opportunities of knowing the best. Oil was long an application, but which has no virtue; spirits has also been long applied, and with very good effect. The common application, which is a soap made with lime water and oil, seemed to answer better; and now vinegar is strongly recommended, and I think with justice, as far as I have seen.

Cold lessens all inflammations, and is a very good application where it can be applied, but it cannot be applied so universally as many others: however, cold has this disadvantage, that the pain, although removed while under the application, occurs with double force when it is removed, much more than from any of the applications, and the reason is evident, for as the warmth returns, the pain is increased by the warmth, even in sound parts; on the contrary, it is recommended, that when a part is burnt to hold it to the fire as hot and as long as it can be held, which undoubtedly lessens the succeeding inflammation, and soon gives ease. This I have often seen, and probably it can only be accounted for on the principle of producing the act of contraction in the vessels.

I have taken a bucket of cold spring water with me, when I have made an attempt on a wasp's nest, and put my hand into it after having been stung, and while my hand was in the water I felt no pain, but when I took it out, the pain was greater than when I put it in. This is not the case with other applications, for their specific virtues are not counteracted by any natural circumstance attending the body, and then they can be applied with a continuance to any part where the skin is thin. The blisters commonly break, and so much the better, as the application can come in contact with the inflamed surface, but on the hand, foot, fingers, and toes, especially in working people, and those who walk much, the blisters seldom break of themselves; they should be pricked with a needle to take off the tension.

When the inflammation has gone through its stages, then the parts should be allowed to dry. This in many parts is very awkward, as when a large surface of the body is scalded, for exposure is necessary, and in some parts it is almost impossible, as behind the ears, armpits, etc. To keep the cloths from sticking to the parts, it is necessary to powder it with some inoffensive powder, such as lapis calaminaris, very fine powdered chalk; this does not hinder evaporation, the principle of scabbing; and if the discharge should be so much at first as to moisten the first powdering, then strew more over the whole, till it forms a hard crust.

This is hardly necessary on the face, but it will rather dry sooner by being at first powdered. In such cases nature will go on infinitely farther than if the parts had been disturbed by our applications.

V. ACCIDENTS ATTENDED WITH DEATH IN A SUPERFICIAL PART.

In the foregoing account of injuries done to the body, and of the modes of restoration, we have been so far from considering inflammation as one of them, that hitherto it has been inculcated to guard against it with the utmost care.

It sometimes, however, takes place, and is one of the modes of restoration when the methods abovementioned fail, as well as a mode of restoring parts under disease, we shall therefore proceed to explain its principle; but as there are accidents already mentioned, which often advance to suppuration, I shall now treat of them.

Among the divisions of accidents, one is where death is produced in the injured parts, and where inflammation and suppuration must take place, in consequence of the dead parts which separate not being within the power of the former treatment to produce a cure; but it should be remembered, that the inflammation, which is the forerunner of suppuration in such cases, is not nearly so great as even the inflammation arising from a wound that suppurates. In many accidents, such as bruises, the skin preserves its living powers, while the cellular membrane underneath has become dead; this will afterwards produce an abscess, and must be treated as abscesses commonly are, remembering that, in the present case, the abscess, after being opened, will be later in acquiring the healing disposition than abscesses are commonly; the dead cellular membrane must separate, which will come away like wet dirty lint.

It sometimes happens, that in one part, the skin; in another, the cellular membrane only shall become dead; and in such cases, I have often observed that the bruised skin sloughs much sooner than the cellular membrane; an abscess, therefore, is frequently forming under the sound skin while the other parts are healing, a circumstance which often disappoints both the patient and surgeon.

When the wound, or the dead part, is considerable, it is probable the treatment will, in general, be very proper, because the degree of mischief calling up the attention of the surgeon, and producing acquiesence in the patient, he will be induced to submit to whatever may be thought necessary. The best application, at first, will probably be a poultice, which should be either simple or medicated, according to the nature of the succeeding inflammation, and continued either till the inflammation has subsided, and suppuration come on sufficient to keep the parts moist, or till the slough has entirely separated, when the sore may be dressed according to its particular disposition. But such accidents as have a superficial part killed, when the slough would readily separate, and the part suppurate kindly, are often treated improperly at first, by the patients themselves applying Friar's balsam, or some such medicines; but these not being within the power of scabbing, inflammation comes on and alarms the patient, a poultice is then commonly applied, which removes the first dressing, and the slough appears, which gives a disagreeable appearance to the wound, and it is supposed to be a foul sore. From such an idea various methods are employed, and the application of red precipitate, etc. but with no good effect; and the patient becomes fretted from a sore, apparently so trifling, being so difficult to heal; but it is impossible that such a sore can heal, while there is a slough to separate. It is, therefore, the surgeon's business to inform himself of the nature of the complaint, to explain it to his patient, who will then become better satisfied, and less uneasy about his own situation. When this piece of slough comes away, the sore will put on an appearance according to the nature of the constitution, or of the part, and is to be treated accordingly.

CHAPTER II.

FUNDAMENTAL PRINCIPLES OF INFLAMMATION.

An animal in perfect health is to be considered as a perfect machine, no part of it appearing naturally weaker than another, yet this is not strictly true; but still if no relative action, with regard to external matter, was to take place, the machine would, in itself, be tolerably perfect for its own actions. As the animal, however, is employed upon common matter, and therefore liable to accidents, which interrupt the natural operations, it becomes absolutely necessary for its continuance, that it should possess, within itself, the power of repair; we find it accordingly endowed with powers of repair upon many such occasions; but where parts give way from their own natural actions, this mischief cannot be repaired; because, if they are not able to sustain their own actions, they cannot recover when diseased or injured. It is found that some structures of parts more readily give way than others, and consequently are much longer in repair, either when diseased or injured by accident. We also find that different situations, of similar parts, give them advantages or disadvantages, with regard to their powers of restoration. This is principally known from injuries being done to them, or in consequence of those injuries from the attack of a disease.

It is also shewn in the common actions of the body, or parts, of which, in health, we have comparative trials. We never can know what a thing is incapable of doing till it gives way, which giving way is either a disease, or productive of it: nor can we know the powers of restoration in the part till tried.

As a proof that parts cannot always be proportioned to the action or powers applied, which have no action within themselves, but are only acted upon by external force, we adduce the instances of a broken patella, or broken tendo achillis, or a thickening of the valves of the heart. In the first, however, there is commonly another power superadded besides simply the actions of the parts, viz. the body falling and being stopped at once. In the valves of the aorta, however, and the valvula mitralis, we have the best examples, for they become thickened from the actions of the parts themselves; while no such effect takes place in the valves of the pulmonary artery, even an anuerism proves the same.

Where there is a difference in structure, there are comparative powers to resist the consequences of actions, attended with injury, such as their admitting more or less readily of thickening, ulceration, or mortification, and their comparative powers of restoration. When we compare the powers of restoration in muscle, nerve, cellular membrane, ligament, tendon, bone, etc. with each other, they are found to be very different. Muscles, skin, and probably nerves, possess the greatest powers of that kind; and the cellular membrane, ligament, tendon, bone, etc. the least, and are, in this respect, pretty equal among themselves. How far elastic ligaments have powers of resistance and repair, I do not know, but I should suppose they had them in a very considerable degree, from the vessels not giving way so readily as in many of the others.

Their comparative powers become pretty evident in most of their diseases, but chiefly, I think, in mortification. As mortification is the most simple effect of debility, it gives the comparative powers of parts in the most simple manner. We find that muscles, skin, and often blood-vessels, stand their ground, while they are deprived of their connecting membrane, which has either sloughed off, or ulcerated; tendons likewise slough off as far as these muscles, and stop there.

I have also observed, that difference in the situation of similar structures in the body makes a material difference both in the powers of resistance to injuries, and of reparation when injuries have taken place. This difference seems to arise in proportion to the distance of the parts from the heart, or source of the circulation. Thus we see muscles, skin, etc. becoming more readily diseased in the legs than any where else, and more slow in their progress towards a cure; but this is not wholly to be laid to the charge of situation or distance from the source of the circulation, some portion of it is to be attributed to position, the legs being depending parts, and those parts which are most distinct happen also to be the most dependent*. We find an horizontal position assist in the repair of such parts, but even then they are not equal in their powers to parts situated about the chest; the difference therefore is principally to be attributed to situation, or distance from the heart. The same disease that shewed the comparative powers between the muscle and tendon, shews also that they are equally affected by position; thus we see ulceration and mortification taking place in the lower extremity, as such, more readily and with less powers of repair, than happens in parts near the chest.

This is still more the case if the person be tall. This is seen by changing a limb from a horizontal position, in which it was easy, to a dependent one, wherein it feels pain; because the new position increases the length of the column of blood in the veins. I am inclined to believe that the retardation of the cure is more owing to a stagnation of the blood in the veins, from the length of the column, than from a deficiency in the motion of the blood in the arteries. As the readiness of a part to fall into disease, and its backwardness to admit of cure, arises from position, it is in some degree compensated by rest and a change of the position.

These differences in the structure, situation, and position of parts in the body, make, I believe, but little difference in the progress of specific diseases: the venereal disease, however, certainly does not make such progress in bone, tendon, etc. as in the skin, nor does the cure advance so rapidly in those parts; but both these effects may be attributed to another cause, which is, that bones and tendons are more deeply seated. I believe, however, that position makes no difference in the disease itself, although it may have some influence upon the power of cure, and perhaps in all specific diseases, in the progress towards a cure; for a venereal sore is always approaching nearer and nearer to the nature of a common sore, and therefore is more and more readily influenced by what influences a common sore.

* We find in most authors the whole laid to this, which I shall more fully discuss in the history of opinions.

But in diseases, for which there is at present no cure, as the cancer, I believe it makes no difference where it is situated, or in what it is placed, except in the case of such parts as have a tendency to such diseases, which no one of the parts abovementioned has more than another.

I have so far considered, in the general way, the comparative powers of different structures, of different situations, and of different positions in some parts of the body when affected by disease. Disease is the only circumstance which exposes these principles to our view, but to see how far the same principle was carried in natural operations, of which the most remarkable is the growth of parts, I made several experiments on fowls. The first was the common experiment of transplanting the spur of a young chicken from its leg to its comb, in which experiment I always found that the spur on the comb, when it took root, grew much faster and became much larger than that left on the leg. This I attributed to the greater power of action in the comb than in the leg, although they are pretty nearly at equal distances from the source of the circulation; but probably position also favoured it, as there was no stagnation in the veins of the head. In the power of producing such effects in disease, as well as in the growth of parts, I was then desirous to know the comparative degrees between the male and the female. I wished also to ascertain if the parts peculiar to the male could grow on the female, and if the parts of a female, on the contrary, would grow on a male.

Although I had formerly transplanted the testicles of a cock into the abdomen of a hen, and they had sometimes taken root there, but not frequently, and then had never come to perfection, yet the experiment could not, from this cause, answer fully the intended purpose; there is, I believe, a natural reason to believe it could not, and the experiment was therefore disregarded*. I took the spur from the leg of a young cock, and placed it in the situation of the spur in the leg of a hen chicken, it took root, the chicken grew to a hen, but at first no spur grew, while the spur that was left on the other leg of the cock, grew as usual.

This experiment I have repeated several times, in the same summer,

* Vide book on Teeth.

with the same effects, which led me to conceive that the spur of a cock would not grow upon a hen, and that they were, therefore, to be considered as distinct animals, having very distinct powers. In order to ascertain this, I took the spurs of hen chickens and placed them on the legs of young cocks. I found that those which took root, grew nearly as fast, and to as large a size as the natural spur on the other leg, which appeared to be a contradiction to my other experiments. Upon another examination of my hens, however, I found that the spurs had grown considerably, although they had taken several years to do it; for I found that the same quantity of growth in the spur of the cock, while on the cock during one year, was as much as that of the cock's spur on the hen in the course of three or four years, or as three or four to one; whereas the growth of the hen's spur on the cock was to that of the proper spur of the cock as two to one. These experiments shew that there is an inequality of powers in different parts of the same animal, and that the legs have much less than the comb; they also shew that there is a material difference in the powers of the male and the female. The spurs of a cock were found to possess powers beyond those of a hen, while at the same time, the one animal as a whole, has more powers than the other; yet when I apply these principles to the powers of cure in local diseases of the two sexes in the human race, I can hardly say that I have observed any difference. It is to be observed, however, that women commonly live a much more temperate life than men, which certainly must have considerable influence both with regard to resisting and curing diseases.

In all complicated animals, among which man is the most complex, the parts are composed of different structures, and we find that in such animals the powers of action of those different structures within themselves are very different; when they are therefore excited to any common action, the varieties produced should be well known and particularly attended to. Besides, every similar structure in different animals does not always act in the same manner. Thus we cannot make a horse vomit; nor can we give many specific diseases, which attack the human subject, to any other animal, more particularly the morbid poisons. The mode, therefore, of action in one animal does not implicetly direct to the mode of action in another; nor does the same structure in the same animal always act in the same way at all times: it acts at various times in a way similar to the same structure in various animals; and besides, the same structure varies its action in different situations in the same animal. Besides, the exterior actions of life make a very material difference in the internal actions of animals, or in the excitement of disease, either universally or locally; for there are parts which cannot bear one mode of life, while there are other parts which cannot bear another. Parts and mode of life being in opposition with each other. A great many of these varieties depends upon the difference in the natural strength and weakness of the parts; but as those vary very considerably in different habits, so the varieties are increased; and likewise, as many occurrences in life produce the principle of strength or weakness, we have those varieties still more increased, as well as disease.

These observations, as heads, I shall treat more fully, but not as my principle subject, attending to them only so far as they are connected with inflammation, and may illustrate the varieties in that action.

I. OF THE DIFFERENT CAUSES WHICH INCREASE AND DIMINISH THE SUSCEPTIBILITY FOR INFLAMMATION EITHER IN THE WHOLE BODY OR IN PARTS.

Susceptibility for inflammation may be said to have two causes, the one original, the other acquired. The original constitutes a part of the animal œconomy, and is probably inexplicable.

Of the acquired it is probable that climate, and modes of life, may tend considerably either to diminish or increase the susceptibility for inflammation.

The influence, however, of climate may not be so great as it commonly appears to be, for it is generally accompanied by modes of life that are not suited to others; and if we consider how much less pernicious many