

**First lines of physiology / by Albert von Haller ; translated from the third Latin edition ; to which is added, a translation of the index, composed for the Edinburgh edition, printed under the inspection of Dr. William Cullen.**

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The Watertown Times of Friday asserts that a lady in the northern part of Herkimer County was so frightened at the appearance of a snake in her path that her hair, previously a glossy black, turned white.

There is another class of superstitions borne down to us from the crabbed times of our Puritan ancestry which I fancy we shall also somewhat shamefacedly own. They were the daily maxims which formed a part of the teaching in every genuine New England home, and their permanence as a part of our mental constitution is an encouraging circumstance to educators who sometimes are inclined to think that even line upon line and precept upon precept fail to make their impression upon the wayward mind of youth. To remove this fear, we stand as living monuments, boldly avowing, first, that we find it constantly difficult to convince ourselves—though our reason tells us that we are absurd—that it is not a moral duty to rise before, or at least, with the sun. Day by day, as we descend to our eight-o'clock or nine-o'clock breakfast, we are conscious of a certain sense of moral torpidity which we know to be unreasonable. It is in the effort to shake off this sense, which is only the remnant of an old superstition, that I write these general axioms on the subject of rising early which helped to make the New England Primer and the Farmer's Almanac a never-failing source of supposed improvement, and which were afterward re-enunciated by Franklin, do not not apply to the present day nor to city life. What is gained even for useful work by rising at six, and then being obliged to take a nap in the middle of the day? Why not do up all our sleeping at once, and have a clear

sweep for work? If, again, one could carefully rake up and cover the embers of his fire at nine P. M., and sleep the sleep of the righteous till six, he might possibly rise at six, or even five, though why, even in that case, any sane person should insist on doing two hours' work, before eating, and call such action virtue, I could never understand. Circumstances alter rules as well as cases, which is what we of Puritan stock find it hard to understand. I myself know two young women of New England birth and training who, though they go into much evening society, and are frequently awake at midnight or after, each week during the New York winter, yet persist in being punctual every morning at the half-past-seven breakfast of the family. True, they have no appetites; true, they take long naps in the afternoon; true, they break down every year by March; yet they gallantly return to the assault every autumn, and would feel ashamed and guilty if they did otherwise. So strong is the force of superstition!

In the future more perfect days it will be considered a sin to awake any one from sleep except in cases of life and death, and our grandchildren may perhaps be free from the inherited weakness of believing, because the flowers and the chickens and the birds wake when the sun does, that therefore a human being should do so. By what logic do we select the one action of waking as suitable for our imitation?—*Anna C. Brackett in Harper's Magazine.*

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## HEIGHT AND WEIGHT.

### The Philosophy of Human Length, Breadth and Thickness.

"How much should a person of given height weigh? Is there a standard between height and weight?" A healthy child, male or female, grows in length by more than one-half its size during the first two years; it increases from 19.675 inches to about 31.10 inches. It trebles or quadruples its weight; that is to say, it weighs  $7\frac{1}{2}$  to 10 pounds at birth; 25 pounds in the first year, 30 pounds in the second. On the average a child from six months to eight years grows in length about 2.4622 inches each year; the weight of the body goes on increasing to the eighth year, rising in boys to 50 pounds and in girls  $47\frac{1}{2}$  pounds. From this age until puberty boys increase in height 2.165 feet each year, reaching at the age of 12 years a height of over 4.52 feet, and girls 4.421 feet on the average. Boys gain about 5 pounds in weight per year, girls a little more, so that in the twelfth year children of both sexes weigh on the average about 75 pounds. From 13 to 20 years youth grow some 11.8 inches; girls 7.8 inches. The increase of weight is even more rapid than before, reaching 145 pounds in boys 18 years old, and in girls of the same age  $127\frac{1}{2}$  pounds. In the 25th year the man is over  $5\frac{1}{2}$  feet in height and weighs  $157\frac{1}{2}$  pounds, while the woman is 5.15 in height and weighs  $127\frac{1}{2}$ . Man in the fortieth year attains his maximum weight, 159 pounds, and then begins to lose flesh. Women continue to grow heavier, reaching about 140 pounds, until the fiftieth year. Between 45 and 60 men become more corpulent, and women rapidly grow older; in both the size of the body diminishes.

It is desirable for all persons, whether suffering in health or otherwise, to know as near as possible what the normal weight should be. We are indebted to the late Dr. Hutchinson for weighing about 2,600 men at various ages. There is, indeed, an obvious relation between height and weight so pertinaciously weighed and measured; starting with the lowest men in the tables, it will be found that the increased weight was as near as possible five pounds for every inch in height beyond sixty-one inches.

The following figures show the relative height and weight of individuals measuring five feet and upward:

STATURE.			Weight, lbs.
Feet.	Inches.		
5	1	should be.....	120
5	2	should be.....	126
5	3	should be.....	133
5	4	should be.....	138
5	5	should be.....	142
5	6	should be.....	145
5	7	should be.....	149
5	8	should be.....	155
5	9	should be.....	162
5	10	should be.....	169
5	11	should be.....	174
6	0	should be.....	178

### The Children's Paradise.

If you should start from Boston and go West more than half way round the world, you would come to Japan. Travellers call it a "paradise for children." There is a saying that Japanese children never cry. Perhaps you can guess why they are so happy if I tell you some things I noticed very soon

The climate is beautiful, the scenery liant and varied. The houses are low and the furniture in the surface

safe, and they have no sharp corners to inflict bumps and bruises.

The doors and windows are made of paper. Soft mats of rice straw serve for carpets; soft cotton mattresses for beds, which can be rolled up and put away. At meals straw tablecloths are laid on mats, and all the family sit on the floor around them. How like a picnic!

The dress of the children is like that of their elders—a plain, loose garment, girded about the waist with a sash. There are no hooks to pull out, no buttons to drop off, and no pins to scratch: a strong silk cord does all the fastening.

Then the garments, instead of being sewed together like ours, are basted together with a strong silk thread, so that they can easily be taken to pieces for washing. Stockings are made with a place for the big toe, like the thumbs in our mittens. A kind of clog is worn in the streets. Pockets are put in the large sleeves. Handkerchiefs and napkins are made of thin, white paper, soft as silk.

The sliding doors and partitions in the houses are almost always pushed back, so that you can see and hear all that is going on. Many a house has an aquarium, with gold and silver fish, or bamboo cages in which beds of flowers make a home for numerous butterflies and grasshoppers.

Mothers play with their children much of the time. Fat little dogs and pretty cats are their companions too. Babies are carried upon the back, and are never afraid of falling. Everywhere their shaven heads and black eyes peep out of folds of garments, or sleepily bob up and down, as their nurses rushes to and fro in the excitement of kite-flying or other play. Japan is the land of toys and dolls and kites and fans and parasols. A little girl will sometimes have over one hundred dolls.

The children have much rice to eat, but hardly any milk, for the queer little cows do not give much. Fruit is eaten green, for it is thought unfit to eat when soft and mellow.

The flowers of Japan have no odor, and the birds do not sing. The stork is one of the favorite birds.

The golden globe (instead of stars and stripes) is the flag that floats over Japan, and the chrysanthemum is the national emblem. It is wrought in tiles for roofs, on opium-pipes, on earthen ware and on many other things.—*Nursery.*

*Geo. A. Parley.*  
HKO.  
FIRST LINES  
OF  
PHYSIOLOGY.

BY  
ALBERT VON HALLER.

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TRANSLATED FROM THE  
THIRD LATIN EDITION.

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TO WHICH IS ADDED,  
A TRANSLATION OF THE  
INDEX,  
COMPOSED FOR THE EDINBURGH EDITION,  
PRINTED UNDER THE INSPECTION  
OF DR. WILLIAM CULLEN.

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FIRST AMERICAN EDITION.

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.....  
1803.



A distinction has been drawn by Rev. George Benson between the kind of intellect in brutes and that in men. It is given for what it is worth. "It has seemed to me that brute reasoning is always practical, but never abstract. Brutes do wonderful things suggested by the objective fact before them, but I think never go beyond it. Thus, a dog left in a room rang the bell to fetch a servant. Had not the dog been taught to ring the bell, (which on inquiry proved to have been the case,) this would have been abstract reasoning, but it was only practical. The Arctic fox, too wary to be shot like the first who took a bait tied to a string which was attached to the trigger of a gun—would dive under the snow, and so pull the bait down below the line of fire. This is purely practical reasoning: but had the fox pulled the string first out of the line of fire in order to discharge the gun and then get the bait, that would have been abstract reasoning. " " " Brutes and boys are just alike, in that nothing occurs to them beyond what the immediate fact before them may suggest. The one kind I call purely practical reasoning, which both have; the other abstract, which brutes never acquire, but which the boy will as his intelligence develops."

*Pro. A. L. S.ley*  
ADVERTISEMENT

TO THE EDINBURGH EDITION. *pp. 110.*

THE correction of this volume for the press was undertaken at the desire of the Publishers. Having already undergone three editions, the present Editor believed, that a careful perusal of the proof-sheets, and attention to the typographical accuracy of the work, would chiefly constitute his share in the publication. On collating, however, the last edition with the original of HALLER, it appeared, that few sentences, and scarcely one paragraph, conveyed the true meaning of the Author. In many places, the sense was totally mistaken, sometimes perverted, and the omissions and interpolations were both so numerous, and so prejudicial to the work, that those who have formed their opinion of the value of HALLER's First Lines, from any translation in the English language, must have formed an opinion of them, highly detrimental to the well deserved reputation of the Author. In the present edition, with much labour, the Editor has endeavoured to correct these mistakes, to supply what was omitted, and to expunge the interpolations; in short, to give HALLER's First Lines in English.

THE very great deviations made by the original Translator from the meaning of the Author, have betrayed the present Editor into an opposite fault, that of making his edition more literal than perhaps is consistent with the true idiom of the English language. For this imperfection he has no other apology to offer: but for the omission of Dr. WRISBERG's Notes, one is necessary. Of these notes, many are excellent; but as most of them are literary, some controversial, and others but add a new conjecture upon points not yet understood, and, finally, as they do not now fulfil their original intention of supplying every discovery made in Physiology since HALLER's time, it was thought proper not to increase the size and price of the volume by their insertion.

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FIRST

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# FIRST LINES OF PHYSIOLOGY.

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## CHAP. I.

### FIBRE.—CELLULAR SUBSTANCE.

I. **T**HE most simple parts of the human body, are either fluid or solid. As the fluids are of different kinds, we shall consider each of them in its proper place; and premise the history of the solids, which are most simple, and the true basis of the body, to the consideration of the other parts.

II. The solid parts of animals and vegetables have this fabric in common; that their elements, as seen by the most powerful microscopes, are either fibres, or laminæ, or unorganized gluten.

III. Fibres for the most part, resemble lines of very minute breadth, or rather slender cylinders. Their most permanent particles are demonstrated to

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be earthy, by combustion, or long continued putrefaction.

iv. These earthy particles derive connection and the power of cohesion, not from themselves, but from interposed gluten. We know this from the preceding observations, (iii.) and the easy experiment, in which a burnt hair, whose parts hang still together, recovers a certain degree of firmness by being dipped in water or oil. Ivory and bones also become friable, by the extraction of their gelly. Long exposure to weather effects a similar change, rendering bones a true earth, absorbent and bibulous. But even bone, become friable from having its gelly extracted, reacquires its osseous hardness, when that gelly is restored. The more simple animals consist entirely of this gluten.

v. Lastly, the chemical analysis of bone, and hair, the gelly of bone, ivory, and horn, the nature of our aliments, &c. prove, that this gluten is composed of water, incorporated with oil by animal life. Nor does any other kind of gluten unite the parts of animals more strongly, as we see in size and common glue.

vi. The primary simple fibre, such as we rather comprehend from reason than sense, is composed of earthy particles, adhering longitudinally, and connected by intervening and cohesive gluten.

vii. But the fibres which appear primary to the sight, are of two kinds. The first is linear, whose length is considerable in proportion to its breadth, and whose elementary particles lie in a straight line, and thus generally parallel to those contiguous. We see examples of this kind of fibre in bone, most easily in those of the foetus, and also in tendons, ligaments and muscles, always recollecting that the eye sees not the most minute fibres, but only the larger ones composed of these, and similar to them in straightness and slenderness. That  
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the ultimate fibres are perfectly similar, we are convinced by the microscopes of Muys and Lecuwenhoeck, in which the muscular fibres, even the most minute, appear exactly like the larger ones, and perfectly linear.

VIII. The second kind consists of laminæ, in which, a breadth often greater, is conjoined with a shorter length. A loose web of these has got the name of Cellular Tunic, though the term Tunic is on many accounts improper.

IX. This cellular substance is composed of an infinite number of small laminæ, which, by their various directions, inclose small spaces and cavities, and join all the parts of the human body, affording an extensive and firm union, with sufficient mobility. But in this web there is the greatest diversity in the proportion of the solids to the cavities; in the breadth and firmness of the laminæ; in the nature of the contained liquor, which is either more watery or more oily; and in the admixture of fibres and filaments, of which there is a great quantity in some places, as in the coats of the arteries, in others almost none, as under the skin.

X. Of this cellular substance when compacted, from the laminæ concreting, and being compressed by the action of the incumbent muscles, distending liquid, or other cause, broad plates are formed, which are either rectilineal in general, and more properly called Membranes; or convoluted into cylinders and cones, with liquids flowing through their cavities, and denominated Vessels; or extending round some place in a plane parallel to it, get the name of Tunics. That tunics are formed of cellular substance, is proved in the aorta, skin, pericardium, and dura mater, by ocular inspection, and especially by maceration. The coats of the muscles, are also evidently cellular, and similar to other tunics. The same thing is also proved from the easy change of the dartos, and the nervous  
membrane

membrane of the intestines, into cellular substance, by inflation; and from the hard and thick membranes formed in encysted tumors, which are mere productions of cellular texture. In the integuments, being very closely compacted in continued gradation, it forms the true skin lying under the epidermis; and being thence continued, it is at last partly resolved into the subcutaneous cellular texture filled with fat.

XI. The vessels which colour the tunics are an addition to the cellular substance, and in no wise essential to the nature of membrane, but super-added to the membrane formed of the cellular substance. Between the meshes of the intestinal network of vessels, when most perfectly filled by the Ruyschian art, white cellular substance remains, even then greatly exceeding the bulk of the vessels, although being preternaturally distended, they occupy a greater space. But I do not know any membranes composed of fibres interwoven with, and decussating each other; unless you consider as such the ligamentary or tendinous fibres which are spread over true membranes.

XII. Cellular substance is found in the human body, wherever there is a vessel or muscular fibre, without exception, as far as I know.

XIII. The other elementary substance of the human body, (II.) which cannot be truly called either a fibre or cellular laminae, is a mere extravasated gluten, concreted, not into fibres, but in the spaces betwixt them. This is manifest in the bones, whose fibres are seen very distinctly in the foetus, with vessels running in the intervals between them; so that the skull in every part, resembles a comb. This fabric is so altered in the adult, that the intervals being filled up by fluid, extravasated in the spaces betwixt the fibres, as happens with the juice of madder, and the edges being

being agglutinated, laminæ are formed. The cartilages seem to be scarcely any thing else than concreted gluten.

xiv. But here the order of nature seems to be, that the fibres above mentioned (iii.) are all originally formed of this gluten. That the cellular substance (vii.) is thus formed, appears from those cellular fibres, produced in the thorax from concreted vapour, which joins the surface of the lungs to the pleura, and perfectly resembling the true and natural cellular substance, even though compacted of inspissated pus. The same appears also from a comparison of the fœtus with the adult; for, instead of the abundant subcutaneous cellular substance, the fœtus has a mere jelly interposed betwixt the skin and muscles, which have already acquired greater firmness; from the morbid dissolution of the membranes of the muscles into a mere gluten; and from a similar change into glue of the skin, tendons, and ligaments of animals, by means of boiling water. Clots of coagulated blood; the sanguineous membranes of Ruyfch; Albinus's membranes formed of mucus, polypus, silk and glue, also illustrate this theory. Lastly, that the bony fibres themselves are formed of compacted gluten, is shown from diseases in which the hardest bones, by a liquefaction of their gluten, return into cartilage, flesh, and jelly. Similar changes are made on the bones of fishes and other substances by Papin's digester.

xv. It seems, then, that an albuminous fluid, with a small portion of earth, first concretes into filaments, from some pressure, whose causes we now pass over. These by the mutual attraction of cohesion, leaving, however, spaces between them, compose the cellular texture, after having acquired some firmness from the closeness of the earthy particles, which follows the expulsion

sion of the too aqueous gluten. This substance, wherever its laminæ are subjected to greater pressure, turns into fibres and tunics ; and, lastly, with unorganized gluten (xiv.) concretes into bone. (xv.) Hence, in general, all parts of the body, from the softest to the hardest, seem to differ only in the latter having more of the earthy particles, and these more closely compacted, with less aqueous gluten ; while in the soft parts there is less earth and more gluten.

xvi. The cellular texture is made up of fibres and laminæ (viii.) which are neither hollow nor vascular, although it is coloured by accessory vessels, but solid. The following are its chief varieties. In some parts it is loose, and formed of long and distant laminæ ; in others thin, and composed of short fibres. I find it shortest betwixt the sclerotica and choroides of the eye, especially of animals, and betwixt the arachnoides and pia mater of the brain. I also find it tender, but more conspicuous, betwixt every two coats of the intestines, stomach, bladder, and ureters ; in the vesicles of the lungs, under the pulp of the glans penis ; and between the small kernels of the viscera and glands. It is composed of still longer fibres, where it accompanies the vessels, under the name of Vagina, through the viscera, and particularly the liver and lungs ; and is vastly firmer in the vessels which go to the head and limbs. Its principal use is to bind together the contiguous membranes, vessels, and fibres, in such a manner as to allow them a due degree of motion. But the cellular substance, as hitherto described, hardly ever contains any fat ; but is moistened by a watery, gelatinous and somewhat oily vapour, exhaled from the arteries, and received again into the veins. The truth of this is easily demonstrable from injections of water, isinglass or oil, made in all parts of the body. When this vapour is wanting,

ing, the filaments cohere, and the contiguous membranes are united, with loss of motion.

xvii. The cellular texture is more lax, and formed of laminæ rather than fibres, where it divides the muscular fibres, even the most minute ; where it loosely accompanies and sustains the vessels ; and within the cavities of the bones, where it is composed of bony as well as membranous laminæ. That is likewise very lax, which, under the surface of the body, is every where interposed betwixt the muscles and the skin ; but the laxest of all is that which furrounds with very wide cells the genital parts of the male.

xviii. Into the empty meshes of this cellular texture (xvii.) there is poured almost every where, in the foetus, first a gelly, then a grumous, and lastly, under the whole skin, and in its pits, a clotted fat. This substance is lighter than water, insipid, inflammable, becomes solid in the cold, is found in greater quantity about the kidneys and in graminivorous animals ; in fishes, while alive, and probably also in man, nearly fluid, though apt to coagulate. In it an acid salt, almost in the proportion of one-sixth, is united with oil.

xix. Through this cellular texture the blood-vessels run and are divided ; from the arterial extremities of which, the fat is deposited and absorbed by the venous. The passage, from the arteries into the adipose cells, is so immediate and free, that they must open by very large mouths, since they admit injected mercury, air, water, size, and oil, which is always very sluggish, even in living animals. It is not secreted by any long ducts of particular fabric, but transudes on all sides through the whole extent of the artery ; inasmuch that, when an artery is filled with water, there is no part of the surrounding cellular substance which is not moistened. The warm fat, during the pulsation of the arteries, easily finds out the same passages.

How

How quickly it is collected, appears from the speedy renovation of fatness after acute diseases.

xx. But that this fat is absorbed by the veins, we are taught from the sudden effects which muscular exercise has in consuming the fat, more especially of animals in which it abounds ; also from its consumption in fevers ; from the cure of dropsies, where the water effused into the cellular substance is in a manner absorbed and thrown out by the intestinal tube ; and, lastly, from the venous transfusion of water and oil, when injected by the syringe, observed in every part of the body. Are nerves distributed upon the adipose cells ? It is certain they run through this substance, and every where divide in it, into the minutest filaments, so that they can no longer be traced by the knife. That they terminate in it, is not probable ; for the fat is both insensible and unirritable.

xxi. The meshes betwixt the laminæ of the cellular membrane, are every where open, and unite in forming one continuous cavity throughout the whole body. This appears from the inflation of the skin over all the body, which butchers, and likewise the surgeons of Ethiopia, effect by a single wound ; from emphysema, in which the air received by a wound of the skin, being retained, causes a swelling throughout the whole body ; from the passage of bodies, put under the skin, to a place remote from that at which they entered ; from the passage of pus, from an inflamed place to remote ulcers ; and, finally, from diseases, in which water deposited in all the cellular substance of the body, is completely evacuated by a single incision. That none of the cellular texture is excepted, appears from a case of emphysema in which the vitreous body of the eye itself was inflated ; and from a disease, in which the  
gelatinous

gelatinous serum of a dropfy was transfused even into the cavernous bodies of the penis.

XXII. The great importance of this cellular substance will be evident to all who consider, that from it alone proceeds the due firmness and stability of all the arteries, nerves, and muscular fibres, and consequently of all the flesh and viscera formed of these : but even the figures of the parts, their just length, cavities, curvatures, flexures, depend entirely on the cellular membrane, being in some places of a laxer, and in others of a denser fabric : for when divided, every part is lengthened and collapses. Of this substance, with vessels, nerves, muscular and tendinous fibres, (a great part of which are however formed of it,) all the viscera, all the muscles, glands, ligaments and capsules, are composed ; on it alone, and its different length, tension, quantity or proportion, the diversity of our glands and viscera depends ; and, lastly, it certainly constitutes by far the greatest part of the body itself, if indeed the whole be not formed of cellular filaments of this kind.

XXIII. It possesses a contractile power, different from irritability, which, though not demonstrable by experiments, disposes the cellular fibre to shorten itself, though for the most part slowly, after having been stretched. This power, excited by cold, renders the skin rigid ; raises the hairs ; draws up the scrotum ; and, after gestation, restores the skin of the abdomen, and the uterus, to their former size. The same force, by a gentle but continual contraction, promotes the secretion of fat of the liquors of the subcutaneous and other glands, and of pus : in the veins and receptacles, it resists dilatation ; and, when that is taken off, it regains its former shortness. In the foetus, this gentle force is among the principal causes of the changes that happen to the body.

XXIV.

xxiv. The uses of the fat are various : it every where facilitates the motions of the muscles, lessens their attrition, and prevents rigidity : it fills up the spaces between the muscles, and the cavities about many of the viscera, in such a manner, that it readily yields to their motions, and yet supports them when at rest : it principally constitutes the weight of the body ; conducts and defends the vessels : it uniformly distends the skin ; serves as a cushion to the body, and renders the whole comely : it probably, by mixing with some humours, abates their acrimony : it has a principal share in forming the bile ; and, by transfusing through the cartilaginous incrustations of the bones, it mixes with the articular liquid, and by absorption, it lubricates their fibres : by exhaling through the pores of the skin, it resists the drying sharpness of the air ; also, by exhaling in a living person from the mesentery, mesocolon, omentum, and round the kidneys, it lubricates the surfaces of the viscera with a bland vapour ; and, by being interposed, prevents their concretion.

xxv. The fat is deposited into the cells during sleep, rest of body and mind, and diminished force of circulation. When collected in too great a quantity, it proves injurious ; by compressing the veins ; and, impeding the action of the heart, it produces asthma, apoplexy and dropsy. The same humour is taken up by the veins ; and, being more rapidly moved along the arteries, by violent exercise, venery, watchings, cares of the mind, salivation, diarrhoea, fever, fasting, it is carried beyond the excretory pores : it is consumed by suppuration. When restored to the blood, it increases acute diseases, tinges the urine, and forms a part of its sediment. After being suddenly consumed, it is soon renewed again from healthy humours : but, in a languid habit, a gelly, instead of fat, is deposited into the cells, causing anasarca, and external hydrocele.

## C H A P. II.

## VESSELS.

XXVI. **T**HE membranes will be better described singly. There are many things common to the arteries. They are long extended cones, decreasing according to the number of their branches. But where arteries run for some length, without sending off large branches, their convergency is not very evident, if any; and at length, where they are called capillaries, and wherever they give passage to a single globule, they are either cylindrical, or diminish very imperceptibly; their transverse sections are every where and without exception circular, when the artery is full. Where they send off large branches, the caliber is suddenly diminished, insomuch that they may be reckoned a chain of cylinders, of which every one is narrower than the preceding. If you reckon them cones, then the basis of the cone, common to all the arteries is in one or other of the ventricles of the heart; and the apex of the cone, either in the beginning of a vein, or in the beginning of the cylindrical part of the artery, or unless it is cylindrical, in an exhaling vessel. In some places they seem to dilate; at least they certainly become wider, after they have been filled and distended with wax; possibly from some obstruction which causes the injected wax to distend that part of the artery more than the rest. Examples of this kind we have in the vertebral artery, at the basis of the skull; in the splenic; in the flexure of the carotid, according to Mr. Cowper's injections; and, lastly, unless I be much deceived, in the spermatic arteries. In all places, likewise, where the ramifications begin, the diameter of the artery is a little increased.

XXVII.

xxvii. There is no external coat proper and common to all arteries. They derive an external and merely incumbent integument, in the thorax from the pleura, and in the abdomen from the peritonæum. In the neck, arm, and thigh, a sort of thicker cellular substance surrounds the arteries. The membrane of the pericardium, which on all sides encircles the aorta, returns back with the vessels to the heart. The dura mater imparts a capsule to the carotid, as it passes out of the skull. But the first true membrane of the arterial tube, is every where cellular, and sometimes adipose as in the thorax.

xxviii. The external surface of this cellular coat is of a looser texture, coloured by a great many small veins and arteries, and permeated by nerves not very minute. It is sometimes so abundant, that its external layers seem hardly to belong to the artery, but appear like an extraneous texture added to it. It is of this appearance in the neck, and round the inguinal, subclavian, mesenteric, cœliac, and hepatic arteries, being chiefly composed of long filaments. These are the *Vaginæ* of the Arteries, of some eminent men.

xxix. As this cellular coat advances more inwardly, and nearer to the cavity of the artery, it becomes more dense, solid, and fibrous, and may be called a proper coat of the artery. That there is no tendinous coat of the arteries distinct from this cellular substance, is evident from maceration, by which the inmost stratum of this arterial tunic becomes cellular.

xxx. Within the former, and nearer the cavity of the artery, we find fibres, in general orbicular; re-collecting, however, that no fibre any where makes a complete circle; but that many of them conjoined, with their extremities turned off sideways, seem to form one ring. These fibres, in the larger trunks, form many strata, sufficiently apparent from  
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their reddish colour and solidity ; but in the smaller arteries they are by degrees more difficult to demonstrate, and seem to be wanting in the arteries of small animals. I have never observed them longitudinal. Under this membrane, but more difficult to demonstrate, is an exceedingly short cellular texture, into which the tephaceous matter is poured when an artery ossifies.

XXXI. The innermost coat of the artery is thin, and finely polished by the current of blood ; it covers with an uninterrupted lining the fleshy fibres, which are not sufficiently continuous, and prevents the blood from insinuating itself into the intervals. It is every where smooth and without valves ; although, from a sort of mechanical necessity, sometimes certain folds, raised into a semicircle at the origin of branches, project, as we see, at the branches sent off from the arch of the aorta. Yet, in arteries of the viscera, the innermost coat is softer, lax, wrinkled, and almost friable, especially in the ductus arteriosus.

XXXII. The arteries themselves have arteries, particularly in their external cellular coat, springing on all sides from the adjacent small arteries, numerous, branchy, reticular, all very minute, even in the fœtus, without injection, very numerous. Nerves every where descend, for a great way along the surface of the arteries, and vanish in the cellular substance ; of which we have examples in the external and internal carotids, and arch of the aorta. From these, do not the arteries derive a contractile spastic force, different from simple elasticity ? Do not fevers, faintings, palsy with atrophy, and the passions of the mind, prove something like this ? But arteries are insensible and unirritable ; and if they are constricted by poisons, they have that property in common with the dead skin.

XXXIII. The sections of arteries are circular, because they are elastic ; this is the reason why, even from

from the small arteries of the teeth, hæmorrhages are sometimes fatal. The aorta, indeed, in the thorax and abdomen, the carotids in the neck, and some other arteries of the dead body, when not distended, appear flat; but their round figure, and circular section, are always restored by injection. By their elasticity, arteries strongly compress the finger that dilates them, and more tightly in the dead than in the living body. In the living body, indeed, it yields to the action of the heart; but when the heart is relaxed, instantly contracts, and regains its former diameter; this constitutes the pulse, whose full explication will properly follow the history of the heart; at present, it is sufficient to say, that all arteries pulsate, although the systole and diastole can be perceived by the finger, only in the larger, not in the smaller ones; and though in the ultimate inflections of the arteries, it almost vanishes; for, by an increased motion of the blood, even the smaller arteries beat violently, as we see in inflammations. They contract lengthwise strongly, and are rendered shorter when cut entirely across.

xxxiv. The strength of the arteries is considerable enough: but the dense, hard texture of the outer cellular coat, as it refuses to yield to a distending force, breaks without much difficulty, almost more easily than the coats of the veins; hence arise aneurisms. The trunks are almost every where weaker, and the branches stronger, so that the impulse of the blood may have considerable effect upon the former, while in the limbs it has very little. Hence, aneurisms, are most frequent near the heart. In the lower extremities, the strength of the arteries, and of the veins, is increased, as well as in the secreting organs.

xxxv. Nature has distributed arteries over the whole animal body, excepting a few membranes, where they have not yet been demonstrated. But  
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she has disposed of the trunks every where in places of safety, because wounds cannot happen to the small ones without danger, or to the large ones without loss of life. The skin has numerous short and small twigs; but the larger trunks, defended by the skin and muscles, creep near the bones. In general, the arteries are in proportion to the parts of the body to which they are sent, yet larger branches go to the secretory organs, spleen and brain; and smaller ones to the muscular parts.

xxxvi. The proportion of the solid part of an artery to its cavity, is not every where the same, nor is it constant even in the same artery. This proportion, in the first place, is least of all at the heart, and increases as the arteries remove farther from it. Secondly, in a full fed plethoric animal, whose blood passes freely, and with great force, through its arteries, the proportion of the solid part is less than in a famished extenuated creature, whose blood moves feebly.

xxxvii. From each arterial trunk, branches are sent forth, and from these again proceed smaller ramifications by repeated divisions, of which you will scarcely find the end, though you may, perhaps, trace a series of twenty. The calibers of any two branches taken together, always exceed that of the trunk from whence they come, in nearly a sesquilateral proportion, or somewhat less. In the capillaries this law does not obtain, and the sum of the calibers of the branches, does not exceed that of the trunk. The smallest arteries which transmit a single globule, have nearly the same diameter with a globule, that is, the three thousandth part of an inch. Every trunk, above its division, expands a little. The angles, at which the branches go out, are generally acute, either half right angles or nearly so; which angle, even in mechanics, carries projectiles farthest. Instances of their going off at right angles,  
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or nearly so, we have in the lumbar and intercostal arteries; of a retrograde course, we have one instance in the coronaries of the heart, and another in the spinal arteries, which are produced by the vertebrals, and several in those of the limbs, as in the tibial and brachial. But most of those which are esteemed retrograde, are sent off, at their origin, at acute angles; such as the ascending artery of the pharynx, the descending one of the palate, the umbilical and mammary arteries, and the nutritious ones of the large bones. Besides, it is common for larger branches to arise under less angles, and smaller ones under greater angles. It is rare that two arteries of a large diameter run together into one trunk. An example of this, however, exists in the artery formed of the vertebrals. In the smaller ones it is frequent, as in both the spinal arteries, and that of the sincipital foramen. In many parts, they have repeated flexures, so that the artery undulates around a straight line, in alternate obtuse angles. This happens most frequently wherever the diameter of the part to which the artery goes, is occasionally much increased, as in the large intestines, womb, face, spleen, lips, and iris. Even the straight arteries in other places, if too much distended, fall into serpentine flexures. Sometimes they are suddenly twisted into a kind of circle, as the carotids under the mammillary process.

xxxviii. They are frequently conjoined by intermediate branches, in such a manner, that the twig of one artery shall run to meet one of the same kind, from a neighbouring artery, and unite with it into one trunk. We find instances of this, in large trunks in the intestines, among the middling ones in the kidneys, womb, &c. and among the smaller ones in all parts of the body; so that there is no part of the human body, in which the neighbouring arterial branches, whether

whether of the same or of different denominations, are not joined by intermediate branches. Of circles formed by arteries diverging laterally, and uniting again with each other, we have instances in the eye and brain. The extremities of the arteries which are either cylindrical or nearly so, send off smaller branches, which, in the same extent, are more numerous, and are generally reticular; so that each branch, by its smaller twigs, forms anastomoses with those of its neighbouring branches: and thus we find it in all membranes. By this means it happens, that, though the passage from the heart to any part of an artery be obstructed, the blood may nevertheless flow through the neighbouring arteries into all the branches of the obstructed one. Thus, gangrene and langour are very powerfully prevented, and obstructions are more easily resolved by the repulsion of the obstacles into the larger part of the trunk.

xxxix. Lastly, the minute arteries terminate in veins, either by a continuation of their canals, so that the ultimate little artery, which is generally reflected, having passed the angle of its reflection, has now become a small vein; or else a branch, sent out at right angles from the artery, is inserted under a like angle into the branch of a small vein. Both these kinds of mechanism are demonstrated to us by the microscope, and by the easy return through the veins, of injections thrown into the arteries. These vessels are sometimes large enough to receive several globules, and sometimes admit only one. A large artery never terminates in a vein.

xl. In the viscera we do not find their distribution so truly reticular but varied, the small branches descending, crowded together, brushy, arbuscular, parallel to the trunk, serpentine or villous, according to the various natures of the parts.

xli. Sometimes the arteries end in another manner, namely, by being converted into vessels of small-

er orders. These are sometimes continuous with the arteries and are real trunks, as in the ophthalmic artery, if you examine the arteries of the tunica choroides, then the circle of the uvea, and lastly, the colourless ones of the iris. That a network of pellucid arteries is continuous with the red branches in the tunica conjunctiva, is evident from inflammation, and the redness of the part when relaxed by vapour, or by cupping, from injection, and the microscopical observations of Lieberkuhn upon frogs, in which colourless globules were seen to pass from red arteries into lateral vessels. In a fabric of this kind, the red blood is easily forced into the smaller vessels.

XLII. In other places the smaller vessels seem to proceed laterally from the trunks of the least sanguiferous arteries, as branches smaller than the trunks. These are called Excretory Ducts. It is with difficulty that these are filled through the red vessels; of this we have, however, examples in the kidneys, the liver, and breasts. And the blood, when vitiated, penetrates the excretory ducts of the whole body without hurting the vessels, since that aberration has no bad consequence.

XLIII. Another termination of arteries is in exhaling vessels; and this is frequent in all parts of the body. The whole skin, all the membranes of the human body which inclose any cavity, all the ventricles of the brain, both chambers of the eye, all the adipose cells and pulmonary vesicles, the whole cavity of the stomach and intestinal tube and air passages, are all of them replenished with exhaling arteries of this kind. These emit a thin, watery, gelatinous humour, which, by stagnation, congestion, and accumulation, from disease or death, is converted into a watery, but coagulable lymph. The truth of this is easily demonstrable from the exudation that ensues from injecting the arteries with warm water. In some places, indeed,

deed, they pour out, not a thin vapour, but blood itself, as we see in the heart, the cells of the penis, urethra, clitoris, and nipple of the female breast; in all which the blood itself is poured out in its natural state. Is not every secretion in true glands or cryptæ, analogous to this exhaling fabric?

XLIV. In every part of the human body, do vessels arising from the sanguiferous ones, but carrying a humour thinner than blood, again send out other smaller vessels, to be subdivided into still less orders? We seem, indeed, not to want examples of this, as pointed out by men of eminence. That the aqueous humour is secreted by minute vessels, generated from the colourless arteries of the iris, is very probable. That the red coloured vessels in the cortical substance of the brain, by the intervention of another order of vessels, separate a juice pervading the medullary substance, is almost certain. Erysipelas, and the yellow inflammation, arising from the yellow or serous globules impacted into smaller vessels, suggest the same opinion.

XLV. Are there then yellow arterial vessels of a second order, which send off lymphatic ones of a third, from whence, by degrees, still less kinds of vessels branch out? Such a fabric does not seem agreeable to the easy transition of blood, mercury, or wax, into the exhaling, perspirative, uriniferous and adipose vessels and pulmonary cells; nor is it very difficult for the blood to stray into the lactiferous, lymphatic, and lachrymal vessels, whither it should seem not able to penetrate, if it went through any other intermediate vascular system, smaller than the blood-globules. Nor is this opinion admissible, from the great retardation which must arise to the humours in a third, and much more in inferior orders of vessels.

XLVI. The VEINS, in many particulars, resemble the arteries. There are six, of which two answer to the aorta, and the remaining four to the pulmonary

pulmonary artery. Their basis is in the ventricles of the heart, and their apices in the extremity of each branch, through all parts of the body, excepting one instance, in the liver. In most parts, they run parallel with the arteries, contiguous to them; but they differ in various respects.

XLVII. The fabric of the veins is thin, every where smooth, difficultly separable into membranes; of which the inmost is like that of the arteries, and round it is a condensed, but very easily distended, cellular membrane, surrounded in a single instance, above and below the heart, with transverse muscular fibres. The cellular substance, which connects them to the rest of the body, is, however, like that of the arteries, every where very lax. Notwithstanding this slender fabric, the veins are every where sufficiently firm, and do not easily burst when inflated with air; being, in most instances, stronger than the arteries themselves. But they burst more easily in man while alive, as appears from morbid instances in the leg, arm, face, &c. Nor do they support themselves after being divided, but collapse so as to make their apertures appear like slits; unless they be prevented by some strong cellular substance placed round them, as we see in the liver and womb. They are moderately irritable, and not by stimuli alone, unless they be chemical; but, in that case, they contract more than the arteries. They have no pulsation, unless, if we may trust all accounts, when the venous channel is somewhere obstructed; or when, in dying people, the blood is thrown back again from the right auricle into the descending and ascending cava, or falls back from the brain.

XLVIII. The veins are much larger than their corresponding arteries, having the square of their diameter often double or triple that of the latter; and sometimes almost quadruple, as near the root of, and in the vessels of the kidneys. In general, however,  
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the diameter of the veins is to that of the arteries as nine to four ; yet the capacity of the capillary veins but little exceeds that of the arteries which accompany them. They differ likewise from the arteries in their division, having more numerous trunks and branches ; for to one artery in the limbs we usually meet with two veins. The larger veins are also more reticulated, and unite by more frequent anastomoses, not only of the small branches, but even of the large trunks, occurring every where amongst the neighbouring veins, upper with lower, and right with left. They prefer the surface of the body ; and through the limbs, neck, and head, they run a long way, perfectly cutaneous, which is very rarely the case with arteries ; from which, on that account, they separate. Then the veins follow the surface, without a corresponding artery, which, in the mean time, runs at a considerable depth, attended by some smaller venous branch. In the smaller branches, and membranous reticulations, and in the internal fabric of the viscera, the veins and arteries commonly run contiguous. The veins are generally less tortuous.

XLIX. In the larger sanguiferous veins, valves are found in great numbers. The innermost membrane rises double into the cavity of the vein, in the manner of a curtain, and being on either side extended deeper along the course of the vein, forms what may be called its cornicles : but the basis, where it arises from the vein in the shape of a segment of a circle, is stronger, and constitutes its agger. With the sides of the vein as it proceeds, they inclose a curtained space, of which the exterior side is the vein itself, and the interior the valve, which by its convexity projects into the cavity of the vein. The basis of this almost parabolic space, or the mouth of the valvular cavity of the veins, always looks towards the heart. They  
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are found in all the subcutaneous veins of the limbs, in those of the neck, face, tongue, and in the veins of the penis : at the origin of the larger branches, there are two, three, four, and sometimes five of them together, which, however, is rare : in the smaller branches they are single. There are none in the veins of the deep seated viscera ; and, therefore, none in the brain, lungs, heart, or liver, or in the whole system of the vena portarum, or in the kidneys or womb, (except one or two valves in the spermatic vein ; ) or, lastly, in those smaller veins, which are less than a line in diameter. Sometimes, though rarely, they have been seen in the vena azygos. In the cava, at the mouths of the hepatic and renal veins, I have observed a sort of wrinkles in their place. In the smaller branches, the solitary valves are long and very acutely parabolical, almost proportionately longer as the vein is smaller. These seem to oppose the reflux of the blood more powerfully than the larger ones.

I. The origin of the veins we noticed in speaking of the arteries. They arise continuous from minute arteries, by inserted branches, or the reflection of a trunk. Others, again, are either continued from veins of inferior orders, or receive additions and roots from them ; as, for instance, in the lymphatic vessels and thoracic duct. Others of a bibulous kind take their origin from the absorbing veins dispersed over the whole body, in the cavities of the eyes, intestines, breast, peritonæum, pericardium, and ventricles of the brain. Hence the venous exudation, easily imitable over the whole human body, by injecting the venous trunks with an aqueous liquor ; hence water, jelly, or oil, pass from the vena portarum into the cavity of the intestines ; hence water, injected into the abdomen of a living animal, quickly disappears. But of these things

things we shall speak again more fully in their proper places.

LI. Little different are those veins which arise from every part of the cellular membrane, and carry back to the mass of blood, dropical waters, moist vapours, dissolved fat, extravasated and corrupting blood, and the poison of opium introduced into the cellular texture ; or bring back the blood itself from the cellular fabric of the penis, clitoris, or nipples of the breasts, after the venereal orgasm. That, into all the glands, veins of this kind open, is highly probable, which, by absorbing the thinner humour, leave the remaining mass of a thicker consistence, as, for example, the bile, sperm, mucus, &c.

LII. That there are smaller orders of veins, as of arteries, resembling those which convey blood, appears from experiments. Thus, in the eye there are the small veins of the iris, and not a few trunks in the adnata ; and, without doubt, veins return from the vitreous humour, which, in health, are pellucid.

LIII. But, in most parts of the human body, other veins are found, full of a reddish, yellowish, or almost pellucid liquor, coagulable by heat ; formed of a very tender coat, and excitable by chemical stimuli. They are intercepted by double valves, for the most part so very frequently, that they almost seem jointed when they are turgid. By degrees uniting, either the whole or greatest part of them meet in the thoracic duct. They arise from the cellular texture throughout the whole body, as I had long ago learned of the lactiferous vessels of the breasts, the vasa efferentia of the testicles, and, lastly, of the lymphatics originating from the mesenteric glands ; and is now shewn of the lymphatic vessels of the testicles, spleen, and other parts. From analogy, and from the analogy of diseases, especially of dropfy, we are induced to believe, that they arise likewise

wife from the large cavities of the body ; nor is it contradictory to suppose, that this kind of vessels receive a thin humour from very minute veins. But all the lymphatics, in their course, meet with a peculiar kind of glands, called Conglobate, into which they enter, having become arterial by the convergence of the venous cones, and dividing into branches ; and again issue from them, to unite into new trunks.

LIV. These glands themselves consist of lymphatic vessels, connected by cellular texture, into which a fluid brought by the arteries, exfudes, and from which it is taken up by the vessels which carry away the lymph. They are covered with a continuous membrane, generally of an oval shape, whether they are simple or compound ; and they follow the course of the larger blood-vessels ; especially of the veins, through the whole trunk of the body, to the insertions of the limbs ; running along the jugular and subclavian veins, the vena cava superior, the aspera arteria, gullet, lumbal vena cava, vena porta, the iliac, hypogastric, crural and popliteal veins, and likewise the vessels of the stomach, spleen, mesentery, and mesocolon.

LV. They are found on the surface of the viscera, in the thorax and abdomen ; and more easily in brutes ; in the lower part of the face, muscles of the tongue and parts adjacent, in the neck, and those parts of the upper limbs which are nearest the trunk, as far as the bending of the elbow ; throughout the whole length of the anterior and posterior mediastinum, and wherever we find conglobate glandules, either in the neck or thorax ; in the whole lumbal region that is contiguous to the aorta ; in the mesocolon, pelvis, vessels and surface of the testicle ; and in the lower limbs, wherever they are supplied with conglobate glandules, as far as the knees. Whether they extend further, and exist in every part of the body, in the brain, eye, hand, foot,

foot, back, fore part of the peritonæum, &c. is not confirmed by sufficiently accurate or numerous observations on the human body. They are every where found on the surfaces of the viscera. They are almost every where collected into bundles, which lie not far from the large blood-vessels. Those from the inferior limbs, pelvis, and loins, run into one duct, which is joined by another bundle coming from the liver, spleen, and stomach; and that trunk, at length, becomes the thoracic duct. The superior vessels, from the whole extent of the breast, the head, and superior limbs, empty themselves into the same duct towards its upper extremity. They seem, however, likewise to terminate in the red veins.

LVI. Of what service these glands are to the lymphatic vessels is not yet well known. In the foetus, as well as the thymus and glandulæ renales, they are turgid with a milky liquor; but it is not certain that this fluid is poured out into the cellular spaces. It is however rendered probable by late experiments, that in these glands some kind of fluid is prepared which is mixed with the lymph; since thin fluids, injected into the arteris, enter the lymphatic vessels. In the progress of life, this fluid vanishes; and the glands themselves, being dried up, almost disappear. The very frequent schirrosities in these glands seem to indicate, that the motion of the fluid passing through them is retarded.

LVII. Their valves (LIII.) are composed of two semicircular membranes, which give way to the fluid that goes toward the larger trunks; and by applying themselves to the sides of the vessel, leave a free passage. But the same valves, if the liquor return from a larger trunk towards the smaller branches, being filled, swell, expand, and shut up the tube.

## CHAP. III.

OF THE CIRCULATION OR MOTION OF THE BLOOD  
THROUGH THE ARTERIES AND VEINS.

LVIII. **T**HE arteries and veins hitherto described, contain either blood or lymph. The red blood, whose nature we shall explain when we treat of secretion, fills the arteries and veins commonly known, which we call red, or those of the first order, and which have their origin in the heart. These it fills, in a living person, in such a manner that at one time they are very loosely and imperfectly distended by it, and at another, they are rendered very full and turgid. After death, the veins are found very full of blood; but occasionally, the small veins, chiefly some time after death, have been found distended with air. The arteries in the dead body, commonly contain only a small quantity of blood.

LIX. This blood is rapidly moved through all the vessels of the living body. The truth of which is demonstrated by wounds, from which, even a mortal loss of as much blood as is necessary for the maintenance of life quickly ensues, almost instantly from the larger arteries, and sometimes very suddenly from the smaller ones, but more difficultly from the veins, unless very large; yet are there not wanting instances of fatal hemorrhages from wounds of the vein in the inner corner of the eye, or of that under the tongue. Lastly, experiments made upon living animals, sufficiently prove the powerful impulse with which the blood is moved, particularly through the arteries. In the large arteries it runs most swiftly; in the small ones, somewhat slower. In the large veins, the blood moves more slowly than in the arteries, in the same proportion as the calibers of the arteries are less than those of the

the veins, almost twice or thrice. Another argument is derived from the compression and relaxation of a vein, by which the motion of the blood is promoted from valve to valve. This motion in the veins, is equable enough; but, in the arteries, it is alternately greater, so that the vessel at one instant rebounds strongly, and at the next is relaxed. This is confirmed in living animals by ocular inspection.

LX. The direction of the motion of the blood through the red vessels, is shewn by experiments of this kind. First, it is certain, that all the arteries and veins communicate; because, from one, and often a small artery, and sometimes also from a vein, all the blood shall be discharged, even causing death and extreme pallidity of the whole flesh, not only of the limb wounded, but of the whole body. Fatal examples have occurred from arteries of the nostrils, gums, fingers, teeth, from a cutaneous pore, lachrymal point, cupping, and the bite of a leech. There must therefore be passages by which the blood speedily flows from the venous into the arterial system.

LXI. That the blood, again, in the arteries, flows from the heart toward the extreme parts of the body, is proved by the microscope, and by tying up the artery of a living animal. For if an artery be stopped by a ligature, a swelling ensues in that part betwixt the heart and the ligature, whilst the other part beyond the ligature, and more remote from the heart, becomes empty, has no pulsation, nor, if wounded, bleeds. The effect of a ligature is also produced by disease; as when some tumor, by compression, or an aneurism, intercepts the motion of the heart. Experiments have been made on most of the arteries even by myself. Sometimes anastomoses, or the escape of the blood by some channel into a neighbouring branch, and the retrocession of the blood in a dying animal, seem exceptions,

LXII. There have been doubts with regard to the motion of the venous blood, and all the ancients were persuaded, that the blood flowed also in the veins from the heart, or certainly from the liver, to all parts of the body. Few have discovered the error: several, indeed, in the pulmonary vein: in the vena cava, fewer; perhaps only Andreas Cæfalpinus, and as an uncommon appearance, Vesalius.

LXIII. Harvey first established, by experiments, the course of the venous blood which returns from every part to the heart, so as to remove every doubt. And, first, the valves point out this truth; for the common office of these valves is, that every pressure, however applied to the veins, determines the blood towards the heart, since they take away the possibility of its returning into the branches, after having once entered a trunk. For, since the valvular portions are concave upwards, towards the heart, the reflux blood enters into and expands them. Thus, that part of the valve which projects loosely within the cavity of the vein, approaches towards the axis, until it meet the opposite side, and shut up the tube. This we know from inflation, ligatures, and injections; for we never can force a liquor easily into the veins against the valves. They do not, indeed, every where shut up the cavity entirely; but they always do it in a great measure.

LXIV. Another office of the valves in the veins seems to be to sustain the weight of the blood, that its upper columns may not gravitate upon the lower, nor the blood, flowing through the trunks, impede that coming through the branches. For if, from the slower motion of the blood, it shall happen that its weight shall bear too great a proportion to the impulsive force, and any part of the sanguineous column begin to descend by its weight, the nearest valve supports it in its relapse, prevents it from pressing on the succeeding column, and affords time  
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for some contiguous muscle, by its pressure, to free the valve, and propel the column. This is the reason for the situation of valves in the veins of the limbs and neck; in which parts they are both more numerous and more robust than elsewhere. This also explains the cause of varices, when the blood, entering the valves, presses their solid convexity downwards, and forces them to descend and dilate. Likewise, in muscular motion, the valves occasion the whole pressure which the veins then sustain, to forward the due course of the blood towards the heart.

LXV. Moreover, the valves placed in the right side of the heart, are so constructed, as we shall hereafter see, that they freely permit blood, air, or wax, to pass from the venous trunks of the cava into the heart, but allow nothing to escape from the heart.

LXVI. Besides, in a living person, ligatures make the thing evident. When either by design or accident, the veins of the ham, arm, or leg, are tied with the limb itself, the limb every where below the ligature swells, the veins become distended and turgid, and, when opened, freely discharge blood; nothing of this kind happens above the ligature, nor are any veins to be seen there. The same happens when the veins are compressed by schirrous viscera, or enlarged glands; and from polypi, tumors of the large veins are frequent. Ligatures retain the blood in any limb round which they are tied, and prevent it from returning to the heart, and from being lost through a wound in another part.

LXVII. The experiments which have been made on living animals, are still more accurate. From them, even from our own, it appears, that, by tying, in a living animal, any vein, whether belonging to the cava or to the pulmonary veins, that part always swells which is most remote from the heart, and is distended with the blood retained by the obstacle, while that next the heart becomes pale and flaccid. Lastly, if both the arteries and veins be tied, the  
veins

veins collapse; but, upon removing the ligature, the veins are immediately filled.

LXVIII. In like manner, the injection of poisons or medicines shews, that, into whatever vein you inject chemical acid spirits, the blood even to the heart is coagulated by the force of the poison. But the affection of the brain by the narcotic power of opium, of the intestines by purgatives, and of the stomach by emetics, clearly proves that the blood, with which these substances were mixed, had passed from the venous branch to the heart, and from thence through the whole body.

LXIX. Moreover, from the transfusion of blood, it appears that the living blood of one animal, injected into the vein of another, completely emptied of blood, replenishes its heart, arteries and veins, so as to restore vigour, turgidity, and even to produce plethora.

LXX. But that the blood passes from the minute arteries into the minute veins, we are taught by injection; filling, without much difficulty, by one arterial trunk, the arteries and veins throughout the whole body, provided the liquor be watery and fluid; and with very great ease those of the head, mesentery, heart and lungs.

LXXI. Lastly, microscopical observations on the pellucid tails, feet and mesenteries, of animals, prove, beyond all doubt, that the blood, carried to the extreme parts by the arteries, is poured either into small veins, continuous with the reflected arteries, or through communicating branches from an arterial trunk into a parallel vein, and that it returns by the veins to the parts nearer the heart. This transition happens both in the most minute veins, which are capable of receiving only one globule, and in those somewhat larger, which admit two globules. That there is no where any spongy or parenchymatous substance interposed between the arteries and veins, is proved both by the microscope

croscope and by injections, which, if there were any cellular space betwixt the arteries and veins, would be extravasated in shapeless masses.

LXXII. The circulation of the blood, is, therefore, now received as a medical truth by every one; namely, all the blood of the human body is carried through the aorta, from the left cavity of the heart towards the extremities of the arterial branches; whence it is entirely transmitted into the minute veins; from thence it returns to the large veins, the cava and heart itself; in which course it perpetually circulates.

LXXIII. Yet instances occur, when, from passions of the mind, from a sudden great revulsion by blood-letting, or from convulsion, the blood has retroceded from the smaller into the larger arteries. And, in like manner, from an obstruction being formed in the venous branches above the valves, the blood has been known to return into the extreme branches. But these deviations, are, for the most part, transitory, and the blood soon returns into its natural course. They may be supposed to happen most frequently in the abdomen and vena portarum.

LXXIV. The course of the humours in the valvular lymphatic veins, appears from ligatures and from the valves: for every lymphatic vein when tied, swells between its smaller extremities and the thoracic duct; but grows flaccid betwixt the duct and ligature. All the valves, like those of the veins, allow air and mercury to flow freely into the thoracic duct; but they resist, and often obstinately, the contrary course, although sometimes in the dead body they have given way.

LXXV. The vapour that moistens the cellular substance, the halitus of the abdomen and other cavities are conveyed from the pellucid into the red veins, that these may transmit their contents to the heart. Hence, when a vein is compressed or tied,  
œdema

œdema enfues, the fluid stagnating, from its passage being interrupted. In the other smaller vessels, experiments cannot be made; but reasoning and analogy support the same conclusion. Experiments concerning the fluid, reabsorbed from the intestines, pulmonary vesicles and skin, shall be mentioned in their proper places.

LXXVI. Therefore all the fluids in the human body are expelled from the heart into the aorta; and except those which are exhaled out of the cavity of the body, or are excreted, they all return to the heart through the minute veins. It remains to discover a passage by which the blood may return from the right to the left side of the heart; but this passage supposes an acquaintance with the history of the heart and pulmonary vessels.

## C H A P. IV.

### HEART.

LXXVII. **T**HE thorax, composed of bones and cartilages, on the whole, resembles a truncated cone, as we shall hereafter mention. The lateral parts of this cone, are two membranous bags, having at their upper end an obtuse termination, above the first rib, at which place they are contiguous, and separated only by some cellular substance. Their obliquity is such, that the right bag is widest, and adheres to the middle of the sternum, but as it descends it inclines to the left side, and comes from the very margin of the sternum. The left bag descends not from the sternum, but from the cartilages of the ribs. The inner and opposite sides of each bag, form what anatomists call the mediastinum. These bags have no communication whatever, and the right may be opened and its lung destroyed, without injuring the left. But the  
membrane

membrane which forms them, is simple, dense, externally surrounded by cellular substance, is called the pleura, is harder than the peritonæum especially towards the back, softer anteriorly, and is naturally insensible. The cavity of the mediastinum, or interval between the right and left bags, broadest above, but also considerable below, contains the thymus, conglobate glands, fat, vessels, and in some diseases, pus.

LXXVIII. Below, the same bags diverging, recede from each other, and leave a cavity central in all its dimensions, which separates them. This cavity is the pericardium. But the bags of the pleura, descending at the sides of the pericardium, and before and behind it, terminate finally, about the fifth or sixth rib, upon the diaphragm, and on it have their basis, which is truncated obliquely, so that anteriorly it is short, but posteriorly descends farther, and is arched upwards. Within these bags are the lungs. Posteriorly, these bags are more tender, contiguous and separated in the same manner by cellular substance, which terminates on the pericardium, and includes, in some measure, the aorta, but more evidently the trachea and œsophagus. This is the posterior mediastinum. Triangular productions of each lamina of the mediastinum form the ligaments of the lungs, one on each side.

LXXIX. The pericardium, or third bag, which is loosely surrounded, first by cellular substance, and then on all sides by the contiguous pleura, as an exterior lamina, touches the sternum by a very small part indeed; since the lungs when distended, cover the heart almost wholly before, and interpose themselves betwixt the sternum, and pericardium below; and the mediastinum, by gradually diverging towards the left side, has an interval, narrow indeed, under the lower end of the thymus, to each side of which, the lungs extend: but this situation

is disturbed, unless you are careful in the manner of opening the thorax. The pericardium has a broad, somewhat round basis, adhering to the tendinous, and by a smaller part on the left side, about the fifth or sixth rib, to the fleshy part of the diaphragm ; in young subjects by loose, but in adults by very firm, cellular substance. Towards the right it is broader, and towards the left it grows smaller. It is somewhat larger than the heart, that it may move freely in it. It never certainly was wanting.

LXXX. Upwards, the pericardium grows gradually narrower, ending above the heart in an obtuse conical appendix, which adheres to the coats of the large blood-vessels almost to the upper edge of the sternum ; first to the inferior branch of the right superior pulmonary vein ; then to the vena cava ; after that to the aorta, on its accession to which it is highest ; then downwards to the same vessel, and the ductus arteriosus ; hence to the left branch of the pulmonary artery, and at last to both branches of the left superior pulmonary vein. On the back part it is again attached to the right pulmonary vein ; then to the left sinus, to both left pulmonary veins, and to the auricle of the same side ; then a long way from the pulmonary vein to the inferior cava, then to the septum of the sinuses, then to the inferior cava. Besides, it adheres to the pulmonary artery, its right branch, and the aorta below the origin of its great branches, surrounding each artery with a cylindrical production, so that it appears like a kind of partition between every two neighbouring vessels. Thus also it contains the vena cava superior in a ring ; and the anterior and posterior cavities of the pericardium are loosely continued between that vein and the aorta. In like manner it surrounds the inferior cava. But this sheath, by which the vessels are surrounded, preserves its nature only for a short space, and immediately returns to the heart with those large vessels

vessels which it there serves as an external coat. But it sends cellular substance like a sheath, along with the great arteries and veins, to the lungs.

LXXXI. The pericardium has its arteries either from those of the thymus, from those which accompany the phrenic nerve above and below, from the larger phrenic arteries, from the mediastinal branches of the mammary, from the bronchial, œsophageal and posterior mediastinal arteries, or from the coronaries which inosculate with the bronchials and others. The trunks of the veins are analogous, but with more evident anastomoses between those of the right and left sides. The nerves are from the superficial cardiacs.

LXXXII. The membrane which properly constitutes the pericardium, is strong, white, compact, more robust than the aorta itself, and through its substance the nerves of the heart and some small vessels descend. The surrounding cellular substance makes its outer surface somewhat rough, while internally, where it is in contact with the heart, it is very smooth, and moistened on all sides by a watery vapour. This halitus, which we have always observed in the living animal, constitutes the water of the pericardium, small in quantity, but always present, limpid, or tinged with yellow or red, somewhat viscid, erroneously denied by some; and in some diseases immensely increased. The nature of this fluid is lymphatic, because it thickens into a gelly by heat, and in diseases, mixed with the mucus which every where exudes from the heart and its pericardium, it concretes into villi and cellular substance. This liquor is secreted, without any glands or visible pores, from the exhaling arteries of the heart, auricles and pericardium; as may be proved by the transfusion of water or size injected into the large arteries.

LXXXIII. The use of the pericardium is to contain this vapour, and the heart, so that it may have

a fixed point, to which, when in motion, as to a fulcrum, it may draw its fibres, without stretching the large vessels, and that it may not shift, pendulous, on changing the position of the body. For these reasons, we find it in all animals that have a true heart. A watery vapour bedews the very hot and very rapidly moved heart. It prevents friction, and its cohesion with the pericardium; for, when this vapour is dried up, the pericardium adheres to the heart, either in some particular place, or over its whole surface, so that it may seem to be wanting.

LXXXIV. Nature has given to most animals, and even to many insects and vermes, a heart; she has denied it to others, and indeed to the most simple animals, being those which are irritable over their whole body, however large, as the *holothuria hydra*.

LXXXV. The veins which carry back the blood from the whole body to the heart, if we except those of the lungs, are two. Anatomists call them the cava, but they either never form one single trunk, or for a very short space. Of these large veins, the inferior is the largest, and in man ascends in the right side directly above the diaphragm. Towards the right it is somewhat gibbous, that it may meet the superior cava, and posteriorly it forms the septum, which intervenes between the right and left sinuses. But the left side of the vein unites with the right auricle, whose fibres are continuous with those of the cava. The same is true of the superior cava.

LXXXVI. A cavity is thus produced, whose right side is free, convex, and composed by the union of the two *venæ cavæ*, and which is filled with fleshy fibres, variously interwoven between the two simple membranes. The same cavity, at its anterior and left part, is perpendicularly oblong, and almost oval; anteriorly it is dilated; and, lastly, upwards, it has an acute blind termination, detached from the heart,  
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and resting upon the aorta. This cavity every where between the external membrane of the heart and its own very thin internal membrane, has very copious fibres, fleshy, detached, almost parallel, yet obliquely intersecting each other, which arising from the right side of the whole cavity, and from the left, are extended round its anterior semicylinder, in the manner of parallel arches. Very minute oblique fibres connect these muscular arches. This anterior and stringy part is called the auricle, but the right and posterior portion is called the sinus, which is smooth along the septum of the auricles, and between the anulus ovalis and mouth of the heart to the left of the vena cava. In the auricle are three considerable muscles, the anterior, posterior, and inferior.

LXXXVII. Towards the left of the septum, which divides the two auricles, almost in the middle between the two venæ cavæ, there is a depression, as if imprinted, deeper above, less deep below, in which the septum is exceedingly thin. I shall call it the fossa ovalis. A fleshy column bounds it on each side, by the junction of which, is formed an arch, convex upwards, whose fleshy fibres are stretched around in the form of arches, while their lower and thinner roots are turned backwards towards each other. This I call the anulus ovalis; others, the isthmus.

LXXXVIII. Where the ascending cava opens into the right auricle, from the left tumid column of the foramen ovale arises a membrane of a crescent shape, naturally entire, but from its thinness sometimes reticular in adults; which being extended round the lower edge of the auricle, always growing thinner as it returns incurvated to the right, circumscribes almost half the circumference of the auricle, and separates it from the vena cava, in the manner of a septum. It is called the valve of Eustachius.

stachius. The foramen ovale we shall describe hereafter.

LXXXIX. Into this sinus and auricle, which, however, compose but one porch of the heart, the blood of the two venæ cavæ is impelled by the muscular power which resides in each of these veins; for as far as they lie within the breast, they are endowed with strong and irritable muscular fibres, by whose contraction the blood is driven into the neighbouring auricle.

xc. In like manner the auricle, when irritated, contracts in every dimension. First, by the contraction of the muscular lacerti of the auricle, its anterior semicylinder is reduced to a plane, while, by contracting at the anterior extremity or beginning of the heart, and at the posterior, or sinus, they draw the middle of the arch backwards. Then the appendix of the auricle descends and contracts transversely, while the lower part ascends; and thus the auricle is shortened. Lastly, the left side approaches evidently to the right, and the right somewhat to the left, and thus the auricle is rendered narrower. Into the mouth of the heart, now free, the blood is impelled like a wedge through the aperture of the valves, so that the flat sides of the valves in the right ventricle are every where applied to the sides of the heart. The blood is now hindered from returning again into the lower cava, on the contraction of the auricle, both by the resistance of the succeeding blood from the abdomen, and by the Eustachian valve; and from returning upwards it is prevented, both by the subsequent blood and its gravity. It is driven back, however, both ways, if there be any obstacle in the lungs.

xc. The heart itself, in some measure, resembles half a cone. The section, passing through the axis of the cone, and dividing it, is almost triangular, but with an obtuse nearly bifid point, and flattened

to the form of the diaphragm, rests upon, and is sustained by it. But the convex surface of the cone is so inclined within the pericardium, under the great blood-vessels, that its thicker semicircular cavity lies in the superior and left side, the obtuse margin of the moderns; while below, and anteriorly, it is extenuated into a kind of edge, or the acute margin. The point is turned a little forwards. This is the situation in man; for, in brutes, the heart being almost parallel to the larger axis of the thorax, its apex only touches the diaphragm.

XCII. The whole heart is hollow; and continuous with the right auricle and sinus, as they are called, it has its properly anterior, though formerly called its right ventricle, broad, resembling the fourth part of a cone, not so long as the left ventricle, but larger, and terminating in the shorter tip of the bifurcated apex. The mouth of this ventricle, where it opens into the auricle, is elliptical, and terminated by a white margin, not so much tendinous, as callous and glutinous, on which a stratum of fleshy fibres rests, and externally some fat.

XCIII. From this margin is extended, within the heart, a membranous ring, formed by a reduplication of the internal membrane of the auricle, floating within the auricle and so far entire. But this same ring, in that part which hangs within the ventricle, is divided into three unequal trapezic portions, in such a manner, that you may, in some measure, give them the name of valves; and reckon three of them. They are, however, continued parts of one ring, only broader here. These were, by the ancients, named triglochines.

XCIV. The surface of these valves which lies next to the sides of the heart is strengthened by tendinous fibres, which, meeting together in their course, are inserted by some very strong cords, lying in rows on each other, partly into the sides of the heart, and partly into papillary or cylindrical muscles,

muscles, arising towards the right from the left part of the right ventricle, bifid, trifid, or even branchy. The largest is that which answers to the biggest of the valves, which is both the uppermost and that which answers to the adjacent mouth of the pulmonary artery. The middle valve lies next the septum of the heart. The least of them is the lowest, and most anterior in the acute margin.

xcv. The use of this valve is evident; for, on the contraction of the right auricle (xc.) the blood contained in the right porch of the heart being forced into the open extremity of the auricle, that is, the mouth of the heart, separates, in the manner of a wedge, the pendulous portions of the ring, called valves, and presses them to the sides of the heart. Thus the right ventricle of the heart is filled, while the uppermost valve (xciv.) shuts the pulmonary artery, lest the blood, with the weak impulse of the auricle, should enter that artery; but that being first received into the heart, by its strong contraction it may be more powerfully expelled into the artery.

xcvi. By this blood, copious, warm and heavy, the sensible flesh of the heart is irritated and excited to contraction: for that the heart, on being irritated, will contract itself in a moribund, or recently dead animal, is proved by the injection of water, and inflation of air, renewing the motions of a heart after having become quiescent.

xcvii. The motion of the heart is performed by muscular fibres; the origins of which, in general, are from rings formed of firm cellular substance, such as I have described in xcii. and with which all the large blood-vessels of the heart are surrounded. The fibres from thence descend gradually in an oblique course towards the left side, and to the apex, in many strata, sometimes a little decussating, of which the middle ones are more transverse, the outermost and innermost more direct. In the flat side  
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of the heart (xci.) the fibres are few ; and so thin, that next to the fat, the cavity is found almost uncovered. The ventricle, which is denominated the left, is surrounded by very firm fibres ; which, in the septum, slightly decussating, are interwoven with those of the right side. Many of these fibres, in their progress towards the apex, descend into the cavities of the heart, and being interwoven, even repeatedly, in the manner of a net, intercept meshes hid amongst the muscular lacerti, and form the fleshy columns mentioned at xciv. Others, at the apex, convoluted in a spiral direction, terminate the bifid ventricles with a firm mass. A very thin and smooth membrane covers both the external and internal surface of these fibres ; but the external membrane, especially about the coronary vessels, contains much fat. I have not been able to observe with sufficient precision, any thing further in the human heart ; because it is the peculiar property of the fibres of the heart to be joined by branchy appendices, so that they cannot be separated any where without laceration.

xcviii. But eminent anatomists, whose ingenuity and candour I respect, have published the evolution and description of these fibres. They allege, that the external fibres of the heart descend to the apex, common to both ventricles ; that in their course, some insert themselves into the septum, while others perforate the left ventricle near the point, and being reflected, return along the inner surface of that ventricle, to the basis, in a contrary direction. But there are other middle fibres, betwixt the aforesaid inner and outermost ones, which being variously inclined, and towards the basis principally transverse, form the septum. Other anatomists have given figures and descriptions of many layers of fibres, of which the external and internal have contrary directions, and the intermediate are transverse. As these do not differ very much from my own observations,

vations, I by no means undertake to deny them, although I have never seen this disposition sufficiently manifest, and am acquainted with great anatomists who have not been more successful than myself.

XCIX. These fibres of the heart, like other muscles, are furnished with nerves of their own, numerous and of various origin. The first and uppermost, on the left side, come from the uppermost cervical ganglion of the intercostal nerve. With it are joined others from the pharyngeal plexus, formed of the soft nerves, proceeding from that ganglion, and from the glosso-pharyngeal nerve; others are added from the trunk of the intercostal nerve; others from the middle ganglion seated on the straight muscle about the passage of the thyroid artery, which has branches both from that uppermost nerve, and from the trunk of the intercostal and phrenic nerves; and others from the recurrent nerve of the eighth pair. The nerves of the heart, originating from these sources, woven together into a plexus, partly before the aorta, on which those, hereafter mentioned, are also added; and partly after forming several small plexuses between the trachea and the large arteries issuing from the heart, form one or more plexuses, in which the nerves of the right and left side are united, though sometimes they remain distinct. From this plexus, or plexuses, some branches pass between the aorta and pulmonary artery to the right artery of the heart; others cross the pulmonary artery, and go between it and the auricle of the same side to the left coronary artery; others behind the pulmonary artery to the same coronary; and others, again, descend very deeply behind the right pulmonary artery to the left sinus and flat surface of the heart. To the plexus, above described, other large nerves are added from the fifth and lower cervicals, and sometimes from the phrenic nerve, and from the lowest cervical ganglion of the intercostal, with  
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which are united very large roots from the lowest cervical nerves. These, larger, very soft, and transverse, are partly mixed with the former plexus, and partly go to the lungs. Lastly, some small branches, uncertain as to course and number, come from the recurrent and eighth pair of nerves, variously inosculated with the intercostals, and blended with the eighth pair. Those nerves, which some eminent anatomists have seen ascending through the foramen of the vena cava, from the great abdominal plexus, to the heart, I have never been able to find; although it is easy to discover the diaphragmatics arising in that place, of which, though having ganglions peculiar to themselves, those anatomists make no mention.

c. That these nerves conduce powerfully to the motion of the heart, is the opinion of eminent anatomists, from a consideration of the common nature of muscles; and from the increase of motion in the heart, on irritating the eighth pair of nerves, or brain, or spinal marrow, and from the languor that ensues upon tying those nerves, for the most part either immediately fatal, or certainly within a few days, although it is possible to tie only a few of them, for the intercostal, and still more those from the uppermost thoracic ganglion, cannot be tied.

ci. But that something else is comprehended in the cause, appears from the motion of the heart remaining undisturbed in the living animal, after excessive irritation of the nerves; from its continuing after the most extensive wounds of the head, and even of the cerebellum and medulla spinalis, nay, even in the heart, when torn out of the breast, chiefly in those animals in which the lungs, being pervious, make no resistance to the powers of the heart; moreover, from the lively action of the heart in the foetus before the brain is completed, and in animals wanting the head. And all our experiments agree, that the quiescent heart, in moribund, and finally  
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in dead animals, when irritated by warmth, vapour, cold, poison, and especially by a current of air, watery liquors, wax, or blood, or by an electric spark, is immediately contracted, and all its fibres excited to quick and violent motion, sometimes general throughout the whole heart, and sometimes confined to one part of it.

CII. Thus, then, there resides in the fibres of the heart an impatience of stimulus; so that in various places of the viscus, even when almost dead, wrinkles, and motions, appear to be propagated through it, as if from radiating points: again, the heart, when torn out and cold, on being pricked, inflated, or irritated, contracts itself; and the fibres of a dissected heart, corrugate themselves orbicularly, when it is no longer supplied either with nerve or artery. This irritability exists in a greater degree, and remains longer in the heart than in any other part of the body; so that, by stimulating it, the motion of the heart may be renewed at a time when that of no other muscle can. The heart of the foetus is more irritable, as well as larger, in proportion, than in adults; and very tenacious of its mobility, even in the cold. This mobility is inherent in the heart, and is neither derived from the brain, nor the soul; since it remains in the dead animal, and in the heart when torn out of the breast; and cannot be accelerated or retarded by volition.

CIII. The heart, therefore, when stimulated by the venous blood thrown into it, contracts. This convulsive contraction is made with great celerity, and a manifest corrugation of the fibres; and the whole heart becomes shorter, thicker, and harder. The left ventricle is drawn somewhat towards the septum of the heart, and the right one more so. The base also advances towards the apex; but the apex more evidently towards the basis. This I have often observed with the greatest certainty in dissecting

dissecting living animals; so that those learned gentlemen must have been some how deceived, who have asserted, that the heart is elongated during its contraction. But the heart does not seem to turn pale in warm blooded animals. Even the septum of the heart is rendered shorter, and draws itself towards the basis. By this action, the fleshy parts of the heart swell inwardly, and compress the blood, as they do the finger when introduced within it. But that the heart is completely enough emptied, appears both from the event; from the evident paleness in animals whose heart is white, as frogs and chickens; and from the uneven internal surface, which has every where eminences and correspondent hollows, and thick reticular columns interrupted by furrows. Besides, the apex of the heart, being turned a little forwards, like the radius of a circle, and being, moreover, driven forwards by the left venal sinus, which is at that time, particularly filled, strikes against that part of the pericardium next the thorax, about the fifth or sixth rib. In strong expiration, it is carried with considerable force upwards and forwards. Both facts are proved by experiment.

civ. The blood, pressed by the contracted heart, (ciii.) endeavours to escape in all directions; but since the contraction begun in the sides of the heart drives the blood towards the axis of the ventricle, that part of the blood which lay betwixt the venous ring (xciii.) and sides of the heart, carries the ring before it, and extends its loose extremities inwards. As this happens to the whole circumference of the ring, it becomes extended, throws back a part of that blood which had descended into the cone of the open valve, into the right auricle; and, lastly, shuts up the venous orifice more closely as the heart contracts more strongly, and without doubt would force the tricuspid valves, as they are called, invertedly into the auricle, if the papillary muscles (xciv.) did not keep down their edges, and  
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by their contraction, which is the same with that of the heart, retain them firmly in that position in which the chords connected with the valve are extended, without being injured.

cv. But the same effort of the blood opens to it another passage. Whilst the right larger valve (xciv.) approaches towards the axis of the heart, it leaves the mouth of the pulmonary artery, which it closed, and the blood opens it, presses the valves placed in the artery close to its sides, and rushes into the artery.

cvi. From the upper part of the posterior, or, as it is called, the right ventricle, a passage leads into the artery, received as it were between productions of the flesh of the heart, and strongly connected to the heart by a cellular, callous ring, from whence the artery ascends to the left and backwards, and passes behind the arch of the aorta. The strength of this artery is moderate, being much weaker than the aorta. From the inner surface of the artery, where it is joined to the heart, the semilunar valves arise. Each of these is formed by a reduplication of the arterial membrane, extended from the part of the artery next the heart, upwards, in an obtuse and sufficiently flat arch. On the whole, they are parabolical with a loose and moveable margin. The middle of the edge is generally divided, sometimes in the foetus itself, by a small callous body, almost conical, but made up of inclined planes; so that the margin, which would otherwise have the shape of a crescent, is now divided into two crescents. Betwixt the two membranes of the valve, arising from the edge and firm root of the valve, appear some muscular or tendinous fibres, partly transverse, some of which even bind the valve to the contiguous side of the heart, leaving sometimes spaces betwixt them in a reticular manner. Other fibres ascend from the basis of the valve; and adhere to the

the callous corpuscle. These draw back the valve, and open it.

CVII. Each of these valves with the side of the artery at this part somewhat enlarged, intercept a parabolical space, which towards the heart is impervious; but open upwards, as we observed of the valves in the veins (XLIX.) When, therefore, the blood is impelled towards the axis by the contraction of the heart, it escapes in the direction of that axis; penetrates like a wedge, betwixt the valves, presses their loose membranous edges against the sides of the pulmonary artery, and flows out freely. This appears from the mechanism, from injection, from ligatures, and from the increased size of the cavities of the right side of the heart, when the lungs, being obstructed, prevent them from being emptied.

CVIII. The blood received into the pulmonary artery, circulates through the lungs. That artery is first divided into two branches; of which the left is less and shorter, and enters immediately into the lungs of that side: but the right branch, larger and longer, passes transversely behind the arch of the aorta to its corresponding lungs. From each of these, by successive subdivisions, very minute twigs are produced, of which, a part exhale a watery liquor into the cells of the lungs, and a part are continued into the veins. That the blood flows in this direction, is proved by the mechanism, by the application of a ligature, which, intercepting the blood between the heart and lungs, dilates the artery; by polypuses obstructing the mouth of the pulmonary artery, in which case the right cavities of the heart become monstrously enlarged, and at length burst, while the left remain empty; and by injection; for water, size and milk, are very easily thrown from the pulmonary artery into the vein, and into the left side of the heart. But in frogs, the anastomoses themselves of the arteries with the veins, are seen by means of the microscope.

cix. Nor can the blood, which has once entered the pulmonary artery, return into the heart; because the valves (cvi.) are of such dimensions, that, when distended, they perfectly shut up the opening at the heart; and are so strong, that they are able to resist a much greater force than the contraction of the pulmonary artery. However, sometimes, from the great pressure of the contracted artery, they grow callous; or one of the membranes is lacerated, and ossious matter is poured in betwixt the duplicature of the valves. For, when the blood, by the contraction of the artery returns towards the heart, it strikes against the open mouths of the valvular spaces, (cvii.) enters them, expands the valves, and forces them towards the central axis; when expanded, they shut up the passage, so that not even a slit remains, for that is prevented by the hard corpuscles (cvi.)

cx. The pulmonary veins, of which we shall say more hereafter, are gathered into branches, and, at last, into four, seldom two, and still more rarely into five trunks; to which custom has affixed the singular name of pulmonary vein. These trunks enter the cavity of the pericardium, from whence they receive an external covering; and are then inserted into the corners of the square, left, or posterior, or as it is sometimes called the pulmonary sinus. The upper veins descend, the lower ones ascend. That these veins bring their blood in that direction which leads to the sinus, is proved by ligatures, which, by impeding the blood, cause a turgescence of the vein betwixt the ligature and lungs.

cx. This left sinus, almost cubical, firmly constructed of various fasciculi of fibres running between two membranes, has, on the anterior and right side, the septum, common to it and the right sinus, (lxxxvi.) but, at its anterior and left edge, it terminates in a conical appendix, notched and crested with processes, which, making two or three serpentine

tine turnings, is called the left auricle, and with its point directed forwards rests upon the left ventricle. As in the right auricle, some of its fibres being bent into the form of an arch, contract the auricle; others, coming from the origin of the appendix, and inserted into its apex, depress it. This sinus, with the left auricle, are somewhat less than the right sinus and auricle.

CXII. In this sinus, the blood waits for the relaxation of the heart; at which time the nifus of the blood acting against the venous valves, and stronger than the action of the sinus, remits. Then the left sinus stretches itself forward across the heart, and at the same time is contracted transversely, and the appendix becomes evidently shorter and narrower. Thus the left porch impels the blood into the left ventricle of the heart, in the same manner as the right auricle impelled its blood into the right ventricle (xcv.) For, as in that, there is a valvular oval membranous ring, which has similar productions, called mitral valves, and which are usually reckoned two in number. These are longer and stronger than those of the right side. They have, in like manner, fleshy muscles, one and one only to each, but much stronger. And, more frequently than in the valves of the right side, the valves, being subjected to the powerful action of the heart, abound every where at the beginning of the tendinous chords with cartilaginous tumours.

CXIII. Therefore there comes into the left ventricle the blood, which the venæ cavæ had sent into the right auricle (LXXXIX.) this auricle had poured into the corresponding ventricle (xcv.) the ventricle had propelled into the pulmonary artery (cv.) and from it, being received into the pulmonary veins, was conveyed into the left sinus (cx.) and driven by it into the left ventricle (cxii.) This constitutes the less circulation, and was known to many of the ancients (LXII.) It is proved, by the

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increased

increased bulk of the left pulmonary veins, and of the vessels of the right cavities of the heart, on the entrance into the left ventricle being obstructed.

cxiv. The left, or posterior, or upper ventricle, the first formed, and in many animals the only one, occupies that part of the half conical heart, which we called obtuse (xci.) It is narrower than the right ventricle, a little longer and rounder, and its cavity, on the whole, smaller. For, the capacity of this ventricle is about two ounces, while that of the right amounts even to three. Its texture internally is in like manner reticular, but more minute; and also at the mouth of the artery smooth. Its force is greater, as the muscular flesh, with which it is surrounded, is much, almost three times, stronger. The septum of the heart belongs mostly to the left, but some part of it also to the right ventricle: the whole of it is equally reticulated; but solid, and does not suffer any injected liquid to pass from one ventricle to the other.

cxv. The left ventricle, from the same irritable nature, already spoken of, (ciii.) being stimulated by the blood thrown into it, contracts, and with great energy forces the blood contained in it towards the axis and basis, while the cone of the heart is retracted nearer to the base. And since there is the same apparatus of valves, the blood distends the venous ring, and removes the right division of the valve from the mouth of the aorta which it shut up, opens to itself that mouth, presses the semilunar valves, there placed, against the sides of the aorta, and rushes into that artery with a violent impetus. This is proved by ocular demonstration in living animals, and by the enlargement of the left ventricle on obstructing the passage into the aorta.

cxvi. The valves of the aorta are not very different from those in the pulmonary artery. Only as the aperture is here greater, so the valves themselves are larger and stronger, and are feldomer without

without those callous globules. The fibres too of the valves, both transverse and ascending, are somewhat more conspicuous.

cxvii. After the contraction of the heart, follows its relaxation or diastole, in which it becomes empty, lax, and soft, recovers its former length, the ventricles dilate from the septum, and the basis recedes from the apex. But as the blood distending the auricles, lies immediately at the orifices of the ventricles, it rushes through the valvular apertures, and separates the opposite sides of the heart, which is thus rendered both larger and longer. After the auricles have emptied themselves of the blood they contained, they become in like manner relaxed, and their opposite sides separate from each other. These ventricles are then filled with the blood, collected in the venæ cavæ and pulmonary veins, by the contraction of the veins; and, like the ventricles, are increased in every dimension, and even the processes of the crested margin are distended and expanded. That there are in the heart dilating fibres, is contradicted by the connection of its fibres, which, being bound together by intermediate branches, cannot be separately moved, and by the dissections of living animals which show that the whole heart is contracted at the same time.

cxviii. But it must be observed, that these motions of the right and left auricles, and of the right and left ventricles, are not performed in that succession in which, for the sake of method, we have described them; for both the auricles are contracted, while the ventricles are relaxed, and the contraction of the auricles precedes the contraction of the ventricles; as we are convinced, from manifest experiments on dying and on cold blooded animals. But both auricles are filled in the first instant, and both of them are emptied in the second instant; and both the ventricles are contracted in the third instant, which however corresponds to the first;  
and

and both ventricles, being evacuated, are relaxed in the fourth instant, which corresponds to the second. Those who have taught otherwise, have not taken sufficient assistance from experiments on living animals. That the auricle, near death, makes frequent palpitations, before the ventricle of the heart performs one contraction, and that the motion of the right continues after the left has ceased, is certainly true. The auricle, with its sinus, forms one cavity, and both are filled at one time, and both emptied in the same instant.

CXIX. But it may be asked, why the heart, with incessant motion during so many years as there are in a lifetime, during so many days as there are in a year, and when, in each hour, in a healthy person, it contracts not much less than 5000 times, never rests, but contraction perpetually succeeds repletion, and repletion contraction, in constant succession; nor is the heart fatigued or pained by so excessive an action, that no other muscle could endure it even for a few hours? To this question, different professors have given different answers, founded upon a compression of the nerves betwixt the large arteries; upon an alternate repletion of the coronary arteries and heart, &c.

CXX. But to me the simplicity of nature seems very conspicuous. When the auricle is relaxed, it is filled by the muscular force of the contiguous veins, and so the heart in like manner contracts itself, when it is irritated by the blood conveyed through the auricle. Therefore, the heart, when it has received the blood, in consequence of that irritability and stimulus by which its fibres are excited to action, contracts, empties itself of the blood, and, being freed from the stimulus, rests and becomes relaxed. But being now relaxed, it is again filled by the contraction of the auricle, which the same stimulus of the venous blood excites, since the incessant action of the heart and arteries continual-

ly supply blood to the auricle. That this is the fact, is proved from observation ; which readily discovers the succession of repletion and contraction in the vein, auricle, ventricle, and artery, in an exhausted animal ; but more evidently, in those animals which have but one ventricle ; as the tortoise, frog, snake, fishes ; and in the chick in ovo, which, instead of a heart, has only a crooked canal. The same is also confirmed by the quiescence of the heart, upon tying the veins ; and by its motion, on removing the ligatures, if this observation be correct, but more certainly on the injection of air or fluids ; and lastly, by the perpetual contraction of the heart of a frog, upon a vesicle of air blown into it ; which, it will force into the auricle, and receive, alternately, for many hours. The left ventricle first ceases its motion ; then the auricle of that side ; then the right ventricle ; after that, the right auricle ; and, last of all, the pulmonary veins, and venæ cavæ. The motion ascribed to the venæ cavæ, proceeds from the auricle, repelling into both these veins the blood, which the heart, when dead, does not receive.

CXXI. Nor do I believe any thing more required, than a continual stimulus applied to a part irritable in the highest degree. For, even in the article of death, the very coldness of the limbs, which the warmth of life has left, constricts the veins, and drives the blood to the heart ; at which time the lungs, being impermeable for want of respiration, transmit no blood to the cavities of the left side. On the other hand, the heart, thoroughly emptied, remains at rest. It is, therefore, possible to transfer the prerogative of dying last from the venæ cavæ and right auricle, to the left auricle, and ventricle ; if you contrive that the right cavities be emptied, and that the left be irritated by blood. But those, who attribute the quiescence of the heart to the compression of its nerves, are refuted by the appearances

appearances in those auricles, whose nerves are not compressed; as, for example, in fishes, and in the chick in ovo, where there is no such compression. If you deduce the quiescence of heart from the coronary arteries, this is contrary to experience; since they are not covered by the valves of the aorta, and since, from the coronaries, when divided, the blood springs to the greatest height during the systole of the heart,

CXXII. Nor, with the powers of the heart, do I conjoin the oscillation of the minute vessels, which is refuted by experiments: nor the influence of external heat; since animals are found to live and thrive in the coldest regions of the north: and though the contractile force of the artery, and the weight of the parts and of the atmosphere, assist the motion of the blood during the diastole of the heart, the same powers resist it during the systole; so that the blood is not moved more easily through the contractile arteries, than even through the rigid arteries of the smaller animals.

CXXIII. But the celerity and force with which the heart propels the blood, are variously computed. The more modern writers have calculated upon the following positions. In determining the celerity, they suppose two ounces of blood to issue out of the heart with such a celerity, that that part of the pulse, called its systole, is finished within the third part of a whole pulsation, or within  $\frac{1}{3}$  of a minute; and the area of the mouth of the aorta, they have estimated at 0.4187 parts of an inch: so, by dividing 3.318 inches, the space filled by two ounces of blood, by the area of the aorta at its mouth, and by multiplying by 225, or number of pulsations, this quotient  $7\frac{2}{3}\frac{1}{4}$  inches, or length of cylinder of the aorta which is filled by two ounces of blood, they find 149 feet and two-tenths of an inch for the space through which the blood would run in a minute, if it proceeded and passed through  
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the cylindrical aorta with the same velocity with which it was expelled from the heart. But the weight of blood pressing upon the heart, they have computed by the jet with which the blood springs from the aorta in a living animal, being seven feet five-tenths; and from the area of the ventricle, 15 inches; which produce 1350 cubical inches of blood, or 51 pounds five ounces, which press against the ventricle of the contracting heart. The heart, therefore, propels a weight of 51 pounds, with a velocity by which it may run through 149 feet in a minute; and this four thousand eight hundred times in an hour.

cxxiv. Although into these calculations many things enter, which are neither established, nor perhaps ever to be cleared up; although the mouth of the distended aorta is wider in a living animal; though the mensuration of the area of the ventricle is uncertain, and the jet of blood perhaps too low, if we consider, that, in the living animal, the blood issues with violence from very minute arteries; lastly, although we cannot determine what part of an entire pulsation the systole of the heart takes up, variations in which will, however, greatly alter the whole computation; yet, in the mean time, it will plainly appear, that the machine we call the heart is very powerful. This opinion is supported by experiment, which shews, that by anatomical injection, it is very difficult to fill all the red blood-vessels, and impossible to fill all the smaller ones; while the heart not only gradually distends with blood all the large, small and minute vessels, but besides, propels the blood with great rapidity. Even into the most minute arteries, the blood is driven by the heart with such force, as to make its alternate motions perceptible. Likewise in the veins, and lastly, in the smaller vessels, both in cold blooded animals, and in the chick in ovo, there is no other force besides that of the heart, by which  
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the blood is driven through these vessels. And, from very small arteries, I have seen the blood projected several feet, describing a parabola, whose height was four, and its extent seven feet; and some assert, they have seen the blood thrown out of the aorta to the height of twelve feet.

cxxv. Moreover, in estimating the force of the heart in living animals, we must consider the powerful obstacles it overcomes: we must compute the enormous weight of the whole blood; for the entire mass, weighing fifty pounds and upwards, when at rest, is easily set in motion by the heart alone, as in the instances of fainting and resuscitation from drowning. We must, moreover, consider the great decrease of velocity, arising from the greater capacity of the branches, which, even in the intestines, it seems we might compute at the 24th or 30th power of the root  $\frac{3}{2}$ . And yet fluids are carried with velocity through the smallest vessels, of which we have examples in the Sanctorian perspiration, which in subterraneous caverns I have seen rising with great velocity, in the manner of smoke; and in the motion of the blood in fishes. Besides, as friction in every machine consumes the greatest part of its powers, it will be readily conceived, that, in the human body, in which a liquid, much more viscid than water, flows in canals so narrow, that they admit but one globule at a time, and not even that, without a change of figure, an excessive retardation must arise from friction, and that the power must be immense, which moves such a mass, in spite of such obstacles and diminutions of its force. But even aneurisms and arteries are burst by the force of the heart; and great weights along with the human body are elevated by the force of its systole.

cxxvi. The blood, when driven into the aorta, finds the mouths of the two coronary arteries near to the valves of the artery, but higher up and not covered

covered by them. Into these, first of all, it rushes, and thus the heart supplies itself with blood. These arteries are almost constantly two, and arise from the heart at an obtuse angle with the trunk; the right goes off between the aorta and pulmonary artery, and the upper and left one between the left auricle and the aorta. All the external branches are surrounded with much fat. Their cavity is not intercepted with valves any more than other arteries. These arteries communicate, by small branches, every where about the septum and tip of the heart; but they do not make a complete ring round the heart. They terminate in two ways.

cxxvii. Their first termination is in the veins, of which the branches accompany the arteries, but the trunks necessarily separate. The left artery is therefore accompanied by the great coronary vein, which is inserted by a large opening, secured with a valve, or several little membranes, into the auricle to the left of the Eustachian valve. It is distributed on the base of the left auricle, and accompanies the superficial branches of the left artery.

cxxviii. The second vein (which you may make a part of the former, since they have both one common insertion,) descends along upon the septum of the heart on its flat surface; and may be properly called the median coronary. The third transversely seeks the root of the right auricle, and terminates within, or at least very near, the large opening of the coronary vein, (cxxvii.) or in an anterior vein. It supplies that part of the right ventricle which lies in the flat side of the heart; and often receives the vena innominata, immediately to be described.

cxxix. There are still some other anterior veins of the heart; but one, more considerable, which runs along that part of the right ventricle next to the margin, and winding in an oblique course, sometimes between the membranes, is inserted into the  
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most anterior part of the right auricle, and sometimes into the trunk of the upper vena cava. This anterior vein sends off along the root of the right sinus, another which runs concealed through the very substance of the heart, and being again inserted into the great coronary vein, completes the venous circle round the heart, like the arterial circle which some have described, but which to me is unknown.

cxxx. But there are a great many more veins, uncertain in their number and position, which, hid amongst the origins of the large vessels, belong to the deep seated and difficultly accessible parts of the basis of the heart. These open by numerous small mouths into the right sinus and auricle; and, though more rarely, into the left sinus. Thus I have seen a particular vein, which, from a latent sinus in the flesh of the right auricle, has ascended towards the aorta and pulmonary artery, and inserted itself on the other side into the greater coronary vein. I have seen another concealed betwixt the mouth of the coronary vein and the aorta, inserted into the right sinus; and another along the remains of the foramen ovale, and septum of the two sinuses, inserting itself into the right sinus; and others again belonging to the venous valves; besides which, there are still others too numerous to describe. I have also seen a vein arising from the left sinus, inserted into the vena cava.

cxxxi. There are other smaller veins, whose little trunks are short, and cannot easily be traced by dissection. These open by oblique short mouths, through all those innumerable pits of the right and left ventricles, and into the septum of the heart, and into both auricles. These are demonstrated by injecting water, air, or mercury, especially into the coronary arteries, after having tied all the corresponding veins; or even into the veins themselves, after having secured the insertion of the largest trunks.

trunks. For, drops of coloured water, bubbles of air, spherules of mercury, exude through the whole extent of both ventricles; and this, without any violence that can be supposed to have burst the vessels. The passage from the arteries into the cavities of the left side, is, however, more difficult.

CXXXII. There are some who suppose that the coronary arteries are filled with blood, not by the contraction of the heart, but of the aorta. Their opinion is founded on the retrograde angle of their origin, on their mouths being covered by the valves, and on the paleness of the heart when contracted. But the two last of these are contrary to fact; and the first perhaps somewhat retards or lessens, but certainly does not obstruct the entrance of the blood; for the injections of air or mercury into the femoral and biliary vessels every where, demonstrate, that in a distended vessel, even more retrograde angles do not prevent fluids from entering the branches. Moreover, in the coronary artery, the pulse is synchronous with the other arteries in the animal body, and the blood, during the contraction of the heart, springs to a greater height (CXXI.)

CXXXIII. Concerning the reflux, there is less room for doubt: into the ventricles and auricles of the heart, right and left, but more into the latter, all the blood of the coronary vessels is discharged, both by the large orifices, (CXXVII. CXXVIII. CXXIX.) and by the small ones, (CXXX.) and by those minute ones, (CXXXI.) which, when the large veins are tied, readily transmit injections. This circulation seems to be completed in a very short space of time, on account of the very great velocity the blood receives from the immediate action of the heart itself. I do not, however, think that it is effected during one pulsation; for the blood-vessels of the heart neither lose their colour, nor are completely evacuated. There is a very free  
passage

passage from the arteries of the heart into the fat. What are the uses of the minute veins? (CXXXI.) They return the blood of those deeply seated arteries, which have no larger corresponding veins.

CXXXIV. The humours of the heart, which are thinner than blood, return by the valvular lymphatic veins, which accompany the coronary vessels, and ascend towards the thoracic duct and subclavian vein; they are very rarely to be seen, but I have observed them in brute animals.

## CHAP. V.

### NATURE OF THE BLOOD AND HUMOURS OF THE HUMAN BODY.

CXXXV. **T**HAT liquid which is contained in the pulsating arteries and their corresponding veins, is called, by one common name, the blood. When superficially viewed, it appears homogeneous, coagulable throughout, and redder in proportion as the animal is stronger and fuller fed; in a weak and famished one it inclines to a yellow. Any admixture of white generally proceeds from chyle. But experiments of various kinds have demonstrated the compound nature of this liquid.

CXXXVI. That fire is contained in the blood is proved from its heat, which, in man and similar animals, is from 92 to 100 degrees, which is higher than the mean degree of atmospherical heat, but less than the greatest. Besides, from blood, when drawn, something volatile or halituous, with a peculiar odour, intermediate between that of the sweat and urine, escapes. When collected in proper vessels, it appears aqueous, with a slight tincture of an alkaline nature.

CXXXVII.

CXXXVII. After the escape of this vapour, the blood of a healthy person, spontaneously congeals into a tremulous scissile mass; but with a degree of heat less than that of boiling water, (and indeed at  $150^{\circ}$ ) it coagulates more completely even when perfectly healthy, though more especially when taken from a febrile person. It sometimes coagulates in the veins of a living person, and is found clotted in wounds of arteries. Even in a living person, and in one dying from the violence of fever, the blood has been coagulated into a tremulous jelly throughout all the veins. The principal part of this coagulum is the cruor, which has the red colour peculiar to itself, and imparts it to the other parts of the blood. This, condensable by rest, or a moderate degree of cold, and coagulable into a liver-like mass by a heat of  $150^{\circ}$ , alcohol, or the mineral acids, is, however, soft, unless hardened by the attrition of life, or equivalent agitation. It is ponderous, and heavier than water by nearly an eleventh part; and, when freed from its water, it is wholly inflammable. In the mass of blood, one half or upwards is cruor; and, in strong robust people, the serum makes only a third part; in fevers, it is diminished to a fourth or fifth part; and in diseases from debility, it is increased.

CXXXVIII. From this coagulum there separates, as it were sweating out of its pores, but afterwards collecting in sufficient quantity to allow the coagulum to sink in it, another part of the blood which is white or somewhat yellowish, and also seemingly homogeneous, though it is not so. This part of the blood is, in general, one thirty-eighth part heavier than water, and almost a twelfth part lighter than the red globular mass; coagulable by a heat of  $150^{\circ}$  or the addition of mineral acids or alcohol, or by agitation; it produces a firmer coagulum than the red cruor (CXXXVII.) and concretes into an insoluble

soluble gluten, acquires a membranous appearance, and finally a horny hardness, with a friability like that of gum. Of it are formed the pleuritic crusts, polypuses, and artificial membranes. In the serum, besides this coagulable albumen, there is contained simple water, which constitutes the principal part of the whole; and some mucous matter, capable of being drawn into finer threads than the red cruor; and not coagulable by fire or by acids as the albumen.

exxxix. Putrefaction alone, and the influence of a temperature of  $96^{\circ}$  dissolves into a fetid liquor the whole blood, but especially the serum; first the serum, and then the cruor more slowly; till, at length, the whole, both cruor and lymph, is changed into a volatile and fetid exhalation; leaving very few feces behind. The blood, when somewhat dissolved by putrefaction, both before it becomes fetid, and while fetid, evinces an alkaline nature, and effervesces with acids. Thence, in consequence of putrefaction, it furnishes less alkaline salt. When putrid, it cannot by any art be inspissated; it is also very difficult to resolve it after it has been coagulated by spirit of wine. By too severe exercise, heat of the atmosphere, and malignant disorders, the cohesion of the blood is dissolved, and it assumes an alkaline nature almost as if from putrefaction.

exl. Besides these constituents of the blood, which are demonstrated without subjecting it to any violence, it also contains a quantity of sea-salt, which is discernible by the taste, and sometimes by the microscope. Both nutrition and chemical analysis demonstrate, that the blood also contains earth, which is contained in the most fluid parts, and especially united with the oil. By some very late experiments, it appears, that a considerable quantity of ferrugineous calx, easily reducible into a true metal by the addition of any inflammable body,

body, is contained in calcined cruor. Lastly, there is mixed with the blood condensed air, and that in a very considerable quantity; the existence of which in the blood and serum is proved by putrefaction, or by removing the pressure of the ambient air. The blood globules are not, on this account, air bubbles, for they are specifically heavier than the serum.

CXLI. By the admixture of neutral salts, the colour of the blood becomes deeper and brighter, as by them it is neither dissolved nor thickened. It is scarcely altered by weak acids. By strong ones it is coagulated. Fixed alkaline salts have almost the same effects as the neutrals. The volatile alkalies rather turn it brown, and coagulate it. Alcohol and distilled oils coagulate it like strong acids. It does not effervesce with any salt.

CXLII. Chemistry has opened various ways for investigating the nature of the blood. From blood recently drawn and perfectly fresh, by exposure to a gentle degree of heat, there is distilled a large quantity of water, composing five-sixths of the whole or more, almost insipid, though impregnated with some fetid oil, more strongly as the distillation proceeds.

The residuum, exposed to a stronger fire, yields various alkaline liquors; of which the first, acrid, fetid, and of a reddish colour, is usually called the spirit of blood; it consists of volatile salt and oil, dissolved in water, and amounts to one-twentieth part of the original mass of blood. There is, moreover, an acid in fat, and in flesh even when putrid, and in blood.

Both before, and along with the oil, that next ascends in the distillation, a dry volatile salt arises, and adheres in branchy fleeces to the neck of the retort; its quantity is small, about an eightieth part.

Another fluid, gradually thicker and heavier, at first yellow, then black, and lastly of a pitchy tenacity,

nacity, acrid and inflammable, is the oil of human blood. Its quantity is small, about the fiftieth part. There now remains, in the bottom of the retort, the spongy and inflammable cinder of the blood, which, being kindled, deflagrates, and leaves ashes behind. From these, by lixiviation, is obtained a salt, consisting of sea-salt, mixed with fixed alkali, and a small quantity of insipid earth. This fixed salt is scarcely the five hundredth part of the first mass, and of this almost one-fourth is alkaline: when subjected to an intense degree of fire, it affords a little acid, which we suppose to arise partly from the sea-salt, similar to that demonstrable in the spirit of blood; and partly from the vegetable nature of our aliments, not yet completely analyzed. Hence it is found in herbivorous animals, as well as in man. But the earth, which is about the hundred and fiftieth part, contains some particles which are attracted by the loadstone.

CXLIII. This analysis shews that the blood contains various fluids, some more heavy and tenacious than others, some aqueous, others inflammable, and that most of them impart to the blood a putrid or alkalescent tendency. For, the blood, when healthy, and not injured by putrefaction, or too violent a degree of heat, is neither alkaline nor acid; but bland, and somewhat salt, although, in some diseases, it is very acrid and almost putrid; as, for instance, in scurvy, where it corrodes its containing vessels; and in dropsies, the waters of which are nearly alkaline. In insects, there is found an alkalescent calx which effervesces with acids.

CXLIV. By viewing with the microscope fresh blood in a small glass tube, or while it is yet moving in the veins of a warm blooded living animal, as a chicken, or of a cold one, as a frog, we perceive in it red globules; which doubtless, constitute the cruor mentioned in CXXXVII. Or are they

they rather lenticular particles of the same kind with those observed by Leeuwenhoeck in fishes, and lately discovered in our own species; it is difficult to determine: nor, often as I have used the microscope, have I ever missed those shadows in the globules which indicate thickness and convexity.

CXLV. The colour of these globules is red; and so much the deeper, and more inclined to scarlet, the stronger the animal is: and in the same proportion, their number increases, when compared with the yellow serum. Their diameter is small, being between  $\frac{1}{2000}$  and  $\frac{1}{3000}$  of an inch. They are said to change their figure into an oblong egg like shape, which I have never been able to observe with sufficient certainty. They are also said to break down into other lesser globules of a yellow colour, which I have neither observed myself, nor can easily admit.

CXLVI. Fibres are obtained in great quantity from the blood, and more sparingly from the serum, by gradually washing it, when poured on a linen cloth, with much water; or by beating with rods, blood poured into water: they will amount to one eighty-fifth part of the whole. These are formed of the gluten, and do not exist in the living animal; since they neither are perceived by the microscope, which yet so easily renders visible the red globules, although so much smaller, nor is their long thread like figure adapted for receiving motion.

CXLVII. From the preceding experiments compared together, arises that knowledge, which we at present have of the blood; namely, that the cruor is composed of globules. The inflammable nature of these globules is proved by the inflammation of dried cruor, and the preparation of pyrophorus from human blood: and, from these, most probably, proceeds the greater part of the  
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pitchy oil that is obtained from blood by the action of fire.

CXLVIII. The serum of the blood, subjected to the action of fire, yields almost the same principles with the red blood, viz. salt, oil, and earth, but more water and no iron. Similar principles, but with a less proportion of oil and salt, are obtained from the aqueous humours formed from the blood; as the saliva, and mucus.

CXLIX. The quantity of blood, contained in the whole body, cannot be very certainly computed. The weight of the fluids, however, is much greater than that of the solids; but many of them, as the gluten in various parts, and the fat, do not circulate. But if we may be allowed to form a judgment, from those profuse hemorrhages that have been sustained without destroying the life of the patient; from experiments made on living animals by extracting all their blood; and from the capacity of the arteries and veins; there will be at least fifty pounds of fluids which circulate, of which about twenty-eight will be true blood: the arteries contain about one-fifth, and the veins the other four parts.

CL. Nor are the proportions of the elements, which we have hitherto mentioned, constant: for, an active life, manhood, and fever, increase the cruor, redness, coagulability, cohesion of the parts, firmness of the coagulated serum, weight and alkaline principles. The serum, and the mucus it contains, are increased by the contrary causes; a less mature age, inactive life, and a watery and vegetable diet; by all which, the crassamentum of the blood is lessened, and its watery part increased. Old age, again, augments the cruor, and diminishes the gelatinous part.

CLI. On these principles, conjoined with a consideration of the solid structure, the diversity of temperaments depends. For plethora arises from

an abundance of the red globules ; a phlegmatic temperature, from a redundancy of the watery part of the blood ; a choleric disposition in the fluids seems to proceed from a more acrid and alkalescent nature of the blood ; as in those who live on flesh, and in anthropophagi, who appear to be more fierce than those who live on vegetable food. In the solids, greater irritability, and hardness, with mobility, are attributed to a choleric habit ; a less irritability, with a more moderate density, to a sanguine habit ; and less density, and less irritability, to a phlegmatic temperament. There is also a sluggish temperament, in which remarkable strength of body is joined with little irritability. In the melancholic, excessive irritability seems united with debility. But we must be cautious not to class too systematically the temperaments, which in nature are not four or eight, but infinite in their varieties.

CLII. The generation of heat seems to be the principal use of the red cruor, as its quantity is in proportion to the temperature of the blood. Being confined, by the largeness of the globules, within the first order of vessels, it hinders them from collapsing ; and, in receiving the common impulse from the heart, on account of the greater density of its parts, it acquires a greater impetus, and sets in motion the inferior orders of humours. Nor is it improbable, that the heart is more duly excited by the ponderous cruor. The globular figure of its parts, imparts to it fluidity connected with density ; that quality, and perhaps the power of generating heat, are increased by the quantity of iron and of oil. Hence, when the red part of the blood is too much diminished by bleedings, there follows a stagnation in the smaller vessels ; fatness and dropsy. From the same reasoning, a due proportion of cruor seems necessary for the generation of new blood. For, in consequence of hemorrhages, the blood de-

generates

generates from its red and dense nature, into a pale and ferous state.

CLIII. The coagulable serum is more especially designed for the nutrition of the parts, as will be hereafter shewn, chap. xxx. The thinner fluids serve various purposes; as, the dissolution of the aliments, the moistening the external surface, and surfaces of the internal cavities of the human body, to preserve the flexibility of the solids, and conduce to the motion of the nerves, the sight, &c. The saline particles seem proper for dissolving the aliment, and stimulating the vessels. The properties of the aërial part are not yet sufficiently known. The heat produces its fluidity, and is not easily raised to such a degree as to coagulate the fluids of the human body.

CLIV. Therefore, health can neither subsist without the thick blood, and a diminution of its quantity causes a stagnation in all the smaller vessels, and universal paleness, coldness and debility: nor can the functions of human life or health subsist without the fluids of the inferior orders, since the cruor, deprived of its watery part, congeals and obstructs the passages of the vessels, and produces too great a heat.

CLV. Is there any difference betwixt the arterial and venous blood? It seems probable, as the former has lately suffered the action of the lungs. But, in experiments, I scarcely find any difference observable, either in colour, density, or any other property; although, in other situations, I have seen it very apparently, for the bright red colour of the arterial blood seems to distinguish it from the dusky dark coloured blood in the veins; but this, in the plain example of the chick in ovo, arises only from the series of globules being deeper in the thicker vein. Nor is there any established difference in the blood of different arteries.

CLVI.

CLVI. From the same blood, driven into the aorta, are generated all the fluids of the human body. These are reducible to certain classes. The means by which they are separated, ought to be accounted for by the fabric of the glands. But we must first consider what the blood suffers from its containing vessels.

## C H A P. VI.

## OF THE COMMON FUNCTIONS OF ARTERIES.

CLVII. **T**HE blood, driven from the left ventricle of the heart into the aorta, which, at its origin from the heart, bends first a little towards the right, and then to the left, and backwards, in a very acute arch, strikes, in a mass, first against the right side of the aorta, and is then reflected to the left side; whence, with a rotatory motion, as much as their fulness permits, it proceeds through the arteries, alternately striking and rebounding from their sides. The size of the aorta is a little increased, where it arises from the heart.

CLVIII. The arteries are, in a living person, always full of blood; since the blood springing from an artery, is not interrupted by alternate stops during the relaxation of the heart, but flows on in a continued stream, and the microscope shews the arteries, in living animals, to be full, both in their systole and diastole; nor can the circular fibres of the arteries contract themselves completely, or entirely evacuate these tubes. Therefore, when into the full arteries there comes a new wave of blood, although it scarcely exceeds two ounces, and bears a small proportion to the arterial system throughout the body; it, however, overtakes the preceding wave, which being farther from the heart, moves slower; it consequently drives the same forwards, lengthens

lengthens the cylindrical artery, augments its diameter, presses the membranes closer to one another, urges the convex parts of its flexures outwards, and produces more serpentine turns, as injections demonstrate. This dilatation of the artery, and change of its caliber, from a less to a greater circle, is called the pulse; the diastole of which, is an expansion of the artery beyond its natural diameter. It is peculiar to life, and results from the heart only, and is not natural to arteries left to themselves. Hence, when the motion of the heart is intercepted, whether its impulse be obstructed by aneurism, or ligature, there is no pulsation; and hence, the sudden cessation of the pulse, in a living animal, on the heart being perforated. The artery is proportionally more dilated, the more slowly the preceding wave of blood escapes, and the more the velocity of the new wave exceeds that of the former.

CLIX. The contraction of the artery succeeds its dilatation. For the heart, having emptied itself, and removed the stimulus of the blood, becomes quiescent. But the artery, at that instant, by the innate elasticity residing in its circular fibres, being irritated by the same stimulus of blood thrown into it, contracts itself, and expels as much of the blood as it had received above its mean capacity: the whole of this quantity passes either into the smaller vessels, or into the veins; for the semilunar valves of the aorta prevent its reflux into the heart. So soon as the artery has freed itself from this wave, being no longer stimulated, it remits its contractile action, and immediately yields to a new wave, propelled by the heart; and a new diastole ensues.

CLX. That the arteries contract, and by that means propel the blood, is proved by their contractile nature; by the evident remission of the dilatation caused by the heart; by the spontaneous evacuation

cuation of an artery through its lateral branches, included between two ligatures; by the return of the blood to the heart, after its artery is tied, which blood, therefore, is not propelled by the heart; by the jet of blood from arteries being greater during the relaxation of the heart, as observed by eminent anatomists; by the vigorous projection of blood from the aorta when tied, below the ligature; by the evacuation of the arteries during the perfect quiescence of the heart; by the veins being fuller than the arteries after death; by the considerable jet of blood, to the extent of two feet, from the aorta in an animal after death; by the small caliber of the ill filled arteries in a famished animal; by the closing of their orifices in wounds; and by the sphacelation of limbs, whose arteries are ossified, and the veins being in that case distended with blood.

CLXI. The mean velocity of the blood may be computed, by diminishing its velocity during the systole, as much as we increase what remains of it during the diastole, to be nearly such, as to move at the rate of two feet in a second. The constant plenitude of the arteries, is the reason why we cannot perceive any succession in the pulsations of different arteries, and that in the human body they all seem to beat at one instant, and at the same time that the heart strikes against the breast. However, there certainly is a succession, and the contractions of the aorta appear to follow in the same order, as its repletion with the blood, expelled by the heart, so that the part of the artery next to the heart contracts first, and that thus the contractions proceed gradually to the ultimate arteries. This is apparent in the example of the intestines, and may be seen in insects, whose long and knotty heart manifestly contracts successively from the beginning to the end. But the mind of the observer cannot distinguish

tinguish the minute portion of time, which amounts only to a few thirds.

CLXII. Where does the pulse cease? In my opinion, in the ultimate and cylindrical arteries. We have noticed with what velocity the blood issues from the heart. But that velocity continually decreases. It is certain, that the aggregate capacity of the small arteries, always bears a larger proportion to the capacity of the aorta, as their division proceeds farther; and thus, notwithstanding the difference in the proportion between the trunks and their branches always decreases, this proportion will be greatest, although it may be variable, between the aggregate capacity of the small arteries in their ultimate division, and the capacity of the aorta at its origin; and there will be a similar retardation of blood to that which occurs in aneurisms. Besides, the proportion of the coats of the arteries to their calibers always increases as they are smaller, until it is greatest where they transmit the globules singly. This is proved from dissection; from inflation, by which every thing being reckoned, they are always more difficultly ruptured as they are smaller; and by calculation, which estimates the size of the globules by the cylindrical membranes of the ultimate arteries. Add to this, the friction of a liquid passing through minute and long tubes, bent and uniting at angles; which kind of friction diminishes remarkably the velocity even of fluid water passing through simple and merely long tubes, and this always in proportion to their smallness; and besides, the smaller an artery is, the greater number of globules come in contact with its sides, and rub against them. In consequence of the conical form of the arteries, the broader wave of blood coming from the trunk cannot pass without resistance through the smaller aperture of the branch, and without endeavouring to distend the branch: but also, the inflections and folds retard the

the blood; since some part of the impelling force is always spent in impinging on the convex part of the fold, and in the change of the figure of the inflected vessel. Large angles likewise diminish the velocity, in proportion as they are more obtuse, and recede from a straight line. Moreover, the viscid-ity of the blood itself must be taken into consideration; since, by rest alone, it immediately concretes into clots; and since it is from the circulatory motion only that this mutual attraction of cohesion in its parts is overcome, so as to prevent it from adhering to the sides of the arteries, as it adheres in aneurisms and wounds; and the globules from concreting together, as they usually do after death. The opposition it meets with in the branches, lessens the velocity of the blood likewise in the trunk: the opposite currents of blood in anastomoses also destroy some part of its motion. Hence the immense retardation of the blood in the minute vessels. We may easily perceive that it is very considerable, although it is difficult to estimate it. In the living animal, the blood flows in the trunk with the rapidity of a torrent: in the minute arteries, it for the most part begins to move slowly, and then to be coagulated. It is also well known to surgeons, that a small branch of an artery near the heart or aorta, bleeds more dangerously than a much larger one that lies at a greater distance. The weight of the incumbent atmosphere, of the muscles and fleshy parts lying above the arteries, and the contractile power of the vessels, make a resistance indeed to the heart, but do not lessen the velocity of the blood, for they add as much during the diastole of the heart, as they take away from its powers during the systole.

CLXIII. It is certain, however, from incisions made in living animals, that the globules of blood, which move singly, do not lose so much of their velocity as, by calculation, they ought to do. There must,

must, therefore, exist some causes, which diminish the powers impeding their motion. And, indeed, it is certain, that, in the minute vessels, the calibers of the branches do not bear so great a proportion to the trunk; their great smoothness also diminishes the friction. The facility, likewise, with which the blood returns through the veins, expedites its passage through the ultimate arteries which immediately communicate with these veins. No great effect can be expected from the weight of the blood, from the action of the nerves, or from their plexuses, of which the first may both retard and accelerate occasionally, and in living animals, the two last have no effect whatever. The power of derivation, whatever that is, and muscular action, are capable of producing an increase of velocity.

CLXIV. The pulse is therefore generated by the anterior wave of blood flowing more slowly, while the subsequent wave flows faster; so that the former is an obstacle to the latter (CLVIII.) But since the motion imparted to the blood by the heart weakens in its progress, and the contractile power of the arteries increases, therefore the excess of celerity of the posterior wave, which comes from the heart, above that moved by the contraction of the minute vessels, will be continually lessening, till, arriving at a part where there is no excess, the pulse will there cease, from the anterior and posterior waves both flowing with the same velocity, and therefore in one stream. This place will not be in the larger branches; for in them, the wave, last coming from the heart, moves quicker than what goes before; as is evident from the inflammatory pulsation, especially of the small arteries of the eye. But, in the ultimate arteries, the pulse vanishes. This is evident from the equable motion of the blood in the minute arteries, often seen by the microscope in frogs. Even in vessels somewhat larger, the sixth part of a line in diameter,

diameter, the pulse ceases to be perceptible in the living animal. In the veins visible by the microscope, there is no pulsation or acceleration of the blood, whilst the heart contracts, demonstrable either by the microscope or in any other way.

CLXV. Even in the veins, the blood presses against their sides, as appears from the furrows hollowed out in the bones, and the swelling of the veins on being tied. Why do not the veins beat? for we do not allow that to be a pulse which is caused by respiration, or by the regurgitation of blood from the right auricle, or muscular part of the vena cava. The reason seems to be, that the blood, when it immediately leaves the heart, is more retarded, and in the ultimate arteries, less. Hence the short space of time by which the velocity of the last wave exceeds the foregoing, is greatest at the heart, and grows gradually less, till at last it totally vanishes. The following experiment is apposite. Water forced in jets through a leathern tube, by means of a syringe, flows out of a bit of sponge fixed at the end of the tube in one uniform and continued stream; and also the analogous experiment, where the same happens when water is thrown, in alternate jets, into the mesenteric arteries; for even then the water flows out of the veins in one continued stream.

CLXVI. The pulse is the measure of the powers exerted by the heart, because it is the immediate and full effect of those powers. Hence, all things considered as alike, the pulse is slow in the state of perfect health, where there is no stimulus, no resistance acting as a stimulus, and the heart propels the blood freely and easily, except where there is some obstacle, by which the blood is prevented from entering the aorta. From that cause, the pulse in asthmatic people is slow: and also from the debility or insensibility of the heart, the usual stimulus is incapable of exciting it to contraction,

traction. A full pulse is caused by the fullness of the artery, joined with a strong force of the heart ; a small pulse by the emptiness of the artery, and a smaller wave of blood sent from the heart. A hard pulse denotes some obstacle or stimulus, or increased action of the heart, with a greater thickness of blood, or a greater rigidity or obstruction of the artery. A quick pulse denotes some stimulus, obstacle, or greater sensibility and irritability of the heart. The pulse is best felt where the artery lies exposed and supported by bone ; but obstructions sometimes render the pulse perceptible in the most opposite situations.

CLXVII. The pulse is slower in animals as they are larger ; because the heart is proportionably less than in smaller animals, and, as well as the other parts of the body, is less irritable, and propels the blood to a greater distance ; and because there seems to be a greater increase of friction, than of power in the heart. Hence small animals are more voracious ; and large ones, as the whale and elephant, eat less. The pulses of a healthy adult in the morning, are at least 65 in a minute ; in the evening they amount to 80 ; during the night they again become less frequent, and gradually return to the morning number. For muscular motion, the action of the external and internal senses, the warmth of the atmosphere, and food and drink, urge the venous blood to the heart, which being thereby oftner stimulated, makes more frequent contractions. This is the cause of the evening paroxysms observable in all fevers. Sleep retards the blood and every other motion.

CLXVIII. A frequent pulse is different from a quick one ; and it is possible for the pulse to be at the same time quick and unfrequent. But it is difficult to observe a quick pulse. The frequent pulse is what is commonly called a quick one. It is frequent in children, and becomes less frequent in the progress

progreſs of life. In the ſalient point, the pulſes are 134; in new born infants, 120; and in old people, they decreate to 60. The febrile pulſe begins from 96. In fevers, or in an adult after muſcular action, 110 or 120 is a moderate frequency: but it is exceſſive at 130 or 140, with which number people ſeldom recover; nor have I ever obſerved it exceed that number. The pulſe beats ſlower in winter, and quicker in ſummer, often by 10 ſtrokes; and under the torrid zone, it increaſes to 120. The paſſions of the mind diſturb the pulſe in various ways. Whatever obſtructs the circulation, accelerates the pulſe; not from the laws of hydroſtatics, or on account of the canal being made narrower, or from the action of the ſoul; but ſimply becauſe the heart being with more difficulty freed from the ſtimulating blood, contracts itſelf more ſtrongly, and at ſhorter intervals. Irritation from acrid blood is frequently the cauſe of the febrile pulſe.

CLXIX. Through the minute veins the blood moves ſlowly, partly by the force of the heart, and partly by the contractility of the arteries. The firſt is proved by a renewal of the motion of the blood, in perſons drowned, which is effected ſolely by the excitation of the heart. But the contractile force of the arteries is proved by what we ſaid in CLX. After death, the blood is moved by its own gravity, and by the elaſtic air, generated during its putrefaction.

CLXX. The blood moves faſter in the larger veins. For wherever the impelling powers ſuffice, and the conveying tubes are rendered narrower, the motion muſt be accelerated; for venous trunks are ſmaller than the branches of which they are formed, in the ſame manner as arteries are leſs than the branches into which they divide. Therefore, if the motion of the venous blood loſt nothing in its way, the proportion of its celerity in the vena cava, to its celerity in the veins of the thirtieth diviſion, would

would be exactly the thirtieth power of the proportion of the sum of the calibers of all the ultimate veins, to the caliber of the vena cava. At the same time the friction is diminished, and the contact of the blood with their sides.

CLXXI. But since the blood moves very slowly in the ultimate arteries and incipient veins, and as the weight of the blood itself, in many places, impedes its return remarkably, and as, from the very thin coats of the veins, but little contractile power can be expected, nature has used various precautions, lest, from the slowness of its motion, the venous blood should stagnate or concrete. Therefore she has restored to the veins, the halitus and fluid lymph, in larger quantity, as it seems, than what the arteries lost, on account of the great exhalation from the lungs.

CLXXII. She has likewise placed the veins near the muscles, which, by their swelling, compress the interposed veins; and since every pressure of the veins, on account of their valves, determines the blood towards the heart (LXIII.) therefore all this force is entirely employed in accelerating the return of the blood to the heart. Hence that wonderful quickness of the pulse (CLXVII.) heat, redness, and quick respiration after muscular action.

CLXXIII. Moreover, those muscles, which strongly compress on every side all the parts contained in any of the common cavities, powerfully promote the motion of the venous blood. In the abdomen, this is effected by the conjunct pressure of the diaphragm and abdominal muscles. Lastly, the pulsations of the arteries, every where contiguous and parallel with the veins, promote the return of the venous blood; since, as we have before shewn, every impulse acting on the veins can determine their blood to the heart only.

CLXXIV. To these is added the power, not yet sufficiently known, of derivation, by which the  
blood

blood is brought from a place where it is more compressed, to one more lax, and where it meets with less resistance. Lastly, respiration is of great efficacy ; in which the blood is alternately brought by the power of derivation from all parts of the body into the spongy lungs ; and again, in expiration, is driven into the trunks of the veins in the head and abdomen. Hence the swelling of the veins, even of the brain, in the time of expiration. The circulation is not indeed assisted by these causes, but the blood is agitated and pressed forwards. The anastomoses have the same effects as in the arteries ; for they facilitate the passage of the blood from places where it is obstructed, to those which are pervious.

CLXXV. By these means, the blood in a healthy person, using sufficient exercise of body, moves with a velocity, which is sufficient to restore, in each pulsation, to the heart, by the vena cava, as much blood as the aorta carried away. But corporeal inaction and debility of the contracting fibres of the heart and muscles, frequently render the motion of the venous blood more difficult. Hence the varices in pregnant women ; and hemorrhoids, to which the absence of valves in the vena porta contributes much. Hence the menses themselves. And when the veins return their blood too slowly to the heart, the subtle vapours being unable to return from the minute vessels to the heart, stagnate and occasion that frequency of œdema in weak people.

CLXXVI. The time in which an ounce of blood, sent out from the left ventricle, returns to the right, and which is commonly reckoned the time in which the greater circulation is performed, is uncertain, and different in every different portion of the body. If, however, you inquire concerning the ounce of blood, when propelled in the quantity we have mentioned, with 4500 pulsations, about seven and a  
half

half ounces will perform in an hour nearly twenty-three complete circulations and a half.

CLXXVII. The effects of the action of the heart and arteries upon the blood, which follow from what has been mentioned, are various, and are estimated by comparing the blood of living with dead, of healthy with diseased, and of inactive with active animals. For the blood of a living animal is warm, is of a scarlet colour, seems homogeneous, although composed of mixed principles, is entirely globular, flows very readily through the most minute vessels, and exhales the volatile halitus, which we have already described particularly. In the dead animal, before it is tainted by putrefaction, it loses much of its red colour; it separates into heavier and lighter principles; exhales no vapour, and when drawn out from the veins, congeals either entirely or nearly so. But even in living animals, when weak, in which there is some pulse or respiration, though very small, the blood cools to a considerable degree. If, again, you compare the blood of a person inactive both in body and mind, with that of one addicted to violent exercise, you will observe in the latter, a greater heat, intense redness, greater compactness, specific gravity, and very great abundance of the volatile principles. All which appearances seem manifestly the effects of the action of the heart and arteries, since, with its increase, they increase, with its diminution, diminish, and with its cessation disappear.

CLXXVIII. That we may understand the manner in which these appearances are produced in the blood, we must consider what are the effects of the heart in expelling it, and of the arteries in alternately compressing it. And, indeed, the heart propels the blood with very great velocity (CXXIII.) The heart throws the blood into the crooked arteries, in a confused manner, so that the right globules, expelled into the mouth of the  
aorta,

aorta, strike against the left side of the artery ; from whence being repelled, they incline towards the right side, and thus all the particles of the blood are agitated with a confused and whirling motion. It necessarily follows, that the blood, impelled into curved canals, must impinge on their sides, dilate them and increase their convexity ; and lastly, in the smaller vessels, capable of receiving but few or only one of the blood globules, in which the greatest number or all the globules come into contact with the sides of the artery, they so exactly rub against them, that they are even obliged to change their figure in order to pass.

CLXXIX. But the arteries, by their elastic force, repel the blood from their sides towards the axis of their cavities, and react upon it pressing against them, and lastly transmit the globules, singly, into arteries through the circular mouths of the ultimate series.

CLXXX. In the arteries there is, therefore, a very great degree of friction ; of the blood globules against the arteries ; of the arteries contracting round the blood like an obstacle ; and of the particles of the blood amongst each other by the confused and vorticle manner in which they are propelled. The effects of this friction are computed from the viscid and inflammable nature of the blood, from the narrowness of the vessels through which it runs, from the strong impulse of the heart, from the powerful reaction of the arteries, and from the weight of the incumbent parts raised by the force of the arterial blood. This friction generates fluidity, by perpetually removing the points of contact between its globules, resisting their force of attraction, mixing together the particles of different kinds, which become more fluid upon mixture, as in the instance of oil triturated with water. Then their rotation and mutual attrition dispose the particles to assume a spherical figure ; for by breaking off their protuberances,

tuberances, it renders those that are ill formed or branchy more spherical. But even the fragments broken from the projecting surfaces of the ill formed globules, acquire a round shape from the same rotation, attrition, and circular caliber of the minute vessels. Hence blood coagulates in the vessels before death; and regains its lost fluidity by restoring the motion of the heart, as we are taught by experiments made on living animals. Does the motion of the blood, and the density proceeding from it, produce the red colour, since it is nearly in proportion to the density, and increases or decreases from the same causes? It seems to depend on the calx of iron triturated with the oil.

CLXXXI. Does the motion of the blood also generate its heat, as in experiments with all kinds of fluids, and even air, but more especially in a combustible animal fluid, denser than water, compressed by contractile tubes, and rubbed in consequence of rapid inflection and extension of the canals themselves? Is this proved by the blood being warm in fishes which have a large heart, and cold in those which have a small one, as if the heat generated were in the proportion of the size of the heart to the body; by the great heat of birds, whose hearts are large; by the increase of heat by every motion, even friction; by the certain congelation of all the human fluids, at a degree of cold in which man freezes and retains his blood warm as long as he lives; and by the coldness of persons whose pulse is weak and obscure? Nor does the heat proceed from any incipient putrefaction in the blood, since the fluids, when perfectly at rest, do not generate that degree of heat nor is the evident phenomenon explicable from the action of such an obscure thing as the vital power; and though sometimes the heat may be greater when the pulse is flow, and less when it is more frequent, the difference may arise from the different

ent

ent nature of the blood, from the different densities of the vessels, or from the abundance or scantiness of the perspiration.

CLXXXII. The same cause also checks putrefaction, by not suffering the intestine motion to be diminished, by admixing antiseptic particles, and by dissipating others which have already begun to be corrupted.

CLXXXIII. But in consequence of the different natures of the particles themselves, which conjunctly constitute the blood, the impetus of the heart produces different effects on the different particles of the blood. Namely, those particles move more quickly, whose greater density makes them receive a greater impetus, and whose apt figure and less extended surface meets with less resistance in the fluid in which they move. Those also move more quickly, which, either from their weight, or from the direction in which they pass out from the heart, move in the axis of the vessel. Besides, those which have the greatest projectile motion will strike against the convexities of the flexures; while those which, from their greater gravity or lentor, have less projectile motion, will move sluggishly along the concavity of the vessel. In this manner is the blood disposed for the secretions.

CLXXXIV. In the first place, the systole of the arteries produces compactness; since, by contracting round the blood as round an obstacle, they compress it where viscid and compressible, they expel the more liquid parts into the lateral mouths, increase the points of contact betwixt the globules, unite the larger, and compact the flat particles into denser bodies. But the density of the blood is partly as the number of globules, and partly as the density of the substance of these globules.

CLXXXV. Besides, these very minute mouths, pervious to one globule, seem to be the measures

in which the sanguineous particles, being approximated to a spherical figure by having their points rubbed off, now assume it and become perfect spheres. This is another source of density, since, of all figures, the sphere is the most capacious.

CLXXXVI. The anastomoses of the arteries remove every danger of obstruction, for to any part of an artery where there may be an incipient obstruction or coagulation of the blood, they admit an opposite current, by which the obstacle is repelled in a contrary direction into a larger part of the trunk, and is comminuted between it and the direct current of blood. The irremovable obstruction or the loss of any vessel, is also supplied by the subsequent enlargement of some contiguous branch, as is proved by surgical facts, in which the principal artery has been cut or tied. The collision of these opposite torrents of blood takes something from its velocity; and the reticular distribution augments the friction of the globules.

CLXXXVII. In like manner as the velocity, so the flow motion of the blood in the ultimate vessels has its peculiar effects. In the larger arteries, the most heterogeneous particles are whirled about amongst each other; in the smaller branches, the progressive motion of the blood being diminished, the lighter particles separate from the very ponderous and red globules, and are forced towards the circumference and branches, while the compact globules remain in the axis. The attractive powers of the particles of the blood are also increased; hence, the oily particles which are both sluggish and large, attract each other, and separate by open lateral mouths; and other thinner fluids are sent off through lateral branches of a smaller orifice, till at length little more than the red blood alone passes into the incipient vein. Heterogeneous particles are also mixed in a single vein, that the blood may be prepared for certain uses, as in the vena portarum.

rum. But all these particulars which prepare the blood for the secretions, we shall consider in the following chapter.

## C H A P. VII.

## SECRETION.

CLXXXVIII. **T**HE fluids which, being deposited from the blood into other vessels, are said to be secreted, seem reducible to four classes. The *first* consists of viscid fluids, coagulable by a heat of about 150 degrees, by alcohol, and by strong acids; although generally, in the living animal, they escape in the form of vapour, and after death are compacted into a gelatinous substance. To this class belong the liquor and halitus of the ventricles of the brain, of the pericardium, pleura, peritoneum, tunica vaginalis, amnion, joints, renal capsules, and probably of the womb, with the juices of the stomach and intestines, and lastly the lymph generally known.

CLXXXIX. The *second* class consists of fluids, of which some, in like manner, are exhaled, but more simple than the former (CLXXXVIII.) and more aqueous, are not coagulable by fire or by spirits of wine; and others are not exhaled, but, being deposited in their respective excretory ducts, are excreted in their proper places by the common outlet of some gland. To the former of this class belong the perspirable matter of Sanctorius, part of the tears, and the watery humour of the eye. To the latter of this class belong the remaining part of the tears, the saliva, pancreatic juice, and the urine. The sweat seems to be a mixture of the perspirable matter and the subcutaneous oil.

cxc. The *third* class differs from both the preceding, being heavier than water, sluggish and viscid, but of an aqueous nature, not congealable into a jelly, but hardening into dry crusts by exhaling their water. Those do not effervesce with any salt, but are contracted and made thicker by acids. By lixivial salts they are dissolved. By fire they are resolved into water, a little volatile salt, and a little oil. Of this kind are the whole mucus in the human body, extended over all the internal passages for air, aliments, or urine, and the cavities of the genital parts ; and semen.

cxci. The *last* class is that of the inflammable juices, which, when recent, are indeed thin and watery, but, by stagnation and by evaporating their water, become thick, oily, inflammable, and often bitter liniments. To this class we refer the bile, earwax, tallow, the oily liniment of the skin, the marrow in the bones, and all the fat throughout the human body ; and castor, and the yolk of the egg. The milk itself, so far as it contains butter, belongs to this class.

cxcii. Other humours are compounded of these which we have described as simple : as the milk, of butter and water ; and the liniment of the joints, of lymph and fat.

cxci. Whoever considers, that in the blood are found a coagulable serum (cxxxvii.) an exhaling water (cxl.) a sort of viscid mucus (cxxxviii.) and lastly an oil (cxl.) will begin to perceive the perfect possibility of the foregoing classes (clxxxviii. to cxci.) of humours being separated from the blood, since their principles exist in the sanguineous mass. But in what manner it is brought about, that oil is separated from the blood in one part, water in another, and mucus in a third, remains to be explained, and requires a description of the secretory organs.

CXCIV.

CXCIV. The coagulable juices are separated almost every where, from the arteries themselves, into excretory canals, continuous with the arteries, without any intermediate organ. The proof of this we have from injections of glue, water, and thin oils, which very readily exude from the red arteries, and are poured out into all the cavities in which that coagulable vapour is naturally found, without meeting with any intermediate knots or retarding cells. Finally, the blood itself, being poured out into most of these cavities, without any permanent lesion, in consequence of stagnation, retardation, or small increase of impetus, shows plainly that the passage betwixt the red blood-vessels and those excretory ducts is neither long nor difficult, and that the yellow serum does not differ much from blood.

CXCV. Another liquid, coagulable by acid spirits and alcohol, is the albuminous humour of the joints, which being composed of fat, medullary oil, and watery exhalation, constitutes an exceedingly soft liniment, very fit for lubricating the cartilages, and lessening friction. For secreting this, there are destined certain conglomerate glands of a peculiar structure, which are so situated in the rough pits of the articulations of the bones, that they may be moderately compressed, but cannot be crushed.

CXCVI. The structure of these glands is peculiar. The larger clusters of glandular acini adhere, for the most part, to the bone by a broad basis wrapped up in fat. Thence, being extenuated into a crested edge, they pour out their liquor from an exceedingly thin border, by open ducts, which however I do not find very evident. Other smaller ones, placed every where in the capsules of the tendons, and between the diverging fibres of the ligamentary capsules of the joints, seem to be almost of the nature of simple glands, and are turgid with yellow mucous serum.

CXCVII.

cxcvii. The uncoagulable juices (CLXXXIX.) of the first sort are secreted in the same manner with the coagulable ones (CLXXXVIII.) to wit, from exhaling arteries, which arise from the red arteries, without any intermediate follicle. In the vessels, which exhale the cutaneous perspiration, and in the lachrymal vessels of the first sort having a watery fluid; injections of water, or thin size exude from the arteries, so as to remove every doubt of this. These arteries are also irritable, so that, from the contact of an acrid substance, they discharge more juice in a given time, than in a state of health.

cxcviii. But in the latter kind, the salival, the secretion is made by means of conglomerate glands, which the ancients first distinguished by their cluster like fabric, and esteemed glands. These are composed of acini or roundish lobules, conjoined together into a larger mass, by loose cellular substance, which is often covered externally by some dense cellular membrane, as a common envelope, as in the parotid and maxillary glands. Through the intervals, betwixt the clusters, run the arteries which are here pretty large, and the veins. But most of the conglomerate glands separate their fluids from the blood, and discharge it in the following manner: Each acinus sends out an excretory duct, which joins with others of the same kind, into a larger trunk, forming at last, in the manner of veins, one canal, which conveys the humour, separated by the gland, to the part for which it is designed, as the cavity of the mouth, intestines, surface of the eyes, &c. There are, indeed, some instances in which either there are no excretory ducts, or they have not hitherto been discovered; as the thyroid gland, capsulæ renales, and thymus, unless these approach to the nature of conglobate glands.

cxcix. The acini themselves are surrounded and limited by some firm cellular substance; and are  
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also subdivided into lesser acinuli, as is evident to the eye, and by the microscope. How does this subdivision end? Is every simple acinus hollow in its middle, receiving the humour transfusing from the arteries in a follicle, and sending it out by an excretory duct? Is this structure rendered probable by eruptions, hydatids, and the kidneys filled with round schirri? Are the larger viscera, appointed for secretion, conglomerated glands? Is this opinion made probable from the morbid round concretions formed in the liver, spleen, kidneys, testicles, and cortical substance of the brain; or from the bunch like appearance which those viscera have in smaller animals? In the cellular substance that surrounds every part of the human body, even the extreme vasculæ, are there hollow spaces and cells, into which a secreted humour is poured?

cc. Nothing of this kind seems to be the case. For, indeed, the acini composing the viscera of animals, are not elementary, but composite lobes, and large in proportion to the animals. The morbid concretions are almost all of them seated in the cellular substance, and in the limbs themselves, where there is not the least room to suspect any thing of a glandular fabric; and are composed of oil, earth, and vaporous particles, extravasated into some of the cellular cavities, where, stagnating and compressing the adjacent follicles, they form to themselves proper membranous tunics. Besides, the watery and fluid nature of the juice secreted in these glands (CLXXXIX.) is an argument that, during its secretion, it met with no retardation, no place in which it stagnated. For the fluids which remain at rest in the warm cavities of the human body, which are full of absorbing vessels, are all inspissated, and approach either towards a mucous or an oily nature. Moreover, anatomical injections would meet with more difficulty in passing from the arteries into the excretory ducts; which would be impervious to thick injections,

injections, and thin ones would be exhaled into the cellular substance. Yet we see, that the superlative art of great anatomists has conveyed thick injections, like wax, directly from the arteries of the salivary glands, liver, &c. into continuous excretory ducts; and this without filling up any intermediate cavities, which, according to the foregoing hypothesis (cxcix.) should happen.

ccI. Therefore, the acini appear to be composed of arteries and veins, divided and subdivided, parted and connected by the intervention of a good deal of cellular substance, which, becoming gradually more compact, assumes a spheroidal figure. This is supported, by analogy in the lobes of the lungs, in the lobules of the thymus, in the structure of insects; but more especially in the testicle, of which the lobules are evidently formed of excretory ducts, connected together into fasciculi by a very soft membrane. The glands do not seem to pour their fluids into cellular substance, as by it the passage to the excretory ducts would be obstructed or prevented. The industry of anatomists has lately discovered very small, white, cylindric vessels, the real elements of the viscera; and it is to be hoped that this discovery will be confirmed by future observations.

ccII. Thin fluids, neither coagulable nor exhaling, but aqueous, are likewise generated in other parts, without the assistance of conglomerate acinous glands. Thus, the urine is deposited from the red arteries into membranous tubes, manifestly continuous, in a manner which readily admits the passage of air, water, or mercury. The nervous fluid seems to be secreted in the brain, in a similar, though less apparent manner.

ccIII. The third class of fluids, the mucous, (cxc.) is almost every where secreted from sinuses or hollow glands. The structure of true glands or follicles, in general, consists of an ample cavity, every where circumscribed by a membrane; but in such a manner,

a manner, that the flesh itself of the part, to which the gland adheres, sometimes forms the one side, and completes the hemisphere of the follicle. In other places, a continued membrane forms the whole of the round or oval receptacle of the gland. The cavity is in general round; but sometimes it is oblong, and situated obliquely betwixt the adjacent parts; as, for example, in the urethra of the male, and in the follicles of the sinus muliebris. They are irritable; and, when stimulated by acrid substances, accelerate their secretions.

CCIV. Into these follicles minute arteries, either from the flesh in which it is seated, or from the membrane which constitutes its convex side, open by extremities extended into the cavity of each crypta, into which they pour their respective juice; after being received into the follicle, it is detained from the narrowness of the excretory duct, and inspissated, the more watery parts being absorbed by the veins, which correspond to the exhaling arteries. The truth of this we are taught from the structure of the simple follicles observable in the tongue, in which both the importing pores, and the excretory ducts, are even visible to the eye; and from the tubuli of the stomach of birds, in which the secreting villi manifestly protrude into the cavity; and lastly, from injections, which force wax colourless into the simple glands.

CCV. The long mucous sinuses, and round glands, are both furnished with excretory ducts, which, for the most part, are sufficiently large; although, in the round glands, they bear no great proportion to the cavity of the gland. These orifices often open into the common large cavity, into which the mucus is poured, without any intermediate duct; as in the back of the tongue, and in the simple glands of the stomach and intestines. These have been denominated cryptæ by Ruyfch. The sinuses have often a similar structure, and open,

open, without an intervening duct, as in the urethra of the male.

ccvi. In another kind of these glands, there are many simple follicles contained in one common covering, which open with ample orifices into one common sinus, without any true excretory duct, as in the tonsils. These are called conglutinated glands.

ccvii. Other simple glands have an excretory duct, by which they excrete their mucus; namely, a membranous, cylindric, narrow vessel, opening with its posterior orifice into the cavity of the gland, and with its anterior orifice into the common cavity for which its mucus is designed. These excretory ducts are of considerable length in the subcutaneous and sebaceous glands, and in those of the palate and windpipe. In some parts, the pore and duct are more easily demonstrable than the follicle, as in the nostrils, larynx, rectum, &c.

ccviii. In other places, several of these ducts, arising each from its respective follicle, run together like the branches of a vein, so as to form one considerable excretory canal, common to a number of follicles. To this kind belong the compound glands of the intestines, and the blind sinus at the root of the tongue, of the class of glands; and of the sinuses, some compound sinuses of the urethra, and the tubulous fibres of the stomachs of fishes and of birds. Glands of this sort may be said to be compounded of simple ones; but where they lie only contiguous, they may be called aggregate or congregated glands; as are those of the fauces, stomach, intestines, &c.

ccix. The inflammable juices (cxcix.) are separated by organs differing in their fabric. The fat and marrow are deposited into cellular substance, without the intervention of glands, from the small mouths of the arteries. The subcutaneous fat every where exudes through small ducts and pores, without

without any glandular follicles. But the earwax and cutaneous suet are secreted by glands of different kinds. Many of the sebaceous glands are visible, with a naked mouth in the skin, and without a duct of any length; as we see in the ears, areolæ of the nipples, in the female nymphæ, and the groove betwixt them and the labia, and in the prepuce of the penis and clitoris. These differ but little from the cryptæ (ccv.) except in the matter which they secrete.

ccx. There are others of the sebaceous glands, which have an excretory duct of some length; as almost all the cutaneous ones, which, being seated in the cellular substance, are necessarily provided with a duct to perforate the skin. This is most evident in the face, where the length of the duct is indicated by maggot like substance pressed out; the bulk of which demonstrates, that a follicle lies under the slender pore.

ccxi. There are still other sebaceous glands of the kind, mentioned ccviii. in which the small ducts of many cryptæ meet together in one larger excretory duct. Thus, in the face, in several places, the large pores are in common to a number of cryptæ. Of this kind, also, are those sebaceous ducts in the eyelids; and the unguinous glands in the secretory organ of the musk-goat, beaver, hyæna, civet-cat, and musk-rat, which pour their sebaceous matter into one common receptacle.

ccxii. The milk, which is composed of water and oil, and perhaps of absorbed fat, and is a fluid of a peculiar nature, is secreted in a conglomerate gland, such as we described at cxcviii. The bile is a matter of controversy; but there are many arguments in favour of the vascular structure, and of the bile being deposited in the pori biliarii, from the vena portarum, without intermediate follicles; especially the Ruyschian art of injection, in which the wax passes directly from the porta into the biliary pores,

pores, without meeting with any intermediate knots retarding it. The milk and bile are both of them however much thinner, and more watery, than the fat, or the sebaceous matter in follicles.

CCXIII. It remains for us to inquire, how it happens, that from one common mass of the blood, the same variety of peculiar fluids are constantly separated, each in its respective place, and that milk is never secreted in the kidneys, bile in the thymus, or mucus in the sebaceous glands. This problem will be at last perfectly solved by one who shall be intimately acquainted with the internal structure of the secreting organs. In the mean time, I shall notice what is hitherto known with sufficient certainty.

CCXIV. In the first place, the blood itself, from which any liquid is to be secreted, assumes in various places, that peculiarity of character, that it contains more particles, of a like nature with those which nature wishes to predominate in the fluid to be secreted. In the liver, the venous blood arrives with a slow motion, loaded with oil, and the semi-putrid vapours of the intestines. To the testicles, the blood is brought slowly, through long, slender and inflected canals, arising at very small angles, under the skin, in a cold situation. In the carotids, it is probable that the stronger, spirituous, and dense parts of the blood ascend; so that that is more watery, which descends into the abdomen and to the kidneys, and forms the saliva of the pancreas, and the gastric and intestinal juices.

CCXV. Besides, the blood is prepared for secretion, by its retardation in the minute vessels, in consequence of which, the red and denser parts alone occupy the axis of the canal; while the other lighter, more sluggish, and less quickly moved particles, recede to the lateral branches, impinge on the secretory mouths arising from the sides of the vessels, and adhere to them by their viscosity.

CCXVI.

CCXVI. These orifices, though possibly of different diameters, are always too small to admit the blood in their natural state. As from an increased action of the heart, many of them admit blood, we may conclude, with probability, that they arise continuous with the red arteries, and are not much smaller than the red globules. Hence the same secretory orifices refuse thick injections of wax or suet, and generally admit thinner liquors injected into the arteries. Therefore, this is the first and most simple mechanism of secretion, viz. that the caliber of the excretory duct admits only those particles, of which the greatest diameter is less than the diameter of the duct. It is only in this way that the yellow arteries convey a pure liquor from the blood, and that the uriniferous ducts exclude the red blood and coagulable serum. But this is not the sole cause, since similar fluids are generated by large, as well as by small animals.

CCXVII. Merely according to this law, the secreted juices may be of many different kinds: for the very minute orifices will only admit fluids of extreme tenuity, as in the small vessels of the brain; while the larger will admit water and jelly; and the largest of all, fat. Moreover, if a number of secretory organs arise, in succession from one secreting artery, and be provided with large orifices, those which arise last from the artery will admit only the thinnest fluids. If, on the contrary, those which arise first in order from the secreting artery, be small, the last ones will receive only the grosser liquids. It may be objected, that though the vessels in the foetus are vastly less than in an adult, yet the humours are the same. But these humours, which are called fat, bile, lymph, and urine, in the foetus, are very different from the fat, bile, lymph, and urine of an adult.

CCXVIII. It is altogether in this way, that most secretions are made by vessels arising immediately from

from sanguiferous arteries (XLV.) These separate gross juices; thick, coagulable, or watery; as the fat; urine, juice of the stomach and intestines, &c. But other secretions of thinner juices are performed by vessels arising from the inferior orders of arteries, not sanguiferous; to the orifices of which, not only no red blood, but no serum, fat, or other gross fluids, can have admittance. Thus the more thin and pure humours must necessarily be separated; as, for example, in the eye.

CCXIX. Perhaps the angle, which the secretory branch forms with its trunk, contributes something to secretion. For it is easily demonstrated, that at right and reflected angles, only the viscid and sluggish juices are expelled, in consequence of the stronger force of the particles keeping the middle of the canal; and that the liquids which preserve their velocity, are those sent off at acute angles. For men of credit have observed, that, in living animals, the velocity is greater in acute angles, and less in right angles. The very structure of the body convinces us, that these angles have some effect on secretion, since in different parts we find the angles at which the branches proceed from the trunks different, and the reticulations different. For the ultimate vessels are, in general, arbuscular, the trunks sending out branches on every side, but at different angles; thus, at small angles in the large intestines, and large angles in the small intestines. Thus in the spleen, the smaller red arteries arise so thick from their trunks, that they resemble a sprinkler; in the intestines, they resemble pencil brushes; in the kidneys they are serpentine; in the liver radiated; in the testicle, they are curled up like a lock of hair; and in the uvea they are anular. But it is no improbable conjecture, that the Creator never made this diversity of fabric in vain. We have not as yet, however, any account of these reticulations that is sufficiently accurate; nor  
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does a similarity in the fluids secreted seem to be connected with a similarity of structure. The veins too have similar reticulations, for the purpose of facilitating the motion of the blood, and not for diversifying the nature of the secretions.

ccxx. The inflexions of the smaller vessels, as well arteries as excretories, greatly retard the motion of the blood; in which the greater part of the force received from the heart is evidently spent in the change of figure in the vessel. The repeated inflexions, therefore, of the secretory arteries collect the viscid parts of the fluids, by giving them time to attract each other. A straight course of the vessels is favourable to celerity of motion, rendering the secretion copious and easy, but impure, as we see in the urine.

ccxxi. That the ultimate arteries, and in like manner the secretory orifices, have different degrees of density, is not improbable, since we actually find it so by experiments in the larger branches. But the denser the capillary arteries are, the more will they admit only the strong, and at the same time minute particles, and exclude those that are lighter, moved with less velocity, and grosser. Irritability produces almost the same effects; for if the secretory orifice be irritated, it will reject the gross humours, and transmit the more fluid ones: instead of mucus in the urethra, it will separate a thin yellow serum; and a similar fluid, instead of the subcutaneous fat: the quantity of secreted liquor will also be increased; as, for example, in the tears.

ccxxii. Lastly, the velocity is greatly increased, if the heart be near, if the artery be straight, if it go off at a small angle, or if the excretory duct arise near the extremity of a considerable arterial branch. The velocity is diminished, if the secreting artery run a long way capillary, losing the greater part of the motion of its blood, from friction, if it arise at a distance from the heart, and at a large angle.

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Finally, from whatever cause the diversity may proceed, an increase of velocity increases the quantity of fluid secreted, carries off the heavy liquids, and renders the secretions thicker and more impure, though fluid, as it prevents stagnation, by which they contract viscosity : but slowness facilitates attraction and viscosity, and renders the secreted juice more pure ; as the similar particles, when brought together, can better attract and join each other, under a slow motion, so as to retain the larger canal, while the thinner parts go off by the lesser lateral branches. Hence, from the impetus of the heart alone being too much increased, all the secretions become confounded.

CCXXIII. These conditions, nature is able variously to unite or separate, and to impart to each organ, in greater or less degrees ; and thus, to modify the secreted humours in various ways. Anatomy furnishes examples, if you compare the secreting apparatus of the bile or semen, which are thick juices, with those of the urine and tears, which are fluid ones.

CCXXIV. From all that has been advanced, we may perceive, that, since the blood contains particles of various kinds ; some sluggish and mucous ; some coagulable, but fluid ; some dense and red ; some watery and thin ; and others fat and viscid (CLXXXVIII. *et seq.*) among all these particles, those which are the largest and most dense, such as the cruor, will continue in the axis of the vessel, and in the trunk, so as to pass on in a continued course into the sanguiferous vein (XXXIX.)

CCXXV. Those particles which are gross and sluggish, such as the fat, must go off by the larger orifices arising laterally from the sanguineous artery, by short ducts ; for in long ducts the oil would stagnate, from its sluggishness. The phenomena of the secretion of fat (XIX.) agree with this description. Such as are coagulable, but specifically heavier

ier than those which are merely watery, and which continue fluid in the living animal, pass from the red arteries, into others which are pellucid, but continuous to the red ones, and smaller; whether these pellucid ones be continued on as trunks, sending off other smaller branches, such as the arteries of the inferior orders (XLI.) or whether they exhale their contents by a short extremity, like the vessels of CLXX.

CCXXVI. Thin watery fluids may evidently pass off by any vessels continuous with the sanguiferous, or inferior orders of vessels (XLIV.) provided they be only small enough to exclude the grosser juices: whether these proceed from the sides of the larger vessels; or whether all the proper fluids being sent off through the larger canals, the smaller canal be continued as the trunk, as in the eye. To the production of these fluids, the most simple fabric, even the direct continuation of the secretory artery itself into the excretory duct, is sufficient, as seems probable in the urine. Therefore, in this case, the structure is direct and simple, with few inflections, and with little diminution of velocity.

Such juices as, being watery, are light, but viscid at the same time, and consequently sluggish and tardy, escape easily by short tubes appended to the sanguiferous arteries, and less than the adipose vessels; and, therefore, it is evident, that these will be separated from the blood more abundantly in some parts of the body, where the velocity derived from the heart is less, the flexures of the artery more frequent, and the length of the capillaries greater.

CCXXVII. Has each part its particular ferments, form of pores, specific weight, and filters filled with their own peculiar humour, and refusing whatever is not analagous to it, which determine the nature of the fluids to be generated? Let those who adopt these ideas, consider the great varieties

there are in fluids, separated in the same part of the body, according to the difference of age, course of life, &c. In the foetus, the bile is sweet; the semen thin, and without animalcules; the milk watery or absent; the urine watery, mucous, and insipid; the uterine mucus very white; the cutaneous vessels full of a red fluid; the aqueous humour red; and the fat gelatinous. In the same organs, in an adult person, the bile secreted is acrid; the semen thick; the milk butyraceous; the urine, yellow, thin, and alkalescent; the menstrual blood, and the aqueous humour, very limpid. But, even in the adult person, how different the aqueous urine, the concocted urine, and the heavy febrile urine, replete with salts and oils? The passions of the mind, which make no change in the body except upon the tension of the nerves, yet wonderfully change the secretions, and expel even the blood and bile through the vessels of the skin. Add to this, the frequent disturbance and alteration of the secretions from slight causes; so that, different augmentations of velocity shall cause different liquors to be secreted by the same organ: for blood has been known to pass into almost all the passages of all the fluids; of the sweat, tears, mucus of the nostrils, and of the womb, milk, semen, urine, and fat. A true milk has been seen separated by glands in the thigh. When the urine is not excreted, on account of some defect of the kidneys, ureters, or bladder, it has been exhaled into the skin, ventricles of the brain, or into the whole cellular fabric. The perspirable matter of Sanctorius, though so fluid, by cold is sent off by the urinary passages; and by fear, or by medicines, through the excretory villi of the intestines. That exhaling viscid matter of the cellular substance is secreted and absorbed, and by the same organs, alternately with the fat, so different from it (xviii.) Salivation supplies the place of the exhaling fluid of Sanctorius, the exhaling

ing fluid supplies the internal. The bile, when absorbed, evidently passes into the vessels of the eyes. It appears, that there is not any thing in the particular fabric of any of the viscera or glands, that can so fix or maintain the nature of the secreted fluid ; that in perfectly entire organs, different fluids may not be separated, by an increase or diminution of velocity, or alteration of the stricture of the nerves. The specific gravities of the viscera and strainers do not correspond, even according to their authors, to the specific gravity of the humours which they secrete ; nor are they at all known by experiments that can be depended on.

CCXXVIII. It now remains for us to discover, how the pure secretions are formed in a healthy person. For all the fluids, when recently secreted, without excepting any, not even the oil, are mixed with a great deal of water ; nor does it seem possible, that any of the thicker juices could be formed, without having a mixture of the thinner ones : how then do the semen, bile, oil, and mucus, get rid of their superabundant water, and acquire their proper viscosity and other qualities ?

CCXXIX. For this end, nature has framed glands and follicles, large and small, for those fluids from which the watery parts are to be separated, in order to render the remaining part more strong and viscid. A slightly mucous water, differing at first very little from the perspirable vapour or from tears, is deposited in the follicles of the nostrils, windpipe, and intestines. This is not continually discharging, because the excretory orifice being less than the follicle (CXCVI.) and the excretory duct being sometimes long and slender, at others repeatedly bent, and inflected or transmitted through hard cellular texture, or closed by some force equivalent to a sphincter, the fluid is so retarded that it can scarcely escape without the assistance of extrinsic pressure ; unless perhaps the follicle being irritated  
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by its quantity or acrimony, press out the liquor incommoding it, by a kind of peristaltic motion. This appears from the morning discharges of mucus by blowing the nose, coughing up from the lungs, and by sneezing after the nocturnal stagnation. In the mean time, the patulent veins, extended into the cavity of the follicle, absorb the more aqueous parts from the thin mucus, so that it becomes thicker as it is retained longer; but if, by the force of some stimulus, it be directly discharged after it is secreted, it comes out thin and watery. Examples of this we have in the urethra, in the nostrils, and in the earwax; as also in the bile, which, at its first separation in the liver, is watery, and has but little yellowness or bitterness. It is therefore detained in a bladder, and there digested by the vital heat; its thinner parts are absorbed by the veins, or exude through the membranes themselves; whence the remainder becomes more thick, bitter, and oily. The same mechanism takes place in the semen; which, being preserved in the seminal vesicle, is there thickened, so as to be very viscid after long chastity; while after repeated venery it is expelled very fluid. In some places nature has made this receptacle double or triple in the same organ, that the fluid might attain the utmost degree of viscosity. In the seminal passages, the rete testis and termination of the epididymis, constitute a large canal, and a large vesicle; while the vessels of the testicle, vas deferens and prostate duct, are narrow. Hence there are nowhere real glands, except for secreting a viscid liquor. And if a viscid liquor be separated from arteries without a follicle, it always stagnates in some considerable follicle. The semen, bile, liquor of the joints, and fat, afford examples of this.

ccxxx. The fluids may be likewise changed in their receptacles by the affusion of some new liquor.

quor. Thus the semen is thickened by the addition of the liquor of the prostate; the chyle is attenuated by mixture with the saliva of the pancreas and the gastric and intestinal juices, and by the affusion of the bile it becomes alkalescent; the albumen of the joints is tempered by the two kinds of fat (cxcv.)

ccxxxi. Lastly, what is absorbed, may have its uses in the animal economy, after it is taken into the blood; thus the semen gives a surprising strength to male animals. For the most part, likewise, in fluids which are detained, an acrimony of an alkalescent nature is generated, which also hath its uses, as in the bile and semen.

ccxxxii. But the most important use of the follicles and receptacles is to preserve their peculiar fluids, for those times in which alone they are subservient to life, and that a large quantity of them may be collected to correspond with their uses at certain periods. Thus the bile is reserved for the time of digestion, the semen for due venery; and the mucus of the nostrils is accumulated in the night to moderate the force of the air passing through them in the day.

ccxxxiii. Therefore, as nature has framed machines which retard the fluids in large or small follicles, so she has made others to expel them at proper times. To some glands she has given particular muscles; as in the testicles of brutes, the urinary bladder, and the gall bladder, and in the intestines, and stomach; or she has subjoined contiguous muscles to promote the discharge, as the biventer, masseter, muscles of the abdomen and diaphragm; or else she has given them a kind of nervous irritability, which, being excited to action by an indescribable stimulus, opens the shut passages to the milk, semen, tears, &c. or from the contact of any thing acrid, as already mentioned, accelerates the discharge of the fluid; as happens

pens to the bile, liquor of the stomach and intestines, and to the sebaceous matter.

## C H A P. VIII.

## RESPIRATION.

CCXXXIV. **T**HE bags of the pleura (LXXVII. LXXVIII.) are filled by the lungs; by which we understand two viscera, one right and another left, in figure corresponding with the bags themselves which they fill, having a broad basis below, and being terminated above at the first rib by an obtuse cone. Anteriorly their surface is flat, laterally convex, and posteriorly it is rounded; internally it is concave, especially that of the left lungs, for the purpose of containing the heart. The right lung is the largest, and is most frequently divided into three lobes; which is seldom the case with the left. They are freely suspended by the great blood-vessels; unless you call that a ligament which is formed at the basis of the diaphragm by the external membrane of the pleura going off to the lungs. Between the lungs and pleura is found a watery vapour, of a coagulable nature, like that of the pericardium (LXXXII.) which transudes from the surface of the lungs and of the pleura, continually in the foetus, and not unfrequently in the adult. In dropfy, this vapour is increased, or thickens to a kind of sebaceous matter; or, lastly, it concretes into fibres, forming adhesions of the lungs.

CCXXXV. The external membrane of the lungs is simple, and thinner than the pleura, although continuous with it. It spreads, from the adhesion of the great blood-vessels of the heart, over the lungs in every direction, and, when entire, may be easily inflated, even after being separated from  
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the lungs. The same membrane passes over the intervals between the lobules, like a bridge. It is joined to the lungs by cellular texture.

ccxxxvi. The lungs are made up of lobes separated by intermediate intervals, in which there is loose cellular substance. Their first division is into two large lobes, and one middle one of a smaller size; which, however, cohere together: they are afterwards repeatedly subdivided into successively smaller lobes, always surrounded by cellular membrane, till at last the lobules are resolved into very small membranous cells, which, in adults, are filled with air, are of various figures, and communicate on all sides with each other. The elementary parts of the lungs, therefore, are not oval bags, surrounded by muscular texture, with a single orifice which receive the air from the windpipe, but they admit the air exhaling from the ultimate branches of the trachea, so that being effused into irregular spaces, it passes and repasses freely from any one portion of the lungs into all the others. This is demonstrated by inflation, for air blown into any, even the most minute lobule, through its branch of the trachea, passes into all the rest. In man and in the smaller animals, the cellular fabric of the intervals is neither shut up from the vesicles of the lungs, nor are the lobes surrounded by any peculiar membrane; in the largest animals, there is no communication between the air vesicles and the cellular spaces which surround the lobules.

ccxxxvii. The air passes into these vesicles through the windpipe. The windpipe arises from the larynx (hereafter to be described,) and receives the air through it alone. Its first part single and simple, partly fleshy and partly cartilaginous, the œsophagus lying below it and to its left, is supported on the broad and flat vertebræ of the neck; in other words, within the cellular substance that surrounds

surrounds the windpipe, there is situated a canal, composed of alternate cartilaginous and muscular rings. The cartilaginous rings, thin and elastic, anteriorly somewhat flat and thick, are joined together by their posterior extremities, which are thinner; and the circle is completed by strong transverse muscular fibres, adhering to both the loose extremities of the cartilage. The lower circles are less; the uppermost is often augmented by an appendix, that next to the division is perpendicular.

CCXXXVIII. The fleshy rings, situated alternately with the cartilaginous ones, are composed of red muscular fibres. Some of these are transverse, connecting the detached ends of the annular cartilages; others descend from each upper to the next lower ring. But other muscular fibres again, descend from the cricoid cartilage, and having reached below the division of the bronchia, vanish upon the lungs. The transverse fibres contract the windpipe; the longitudinal ones shorten it. Within the lungs, between the imperfect rings, there is a sort of muscular fabric, but less uniformly disposed.

CCXXXIX. In the cellular coat which surrounds the muscular one, but especially behind, in the interval between the cartilages (CCXXXVI.) are placed numberless simple glands, which, by very small ducts, like pores, opening into the cavity of the windpipe, deposite within that cavity a watery and pellucid mucus, not coagulable into films, and very bland, which is of the greatest use in defending the exceedingly sensible membrane from the impurities of the air, which is loaded with particles, irritating by their mechanical figure or chemical acrimony. Numerous conglobate glands are situated around the trachea and its bronchia, but these are of the lymphatic kind, although their black fluid frequently penetrates into the trachea. Lastly,

ly, the internal tube of the windpipe is lined by a membrane, covered by epidermis, continuous with the skin and membranes of the mouth, smooth, soft, and very irritable. It is connected with the muscular coat by cellular substance.

CCXL. The vessels of this entire part of the windpipe, in the neck, come from the lower thyroids; in the thorax, from other small branches of the subclavian trunks, or the mammaries, or the bronchials properly so called. Its nerves, arising from the recurrent and intercostals, are numerous.

CCXLI. In the upper part of the thorax, the windpipe is received between the laminae of the posterior mediastinum; and at the third vertebra, or a little above, is divided into two branches similar to the trunk, formed in like manner of imperfect cartilages, and furnished with similar glands; each of these enters the lung to which it corresponds, and the right is something shorter and larger than the left. Having entered the lungs, the cartilaginous rings gradually degenerate into fragments, become more difform, gnomonic, angular, triangular, and intermixed with a larger portion of membrane, till at length, by the diminution of the cartilages, the ultimate branches of the bronchia become membranous.

CCXLII. Its ultimate branches are invisible, and exhale air into the cellular spaces of the lungs in adults, and from the same spaces receive the arterial expired vapour.

CCXLIII. The vessels of the bronchia, are the bronchial veins and arteries. The latter are generally two; one coming from the upper intercostal of the aorta, which is distributed either to the right only, or to both the lungs; the other, from the trunk of the aorta, goes to the left lung. Sometimes there are more; as when there are three, by the addition of a second from the aorta. At other times,

times, there is only one artery common to both lungs. The thoracic part of the bronchia, situated without the lungs, has its proper vessels from the aorta, or from the subclavian, or the mammary, or the intercostal. The bronchial veins are very commonly two; the right from the vena azygos, the left from a peculiar branch of the subclavian vein, the left superior intercostal. These blood-vessels accompany the branches of the trachea; and descend into their membranes, the arteries inosculate with the pulmonary arteries, and the veins with the veins, forming a vascular web in the internal cellular substance. There are some instances where the pulmonary vein itself has given small branches to the lungs, to the windpipe, and to the surface of the lungs.

CCXLIV. But there are other larger vessels belonging to the lungs, the pulmonary artery (CVI. CVIII.) and the vein (CX.) The great artery, in the foetus larger than the aorta, and in the adult but little less, has two branches; the right larger but shorter, the left narrower and longer. In the foetus, the trunk itself is continued into the descending aorta, and is known by the name of ductus arteriosus. In the adult, that trunk degenerates into a solid ligament. The four pulmonary veins accompany the branches of the artery and of the trachea, through the lungs, surrounded by a good deal of cellular substance; which substance, being increased, at last composes the lungs themselves. Within this cellular fabric, the air-vessels and blood-vessels are subdivided, and in the ultimate cellular spaces, the ultimate veins and arteries spread, reticularly interwoven; and here the small arteries exhale a plentiful vapour into the aerial cells of the lungs, and the veins absorb a watery vapour from them. Hence coloured water, the whey of milk, or thin wax, being injected into the pulmonary artery, flow with froth into the windpipe; or, on the contrary, penetrate from the

the bronchia into the pulmonary artery. In like manner, injections pass from the pulmonary vein into the bronchia; or from thence, into the veins. Lastly, they readily pass from the arteries into the pulmonary veins; or return from the veins into the arteries.

CCXLV. The lymphatic vessels, as in other parts, form a network upon the surface of the lungs, from whence branches run to the cavity of the posterior mediastinum, to the glands seated on the œsophagus, and to the thoracic duct. The nerves are small, especially the anterior, the posterior ones being somewhat larger: they come from a nerve of the eighth pair; but they receive some addition, accompanying the large blood-vessels, from the recurrent, and likewise from the cardiac plexus. Hence the lungs have but little sensation; but that of the little nerves, divided upon the substance of the bronchia, is very acute. Nor are the lungs of an irritable nature.

CCXLVI. The quantity of blood which enters into the lungs is exceedingly great, equal to (or even perhaps greater than) that which is sent in the same time throughout the rest of the body; which, therefore, indicates this viscus to be subservient to some very important purpose. That this use depends manifestly upon the air, appears from the universal consent of nature, in which we scarcely find an animal which does not respire; also from the structure of the lungs in the fœtus, in which being useless, on account of the absence of air, they receive only a very small portion of that blood, which the pulmonary artery conveys from the heart. We come, therefore, to speak of respiration, or the inhalation and expulsion of air by the lungs.

CCXLVII. Air, physically considered, is an element, fluid, invisible, elastic, with an indestructible spring, and soniferous. But the air, which we commonly receive into the lungs, is impure, filled with a great quantity of watery and other vapours, also  
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with salts, and the universal acid, with the seeds of plants and animals, and other foreign particles; and is ponderous; weighing, however, 850 times less than water, a cubic foot of air being between 610 and 694 grains. This air, which surrounds the earth on all sides, being compressed by its incumbent columns, perpendicularly and laterally, enters with great force wherever it meets with less resistance, as appears from experiments made in vacuo, and from the phenomena of the air-pump; so that its pressure on the human body is not less than 30,000 pounds. It is repelled chiefly by the pores of membranes, though these are permeable by water: it likewise penetrates oil or mucus with difficulty.

CCXLVIII. The ambient air is excluded from all parts of the human body, by dense skin, which, even when dry, is impervious to the air; by the fat lying under it; by the narrowness of the absorbent vessels, and by the equability of the resistance. We must investigate why the air enters the lungs, which in an adult are always filled with air, and therefore resist the pressure of the whole atmosphere with an equivalent force. That the lungs always contain air, is evident; because, however you compress them, they are still lighter than water; and even after they have been inflated but a few times, they always swim; whereas, in the foetus, before air has been admitted into them, they sink to the bottom.

CCXLIX. On the equilibrium being destroyed, the air invariably descends in every direction to that place where it meets with least resistance (CCXLVII.) But air that is dense and heavy descends more easily than that which is light, whose force scarcely exceeds that of the air in the lungs, nor is able by the same force to overcome the resistance of the bronchia, and of the force by which the air contained in the lungs is compressed. Hence an animal lives with greater ease in a dense than in a light atmosphere: although that air is always better tolerated,  
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which is pure in proportion to its levity ; such as that of the highest mountains of the Alps. Therefore, that the air may enter the lungs, they must make a less resistance to it than before ; namely, the air, which is already in the cellular fabric of the lungs, must be rarefied : but this effect will be produced, if the cavity of the breast, which is filled by the lungs, be dilated. The air, which is always in the lungs, expands into this increased space, by which, being weakened in its spring, it makes less resistance to the external air ; consequently a portion of external air descends into the lungs, sufficient to restore to the air, now contained in the lungs, the same density with that of the external air.

CCL. We must, therefore, describe the powers which dilate the breast. The breast or thorax is composed of bones, muscles, and cartilages ; being almost of the shape of an elliptic barrel, somewhat compressed before, but behind divided by an eminence, whose hoops are the ribs, and of remarkable strength. In the lateral parts of this structure, the lungs are situated ; the central and lower parts contain first the pericardium, and then some of the abdominal viscera.

CCLI. The basis of the thorax is formed by a column, a little curved, at the upper part gibbous backwards, so that its summit is situated most behind. To this twelve vertebræ are affixed. But they also coalesce, by the union of their bodies into a single column, which projects forwards between the two cavities of the breast ; divides the right from the left ; and is plain in the forepart, and broad towards the sides. A slight sinuosity receives the ribs into that place where the arch separates from the body. They are bound together into one column, both by the elastic plate interposed between the bodies of every two, and coalescing with both ; and by other ligaments and spines lying upon  
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on one another, and by the junction of the ribs ; on which accounts they scarcely admit of motion amongst themselves. The sides of the breast are formed of twelve ribs. These are in general bent in the form of an irregular arch, having a considerable curvature laterally and backwards, but extending in their forepart towards a right line. The bony parts of the ribs are, however, parallel with each other. The greatest part of the rib is bony ; of which the posterior portion is round and thick, and the anterior thin and flat. The anterior remaining part of the rib consists of a cartilage ; which in general preserves the figure of the rib, broad, flat, adhering to an irregular hollow of the bony part ; and which does not change into bone, unless in extreme old age.

CCLII. The posterior, bony, and thick part of each rib terminates in a head. These are inserted into pits scooped out of the bodies of the uppermost and two lowermost vertebræ, and in the contiguous margins of each of the other two. The vertebræ are tied to the ribs by strong ligaments, of which the principal is distributed upon each adjacent vertebra, in a radiated manner from each rib ; other ligaments tie the transverse process to the tubercle of the rib, and others connect the contiguous ribs, and also the transverse processes, with each other. Moreover, between the angle of incurvation and the articulation with the vertebræ, each of the ten upper ribs has a tubercle, which, being connected with the plain side of the transverse process of the corresponding vertebra, are tied by short and strong ligaments to that process, in such a manner, that, while the juncture is very strong, the rib can ascend and descend for a short way.

CCLIII. Of the anterior cartilages, the seven uppermost reach to the sternum, and strengthened by short ligaments, they enter with a double head into lateral depressions in that bone, which are incrustated with cartilage.

cartilage. Of the five remaining ribs, the uppermost is agglutinated by strong cellular substance to the seventh, and each lower one to the one immediately above it, so that they form a continuous margin, which is itself fastened to the sternum. The cartilages are connected with each other both by proper ligaments, and by cartilaginous appendages joined by cellular substance: the two lowermost are free, and connected only with the muscles. These inferior cartilages are united to one another and to the sternum by strong ligaments.

CCLIV. The first rib is the shortest and most solid. As they follow in succession to the seventh and eighth, every two of them form larger and more moveable circles. The eighth is the longest of all; and below it, they always become shorter, the lower they are.

CCLV. The upper rib descends; the second joins the sternum almost at a right angle, while the others ascend both to the vertebræ and to the sternum, but more to the latter. The bony part of the ribs is placed in such a direction, that the uppermost have their anterior surface declined forwards, almost transversely. About the third rib it is placed almost perpendicularly; and below the middle ones, it projects a little forwards. Besides, the strength of the ribs is very different. The uppermost, being short, transverse, rather united than articulated with the sternum, and, lastly, often consolidated, make the greatest resistance. The mobility of the lower ribs increases successively to the lowest, which, adhering only to muscles, moves most freely of all.

CCLVI. The sternum in general is a thin spongy bone, in adults of a single piece, but in the fœtus variously multiply. Its upper part is broader, octagonal, and supported by the clavicles, which are united with it by a triangular head, and very strong articulation, and by the first rib on each side.

The next part which is longer and narrower, grows broader downwards, and its sides receive the ribs into proper angular cavities. The lower part, which is less and shorter, is obtusely shaped like a tongue. This is continued into a detached appendage, partly bony, and partly cartilaginous, which is called the ensiform cartilage; of various shapes, being sometimes obtuse like a little tongue, sometimes pointed, sometimes bifid, and sometimes perforated.

CCLVII. In order, therefore, to dilate the seat of the lungs, and thus to produce that condition which causes the external air to descend into the lungs, the thorax must be elevated. For thus all the sections of the thorax form right angles, and its capacity is increased. This motion is performed by various muscles, which either operate constantly, or only at certain times. The whole of the intercostal muscles, always elevate the ribs. Under this name we comprehend 22 muscles; of which 11 are external or subcutaneous; and as many internal, separated from the pleura only by fat and cellular substance. The origin of the external intercostals is at the posterior articulation of the ribs (CCLII.) their anterior termination is in the bony part of each rib, at some distance from the cartilage, so that the remaining space between the cartilages, all the way to the sternum, in place of the muscles, is filled with an aponeurosis. Their direction is such, that they descend obliquely forwards, from the lower edge of the upper rib to the upper edge of the lower rib. Almost all authors agree, that they elevate the ribs; because they descend from the upper and more fixed, to the lower and more moveable rib, in such a manner, that their lower point lies more distant from the vertebral articulation, or fulcrum of the lever of the ribs.

CCLVIII. But the internal intercostals arise at some distance from the vertebræ, near the outside of the tubercles (CCLII.) From thence they proceed as far as the sternum, into which the first of this kind are inserted above. Except the anterior part of the first internal muscles, their direction is contrary to that of the former ; so that they descend backwards, from the lower margin of the upper rib, to the upper edge of the lower rib. Therefore their action is disputed, because their lower insertion is made into a point of the rib, nearer its articulation with the vertebræ, which, therefore, seems to be the least moveable : however, they elevate the ribs notwithstanding this ; for the immobility of the upper rib, arising from its articulation, weight, and ligaments, far exceeds the mobility produced by its greater distance from the fulcrum. This is proved by the dissection of living animals ; in which it appears, that the internal muscles act during the elevation of the ribs, and rest when they are depressed ; by threads fixed to a flexible human skeleton, and drawn in the direction of the internal intercostal muscles, which always and invariably raise the inferior rib towards the superior ; and by the firmness of the upper ribs, which serve as a fixed point to the lower ones : for the first ribs are from eight to twelve times less moveable than the other true ribs ; while the difference of distance from the centre of motion, is scarcely the twentieth part of the whole lever. And lastly, by experiment on the dead subject ; for, on raising its thorax, the internal intercostals swell.

CCLIX. By the action, therefore, of these muscles, the thorax is elevated, not altogether as one machine, nor would respiration be assisted by such a motion ; but the ribs, turning upon their articulations, behind are but little moved, while with their anterior extremities, they descend and form larger angles both with the sternum and vertebræ ;

and in the middle of their arches, they ascend and raise their lower edges forwards. At the same time, the sternum is thrust forward from the vertebræ and from the junctures with the ribs. Thus the ribs are both farther from the vertebræ, and the right ribs recede from the left; and both diameters, from the right to the left, and from the sternum to the vertebræ, are increased by almost two lines each; and as this occurs in every imaginable section of the thorax, the cavity of the breast will be sufficiently dilated. This happens especially in women, and in men whose breathing is somewhat laborious. These effects are produced least of all by the first ribs, but more by the succeeding ones. In strong inspirations, the ribs descend both behind and before, and, along with these, the sternum; and the spaces between the cartilages are lessened. But this dilatation is neither sufficient for healthy respiration, nor is it almost observable in men; although even then, the intercostal muscles, by retaining and elevating the ribs, very much assist the inspiration in a secondary way, by affording a fixed point to the diaphragm, so that the whole force of that muscle may be spent, not in depressing the ribs, but in lowering itself. The greater part, therefore, of the space which the thorax gains in inspiration, arises from the action of the diaphragm.

CCLX. By the diaphragm we understand a muscle expanded in a curvilinear plate, which, in general, separates the pulmonary bags from the abdomen in such a manner, that the middle and tendinous part is the highest, and supports the pericardium; that the lateral portions, which arise from the solid parts of the thorax and loins, are every where lower; and that its posterior portions are lowest of all. The fleshy fibres of this muscle arise from the internal or posterior surface of the ensiform cartilage to the very point, and from the sixth, seventh, eighth, ninth, tenth, eleventh ribs, and

and apex of the twelfth ; after which follows an interval, in which the naked pleura is contiguous to the peritonæum. Thereafter muscular appendages of the diaphragm, much stronger, collected into two, three, or four round muscles on each side, arise fleshy from the transverse process of the first lumbar vertebra, and from the side of the body of the second ; and tendinous from the middle of the body of the second, third, and fourth, and from the cartilages placed between them, on the whole higher up in the left side, and lower down in the right.

CCLXI. All these fibres (CCLX.) becoming tendinous, form the centre of the diaphragm, which resembles, in figure, an obtuse gnomon, and supports the pericardium with its middle and broader angle, while the lateral wings, of which the left is narrower, descend backwards. This central portion is more moveable than the rest ; but in the middle tendinous part, and neighbouring muscular substance, it is resisted by the heart ; the lateral wings and contiguous portions are the most moveable. The fibres of this tendon form a most beautiful web, principally indeed on the upper part ; which stretches from each muscular portion, to the muscular portion opposite to it : and then they form remarkable inferior fasciculi, transverse, right, left, and posterior, which last portion is the uppermost.

CCLXII. There are two holes in the diaphragm ; of which the right, in the right side of its tendon, is obtusely square, and circumscribed by four strong tendinous fasciculi ; the left, which is elliptical, lies betwixt the right and left fleshy portions, arising from the middle of the bodies of the lumbar vertebræ : under this opening they decussate and cross each other once and again, but above they end in the tendon. Therefore it is probable that the latter is contracted during the action of the diaphragm, and that the former remains immovable.

able. For tendons are but little changed during muscular motion.

CCLXIII. The structure of the parts, and the dissection of living animals, demonstrate, that the fleshy portions of the diaphragm, by ascending on all sides from fixed points to middle and moveable parts, depress these, and by that means draw downward the lateral bags (LXXVII.) of the thorax, which contain the lungs; and thus augment the perpendicular diameter of the breast. The muscular portions are more depressed; the tendon less, both because it is fixed to the pericardium, and because its own substance does not contract. The œsophagus and even the vena cava are compressed, while the diaphragm acts. The diaphragm almost alone performs the office of respiration in a healthy man who is at rest; and also in those whose ribs are fractured, or the sternum burst, or where the person will not make use of his ribs on account of pain. The force of the diaphragm also, in dilating the breast, is greater, according to calculation, than all the rest of the powers which contribute to respiration. The extent of an inspiration is thus far limited, because, during the extreme action of the diaphragm, the lower ribs are drawn inwards, and the breast is so far straitened. To oppose this, the intercostal muscles interfere in a moderate inspiration; in an excessive one they are not equal to the diaphragm. The phrenic nerve, when irritated, more evidently than in most other muscles, forces the diaphragm to perform its office. The lungs themselves are entirely governed by the air, ribs, and diaphragm; being in immediate contact with these, as appears through a large incision, or through the pleura, or pellucid part of the diaphragm, when the containing parts remain entire.

CCLXIV. In violent inspirations, occasioned by an increased quantity of blood driven into the lungs,

lungs, or by any obstacle occurring in them, several other powers elevating the thorax, assist in dilating the breast, which are inserted into the thorax, clavicles, or scapulæ; such as the *scaleni* muscles, *maстоidei*, *trapezii*, *cervicales descendentes*, *serrati superiores*, *pectorales*, and *levatores parvi*, for which anatomy must be consulted.

CCLXV. Thus, there are powers which increase the capacity of the thorax in all its three dimensions (CCLXIII. and CCLIX.) By these the cavity of the breast is dilated, so that it compresses the lungs less than before: into that space the lungs strive to extend themselves, since they are never destitute of air, which, as soon as the pressure is taken off, becomes rarefied, and expands itself. Independent of the action of the muscles, the lungs possess no peculiar inherent power of attracting air: and, even when they are most full of air, on closing the trachea, the animal, however, attempts to inspire, by the efforts of its intercostal muscles and diaphragm. It follows, that the air (CCXLVII.) gravitating, and pressed on all sides by the incumbent columns of the atmosphere, must enter the thorax; and with greater force the less air is in the lungs; and with the greatest, if they contain no air: but air will not enter the thorax, if the air, being admitted to the lungs through a wound in the breast, compress their surface. In this action, therefore, which is called inspiration, the bronchia are every way increased, both in length and breadth; because all the diameters of the thorax are increased, and the inflated lungs remain immediately contiguous to the pleura. At the same time, the vessels, which are joined with the bronchia by a cellular sheath, become longer and are extended, and the small angles become larger; by which means, the circulation is facilitated. Besides, when the vesicular substance of the lungs is filled with air, the space through which the capillary

lary vessels of the lungs run, is increased, the branches of the arteries and veins are stretched out at greater angles, the lobes press less upon each other, the compression of the neighbouring parts is lessened, and, therefore, the blood sent from the heart will flow with greater ease and celerity through the large and small arteries of the lungs. Hence, by inflating the lungs, and by that means facilitating the passage of the blood to the left ventricle, moribund animals are resuscitated, and in the same way persons who are taken out of the water apparently drowned. But, on account of its great levity, the pressure of the air upon the blood does not deserve notice, as being three hundred times less than the force of the heart; and insufficient to force the air against the blood, which may easily be done by a syphon.

ECLXVI. Is air contained between the lungs and the thorax? Is this air rarefied in inspiration, and afterwards becoming condensed, and compressing the lungs, does it cause expiration? Is this opinion confirmed by the analogy of birds, of which it is strictly true? Every thing concurs to confute this opinion: behind the pleura, in living quadrupeds, as well as in dead human bodies, the naked lungs are visible, without any intermediate space betwixt them: on perforating the pleura, the lungs retract themselves towards the vertebræ, as soon as the air comes in contact with them. In birds, the lungs, being pervious, admit the air through large holes into the cavity of the thorax. But in these there is a manifest space betwixt the lungs and the pleura, which would be equally manifest in quadrupeds, if the lungs were not contiguous with the pleura. Large wounds, admitting the air into one cavity of the thorax only, diminish the respiration; but such wounds, as let the air into both cavities, suppress it. When the thorax is opened under water, it emits no bubbles of air through the said water;

water ; but in birds, in whose thorax there is air, it does. The imaginable space betwixt the lungs and the thorax is filled by vapour, or a very little water. Adhesions of the lungs injure the respiration but in a small degree ; which ought entirely to cease, if any intermediate air betwixt the lungs and thorax were necessary to respiration. Finally, the external air, being admitted to any of the membranes of the human body, inflames them, if they be not defended by plentiful mucus, and of this the pleura is destitute.

CCLXVII. Respiration, whether by the admixture of a subputrid vapour, or in some other way, certainly vitiates the air, and renders it unfit either for inflating the lungs or supporting flame ; and lastly, it deprives that element of its elasticity. It is probable that this happens from putrefaction, since, by a crowd of men the air is rendered pestilential, and fevers of the most malignant kind are generated in a few hours. In whatever way it happens, we are certain, that, in the lungs, the air is vitiated ; loses its elasticity ; and cannot keep the lungs distended, so as to transmit the quantity of blood now increased by the dilatation of the pulmonary arteries, into the veins. Nor can the will dilate the breast beyond certain bounds, or assist the passage of the blood. A state therefore will take place, in which the blood cannot pass through the lungs.

CCLXVIII. Thus a new resistance to the blood continually coming from the heart is generated : and in long retentions of the breath, as in making violent efforts, the venous blood, especially of the head, stagnates before the right ventricle of the heart, which is closed up, because it cannot evacuate itself into the lungs ; and tumefies the face with redness, and sometimes bursts the veins of the brain, neck, intestines, kidneys, or lungs, and even the right auricle of the heart. This is the cause of  
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excessive anxiety of mind ; this is the cause of death in compressed air, in persons drowned or strangled, which is much more sudden than is commonly imagined with regard to drowned people. A living person therefore, that he may remove those inconveniencies which arise from the passage of the blood being obstructed, slackens the powers of inspiration, and excites to action those of expiration, in order to free the breast from the too greatly rarefied air.

CCLXIX. These powers are, first, the elasticity of the ribs, which being drawn upwards out of their natural situation, as soon as the elevating powers cease to act, spontaneously replace themselves at more acute angles with the sternum and vertebræ. There is also the elastic force of the bronchia and vesicles distended with air, by which they endeavour to contract. Hence expiration is performed more easily and quickly than inspiration ; and hence it is the last action of dying people.

CCLXX. These are assisted by the abdominal muscles ; the oblique, straight and transverse. The former of these are fastened by one part to the lower ribs ; and by another part, they are attached to the os pubis and ilium, which are immoveable, when compared with the breast. Therefore, the straight muscles, being contracted, flatten the arch into which the abdominal viscera were protruded by the depression of the diaphragm, reduce the convexity of the abdomen nearer to a straight line ; force the abdominal viscera upwards and backwards against the diaphragm, which alone can give way ; and press it up into the thorax, which is thus rendered shorter. The oblique muscles, for the same reasons, compress the lateral parts of the abdomen, carry the liver and stomach backwards, and press them towards that place where there is the least resistance. Lastly, all of them draw down the ribs which were elevated by the intercostals. The  
transverse

transverse muscles, indeed, do not draw down the ribs; but they pull the cartilages of the false ribs a little inwards, render the whole abdomen much narrower, and force the same viscera against the diaphragm. As accessory powers may be reckoned the sternocostal, and the long internal intercostal muscles, which are called depressors. By this joint force the elevated ribs descend; the middle ones more, the uppermost less, the lowest most of all; their margins are drawn inwards: the cartilages ascend, and return into acute angles with the sternum; and the sternum itself recedes backwards with the ribs. By these means the thorax, by the converse of CCLIX. is rendered narrower in every direction and shorter, and expels as much air out of the lungs as is sufficient to remove the uneasiness (CCLXVIII.)

CCLXXI. In violent respiration, when the inspirations are fuller, the more powerful expirations derive assistance from some other causes, as the sacrolumbalis, longissimus and quadratus muscles. By this force, leaden bullets, weighing above a dram, may be blown to the distance of 363 feet; which force is equal to a third part of the pressure of the atmosphere. But, in a healthy person, the muscles of the abdomen alone suffice, and the lungs are not so much emptied as in blowing.

CCLXXII. The effects of expiration are the compression of the blood-vessels of the lungs; the diminution of the angles of the bronchia; the resting the weight of the adjacent vessels on the reticular vessels; the expulsion of the corrupted air from the lungs; the propulsion through the veins of that part of the blood which is impacted in the capillary arteries, to the left side of the heart, and the impeding that part of the blood which is coming from the right ventricle. Expiration, therefore, stops the ready entrance of the blood into the lungs; and as the whole thorax is compressed at the same time,

time, it repels the venous blood into the veins of the head, and fills the brain and its sinuses.

CCLXXIII. In this manner the necessity for respiration arises anew, as often as the collapsed vessels of the lungs resist the blood expelled from the right ventricle of the heart: this is one cause of death in those animals which expire in vessels exhausted of air. The lungs in those which have remained long in vacuo, from having the air drawn out from them, become dense, solid, and heavier than water; and, therefore, impervious to the blood. Of the same kind is the death of those who are killed by lightning, and perhaps by the noxious vapours of caverns. Therefore, in consequence of a most intelligent structure, at the first perception of the uneasiness arising from the opposition to the passage of the blood through the lungs, the expiring powers become relaxed, the inspiring powers are excited into action, and the motion of the blood through the lungs is rendered free and accelerated.

CCLXXIV. Are there other causes of alternate respiration? Is any thing to be derived from the compression of the vena sine pari, of the phrenic nerve, or from the blood not being sent to the brain? But these are disproved by comparative anatomy; which, where there is no such nerve or vein, finds the same alteration in respiration every where. Does it proceed from the alternate contraction of antagonist muscles, among which, those of expiration relax those of inspiration, and the reverse? But, according to this argument, all the muscles of the human body would be perpetually alternating in their motions.

CCLXXV. From what has been said, it sufficiently appears, that respiration is absolutely necessary to a healthy adult; because, whether the lungs remain long in a state either of expiration or of inspiration (CCLXXIII. CCLXXVIII.) death will be the consequence.

consequence. Therefore, no animal, that has lungs like ourselves, after it has breathed for some time, so that the air shall have penetrated into the inmost parts of the lungs, and the pulmonary artery shall have brought a new quantity of blood to that viscus, can subsist longer than a few minutes without the use of air, without perishing, or at least falling into a state which differs from death only in the possibility of recovery. In an animal recently born, this necessity for air does not take place very instantaneously.

CCLXXVI. But the use of respiration is different from this necessity; which nature might have avoided, either by forming no lungs at all, or by constructing them similar to those of the foetus. The use, therefore, of respiration, must be very considerable, since all animals are furnished either with lungs, or with gills, or with a windpipe distributed through all parts of the body.

CCLXXVII. To investigate this utility, let us compare the blood of the adult with that of the foetus, and with the vital fluid in fishes. It appears, that in the foetus the blood is destitute of its florid redness and solid density; that the blood of fish is cold, and has less density, and a tender crassamentum. It is therefore probable, that the blood acquires both these properties in the lungs.

CCLXXVIII. Is animal heat generated principally in the lungs? Does it arise from the alternate extension and contraction, relaxation and compression, of the vessels (CCLXV. and CCLXXII.) by which the solid parts of the blood are perpetually rubbed together, and suffer attrition from their constriction? The lungs, therefore, will add to the office of the rest of the arteries, because in them the blood is alternately relaxed and compressed more than in any other part of the body. But when the lungs are obstructed, ulcerated, and almost destroyed, morbid heat is increased in the human body: and in the  
lungs,

lungs, the cold air comes most nearly in contact with the blood.

CCLXXIX. The density is, indeed, promoted by the copious discharge of watery vapour from the vessels of the lungs, by which the rest of the mass becomes specifically heavier. In the same manner as in other arteries, the blood, being alternately retarded and accelerated, is figured by the moulds of the ultimate arteries, becomes spherical, and therefore denser, having more ponderous globules, and less light fluid. The pulmonary vein also being smaller than its corresponding artery, is of considerable use in compressing the globules, and in increasing their attraction. Nevertheless, cold animals, with very small lungs, have dense and coagulable blood; as also the chick in ovo. The course of the blood through the lungs is shorter: through the whole body the course is longer, and the artery weaker; the ventricle, by which the blood is propelled, is also weaker.

CCLXXX. Is the air itself received into the blood in the lungs, and does it there produce necessary vibrations? Is this demonstrated from the resistance of the body to the weight of the external air; from the air found in the blood-vessels, in the cellular substance, and in the cavities of the human body; from the cracking produced by extending the joints; from air being manifestly poured from the trachea into the hearts of many animals, as the locust; from the escape of air from the blood and animal fluids in Mr. Boyle's vacuum; from the necessity of a vital oscillation in the blood; and from the increased redness of the pulmonary blood?

CCLXXXI. That no elastic air is here received into the blood, is demonstrated from its not being able to enter into the blood, if it retain its elasticity; from the inutility of its reception, if its elasticity be lost in the blood; from the perfect immutability of the blood by cold; from the minuteness  
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of the inhaling vessels ; from the sides of the vesicles being perpetually covered with mucus ; from the elastic nature of air being unfit to pass through capillary vessels ; and from its repulsion by water, that hinders it from passing through moistened paper, linen, or leather. Again, air thrown into the trachea never passes into the heart ; or only when it is driven with excessive force. In the vessels and humours of the human body, air, from a state of inelasticity, becomes elastic in consequence of putrefaction, frost, or an external vacuum. But such air exists in every liquid, and is taken into our bodies with the aliments, and with vapours, mixing slowly and difficultly. There never were any elastic bubbles of air observed in the blood of a living animal, unless after wounds ; air being inflated into the blood-vessels of any animal, kills it certainly and speedily. Nor is there any thing sufficiently certain in the increased redness of the blood in the pulmonary veins. Lastly, air indeed is absorbed by most fluids, and by water, but slowly, and only at the end of several days after the former air has been exhausted by the pump. It then likewise lays aside its elastic nature ; and no reason has been advanced why the air should either be more speedily absorbed by the blood, or why it should retain its elasticity after its absorption.

cclxxxii. Is the blood cooled in the lungs ? Is this proved from the death of animals in air heated to the same degree with the animal, as is believed to have happened from very sultry summer weather, and scorching east winds ? Are the pulmonary veins, therefore, less than the arteries ? Does the desire of cold in hard working people arise from thence ? That the blood is cooled in the lungs, is thus far true, that it warms the contiguous air, and therefore imparts to it something of its own heat. But that this was not the design of nature, is evident ; since no one has said, that the venous blood  
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is hotter than the arterial, although some assert that it is colder ; and nobody ever observed the left ventricle of the heart colder than the right. But the venous blood enters the lungs. If it be cooled there, it follows that the arteries must receive it still colder. Therefore, the blood recovers that heat which it lost, and even more : and besides, a person may live in an air much hotter than the blood itself, of which we have a familiar example in baths, and warm climates. The size of the pulmonary artery in the foetus, which does not respire, is greater ; and the larger area of the right auricle and ventricle of the heart, which is likewise much greater in the foetus, seems to be a receptacle subservient to frequently necessary retardations, and the narrowness of the vein contributes to the acceleration of the blood.

CCLXXXIII. Does the blood derive its redness from the air ? This is contradicted by what we see in cold animals, which, though they make almost no use of the air, have blood equally red with that of warm animals ; by the certain connection of redness in the blood of frogs, with their having plenty of food, and of paleness with want of food ; and by the air, as we have just now said, having no access to the blood. Nevertheless, redness is produced, and restored to the blood by the contact of air, and is destroyed by its removal. Does some subtle element from the air penetrate the blood, and cause its colour, as light is required for the colours of plants ?

CCLXXXIV. Is the use of the lungs, to absorb nitre from the air to the blood ? Is this the cause of the florid colour, observable on the surface of a cake of blood, while the bottom part is black. Does this preserve the animal from putrefaction ? It is certain, that some volatile principle of acidity exists in the air, which, with a suitable earth, forms nitre ; for nitrous earth, after being exhausted,  
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when exposed again to the air, becomes reimpregnated with nitre. But the same principle of acidity, we know by certain experiments, with different earths, forms a vitriolic salt, or alum, or sea-salt. For the caput mortuum of sea-salt, which remains after the distillation of the acid, recovers from the air the property of furnishing more acid by distillation; and in snow, there is cubical salt: from marcasites, true vitriol exudes; and colcothar recovers the acid, which was drawn from it, and alkali becomes vitriolated tartar. Is this, therefore, the use of respiration? The quantity of these salts, which exists in the air, is too small; and respiration is most salutary on the highest mountains, where they are most rare; nor have any marks of a nitrous salt ever been detected in our blood.

CCLXXXVI. Why do tortoises, frogs, lizards, snails, earwigs, and many other insects, live long without air? In them, the lungs are given, not so much for the preparation of the blood, of which they have but a small quantity, as for assisting them in swimming; hence their lungs are supplied with veins from the cava, and with arteries from the aorta. Insects inhale and exhale air, through points in the skin. Why do all animals, however small, such as little birds, perish in air that is not renewed? Because the air, which has once entered the lungs, is contaminated by inelastic, watery, and alkaline vapours, and therefore it becomes noxious: not because it becomes lighter; for the mercury falls but little in air, which has not been renewed, and which has killed an animal. Hence, on the other hand, animals survive longer in air which is more compressed than that of the atmosphere: for in that case, the proportion of the elastic element is greater, and therefore the air is more slowly contaminated. But, even in other cases, confined air becomes deleterious, and filled with vapours, by stagnation alone. Why do animals swell in an exhausted receiver?

ceiver? From the expansion of the air, which existed in an inelastic state in the blood.

CCLXXXVII. There is a certain connexion between the pulse and respiration. According to the common course of nature, three or four pulsations are reckoned to one respiration. If the quantity of blood sent to the heart be increased, the frequency, both of the pulse and respiration, are increased. This is the reason of the panting in a person, taking exercise, which accelerates the motion of the venous blood (CXLII.) If the blood meet with much resistance in the lungs, and do not pass freely from the right into the left ventricle of the heart; to accelerate its course, both the number and magnitude of the respirations are increased. This is the cause of sighing, yawning, and panting; of which the first is a deep inspiration; the second slow, and very great; and the third, frequent and imperfect. The number of respirations, however, does not always increase with the pulse; of which we have an example in fevers, in which the lungs are not affected.

CCLXXXVIII. The mucus, which lines the sensible membrane of the bronchia, may become troublesome, both by its quantity and acrimony; it has been even known to cause suffocation in a dropy of the lungs. Therefore, its superabundance, adhesion, or acrimony, is removed by coughing; namely, by irritating the respirative system, the mucus or concretions are loosened and expelled by large inspirations, and expirations, alternately succeeding each other with rapidity, and by strokes of the abdominal muscles.

CCLXXXIX. Laughter differs from coughing in its cause, which resides commonly in the mind, or at least consists in the titillation of some of the cutaneous nerves; and also, because, after one deep inspiration, there are frequent but imperfect expirations, through the contracted glottis, and the air is  
not

not totally evacuated from the lungs. Hence laughter, in a moderate degree, conduces to health ; because, in place of one full inspiration, several inspirations and expirations happen in the same time, and thus the concussion is greater. Hence its danger, from stagnation of the blood ; because the expiration is not full, and therefore the blood is admitted into the pulmonary artery, but is not suffered to pass through it. Weeping begins with a deep inspiration, after which follow short alternate inspirations and expirations ; and it is finished with a deep expiration, which is immediately followed by an inspiration : hence it has nearly the same good and bad effects ; and, when moderate, it relieves the distress arising from grief. Hiccough is a very great, sonorous, and sudden inspiration. Sneezing consists of one deep inspiration, succeeded by a single powerful expiration ; and by the torrent excited, the acrid matter, irritating the nostrils, is blown away.

ccxc. The secondary uses of respiration are very numerous. It exhales copiously, and removes from the blood something highly noxious ; for by remaining in the air, it will cause suffocation ; and the breath of many people, crowded in a close and small place, impregnates the air with a suffocating quality. On the other hand, it absorbs from the air a thin vapour, of which the use is perhaps not sufficiently known. It is also a force, which perpetually compresses the abdomen, and all its viscera ; it evacuates the stomach, intestines, gall bladder, receptacle of the chyle, urinary bladder, intestinum rectum, and the womb ; it comminutes the aliments, and forces the blood through the liver, spleen, and mesentery. It causes a kind of flux and reflux in the blood, so that it is alternately pressed back towards the extremities of the veins, and a little after is propelled towards the heart by an accelerated velocity, as into an empty space. Moreover, inspi-

ration

ration attracts the odoriferous particles from the air, and conveys them to the sensorium. But even sucking, so necessary to the new born infant, is effected by inspiration, and by forming a larger space, in which the air contained in the mouth is rarefied, so that the pressure of the external air forces the milk into that part where it is least resisted. Lastly, the voice itself depends upon the air, and seems to be the principal manifest effect of respiration. This, therefore, appears a proper opportunity for describing it.

## C H A P. IX.

## VOICE AND SPEECH.

CCXCI. **T**HE principal organ of the voice is the larynx; for, when it is injured, the air passes through the windpipe, without yielding any sound. By the larynx, we understand an assemblage of cartilages, joined into a hollow machine, which receives the air from the fauces, and transmits it into the windpipe, connected with it by ligaments and muscular fibres. Among the larger of these cartilages, the annular and scutiform in adults ossify internally. The anterior and larger part of the larynx, which lies almost immediately under the skin, is composed of two cartilages; the thyroid and cricoid, to which the lateral parts of the larynx also belong in such a manner, that the portions of the cricoid cartilage always become larger, as they are higher seated. The back part of the larynx is composed first of the said annular cartilage, and afterwards of the arytenoid cartilages, connected by muscles. The epiglottis, loosely connected with the thyroid cartilage, is either raised or inclined over the larynx. The vessels arise from the upper and lower thyroids; the nerves are numerous;

merous; the inferior ones come from the recurren-  
ents; the superior ones from the eighth pair, inos-  
culating in various ways; some also from the inter-  
costal. The former of these nerves is remarkable  
for its origin in the thorax; for its reflection round  
the aorta and right subclavian; for its giving rise  
to some of the nerves of the heart, and for the ex-  
periment, which proves, that the voice is destroyed,  
by tying this nerve.

CCXCII. All these cartilages are connected togeth-  
er by various muscles and ligaments, so that the  
whole may possess mobility, while some of its parts  
are firm, and others extremely moveable. The  
scutiform or thyroid cartilage, situated on the fore-  
part, is composed of two, almost quadrangular  
plates, inclined to each other in an obtuse angle,  
projecting forwards. In these plates, two apertures,  
one on each side for the internal vessels of the  
larynx, are found sometimes, though rarely. The  
upper processes of this cartilage, terminating in a  
thick point, inclining upwards and backwards, are  
connected with the horns of the os hyoides, by  
strong ligaments, sometimes mixed with bone. The  
lower processes are shorter, are adapted to the slight-  
ly hollowed, and almost flat surfaces of the cricoid  
cartilage; and are connected by a very firm artic-  
ulation, on account of the shortness and strength  
of the cellular substance, which unites them. The  
middle anterior part is joined by strong perforated  
ligaments, to the middle of the annular cartilage;  
and likewise by other superior ligaments, proceed-  
ing from the descending horn of the scutiform  
cartilage, to the upper part of the annular carti-  
lage.

CCXCIII. The cricoid cartilage, anteriorly thick  
and hard, is increased backwards, in form of a ring  
unequally truncated; and, in the middle, it is di-  
vided into two cavities by a protuberant line. It  
is firmer than the rest of the cartilages, and forms  
their

their basis. From it longitudinal muscular fibres and ligaments descend to the windpipe (ccxxxviii.) The pharynx connected with each of these cartilages by many muscular layers, receives the larynx into its cavity. From this cartilage a short ligament proceeds to the arytenoid cartilage on each side.

ccxciv. The figure of the two arytenoid cartilages is very complex. It spontaneously divides into two parts, of which the lower is larger, and is connected by a moderately concave base with the thick cricoid cartilage, forming a moveable articulation. It sends a process forwards, which separates the glottis, and sustains the inferior part of the ventricle of the larynx. They ascend upwards, of a triangular figure: the posterior base is hollow, and the anterior side is convex, and divided by three furrows. They are extenuated upwards, till they are at last terminated by a pretty thick, oval, cartilaginous head fixed on them. The lower part of these cartilages is connected by numerous muscular fibres, partly transverse, and partly oblique; of which the different directions are evident, though they cannot be separated. These are called the arytenoid muscles. In their upper part, the arytenoid cartilages are separated by a perpendicular chink, which has been improperly by some called the glottis.

ccxcv. The arytenoid cartilages are connected with the thyroid by transverse ligaments, for the most part sufficiently strong and elastic, but covered with the common mucous membrane of the larynx. These ligaments arise below the middle of the arytenoid cartilages, and are inserted into the flat angle of the thyroid cartilage (ccxcii.) and may be separated from each other, by removing the arytenoid cartilages from being in mutual contact, and may be again brought into contiguity by the  
cartilages

cartilages approaching each other. This constitutes the true glottis, and is continuous, but at right angles with the above mentioned chink (ccxciv.)

ccxcvi. From the same angle of the thyroid cartilage, under a notch, from a firm ligament, a cartilage arises, with an erect slender stalk, of an oval shape, convex before, behind concave, and with its superior extremity reflected backwards and concave. It is kept erect by its own elasticity, so that it rises upright behind the tongue; but it can be so inclined whenever the root of the tongue is pressed backward, that, having become transverse, it completely shuts up and protects the passage into the larynx, which descends between this, the epiglottis, and the arytenoid cartilages. The epiglottis is joined to the tongue by pale membranous fibres, and to the os hyoides by much membranous expansion. It either has no fibres from the thyroarytenoidal and arytenoidal muscles, or they are too minute to counteract its elasticity.

ccxcvii. At the sides of the ligaments of the glottis (ccxcv.) two other upper and softer ligaments, less tendinous or elastic, proceed parallel from each arytenoid cartilage to the thyroid. Betwixt these two (ccxcvii. and ccxcv.) ligaments of each side, a peculiar cavity or ventricle descends, having the figure of a compressed parabolic space, extending downwards betwixt the double membrane of the larynx, with its superior orifice, of an elliptic form, constantly open into the larynx.

ccxcviii. Lastly, all the internal cavity of the larynx is lined with the same soft, irritable, mucous membrane, we before described in the windpipe (ccxxxix.) This membrane is moistened by a great number of glands. The uppermost are small, and composed of simple glands (ccviii.) They are seated on the anterior convex part of the epiglottis, and send prolongations through its various perforations and larger sinuses, to its concave side, which

which are there continued into similar firm glands. Moreover, upon the anterior furrowed surface of the arytenoid cartilages (ccxciv.) there is on each side a gland, of a loose conglomerate fabric, resembling much a gnomon, composed of round acini, doubtless mucous, of which a loose portion descends on each side as far as the annular cartilage. In the ventricles, there are numerous mucous sinuses. Lastly, all the internal surface of the larynx is full of large mucous pores. All these glands secrete a thin and watery, but at the same time, viscid mucus.

ccxcix. Has the thyroid gland any similar use? It is of the conglomerate kind, but soft, the coverings of the lobules being much more tender than in the salival glands, it is very large, is anteriorly seated upon the thyroid and cricoid cartilages and windpipe, surrounding with lateral productions the sides of the thyroid, is joined to its companion by an isthmus, which is narrow and emarginated below; and by a middle very thin process it ascends on the forepart, almost to the os hyoides. This gland is full of a serous, yellowish, and somewhat viscid humour: Does it discharge this fluid into the windpipe, or into the œsophagus? Into neither are ducts certainly known to open. Does it retain its fluid entirely, and afterwards restore it to the veins, like the thymus, which is analogous in its structure? Is it a conglobate gland? That the use of this gland is very considerable, appears from the remarkable size of the arteries which it receives from the carotids, and of its inferior ones from the subclavians. The veins return into the jugulars and subclavians. It has a peculiar muscle, not however constant, arising from the margin of the os hyoides, and sometimes from the lower edge of the thyroid cartilage towards the left, which descends without a fellow, and spreads its tendinous fibres over the gland, upon which also the sternohyoidei and sternothyroidei muscles are incumbent.

ccc. The whole larynx is suspended from the os hyoides, both by ligaments inserted into the superior horns of the thyroid cartilage, and by the middle of its basis, united to the junction of the plates, constituting that cartilage. The larynx, and os hyoides connected with it, may be raised considerably, even half an inch above its mean altitude. This is performed by the biventer muscles, together with the geniohyoidei, genioglossi, styloglossi, stylohyoidei, stylopharyngei, thyropalatini, hyothyroidei; either conjunctly or partially. During its elevation, the glottis is rendered narrower, and the ligaments before mentioned (ccxcv.) approach nearer together. Thus, by the assistance of the action of the arytenoid muscles, both oblique and transverse, the glottis may be accurately closed, so as to resist with and incredible force the pressure of the whole atmosphere.

ccci. The whole larynx may also be depressed about half an inch beneath its ordinary situation, by the sternohyoides, sternothyroides, and coracohyoides, as they are called; and, when these are in action, by the anterior and posterior cricothyroides. By this motion the arytenoid cartilages remove from each other, and the glottis becomes wider, which is also drawn open by the muscles laterally inserted into the arytenoid cartilages, and by the cricoarytenoidei postici and laterales, and thyroarytenoidei: these also, by resting upon the ventricles of the larynx (ccxcvii.) are capable of compressing them. The particular cartilages which form the larynx, can scarcely be moved separately.

ccci. From the larynx the air comes into the mouth and nostrils. By the mouth, we here mean that large and irregularly shaped cavity, situated between the soft and hard palates, both concave in the middle, and the muscles lying under them, and the lower jaw. The nostrils ascend forwards above  
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the soft palate ; they are two broad cavities, included between the septum medium, and the ossa cavernosa, and some other parts. They are every where bony and cartilaginous.

ccci. The tongue lies in the middle of the mouth ; it is a broad piece of flesh easily changeable into any kind of figure, and readily moved without delay to any part of the mouth : by its own fleshy fibres, and by the muscles attached either to itself or to the os hyoides, which is joined to it by many fleshy fibres and membranes, it may with great facility be made to assume any position or figure. It is drawn forwards by the genioglossi and geniohyoidei muscles ; backwards by the styloglossi, stylohyoidei, ceratoglossi, basioglossi, chondroglossi, and biventer ; downwards, by the sternohyoidei, and ceratohyoidei ; and upwards, by the styloglossi, stylohyoidei, by the biventers, and likewise by the mylohyoidei.

ccci. So much for the anatomy. It remains that we demonstrate what effects are produced by air, when expelled, during expiration, by the powers above described (cclxix. cclxx.) from the lungs through the windpipe into the larynx, and from thence forced through the glottis into the mouth variously configured. These effects are, voice, speech, and singing. Sound only is produced when the air is expelled with so great a velocity through the contracted glottis, that it impinges on the ligaments of the glottis, and thus produces in the larynx that tremor, which, being vibratory on account of its elasticity, it continues and increases. Therefore, from the united vibrations of the ligaments (ccxcv.) and of the cartilages of the larynx, a sound is produced, which we call the voice, peculiar in every class of animals, and which depends entirely on the larynx and glottis. When there are no vibrations, a whisper is produced.

cccv. The strength of the voice depends upon the quantity of air expired, and the narrowness of the glottis; and, therefore, upon capacious lungs easily dilatable, an ample, cartilaginous and elastic larynx and windpipe, the free resonance of the nostrils, and a powerful expiration. But the acuteness or gravity of the tones, we observe to arise from various causes. The former proceeds partly from the narrowness, and partly from the tension of the glottis, and the latter from its relaxation and dilatation. For hence, the air, in a given time, impinges upon the ligaments of the contracted glottis with more numerous undulations, and causes more frequent vibrations; but when the glottis is dilated, the contrary of all this follows. And from the greater tension of the ligaments, the tremors in like manner become more numerous from the same stroke. Therefore, to produce an acute sound, the whole larynx is drawn upwards and forwards; and with greater force as the voice is required to be sharper, insomuch that the head itself is sometimes inclined backwards, that the muscles elevating the larynx may exert their full powers. The truth of this is confirmed by experiment, for by applying the fingers to the larynx when acute sounds are emitted, the elevation of the larynx, which is about half an inch for the octave, is easily felt: and by comparative anatomy, which demonstrates the glottis to be very narrow and cartilaginous in singing birds, and wide in hoarse animals, and such as are low or mute. This is also illustrated by whistling, where the sharpness of the sound evidently proceeds from the contraction of the mouth: and by musical instruments, in which the narrowness of the opening admitting the air, and the celerity with which it is impelled, are the causes of an acute tone.

cccv. Gravity of the voice is produced by opposite circumstances, the depression of the larynx  
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by the causes (ccci.) already described ; a wide glottis and a very ample larynx. This is proved by the touch, which easily perceives the descent of the larynx in persons singing, in like manner about half an inch for every octave ; by the greater gravity of the voice in males, and by the lowest tones of the voice degenerating into a silent breathing.

cccvii. Does every diversity of tone proceed from the length of the ligaments of the glottis, which is augmented when the scutiform cartilage is drawn forwards, and the arytenoid ones backwards ? Is it according to this rule, that the most acute tones are produced, by the ligaments being rendered very tense, and therefore vibrating with great celerity ? This is asserted by some late anatomists, from experiments, which have been also repeated by some eminent men ; they have observed, that, when the chords or ligaments of the glottis are tense, the peculiar voice of every kind of animal is produced by blowing air into its trachea ; that this voice was rendered more acute by stretching the ligaments, and more grave by loosening them ; that by shutting the whole ligament, the voice was suppressed ; by shutting the half, the voice was rendered an octave higher ; by shutting a third part, a fifth higher, &c. There are not wanting, however, doubts concerning this new theory, arising from the cartilaginous and bony, and consequently immoveable and inextensible, glottis of birds ; from the certain production of more acute sounds, in whistling, from the mere contraction of the lips ; from the example of women, in which the larynx is softer, but the voice more acute, than in men ; from experiments which show, that more acute sounds are produced by bringing the ligaments of the glottis nearer into contact with each other ; and from the total absence of machinery for stretching the ligaments, and drawing the thyroid cartilage forwards from the annular one.

one. But since it appears from experiments, that the tension of the ligaments suffices for producing acute sounds, without the contraction of the glottis, it is probable that difference of tension in the glottis contributes more than a difference of its diameter to the diversity of voice.

cccviii. Singing, is when the voice, modulated through various degrees of acuteness and gravity, is expelled through the larynx, while vibrating and suspended between contrary powers, which chiefly distinguishes it from speech. It is a laborious action, on account of the perpetual action of the muscles positing the larynx; and it increases the animal heat, because acute tones require a contracted glottis, which retards the expiration, and at the same time a great deal of air to give them strength (cccv.) and, therefore, deep inspirations are necessary. It tends very much to dry the windpipe, from the accelerated passage of the air; and renders a great deal of mucus necessary, which is the reason why there are such numbers of mucous receptacles in the larynx, amongst which I very much suspect the ventricles before described (ccxcvii.) ought to be numbered.

cccix. Speech is performed when the larynx is at rest, in tones differing but little in acuteness and gravity: by variously modifying the voice by the organs of the mouth. Canorous speech has both variations in the tone, and modifications of the voice by the organs of the mouth.

cccx. All speech is reducible to the pronunciation of letters, which differ in various nations, although they agree in the greatest number over the whole world. Of these, some are called vowels, which are expressed by the mere emission of the voice through the mouth, without the application of the tongue to any part of the mouth. But consonants are formed by a collision of the tongue against some part of the mouth, lips, or teeth. The  
nature

nature of our work forbids us to be more particular, and prevents us from explaining a most ingenious art, which, a rare occurrence in physics, has so clearly determined all the corporeal causes of each letter, that, by mere inspection and touch of the organs during their pronunciation, it has taught speech by imitation.

## C H A P. X.

## BRAIN AND NERVES.

CCCXI. **T**HE remaining actions of the human body we shall consider according to the order in which they receive the blood. Of the coronary arteries we spoke, when we gave the history of the heart. Next to those, the carotids arise from the aorta.

CCCXII. The aorta, which comes out from the anterior part of the heart (CLVII.) in order to bend itself towards the vertebræ of the thorax, inclines backwards, and to the left, in an angle that is round indeed, but not very large, forming a considerable arch. From the convexity of this arch, three branches arise. The first ascends towards the right side, and is immediately subdivided into two large arteries, of which the lowermost proceeds in the direction of its trunk, under the denomination of the subclavian. The other ascends along the windpipe to the head, and is called the right carotid. The left carotid springs next from the same arch, a little inclined to the left side; and the third, which is still more inclined to that side, is called the left subclavian, and is somewhat less than the right. At the origins of these branches, the continuous side of the aorta is a little thicker, and projects a little to the left. Variations from this course are rarely observed.

CCCXIII.

cccxi. The carotid artery, inclosed along with the jugular vein and nerve of the eighth pair, in copious and dense cellular substance, commonly arrives at the upper part of the thyroid cartilage, without sending off any branches. There it divides into two trunks. The anterior, which is called the external carotid, is more in the direction of its trunk, and rather larger. It sends off the thyroidea superior, the tortuous lingualis, and then the labialis; and from its posterior part, close by its division, the pharyngea ascendens, which, besides the pharynx and muscles of the velum palati, supplies to the dura mater, through the foramen common to the jugular vein and nerve of the eighth pair, a considerable branch, sent off at the basis of the os petrosum, near to the foramen magnum, and cuneiform process of the sphenoid bone.

cccxiv. Then, from the exterior side of the external carotid, springs the occipital artery; which also sends a branch to the dura mater, which is distributed, at the basis of the cerebellum, through a peculiar foramen of the dura mater in the angle which the os petrosum forms by departing from the mamillary process: another branch passes over the atlas to the dura mater, both under and into the skull; and a third sometimes goes through the fossa jugularis to the dura mater. The next artery, the auricularis, goes to the back part of the ear, to the membrane of the tympanum, and to the temples.

cccxv. What remains of the external carotid artery, ascends through the parotid gland, to which having given some branches, as well as to the face and eyelids, it sends out, in the first place, the temporalis, which is considerable. The trunk of the carotid, being inclined behind the lower jaw, loses itself under the denomination of maxillaris interna.

In that place, it directly sends off a large trunk to the dura mater, which passes through a peculiar opening of the broad pterygoid wings, to the

the vicinity of the middle fossa of the brain ; and is largely distributed upon the dura mater, in the region of the temples and forehead, as far as the falci-form sinus. Sometimes this artery is double, and often sends a conspicuous branch to the lachrymal gland of the eye. Moreover, the same maxillary artery enters the upper part of the nostrils by a triple trunk, where it is spent, after having given off branches to the teeth of the lower and upper jaws, the infra orbitalis, a branch to part of the face and eyelids, and the palatine to the bone of the palate, with small twigs to the dura mater, both through the smaller pores of the great wings, and accompanying the third and second branch of the fifth pair of nerves, and the dura mater filling up the lower orbital fissure.

cccxvi. But the other trunk, which is posterior, and commonly called the internal carotid (cccxiii.) ascends without a branch. This artery, having first made a remarkable serpentine flexure, enters through a peculiar foramen in the os petrosum, where it is surrounded with a vagina from the dura mater, like that which comes out through all the openings of the skull : ascending upwards, then inclining forwards, it penetrates into the cavity of the skull, and ascends tortuously bent along the fella equina, in the middle of the blood of the cavernous sinus, having given small branches to the fifth pair of nerves, dura mater, and infundibulum, with one larger to the eye, part of which returns again through a peculiar hole into that part of the dura mater, which lies upon the middle of the orbit. The rete mirabile is peculiar to some animals, and does not exist in man.

cccxvii. But the trunk of this internal carotid passes over the anterior part of the fella equina ; and being incurvated backwards, and received within the arachnoid membrane, after giving branches to the pons and crura of the brain, and a twig to  
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the choroid plexus, and a branch that accompanies the optic nerve, it then divides into an anterior and posterior branch. The former being conjoined with its fellow artery of the other side by a short anastomosis, is then incurvated backwards and upwards, along the corpus callosum, and goes to the middle and posterior part of the brain, and sometimes sends branches to the falciform process, and at its very origin to the third ventricle, the fornix and thalami. The latter, being joined by a moderate anastomosis with a branch of the vertebral artery, unless that arise from the undivided trunk of the carotid, afterwards ascends a long way through the fossa of Sylvius to the lateral part of the brain; and also sends branches to the choroid plexus. All the branches of the carotid, contained within the skull, have a thin, solid, and more brittle substance than the other arteries of the body.

cccxviii. The vertebral artery commonly arises from the subclavian of the same side, (though the left has been sometimes seen to spring from the trunk of the aorta,) in a deep situation, and without giving branches, it enters the foramen in the transverse process of the sixth vertebra of the neck; after which, it ascends with alternate flexures through the processes of the other vertebræ of the neck; through each interval, it sends off small branches to the muscles of the neck, and communicates with the lower thyroïdal: with other branches, somewhat larger and posterior, it accompanies each nerve to the pia mater of the spinal marrow; and by anterior branches, not so numerous, but larger, it communicates in the spinal marrow with its anterior artery. Lastly, having become transverse by a small flexure at the second vertebra, and by a large one round the process of the first, having there given off two considerable branches to the muscles of the neck, and during its passage through the foramen magnum, having sent small ones to the

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dura

dura mater of the foramen magnum and neighbouring cavity of the cerebellum, it finally enters the cavity of the skull through that foramen. There, while it ascends along the medulla oblongata, the right trunk gradually approaching the left, unites with it at a very acute angle (a most uncommon circumstance) into one artery, the basilar, which being stretched under the pons Varolii, is suspended in the pia mater. From the vertebral arteries, before they are conjoined, or from their common trunk just formed, arteries both going to the lower surface of the cerebellum, and entering deeply into the fourth ventricle and the internal substance of the cerebellum, arise. These send off the spinal arteries. There are instances where these arise from the united trunk; or from the trunk in one side, and from a branch in the other. Then the basilaris, besides branches to the medulla oblongata and crura of the brain, sends off other lower arteries of the cerebellum. Amongst these branches also arises the artery, which accompanies the auditory nerve. Finally, the basilaris, at the forepart of the pons, divides on each side into two branches. One of these goes to the upper part of the cerebellum, to the fourth ventricle, to the crura of the medulla of the cerebellum, the nates, testes, and pineal gland: in place of this, also, there are two trunks. The other, the profunda cerebri, is distributed to the posterior lobe of the brain, the choroid plexus, the plexus lying on the pineal gland, that gland itself, the thalami, corpora striata, fornix, and whole anterior ventricle.

cccix. From the foregoing history of the arteries belonging to the brain, it appears, that in every pulsation a great quantity of blood is sent to this organ, equal to a sixth part or more of the whole blood in the human body, and conveyed by trunks which arise very near the heart, and from the convexity of the aorta. It is therefore not improbable,

probable, that the strongest parts of the blood, and those most retentive of motion, go to the head. Is not this evident from the effects of mercurials being almost confined to the head; from the sudden action of inebriating spirits upon the head; from the speedy stupor excited by camphor; from the face being oftner affected by heat and sweat, than any other part of the body; and from the eruption of highly volatile miasmata upon the face? The safe situation in which the arteries of the head ascend, defends the large and important vessels from injury. The frequent reciprocal inosculations of the trunks going to the head, as well as of their branches, diminish the danger of obstruction. Hence, when the carotids are tied, animals neither die, nor seem to be very uneasy. The considerable flexures of the vertebral and carotid arteries, serve to moderate the impulse of the blood coming to the brain, since a great part of the velocity, which it receives from the heart, is thus spent in changing the figure of the inflections. Some reputable authors have observed, that the arteries are somewhat larger at this place.

cccxx. The history of the brain properly commences with its integuments. A part so tender and so necessary to life, is, in the first place, surrounded by an osseous sphere composed of many pieces, which, therefore, admits of extension, while it effectually resists external pressure. To every part of the internal surface of this sphere, a very strong membrane adheres, composed of two plates sufficiently distinct. It is firmly attached by an infinite number of small vessels, even penetrating to the exterior parts of the head, as by so many footstalks; in a healthy person it is no where detached, but adheres somewhat less firmly to the very smooth bones, but with excessive strength to the commifures of the bones of the skull, which, from their figure, are called futures. In young subjects, the  
adhesion

adhesion of the dura mater to the skull is so great, that the fibres to which it is connected are separated at the same time with it. In adults, many of the vessels being effaced, the dura mater becomes less inseparable : but yet it cannot be detached from the skull without some violence. Hence those bloody drops which appear on removing the cranium. Hence all that has been advanced concerning the motion of the dura mater is erroneous. As to the motion which has been remarked in wounds by some observers, it arose either from the pulsation of the arteries, in a place whence the resistance was removed, while the rest of the cranium afforded insuperable resistance to the action of the heart, or from the turgescence of the brain. The dura mater has neither irritability nor sensibility, and is destitute of nerves, though those going to other parts have been, by some, ascribed to this membrane.

cccxxi. It is the external lamina of the dura mater, which adheres to the bones, and serves them for a periosteum. It passes out of all the holes of the skull along the nerves and vessels, and coheres with the periosteum of the head, vertebræ, and, lastly, of the whole body ; from which circumstance, the name of mater given to it by the barbarians, is derived. The internal plate of the dura mater is, in most parts, continuous with the former : but, in some, it recedes a little from it, as in the great sphenoidal wings ; at the sides of the fella equina, where a good deal of blood is poured betwixt them ; and upon the fella equina itself : having left the external lamina, which adheres firmly to the bones, it descends double to form the falx, which arises first from the multiform bone behind the crista galli, then from the crista, afterwards from the whole juncture of the two frontal and parietal bones, and, lastly, from the middle and back part of the occipital bone ; it becomes  
broader

broader as it proceeds backwards ; it is interposed betwixt the hemispheres of the brain ; and hangs over the corpus callosum, at a greater distance in the forepart, but very near behind, where it also is extenuated to an edge. That there are shining fibres in this part, dispersed towards the longitudinal sinus, from its junction with the tentorium, in the shape of palm branches, is certain ; but it does not therefore follow, that they have any muscular motion : betwixt these fibres frequently there is no membrane, so that they form natural foramina. The falx is joined to the middle of the tentorium, and is continuous with it. In the same manner, but in a different situation, the same lamina forms the short falx of the cerebellum, separating its lobes, together with the strong tentoria, which, arising from the cruciform protuberance of the occiput, are interposed transversely betwixt the brain and cerebellum, and, at last, adhering to the petrous bones and anterior clinoid processes, leave an aperture nearly oval for the medulla oblongata. These productions of the dura mater, prevent any part of the brain from pressing on the rest, in any situation of the body ; and, likewise, one lobe from compressing another, in concussions of the brain. Hence, in the swiftest quadrupeds, where the danger from concussion is greater, the brain and cerebellum are divided by a bony partition.

cccxxii. Upon the external surface of the pia mater, not far from the sinus of the falx, are placed glands, seated in the reticular texture of the dura mater, which partly are inclined towards the sinus and its cavity ; so that some of them are contiguous to the cavity of the sinus, while others are so placed at the insertion of the large veins into the pia mater, that, together with the former just mentioned, they make up a continued series ; these are sometimes soft, oval, and white, sometimes red, and hard, like warts. They have also been noticed in  
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the tentorium cerebelli. But the vapour, which exhales from the surface of the pia mater, is not secreted by these glands: for every where, even where there are none of those glands, as in the ventricles, a copious vapour transpires from the ultimate arteries, as is proved by injections of water or lize, which exude from every part of the surface of the pia mater.

cccxxiii. The next covering of the brain, much closer to it, and expressing its figure, as the former does that of the cavity of the skull, has been denominated, from its tenuity, arachnoid. Pellucid as water, very thin, and as far as its thinness permits, firm, it completely envelopes the brain, passing over its larger and smaller furrows, and inclosing the larger vessels, so that they lie between the arachnoides and pia mater. It is not a lamina of the pia mater, from which it differs in situation, in being connected with it by cellular substance, and in the example of the spinal marrow, although it is resolved into a cellular nature between the hemispheres of the brain.

cccxxiv. The third covering of the brain, is the pia mater, or soft membrane of the brain. This immediately invests the whole surface of the brain and spinal marrow on all sides, is tender, and composed of a vast number of small vessels joined together by cellular texture: but these vessels it sends into the brain in a regular order, like little roots. It descends into all the sinuosities, and insinuates itself into the fissures of the brain, cerebellum, and spinal marrow, and is the bond by which the lobules of the brain are joined together, being possessed of considerable firmness in proportion to its tenuity. Being received into the cavities of the brain, it changes its fabric, and becomes soft and almost of a medullary consistence, especially when the subject is dissected some time after death, although the vessels still point it out.

cccxxv.

cccxxv. The veins in the brain are not constructed as in other parts of the body. For neither have they any valves, nor do they accompany the arteries, nor have their trunks the common structure which prevails in other veins. Therefore, from the innermost cavities of the brain, the veins which rest upon the ridges of the striated bodies, the veins of the choroid plexus, of the lucid septum and of the anterior ventricles, are collected into trunks, which at last meet in one great vein, or often two, which, being accompanied with many small arteries of the choroid plexus, descends backwards to the partition of the brain and cerebellum. In that place, it receives veins arising from the posterior and lower part of the brain, and some of the cerebellum, and meets with a sinus or vein, included in a reduplication of the inner lamina of the dura mater, and being changed into this sinus, it generally descends into the less transverse sinus, most frequently of the left side, though sometimes dividing, it sends a branch to each side. This is called the fourth sinus.

cccxxvi. The superior and superficial veins of the brain are large, and spread in the windings with which the brain on all sides abounds. Into those veins, over the whole surface of the brain, are inserted some veins of the dura mater; while others of them enter by peculiar orifices into the falciform sinus. Then the veins being gradually collected into trunks, proceed, the greatest number of them forwards, a few either directly, or backwards, and these most especially from the forepart, and insert themselves, with their terminations obliquely truncated, into the long falciform sinus which is formed by the internal lamina of the dura mater, from the right and left side meeting together below in the upper edge of the falx. Therefore it is of a triangular figure, convex in its upper side. It begins with a slender origin at the foramen cæcum,

cæcum, which lies before the crista galli ; it ascends and follows the course of the falx ; where that joins the tentorium, being generally inclined to the right, it takes the name of the right transverse sinus, and goes by a peculiar channel impressed in the occipital and temporal bones, first transversely, then incurvated, to the foramen jugulare, where, becoming very large, it receives the inferior petrous and the occipital sinuses, and empties itself into the jugular vein. But the left transverse sinus, resembling the former, and also leading to the jugular vein, is rather inserted into its right side, than continued as its trunk. Into it the fourth sinus (cccxxv.) and the occipital one, usually insert themselves. But there are some instances of a reverse arrangement, so that the longitudinal sinus terminates in the left transverse sinus ; and then the right transverse sinus receives the fourth and the occipital one. At other times it is equally divided into two transverse trunks ; and sometimes a middle sinus joins the transverse ones. There even have been found two similar sinuses parallel to each other.

cccxxvii. Irregularly parallel with the lower and thicker margin of the falx, runs a slender and rounder sinus, more resembling a vein ; it receives veins from the falx itself, which also communicate with the upper sinus ; and from the adjacent hemispheres of the brain, and from the corpus callosum. Where the falx joins with the forepart of the tentorium, it is inserted into the fourth sinus.

cccxxviii. The lower veins of the brain, which lie next to the basis of the skull, are variously inserted. The anterior veins coming from the fossa Sylvii, collected into some trunks, are inserted into the cavernous sinus, or that triangular interval, between the external and internal plates of the dura mater, which is at the side of the sella equina.

Other

Other veins, from the pons itself, lead into the upper sinus petrosus. Other posterior veins, which come from the posterior lobes of the brain, are inserted in great numbers into the transverse sinuses in the tentorium.

cccxxix. The upper veins of the cerebellum, meeting together in large trunks, partly terminate in the fourth sinus, and partly in the transverse sinuses. The lower veins, from the cerebellum and medulla oblongata, insert themselves into the upper sinus petrosus; and some of these also into the transverse sinus very near the place where it goes out.

cccxxx. There are many sinuses, besides those now mentioned. The most anterior of them, which commonly has a circular appearance, surrounds the pituitary gland, and between the clinoid processes, communicates with the cavernous sinuses; and between these processes and the carotid, with the lower petrous sinuses, and lastly, by the way of the sixth pair, with the upper petrous sinuses behind the fifth nerve. There are some instances where this sinus receives the ophthalmic vein; and sometimes the transverse, joining to the cavernous sinus, supplies the place of this circular sinus, or else co-exists with it.

cccxxxi. The upper petrous sinus runs backwards in a groove of the os petrosum. It arises from the anterior extremity of the sulcus of the os petrosum, where it communicates with the cavernous sinus; it receives veins of the dura mater which are inserted into it, and sometimes anterior veins of the brain itself, mentioned before (cccxxviii.) and is inserted into the angle of the transverse sinus, where it begins to be bent, and sometimes into the inferior petrous sinus. Another vein, passing along the top of the os petrosum, is in like manner inserted into the angle of the transverse sinus. The lower sinus petrosus, which is shorter  
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and larger, goes round the root of the bone of this name, and communicates with its fellow behind the clinoid process; after twice communicating with the cavernous sinus, and with the upper sinus, under the nerve of the fifth pair, it is finally inserted into the jugular fossa; it also receives some veins of the dura mater from the region of the vertebræ. To the same outlet also, the posterior occipital sinus on each side leads. These are pretty large, go round the margin of the foramen magnum, till, arriving at the falx of the cerebellum, (cccxxi.) they are sooner or later inserted, generally after being conjoined into the fourth sinus, and with that into the left transverse one, or immediately into this sinus itself, or lastly, by a divided extremity into each of the transverse sinuses. It receives the lower and posterior veins of the dura mater, and some from the vertebræ.

cccxxxii. The anterior occipital sinus, irregular and multiform, partly transverse, and partly descending to the great foramen, is united in various ways with the lower petrous sinuses; from whence branches either accompanying the nerves of the ninth pair, or passing through a peculiar foramen, communicate with the external vertebral vein; while other branches, going downwards, open into the venous circles of the spinal marrow. But the cavernous sinus of the dura mater, (cccxxv.) which is surrounded with a good deal of cellular substance, besides the sinuses (cccxxix. cccxxx.) and large veins already described, also receives the ophthalmic and principal vein of the dura mater; it likewise transmits peculiar veins, accompanying the first, and second, and third branches of the fifth pair, the principal artery of the dura mater, (cccxvi.) and the internal carotid, (cccxvi.) and also through a foramen in the great wing, which is not constant; it sends branches which anastomose with veins on the outside of the skull belonging to the jugulars, and especially with the large pterygoid plexus of the nasal veins.

In

In the same manner, the veins of the pericranium pass through foramina in the parietal bones into the longitudinal sinus, the occipital veins through the mastoid hole into the transverse sinus, and the external vertebral veins through the anterior canal of the occipital bone, into the fossa jugularis; and others from the anterior occipital veins accompany the nerve of the ninth pair. Thus there are an infinite number of ways open to the blood, by which it may escape from the sinuses, wherein it is often collected in too great quantity, in various directions, according to the laxity or declivity of the part. Hence no violent symptoms follow upon tying a vein, however large, or even both the jugulars.

CCCXXXIII. The quantity of blood which goes to the brain, the great impulse with which it is sent into the carotid arteries, (cccxi.) the immunity of a part defended by bones from every kind of pressure; the slow motion of the blood through the abdominal viscera and lower extremities; the perpetual exercise of the brain and senses, which determines an influx of blood to these parts, and other circumstances, cause the head to be surprisingly filled with blood, immediately on any increase of the circulation. Hence the redness of the face, the turgescence of the eyes, the sparkling, the headache, the throbbing, the hæmorrhages from the nose, which are so frequently produced by violent exercise. Therefore, it is evident, that, if the veins in the brain were thin and round, the imminent danger of rupture and apoplexy, even now frequent, could not possibly be avoided. On this account, to the veins which carry out the blood from the brain, nature has given another form more easily dilatable, because it makes an unequal resistance; and another texture, of great firmness, and more difficultly ruptured, especially in the large sinuses, which perform the office of trunks; for the smaller sinuses are either rounder, half cylindrical, or  
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of an irregular figure. Within, nature has furnished the sinuses with cross braces, formed of strong membrane, passing from the right side of the bottom of the sinus to the left, which, in excessive distentions, strengthen the acute angle which is most distended, and secure it from rupture. She has likewise, in these veins, provided numberless anastomoses, both mutually amongst themselves, and with the external vessels of the head, and with those of the spinal marrow, that they may, with greater facility, discharge their superabundant blood, (cccxxxii.)

cccxxxiv. Is arterial blood also poured into the sinuses of the brain? Do they pulsate, by being excited by that blood? It is allowed, that they have no pulsation; because the dura mater every way adheres to the skull, and most firmly in the regions of the sinuses. They certainly receive liquors injected by the arteries. Whether are these exhaled through the small vessels, or do they, in the first place, circulate through the veins? The latter opinion is much more probable.

cccxxxv. All the blood of the brain is finally conveyed into the jugular veins, which are very dilatable, and for that reason protected by valves, against the regurgitation of blood from the auricle, and surrounded with a great quantity of cellular substance. For the blood, which comes from the head to the vertebral veins, is very inconsiderable. The jugulars, so directly correspond with each of the principal branches of the vena cava superior, that they bring back the blood to the heart in the shortest way, and that the right one proceeds in a straight line from the right auricle. They separate nearly as the arteries, into a facial and cerebral branch.

cccxxxvi. The external jugular is a cutaneous vein of the neck, which gives off the temporal one: it is united by a broad anastomosis with the internal jugular at the basis of the lower jaw; and sends a  
branch

branch through the os mamillare into the transverse sinus. The internal vertebral empties itself through the transverse processes of the neck into the transverse sinus, when the canal belonging to it is open.

cccxxxvii. The sinuses of the spinal marrow, which are two in number, and lateral, run along its whole length, are joined at each vertebra by a semicircular arch, and are finally united with the jugular and occipital sinuses: they send branches, however, to the spinal marrow, communicating with the anterior and posterior spinal veins.

cccxxxviii. In consequence of the innumerable anastomoses of the veins, the blood returns with the greatest facility from the head, of which the repletion is attended with much danger. During inspiration, the brain is also more easily evacuated, and subsides when the skull is opened; during expiration, on the contrary, it swells. Hence, blowing the nose, sneezing, and coughing, are dangerous to those whose brain is turgid with retained blood.

cccxxxix. Have lymphatic vessels been seen with certainty in the brain? They have been described in the large choroidal plexus, amongst the fibres of the olfactory nerve, and in the pia mater. For my own part, I have never seen them, and it is probable that there are none, since there are no conglomerate glands in the brain, which are always found near these vessels. As for the various accounts which are given of the pituitary gland, of the infundibulum, and of the ducts which lead from thence into the veins of the head, absorbing water from the ventricles, they are not supported by any anatomical demonstration: which makes it probable, that the vapour, which is secreted into the ventricles of a healthy person, is, in like proportion, absorbed again by the inhaling veins; and that if there be any excess, it descends through the bottom of the ventricles to the basis of the skull, and into  
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the loose cavity of the spinal marrow. That this is the case, appears from palsies, which ensue after apoplexies ; and from the watery tumours in the lower part of the spinal marrow, in hydrocephalic patients.

CCCXL. It now remains for us to speak of the encephalon itself. There are several parts included under this general denomination. By the brain, properly so called, we understand the upper part of that viscus, which is contained in the skull, and which alone occupies its anterior portion ; but behind, it lies above another part, called the cerebellum, which is situated in the posterior and lower cavity of the occipital bone, under the tentorium. Its lower, middle, and white portion, lying under the brain, and before the cerebellum, is in part called the pons, and in part the medulla oblongata.

CCCXLI. The figure of the brain resembles that of half an egg, which is deeply divided longitudinally, not through the whole, but through more than the half of its length, into hemispheres, resembling the quarters of an egg. Both the upper and lower surfaces in man, are full of convolutions, which, with alternate round angles, pretty deeply divide the brain into undulated lobes. But the largest is, that which ascends on both sides outwards from the sides of the fella turcica, and divides the hemisphere into two lobes. Upon the surface of these lobes, lies the cortex, which is extremely soft, and of an ash colour, tinged with yellow or red. It is the most tender of all the parts in the human body. The internal parts are occupied by the medulla, which is almost white, but redder in the foetus ; perforated by very numerous, rectilineal and simple arteries, more solid and more capable of sustaining its figure, notwithstanding it is very soft, and in greater quantity than the cortex. The greater posterior branch of the carotid artery (CCCXVII.) divides each hemisphere of the brain into a smaller anterior lobe, and a larger posterior lobe.

CCCXLII. The fabric of the cortex was long a subject of controversy; but it is now sufficiently evident, from anatomical injections, that much the greater part of it consists of vessels, which arise in every part from the branches of the pia mater, like footstalks, enter into the cortical substance, and convey a fluid thinner than blood; and sometimes, in diseases from strangulation, and in animals, especially in birds, they receive even the true blood. The remaining part of the cortex which is not filled by any injection, is probably either an assemblage of veins, or of yet more tender vessels; for no dissimilarity, which would lead us to conjecture one part of it to be tubular, and the other part solid, is apparent in the cortex, in its healthy state. Besides, of the apparently uniform cortex, a greater portion becomes vascular, the greater the industry which has been employed in filling the vessels, and the greater the tenuity of the injection. The idea of its being glandular, has been discarded by universal consent; nor indeed was there ever any opinion received with less probability than this.

CCCXLIII. In order to understand the nature of the medulla, we are to consider the internal structure of the brain, compared with the brains of brute animals and fish. That part of the brain which lies immediately under the external convolutions, is of a white colour, and becomes gradually broader and more abundant; so that at length, it composes the whole oval section of the brain, except only cortical convolutions on its surface. In this part, the two hemispheres of the brain, which I before observed were not entirely divided, are united by a central portion of medulla. That part of the medulla which lies under the falciform process, but at some distance from it, is called the corpus callosum; in the upper surface of which run two parallel white stripes, formed by the pulsation of the arteries, diverging forwards, and terminated at the anterior

anterior commissure, and in like manner divided backwards. The anterior extremity of the corpus callosum, is lost in the substance of the crura cerebri, coming from the anterior lobes of the brain: the posterior extremity, which is broader, with its shorter termination bent in the shape of a talon, penetrates inwards, and descends with another portion into the inferior horn of the ventricle; and with its longer termination is continued into the hippocampus. Moreover, the whole surface of this substance is streaked with transverse fibres, which are continued, but extenuated, into the adjacent medulla of the brain. Even its interior substance is of a striated nature, and its lower surface has its raphe and transverse fibres.

CCCXLIV. What follows is more difficult to be understood; for the brain is not solid, but from the bottom of its medullary portion, which is incumbent upon the multiform bone, where the greater crus of the brain passes out from it, a cavity commences, covered only with the pia mater, which gradually ascends backwards, and then turning, continues its course forwards and upwards. Then it divides itself near the posterior extremity of the corpus callosum; and with its shorter posterior portion it ends in the posterior lobe of the brain, with its extremity directed inwards, and filled with the talon mentioned above; but its anterior portion is extended along the side of the corpus callosum, parallel to the horizon, and with a horn increasing in breadth outwards, it terminates in the anterior lobe of the brain. The cavity thus formed, of which there is one in each hemisphere of the brain, and which do not communicate, is called the ventriculus anterior or tricornis. It is naturally filled with vapour, which is frequently condensed into water or jelly.

CCCXLV. This cavity has no vacuity, for the upper and lower portions of the brain mutually touch each other.

other. Below, its floor is variously figured. Anteriorly, it consists of a horn, having in its lower part an eminence, which is slightly convex, long, diverges backwards, is covered with an extremely vascular membrane, and is outwardly cinereous. They are called the corpora striata; because inwardly they exhibit, intermixed with much cortical substance, alternate white oval streaks, parallel to one another, and longer behind, besides lesser spots and points, as if of medullary substance. More inwardly and posteriorly, two other similar eminences, more of an egg like shape, towards the third ventricle and other parts in a great measure cinereous on the outside, and obscurely striated, incline towards each other, so that they frequently cohere on the upper part, by the intermixture of their cortical substance: these, going inwards and descending through the horn of each anterior ventricle to the basis of the skull, generate the optic nerves, of which they are called the thalami. Between the corpora striata and thalami, there is an intermediate, parallel, and white band of medullary substance, which is called the centrum semicirculare geminum, produced from the anterior commissure, and frequently from the crura of the fornix; but especially from the medulla of the brain itself, before the thalami. This commissure, which is broad and strong, joins together the anterior part of the brain before the thalami. The centrum geminum, which is broadest behind, arises with many fibres from the junction of the pes hippocampi with the medulla of the brain. The corpora striata, with the thalami, constitute the medullary crura of the brain; which, in the basis of the cerebrum, pass over the medulla of the cerebellum, and are joined together at the anterior extremity of the bridge, to be described hereafter. Where they approach nearest to one another, each sends out an hemispherical eminence, called mamillary. The fibres of the medulla of the brain itself,

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interwoven with the medulla of the cerebellum, descend into the medulla oblongata; and, being then collected into a bundle, they go to the corpora pyramidalia.

CCCXLVI. The corpus callosum projects in the middle over the common axis of those ventricles. Behind, it rests contiguously upon the fornix. Before, two similar medullary partitions, which are called the septum lucidum, triangular, united below, with their vertex inclined backwards, and including an anonymous central cavity, descend from this body along the corpora striata, even to the union of the thalami. This septum below is continued to the fornix, which is a ceiling supported on four pillars, having its anterior origin from the medulla of the brain, and sometimes from the mammillary protuberances, and the commissure which we have mentioned; and behind that, particularly under the thalami, often both from the centrum geminum and curved line of the thalami. This fornix is incumbent upon the interval between the corpora striata, and upon the interval between the thalami; and degenerates partly into a broad thin fimbria, the pes hippocampi, where it is divided into toes; and partly into other tubercles, which are continuous both with the fornix and corpus callosum, but more evidently continued from the latter, as larger, and are semi-cylindrical, having the fimbria attached to them. These descend into the lower anterior horns of the ventricles; and at last terminate in an arch, convex outwards, and commonly divided by ten furrows, imprinted on it by the convolutions of the brain, and in a four toed hoof, whence the name of hippocampus, which is externally covered by an exceedingly thin medullary lamina, but internally consists of cortical substance. At the beginning of the division of the pes hippocampi, the tænia ends in two white striæ, a long and a short one, inserted into this foot and into the brain, or in one inserted  
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into the most internal unguis. A like protuberance, continuous with the corpus callosum, enters into the posterior horn of the ventricle, crooked inwards at its extremity, like the spur of a bird, the posterior part of the descending horn of the ventricle being occupied by a column continuous with it. Between the diverging posterior crura of the fornix, the medullary portion, which is behind the middle plexus of the ventricles, and marked generally with transverse and palmated streaks, is called the psalterium.

CCCXLVII. In the anterior and lower part of the ventricles, on each side, begins the choroid plexus, included in the pia mater only, lying naked in the rest of the cavity of the skull, made up of a great many small arteries (cccxvii. cccxviii.) and veins originating from the large trunk, (cccxxv.) all which numerous vessels, joined together by the pia mater, resemble a curtain variously folded. It is often, but not always, intermixed with many pellucid glands of a round figure, resembling hydatids. It ascends from the basis of the brain, through the descending horn of the ventricle, and becomes dilated as it proceeds upwards; but afterwards becoming narrower, it goes along the optic thalamus, to the posterior extremity of the septum lucidum. When these plexuses have reached the anterior extremity of the thalami, they cohere, and are continued with a remarkable vascular plexus, which gradually descends along the roof of the third ventricle as far as the pineal gland, and is continued into the pia mater of the posterior lobes of the brain. From this proceeds the internal warmth of the brain, and it undoubtedly exhales and inhales. The choroid plexuses are very broad where the anterior ventricles begin to descend; contracting gradually downwards, they project in the inferior anterior end of the ventricle, covered only by the pia mater.

CCCXLVIII. Between the thalami, applied to each other almost with a plain surface, there is a natural

fissure, which is terminated by the crura of the brain meeting together in the basis of the skull: this is called the third ventricle. It leads by a perpendicular funnel, forwards into a cortical column; it is hollow in brutes, less evidently tubular in man, and connected to the pituitary gland.

CCCXLIX. This gland, flattened on both sides, simple, of uncertain structure; in the anterior larger part, almost round, and of a reddish colour; in the posterior part less, cinereous, transversely broad; covered with the pia mater of the brain; lies upon a proper depression of the fella turcica, and seems to be a kind of appendix to the brain.

CCCL. Backwards, the thalami, are conjoined in the bottom of the ventricle, by a central medullary fascia, or posterior commissure, and by a smaller transverse chord; from which, on each side, an arched white band goes out in the upper part, which loses itself in the centrum geminum, and in the anterior commissure, and sometimes in the crus of the fornix. On the fore and upper part, the thalami have a protuberance, which is formed by the triangular fornix situated between the two thalami.

CCCLI. This eminence separates the upper triangular cavity of the third ventricle, filled up with the fornix, from the inferior calamus scriptorius, so that the cavity is continued both to the anterior and posterior extremity of the third ventricle, from the top to the bottom. But the anterior commissure is also a medullary band which unites the thalami before the anterior crura of the fornix.

CCCLII. For a posterior, transverse, figured eminence is applied to the thalami, which conjoins the medulla of the right and left posterior lobes of the brain. It is marked behind by four oval eminences, which are outwardly smaller, called the nates and testes, and which consist externally of some medulla, and internally of cortical substance.

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The superior ones in man are the largest, and are called the nates. Upon these is seated a cortical gland, ovally conical, supplied with many vessels, into which the choroid plexus degenerates: this is the celebrated pineal gland so frequently diseased, which is joined to the brain by small footstalks sent into the linea alba through the thalami in their passage forwards. Between this eminence, marked with these four protuberances, and the crura of the medulla oblongata, a canal resembling an aqueduct, and manifestly open, passes from the third to the fourth ventricle.

CCCLIII. The whole medulla of the brain below, is collected together in its basis, into two very thick compressed columns, having their surface longitudinally marked with lines, and consisting externally of medulla with some cortical substance internally. These are the crura of the brain. These, meeting together backwards, are covered by the subjacent crura of the cerebellum, and are inserted by apparent strata of fibres into the pyramidal bodies of the medulla oblongata; and with other deeper transverse fibres, which separate the inner fibres that come from the cerebellum from the preceding, constitute, together with the medulla cerebelli, the beginning of the medulla oblongata.

CCCLIV. The cerebellum, as it is less, so it is more simple than the brain. It has two lobes, but no where deeply parted, united above and below by a central ring of the same fabric with itself, called the vermis, at the side of which there is a broad smooth eminence of the same nature with the cerebellum. This part of the encephalon contains a great deal of the cortical, and little of the medullary substance. And here, likewise, the cortex is placed in the circumference, but marked with furrows, which are mostly parallel, so as to form circular arches. Thus the lobules are defined,

ed, but not deeply, each of which contains its medulla, and by the gradual union of many of these medullary branches into one trunk, an arbuscular appearance is produced. This medulla, collected together into the large crura of the cerebellum, and internally marked with serrated and intricate cortical lines, has a threefold termination. One part ascends towards the basis of the nates, where it joins the medulla of the brain under the testes; and the right is also joined to the left by a transverse medullary band behind the nates. From this, some distinct fibres ascend outwards, and join themselves to the transverse ones of the bridge. Between these first processes of the cerebellum, is stretched a medullary lamina, behind the fourth ventricle, sending forth fibres beyond the process. The second portion descends into the spinal marrow, and terminates in peculiar studded protuberances, having other cortical protuberances adjacent, both of which are anonymous. The third portion, which is larger, and situated in the middle, going transversely downwards, passes under the crura of the brain, which it embraces; and being twice alternated with their medullary fibres, (CCCLII.) by its own transverse fibres, it is in a great measure blended with them.

CCCLV. Thus, from the crura of the brain descending over those of the cerebellum, and from the medulla of the cerebellum transversely surrounding that of the cerebrum, there is produced, in the first place, the pons, which is almost oval, but more flattened on both sides, depressed in the middle, and every where marked with transverse fibres. Then, continuous with the pons, the medulla oblongata is formed, which is internally variegated and streaked with some cortical substance, is of a conical shape, and descends directly to the great foramen. This medulla has two pairs of tubercles before the pons; the outermost of the figure of  
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an olive, and the innermost of a pyramidal shape, diminishing conically downwards: these are divided in the middle by a furrow, into which the pia mater enters. But betwixt this medulla and the vermiform process of the cerebellum, is formed a cavity, limited by the four lesser processes, which ascend and descend; at first it is narrower, but above the tubercles (CCCLIV.) it grows broader, and is of a rhomboidal figure: it is called the fourth ventricle, and is shut behind by the valvula magna, or medullary velum, which unites the processes going from the cerebellum to the nates, and the vermis, with the transverse band lying under the testes, and shuts the ventricle behind, (CCCLIV.) This ventricle has a moderate furrow, bounded on each side by tumid edges, inscribed on the medulla oblongata, and corresponding to a canal which is covered by the nates and testes, and is called the aqueduct, (CCCXLVIII.) In this last ventricle, as in the foregoing, there is a plexus choroides, only less, and a sulcus called calamus. Each of these sulci is continued down along the medulla spinalis, the anterior most evidently, the posterior less so. In the former, transverse fibres are detached from the right to the left side, both in the medulla oblongata and spinalis. But two or three of the transverse streaks of the fourth ventricle, terminating in the soft nerve, arise from the eminences inclosing the sulcus; others go to the eighth pair, and others of the same kind ascend to the crus of the cerebellum.

CCCLVI. All the medulla of the brain and cerebellum passes out from the skull, through different openings, to the places for which it is destined. The smaller bundles of this medulla we call nerves; but the larger, which is a continuation of the oblongata, we call the medulla spinalis. The nerves are medullary fasciculi, very soft in their origin, and composed of chords of fibres meeting from the brain,

brain, even there in some examples, distinct, straight and parallel in the nerve. These chords, after having proceeded some way, and being covered with the pia mater, which is somewhat red and firm, are united into a more constant fascia; and then, conjoined with others of the same kind by cellular membrane, divided, and contiguous, go on to their proper opening in the dura mater, and run along its canals and intervals, till they meet with an opening in the skull, out of which they pass through a funnel of the dura mater. The nerve, having arrived without the skull, is commonly surrounded by the dura mater, and becomes solid and firm. This is the case in the optic nerve, in the fifth pair, and in others; but in some again there does not appear to be any dura mater surrounding the nerve, as in the olfactory nerves, in the soft portion of the auditory nerve, and the intercostal. The nerves, now naked and less defended, amongst the muscles, are composed of chords, each of which has its medulla, and its sheath of pia mater. The ultimate chords of this kind unite into other larger chords, surrounded by much cellular substance, through which run many small arteries and veins; and sometimes fat itself is deposited. But the general covering, common to the whole nervous bundle, is formed by some indurated cellular substance, often resembling a true membrane, which envelopes them all, and combines them into one nerve.

CCCLVII. The whole of the nerves of the head arise from the lower part of the medulla of the brain or cerebellum. The olfactory nerve arises by a lateral fibre from the interval betwixt the anterior lobes of the brain, and by a direct fibre from the medulla of the anterior lobe itself. A great part of the optic nerve springs from the thalami, (CCCXLV.) but some part likewise from the crus of the brain, while the nerves decussate it. The third pair arises from the bottom of the crus of the medulla of the brain,

brain, behind the mamillary processes. The fourth, whether simple or bifid, proceeds from the side of the process of the cerebellum to the testes. The fifth arises plainly from the peduncles of the cerebellum. The sixth from the bottom of the pons, from the deep sulcus (cccliv.) between it and the medulla oblongata. The seventh arises with one portion, which is softer, posterior and larger, from the medulla oblongata, and by two transverse striæ, from the fourth ventricle itself; and with another harder portion, from that part of the crus of the cerebellum next the pons. The eighth from the interval between the corpora olivaria and pyramidalia, out of a furrow of the medulla oblongata; and, according to the observation of other eminent anatomists, from the fourth ventricle itself. The ninth arises from the corpora olivaria and pyramidalia. The tenth is a nerve of the neck, as appears from its double root, its conjunction with the upper and lower adjacent nerves, and its place of origin. Therefore, no nerves arise properly from the cerebellum, unless the fifth and fourth; for the anterior nerves, the olfactory, optic, and third pair, come from the brain only; and all the rest from those parts where the medulla, both of the brain and cerebellum, are conjoined.

ccclviii. The spinal marrow is a very soft medullary rope, which descends from the medulla oblongata, as low as the second vertebra of the loins. In the neck it is flat before and behind, and gibbous at the sides; in the back it is almost quadrangular. It is largest where it goes out from the head; from thence it becomes smaller in the top of the neck, then larger at its lower part; again it is smaller throughout almost the whole back, but thicker at bottom; and lastly, it ends in tubercles, one conical, another oval. Like the brain, it is invested with its own pia mater, which enters deeply into its anterior fissure, and almost divides the medulla

dulla into two. Within it has some obscure cortical substance ; its anterior artery arises in the skull, from the branches of the vertebals ; it is retrograde, descending through the whole length of the pia mater, perpetually making alternate sinuous flexures, forming inosculations about many, but not all of the nerves, with branches of the vertebral, intercostal, lumbar, and sacral arteries ; till at last, covered with a peculiar coat from the pia mater, it goes out at the coccyx and disappears. Two posterior arteries, similar, but smaller, arise from the lower arteries of the cerebellum : these are more serpentine, and have frequent mutual inosculations. The spinal veins accompany the arteries in their descent from the brain itself, and send out branches in like manner, accompanying the nerves into as many circular sinuses, situated in the dura mater, as there are vertebræ, all of which so communicate one with another, that each communicates with those above and below it, by a straight duct, in each direction, and, by a branch sent outwards, unites with the vertebral, intercostal, lumbar, and sacral veins. The uppermost of these sinuses inosculates with the anterior occipital sinuses, (CCCLII.)

CCCLIX. But the spinal marrow is surrounded by another covering, loosely and at some distance, which is not vascular, but pellucid like water, tolerably firm and continued from the brain. It is called arachnoid, is longer than the pia mater, being extended to the bottom of the os sacrum, and there it alone includes the bundle of contiguous nerves. But in what manner it accompanies the nerves in their passage out, has not been hitherto described. Between that membrane and the dura mater, there is a vapour, which is frequently condensed into a reddish water, and produces a true dropsy.

CCCLX. Lastly, the dura mater of the spinal marrow is continuous with that of the brain, surrounds the

the arachnoides, in like manner descends to the bottom of the os sacrum, larger at its beginning, at the bottom of the neck, and at the loins, but slenderer in the back, and at last terminates in a slender cone, attached by many ligaments to the periosteum of the os sacrum. As the nerves pass through this membrane, it gives them an external covering, which directly enlarges with them into a ganglion, or hard, oval, reddish knot. To this dura mater in the intervals between all the nerves, a denticulated ligament internally adheres, which arises from the skull near the passage of the ninth pair of nerves, and connects the arachnoid to the dura mater by triangular productions, in each of the intervals, between the anterior and posterior bundles of the nerves down to the bottom, and twelfth vertebra of the back. Externally, the dura mater is surrounded by some lubricating fatty matter, and then by the internal covering of the vertebræ, which are themselves so constructed into a canal, that the spinal marrow is not compressed by it in any of its flexions.

CCCLXI. The fibres of the spinal marrow appear distinct in dropfical subjects, and in brute animals. These arise from the whole anterior and posterior surfaces of the spinal marrow; and commonly the anterior chords included in the pia mater, converge like rays into a larger fasciculus; to which a similar fasciculus of the posterior filaments accedes, forming one nerve, which, passing out through a hole of the dura mater, between every two vertebræ, produces a nerve. The vertebral nerves are about 30 in number. In the neck, numerous radiated nervous fibres compose one large and almost transverse nerve. In the back, they descend, in general, smaller; but so that the lower and larger ones are commonly contiguous to one another. The large and long lumbar ones join to form the cauda equina. The lowest nerves of the os sacrum are very small, the

the uppermost ones large. Many of the dorsal nerves, together with the lumbar and sacral ones, covered with their proper pia mater, accompanied by their arteries, and inclosed in the arachnoid membrane, constitute that chord which is called the *cauda equina*.

CCCLXII. Those nerves are distributed to all parts of the body in a very complicated manner, which does not admit of a description in this place. But the following particulars cannot be passed over. All the spinal nerves, except one or two in the neck, after passing out of the vertebræ, have both an anterior and posterior trunk. The former is sent to the muscles only. The latter forms a nervous root, which joining with its fellows, and with a small accessory branch, which comes through the pterygoid canal, from the sixth nerve of the brain, and the second branch of the fifth, forms one of the principal nerves of the human body; which, communicating with almost all the other nerves of the whole system, sends out nervous branches to the heart, and to all the viscera of the abdomen. It has as many ganglia as it has roots from the spinal marrow, unless when several of them join into one ganglion. It communicates variously with the crural, brachial, and diaphragmatic nerves, also with the par vagum and ninth pair. Another principal nerve is the eighth or par vagum, arising from the brain, and joining itself to the intercostal in the bottom of the neck, in the thorax, and in the abdomen; this passes out of the skull in three chords, of which the larger sends branches to the larynx, throat, the cardiac plexuses themselves, (xcix.) lungs, œsophagus, stomach, and liver. The third of these is the phrenic nerve, arising from most of the lower nerves of the neck, and having received an augmentation from the brachial nerves, and sometimes from the root of the ninth, it descends along the pericardium, and inserts itself into the upper surface of the diaphragm; below, it is supplied from the  
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great plexus of the intercostal nerve. Lastly, the accessory nerve, arising by many small roots from the six or seven uppermost posterior cervical nerves, and from the medulla oblongata, returning into the skull, joins the eighth pair and seems to produce some sympathy betwixt that important nerve and the spinal marrow. Finally, the nerves of the limbs originate from plexuses, and are on account of their length, harder and larger, than the nerves which go to the viscera: those which go to the hand, arise from the four lower nerves of the neck, and first and second of the back; those of the lower extremities from the nerves of the loins and os sacrum.

CCCLXIV. The nerves divide into branches like the blood-vessels, but in acute, and often manifestly retrograde, angles, growing gradually softer and smaller, though sometimes they become thicker, as they recede from the brain; at length, with their ultimate extremities, which are seldom visible, seem to terminate in a pulp, by depositing the firm integuments with which they were covered, after the manner which we observe in the optic nerve. But the rectilinear course of the fibres, continued from the brain itself, is such, that they are never divided in any ramification, but only recede from each other, where they had been connected by cellular substance. This appears from disorders, confined to some particular parts, not extended to the whole, produced by affections of the brain; as a loss of the voice, deafness, dumbness, and palsies of particular muscles. They are connected by cellular substance to the adjacent parts, have hardly any elasticity; do not contract on being divided, but only expel their medulla by the contraction of their integuments. In whatever way they are irritated, they do not contract, nor are they rendered shorter during the motion of the muscles which they excite. A great many nerves are sent into the muscles;

cles ; many to the skin ; fewer to the viscera ; very few to the lungs ; and none to the dura or pia mater, arachnoides, tendons, capsules, ligaments, and lastly the whole secondary membranes. Like the vessels, they make frequent anastomoses with each other, or out of one trunk they are divided into many branches : and it is principally in the concurrence of branches, arising from different trunks, that the ganglia are found. These are hard nervous tumors, for the most part vascular, and included in a firm membrane, of which the use and structure are uncertain, and in which the straight course of the nervous fibres is interrupted. They are not found in the nerves of the senses, or in the eighth pair ; or in the phrenic nerves ; or in the nerves of the extremities ; but are peculiar to the spinal nerves, to the intercostal, which is in fact a spinal nerve, and to the fifth pair.

CCCLXV. These are nearly what we have learned from anatomy concerning the brain and nerves ; the physiological uses of these parts remain to be investigated. Every nerve which is irritated, by whatever cause, produces an acute sense of pain. Sensation is a change of the mind, produced by a change of the body. It is the medullary part of the nerve which feels. If a nerve be appropriated to any peculiar sense, that sense perishes when the nerve is compressed or divided ; and the sensibility of the whole body is destroyed, when the brain is compressed ; or of those parts whose nerves originate below the seat of pressure, if you compress the spinal marrow. If certain parts of the brain, from which particular nerves arise, be compressed, then these senses only are lost, as the sight or hearing. Those parts of the body which receive nerves, possess sensibility most acutely, when they receive many, as the eyes and penis ; obtusely, when they receive few nerves, as the viscera ; and those which have no nerves, as the dura mater, tendons, ligaments,

ments, fecundines, the broad bones, and cartilages, have no sensation.

CCCLXVI. It is extremely probable, that all sensation arises from the impression of a sensible object on some nerve of the human body; and that the same being transmitted to the brain along that nerve, is at last represented to the mind, after it has reached the brain. It therefore seems to be false, that the mind perceives immediately by means of the sensoria and branches of the nerves. For this opinion is refuted, by the pains felt after amputation, by the entire cessation of pain when a nerve is compressed, and by the diseases of the senses from injuries of the brain. That the effect of the senses is preserved in the brain, is evident from the loss of memory which succeeds compressions or injuries of the brain; also from the delirium which happens in some diseases, and the stupor and sleepiness which happen in others. We have already observed, that the dura mater has no sensation.

CCCLXVII. Another office of the nerves is to excite the muscles into powerful action. When a nerve is irritated, the muscle to which it goes is immediately convulsed; or the muscles, if it send branches to several. This happens during the life of the animal, and a little after its death while all the parts are still moist. By great irritation, other muscles are thrown into convulsions, and even the whole body. Nor is it necessary that the nerve should be entire; for even when it is cut, on being irritated, it will excite similar motions in the muscles. On the other hand, when a nerve is compressed or tied, a palsy follows; for the muscles which have their nerves from that one, lie unmoved, when they are commanded by the will to act. They again recover their mobility, when the compression is removed, provided the nerve has received no injury.

CCCLXVIII.

CCCLXVIII. When the medulla of the brain is deeply wounded or irritated in its crura, dreadful convulsions ensue throughout the whole body ; the difference of the part irritated produces no exception ; nor does the brain, cerebellum, or corpus callosum, enjoy any prerogative in this respect. The same consequences follow, if the spinal marrow be irritated. But if the encephalon itself be compressed, in any part whatever, there ensues a loss of sense and motion in some part of the body, which appears to be exactly that which has its nerves from the part compressed, according to observations of injuries of particular portions of the brain, in which the origin of the nerves being compressed, the voice is lost ; or the motion of one arm or leg, or of one side of the pharynx. In injuries of the spinal marrow, it is still more evident, that those parts which receive their nerves from the place injured, are convulsed if that be irritated, or rendered paralytic if it be compressed. But when any more considerable portion of the brain is compressed, either from blood, water, scirrhus, an impacted bone, or other mechanical cause, the greatest part, or the whole of the body, loses its power of motion ; the voluntary organs, if the lesion be in a less degree, and all of them when it is greater ; all these disorders cease upon removing the compressing cause. Lastly, if the spinal marrow in the neck be injured, death quickly ensues ; because, from that part the nerves of the heart (xcix.) principally arise.

CCCLXIX. These things being considered, there seems to be no doubt, that all motion in the human body, proceeds in a great measure from the brain, and its annexed cerebellum and spinal marrow ; and that it is thence conveyed through the nerves, to all the muscles and parts of the body. Besides, the cause of motion cannot reside in the parts themselves, since it would then remain after the brain is destroyed,  
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and would not be increased by irritating the brain, or weakened by compressing it.

CCCLXX. Is there in the brain any principal part, which is the origin of all motion, the end of all sensation, and where the soul has its seat? Is this proved by the frequent observation of the integrity of the senses, and power of motion remaining after severe injuries of the brain? Is it in the corpus callosum? Is this shewn by the greater mortality of wounds or diseases in the corpus callosum? Is this body sufficiently connected with the nerves? Are there any experiments which derive from it the fifth, seventh, and other nerves? Does not the same, or even greater mortality, accompany wounds of the medulla spinalis? Yet this is not the seat of the soul, since, though it is compressed or even destroyed, the person will survive a long time, with the perfect use of all his senses. Nay this opinion is opposed by numerous facts; birds have no corpus callosum; and wounds in that body, are not in the least more mortal than those in other parts of the brain, as appears from undoubted experiments.

CCCLXXI. Nor does the cerebellum enjoy the prerogative of exciting the vital actions, nor are the provinces of vitality and animality distinct; nor does the cerebellum generate the nerves of the heart and other vital organs, and the brain those which go to the organs of sense and voluntary motion. From the cerebellum the fifth nerve is most evidently produced; but that goes to the tongue, pterygoid, buccinator, temporal, and frontal muscles, the ear, the eye, the nostrils, all which are parts either moved by the will, or destined for sense. Again, the same nerve, as the eighth, sends vital branches to the heart and lungs, animal and voluntary ones to the larynx, and sensitive ones to the stomach. Lastly, it is not even true, that disorders of the cerebellum occasion death so certainly and speedily. For, from certain observations, even of

our own making, it has borne wounds and scirrhi, without taking away life; nor is it very different from the brain, being only softer and more tender; and, lastly, we read, and that not very rarely, of wounds of the cerebellum being cured. The power, however, of this part, in exciting convulsions, is somewhat greater.

ccclxxii. Concerning the seat of the soul, we must inquire experimentally. In the first place, it must be in the head, and not in the spinal marrow. For though the latter be affected, the integrity of the mind remains the same. Again, it appears, from the experiment of convulsions arising when the inmost parts of the brain are irritated, that it lies not in the cortex, but in the medulla; and not improbably, in the crura of the medulla, the corpora striata, thalami, pons, medulla oblongata, and cerebellum. Finally, by another not absurd conjecture, it lies at the origin of every nerve, so that the concurrence of the first origins of all the nerves, makes up the cenforium commune. Are the sensations of the mind represented there, and do the voluntary and necessary motions arise in that place? This seems very probable. For it does not seem possible, that the origin of motion can lie below that of the nerve; for that would be a gratuitous supposition of immobility or insensibility, in some part of the nerve, though perfectly similar to the rest. Nor can the origin of motion (ccclxix.) be placed higher in the arteries, for they neither have feeling, nor are excited to voluntary motion. It therefore follows, that the seat of the mind, must be where the nerves first begin.

ccclxxiii. We come now to the explanation of the manner in which the nerves are the organs of sense or motion; which, as it lies hid in the ultimate elementary fabric of the medullary fibres, seems to be placed above the reach both of our senses and reason: but we shall endeavour to make

as great an approximation to the truth as possible, by experiments. First, it is demonstrated, that sensation does not come through the membranes from the sentient organ to the brain, and that motion is not transmitted through the coverings from the brain into the muscle. For the brain itself, deeper than these membranes, receives the impressions of sense, and when injured throws the muscles into convulsions. Moreover, it is certain, that the nerves arise from the medulla of the brain; the truth of which is manifest in all the nerves of the brain, more especially in the olfactory, optic, fourth and seventh pair, which continue their medullary fabric a long way before they receive the covering of the pia mater.

CCCLXXIV. We must, therefore, inquire into the nature of this medulla. It is a very soft pulp, harder in insects and idiots; in other respects every where alike. It is disposed, however, to be formed into fibres, or parallel threads, lying upon one another lengthwise. This appears from innumerable observations, especially in the corpus callosum, corpus striatum, thalami of the optic nerves, spinal marrow, in the brains of fishes, and especially in their thalami optici. Again, that the fibres of the brain are continuous with those of the nerves, so as to form one continued substance, appears very evidently in the seventh, fourth and fifth pair of nerves. There is a great deal of oil in the medulla, upwards of a tenth part of its whole weight.

CCCLXXV. But here a controversy begins concerning the nature of this fibre, which, with other similar fibres, composes the substance of the medulla and of the nerves. Many recent philosophers have supposed it to be a solid thread, and only moistened by vapour exhaling into the cellular fabric which surrounds the nervous fibres, and that, when it is struck by a sensible body, the vibration excited is conveyed to the brain.

CCCLXXVI. But the phenomena of wounded nerves will not allow us to imagine the nervous fibres to be solid. For, if a nerve when irritated, vibrate, (after the manner of an elastic chord, which trembles when it is taken hold of,) the nerve ought to consist of hard fibres, fixed by their extremities to hard bodies, and tense; for chords which are soft, or not tense, or not fixed, do not vibrate. But all the nerves, at their origin, are medullary, and very soft, and exceedingly far from any kind of tension; and they retain the same soft texture, and are not covered with membranes, where they pass through well protected channels, as the intercostal nerve and the second branch of the fifth pair; some also are soft throughout their whole length; whatever size they may be of: as, for example, the soft olfactory and acoustic nerves, in which last we would most readily expect tremor; as in sound. Again, although the nerves be hard, they become soft in the viscera, muscles, and sensoria, before they act. Therefore, the nervous fibres, being neither tense in their origin, nor in their termination, cannot possibly vibrate in an elastic manner. But also, in particular and most important cases, they cannot vibrate; because, through their whole length, they are firmly tied to solid parts, by means of cellular substance: for example, the nerves of the heart are tied to the great arteries, and to the pericardium. Finally, that the nerves are totally devoid of elasticity, is demonstrated by the experiment, in which the nerves, cut in two, neither become shorter, nor draw back their divided ends to the solid parts; but are rather elongated from their laxity, and expel their medulla in form of a protuberance. Besides, the extremely soft medulla of the brain exhibits all the phenomena of pain and convulsions, which are produced by nerves, without any possibility of tension.

CCCLXXVII. Add to this, that the motion of an irritated nerve is propagated downwards, and that muscles that are seated above the place of irritation, are never convulsed. This is altogether inconsistent with elasticity; for an elastic chord propagates its tremors from the point of percussion, to both extremities. But, if the phenomena of sense and motion cannot be explained from the nature of elasticity, the only probable supposition that remains is, that there is a liquor which comes from the brain, descends into the nerves, and flows out to the extreme parts of the body; the motion of which liquor, accelerated by irritation, operates only according to the direction in which it flows; and the convulsions cannot ascend upwards, because of the resistance made by the fresh afflux of the fluid from the brain. But the same liquid being put in motion in an organ of sense, by a sensible body, transmits its motion upwards to the brain; for then it is not resisted by a contrary sensorial torrent coming from the brain.

CCCLXXVIII. It is therefore probable, that the nervous fibrils, and the medullary fibres of the brain, which have the same nature, are hollow. Nor is the smallness of these tubes, which are not visible by any microscope, of any force against the proposed arguments; nor the absence of swelling in a tied nerve, which is not exactly true; with other arguments of the like kind, which indeed show the weakness of our senses, but have not any validity against the real existence of nervous fluids. If they are tubes, it is very probable that they derive their fluids from the arteries of the brain.

CCCLXXIX. But the nature of this fluid is disputed. Many, especially the moderns, will have it to be extremely hard or elastic, ethereal, or even electrical; but the more ancient opinion is, that it is rather aqueous, incompressible, and albuminous. . Indeed it is not to be denied, that there are  
many

many arguments against admitting either of these opinions. An electrical matter is, indeed, the most powerful, and fittest for exciting motion ; but then it cannot be confined within the nerves, but penetrates throughout the whole animal to which it is communicated, and fills with its energy the flesh and fat, as well as the nerves. But, in a living animal, the nerves only, or such parts as are pervaded by nerves, tremble when irritated ; and, therefore, this liquid must be of a nature which permits it to flow through the nerves, and yet confines it within their tubes. Also a ligature on a nerve takes away sense and motion, but does not stop an electrical current.

CCCLXXX. A watery and albuminous nature is common to most of the juices in the human body, and may be therefore readily imagined to exist in the nervous fluid, as indicated by the water which exudes into the ventricles of the brain from the same vessels ; by the gelatinous fluid, which flows out in cutting through the brain in fish, and the larger nerves of animals ; and by the tumor which arises in tied nerves. But is such a nature capable of explaining the wonderful force of convulsed nerves, observable in the dissections of living animals, even the smallest, and in the great strength of mad and hysterical people ? Is the hydrostatic example of capillary tubes of any weight ; which, although it may explain the strength in the motion, is nevertheless inconsistent with the celerity ?

CCCLXXXI. For, the nervous fluid, which is the instrument of sense and motion, must, be exceedingly moveable, so as to carry the impressions of sense, or commands of the will, to the places of their destination, without any imaginable loss of time, and cannot receive the cause of its motions only from the heart. Moreover, it is very thin and invisible, and destitute of all taste and smell ; yet  
reparable

reparable from the aliments. It is not on any account to be confounded with that visible, viscid liquor exhaling into the intervals of the nervous chords.

CCCLXXXII. That this liquor moves through tubes rather than through the spongy and solid substance of the nerves, we are persuaded from its celerity, and from the analogy of the whole body; of which all the liquids, the fat excepted, flow through their proper vessels.

CCCLXXXIII. Therefore, upon the whole, it seems to be certain, that, from the vessels of the cortex, a liquor is secreted into the hollow tubes of the medulla, which, being continued into the small tubes of the nerves, and propelled to their extremities, is the cause both of sense and motion. But there will be a twofold motion in that humour; the one flow and constant, from the heart; the other not continual, but exceedingly swift, which is excited either by sense, or any cause, as motions arising in the brain.

CCCLXXXIV. The same nerves most evidently are subservient both to sense and motion; so that we are not allowed to adopt two distinct systems of nerves, one motory, the other sensitive. If sense sometimes remains after motion is destroyed, this seems to be because much more strength is required for the latter. Dying people hear and see, when incapable of motion.

CCCLXXXV. What becomes of this nervous fluid, which cannot but be secreted in very great abundance, from so large a quantity of blood moved with such velocity, if you compare it with the very copious secretion from more sluggish blood, and at a greater distance from the heart, in the small renal and mesenteric arteries? It is not improbable that it exhales through the cutaneous nerves; the lassitude, supervening in a few hours both to sensation and motion, and its removal by spirituous medicines,

medicines, shew that this liquid may both be lost and repaired. Many have thought that it also exhales into various cavities of the body ; as that of the stomach, and intestines. We may expect some part of it to be absorbed, that the noblest fluid of the body may not be too quickly dissipated. That it nourishes the body, is improbable : it is too moveable to expect adhesion from it : that is the office of flow and viscid fluids.

CCCLXXXVI. What is the purpose of so many protuberances in the brain ; of the ventricles, nates, and testes ; of the distinction of the brain from the cerebellum ; and of so many transverse chords communicating from one side of the brain, cerebellum, and spinal medulla, to the opposite side ?

CCCLXXXVII. The distinction of parts necessary for important uses, seems to have produced the necessity of the ventricles. That the corpora striata and thalami might keep their medulla distinct, it was necessary for a vapour to be interposed between them ; and the same reasoning is true with regard to the brain and cerebellum. Perhaps, likewise, the necessity of introducing warmth into the thick medulla of the brain, may have produced the necessity of a cavity through which the arteries may enter in great numbers and crowded together. Perhaps also it was proper, that, into the inmost parts of the brain, small vessels only, without any large ones, should enter. We may also suspect, that the softness of the fibres of the brain requires shortness, in order to sustain their own weight.

CCCLXXXVIII. We are not yet acquainted with the uses of most of the protuberances, and we ought to learn them from diseases, and from anatomical experiments made on animals resembling man. But we have little hopes of success, in parts that are so small, so deeply situated, and hardly ever to be touched, without inflicting a fatal wound. Do so many distinct provinces of ideas exist in them ; as  
in

in the optic thalami? But most of these protuberances produce no nerves.

CCCLXXXIX. The internal bands and ducts seem to make some communication of motions, and perhaps of sensations. Some of these join the brain with the cerebellum; others join the spinal marrow with the nerves of the brain, as the accessory nerve; and most of them join the right and left parts together, as the anterior commissure (CCCXLV.) and the two posterior (CCCL.) the corpus callosum (CCCXLIII.) the striæ between the process from the cerebellum to the testes (CCCLIV.) and the medullary cross bars, in the bottom of the third ventricle, and in the medulla oblongata and spinalis (CCCLV.) For this manifestly seems to be the reason why, as in infinite examples, from an injury of the right side of the brain, the whole muscles of the left side of the body become paralytic, and the reverse although it seems unaccountable, that this decussation does not always happen. Moreover, by this contrivance, nature seems to have provided, that, when any part of the brain is injured, the nerve arising from it is not always rendered useless. For if a nerve receive its fibres, both from its own hemisphere of the brain, and from the opposite one, by communicating bundles, its office may, in some measure, be continued entire by the fibres which it receives from the opposite side, after those of its own side are destroyed. Accordingly, we have numberless instances of wounds of the brain, even attended with a considerable loss of substance, which yet have not been followed with permanent injury to any nerve, or to any of the mental faculties. Many of the other appearances, such as the smaller stripes, resemblances of nerves, and even protuberances, are produced in the brain from mechanical necessity, the pulsation of the vessels, and the figure of the incumbent parts.

cccxc. We have said, that the nerves are the organs of sense and motion : we shall therefore proceed first to explain motion, because it is more simple, uniform and perpetual, as it exists in the foetus before most of the senses.

## C H A P. XI.

### MUSCULAR MOTION.

cccxcI. **T**HE organ of motion in the human body is not single. And, in the first place, in every animal and vegetable fibre, in hair, feathers, membranes, cellular substance, in the humid muscular fibre, and, lastly, in animal and vegetable gluten, there is a contractile power, by which they both resist extension, and, when the extending power is taken away, acquire their former shortness; nor does this power ever cease endeavouring to bring the elementary particles into the closest contact the mechanism of the part can admit. After death, even for many days, it does the same, so that the fibres of a divided muscle contract towards each extremity, and leave a wide gap in the middle; also arteries, when divided, contract themselves in length.

cccxcII. I call this force dead, because it continues to act after death, and so far is different from the powers of life. In the living animal indeed it is somewhat more lively; for, both from cold and fear, the skin is stimulated, so that it grows harder, and erected, and along with this hardness contracts itself in length. Again, the cellular fibres are perpetually endeavouring to shorten themselves, and always tend to their own contraction. Hence, when the skin or any other membrane is extended, as soon as the cause of extension is taken off, it returns by a gentle effort to its former shortness. But it  
also

also resists distention in another way, with a perpetual effort ; and, by a gentle but continual approximation of its own elements, it propels the contained fat or water, or other bodies accidentally introduced. The same power also seems to limit the excretion of vapour ; for when the fibres and plates of the cellular texture are preternaturally relaxed, an immense quantity either of fat or of watery humour is deposited in that texture. This debility seems to be the principal cause of a true dropsy. The same cause being always efficacious, and at work in the heart, joints, and every where throughout the body of the embryo, brings into nearer contact the arteries, auricles, and ventricles ; produces flexures ; and contracts the heart, when in a manner dissolved, into a cone. By an unknown or hidden power, it also seems to determine the shape of most parts of the human body ; by expelling the gluten received into the cells, bringing the terrestrial particles nearer to one another, and giving the proper solidity, curvature, and situation, to the different parts.

cccxciii. It is the nature of this power to act continually, by a gentle but uninterrupted effort. It is common for it also to be excited by poisons, in every membrane, fibre, and cellular texture ; but never by cutting or puncturing with a sharp instrument. These are the proper characteristics of the red muscular fibre. The structure of this fibre it is now necessary for us to consider.

cccxciv. Muscular fibres in the human body, are bundles of red threads, by which manifest motion is performed. When many of these fibres are collected together, and are evidently red, they are called a muscle. The extreme simplicity of the fabric has been the cause of the obscurity that prevails in understanding how small and soft fleshy fibres can produce, with such strength, most extensive

five

five motions, both in man, and most especially in the crustaceous insects.

cccxcv. In every muscle there are fibres, which are long, slender, soft, somewhat elastic, almost constantly parallel on the whole, and, furrounded with a good deal of cellular substance, are collected into lacertuli. These bound together, by loose cellular substance, generally with some fat, unite into larger bundles, which are always divided by cellular bands, and membranous partitions, till at last a number of them, either parallel or inclined, furrounded with a thin cellular membrane, continuous with their partitions, and separated from the neighbouring muscles by some coarser cellular substance, constitute a single muscle. In every visible fibre there appears a series of filaments, which, by oblique extremities being mixed and agglutinated with others of the same kind, are combined into one larger fibre.

cccxcvi. The generality of muscles, but especially all those which are inserted into bones, and all which are pressed strongly by other fleshy incumbent parts, do not consist of fibres of one kind. For the fleshy fibres (cccxcv.) being collected together, commonly compose the swelling in the middle of the muscle, which is called its belly: these fibres degenerate by degrees at each end of the muscle, become more slender and hard, and having laid aside their red colour, acquire a silvery splendor, and being compressed closer together, are included in a small quantity of short cellular substance, are coloured with fewer vessels, and become indolent and scarcely irritable: they are denominated tendons if they are collected into a narrow round chord, but if into a broad flat surface, aponeuroses. The cellular texture which covers the whole tendon is called its vagina, and resembles the coat of a muscle. That fleshy fibres actually change into tendinous, is rendered probable by comparing the  
fœtus,

foetus, in which there are very few tendons, with a young person, in whom there are many more; and with an adult or old person, in whom are the greatest number. Muscles which are not inserted into any bone, have commonly no tendons, as the heart, the sphincters, the tongue, and muscular membranes of the viscera and vessels. But those commonly end in long tendons, which are required to pass round the joints and heads of the bones, and in that extremity which is most moveable. In the foetus the muscles are evidently inserted into the periosteum only; but in adults, where the periosteum is intimately united with the bone, the tendons being blended with the periosteum, adhere into the pits of the bone itself.

cccxcvii. The tendinous fibres indeed often lie in a straight line with the fleshy ones, and are, as it were, a continuation of them. But it is not at all rare for the fleshy fibres to be obliquely inclined to the tendon, and to adhere to it, so that it grows thicker in its progress by continually receiving new fibres. This is called a pennated muscle. Other tendons lie in the middle betwixt two plates of fibres, one on each side, meeting together in an obtuse angle downwards. There are instances of several tendons pennated on each side, being conjoined into one muscle. There are also other modes of union of the tendinous with the fleshy fibres.

cccxcviii. Within the cellular tunic that surrounds the fibres, the arteries and veins are subdivided into rectangular reticulations, for the most part accompanying and contiguous to each other; thence the vapour and fat effused into the coarse and fine cellular substance; thence their absorption. Lymphatic vessels run along the muscles of the tongue, neck and face, but are difficultly demonstrated in the limbs. Along with the blood-vessels, nerves are also distributed through the cellular substance of the muscles, more numerously than to other

other parts of the body, except the eye ; they lay aside their hard involucrum, become softer and vanish before they can be traced to their ultimate extremities. They enter the same muscle in many parts, without preference to any particular one. In the tendons they cannot be demonstrated. Nor are there any nervous fibres which surround and constrict the muscular lacerti. Those who have described them saw nothing but cellular substance.

cccxcix. The structure of the ultimate fibre, considered as the elements of a muscle, when investigated by the microscope in man and other animals, has always appeared similar to the structure of the larger fibres ; and except very minute filaments, connected by cellular substance, nothing upon which we can rely has been observed. There is no series of vesicles or chain of rhombs. Are these fibres hollow ? Are they continuous with the arteries ? Does the difference betwixt muscular and tendinous fibres consist in the latter being rendered solid by being compressed and having their fluids expelled ? That the blood is not concerned, is proved by the slenderness of the fibres, which are smaller than the blood globules, by the whiteness of the muscles, after the blood is washed from them, and by physiological reasons (ccccxi.) And, in general, more strength may be expected from a solid fibre.

cccc. A muscle is endowed at least with a three-fold power. First, the dead one, common to it with other animal fibres. Then another, which we have called the *vis insita*, possessing different phenomena. For, in the first place, it is peculiar to life, and to the first hours after death, and it disappears much sooner than the dead one. Again, in most cases, its action consists in alternate oscillations ; so that moving to and fro, at one moment it contracts itself towards the middle ; and at the next,

next, extends itself from the middle towards the extremities, and so on successively for several times. Moreover, it is manifest, quick, and performs very considerable motions; the dead force, only such as are small and scarcely apparent. It is excited both by the touch of a sharp instrument, and in the hollow muscles by inflated air, by water, and every kind of acrimony, but more powerfully than by any other stimulus by electricity. Lastly, it is peculiar to the muscular fibre, and in no other part of the human body is it found possessed of the qualities above mentioned. But its phenomena deserve to be more particularly explained.

cccci. It is natural to every muscle to shorten itself, by retracting its extremities towards its belly or middle. In order to discover the moving power from the fabric which we have described, it will be of use to consider the phenomena of muscular contraction. Every muscle when in action becomes shorter and thicker. This contraction of its length is various; less in some, more in others; and in particular instances very considerable, for example, in some of the sphincters, iris, diaphragm and intercostals, insomuch that it appears that the length of a muscle may be contracted much more than one third, which computation was derived from an erroneous hypothesis.

ccccii. The intestines are exceedingly tenacious of their vis insita; they continue to contract, after they are taken out of the body, and even after they are cold. The heart is even more tenacious than these, if you consider all things; as is most evident in the chick, and in cold blooded animals. Different muscles are most readily excited, by different stimuli; as the bladder by urine, the heart by the blood, and the intestines by air. Though their nerves are removed, on their connexion with the brain cut off, muscles lose but little of their irritable nature. It appears also, that this irritable  
disposition

disposition is very widely extended through the animal fibre, from the examples of polypi and other insects, which have neither brain nor nerves, and yet are exceedingly impatient of any stimulus; and from the analogy of plants, of which very many flowers and leaves open or contract, according to the various degrees of heat and cold, some even so quickly, that they are nothing inferior in this respect to animals. This power is totally different from any other known property of matter, and is new. It does not depend either upon gravity, or attraction, or elasticity, for it is inherent in soft fibres, and is destroyed, when they become indurated.

ccccciii. But that a cause of motion is conveyed through the nerves into the muscles, is certain from the observations, already noticed (ccclxvii. et seq.) For the nerve alone possesses feeling; alone conveys the dictates of the mind; and neither retains any influence over, nor receives any perceptions from any part, whose nerve is either tied or cut, or which has no nerve. On irritating the nerve or spinal marrow, even in a dead animal, the muscle or muscles, which have nervous branches from those parts, are most violently convulsed. When the nerve of any muscle is cut or tied, or the part of the spinal marrow, or brain, from whence the nerve has its origin, is compressed, the muscle becomes paralytic and feeble, and cannot by any power be recalled into action similar to the vital one. But if the compression be removed from the nerve, the muscle recovers the power by which it is put into action. When the nerve is irritated below the place where it is cut, the muscle to which that nerve belongs is contracted. Numerous experiments have been made, to prove this, especially on the phrenic and recurrent nerves.

cccciv. This power is not the same with the vis insita. The former is adventitious to the muscle; whereas the latter is inherent in it. The former  
ceases

ceases along with life ; whereas the latter, according to certain experiments, subsists long after it. The former is suppressed, by tying a ligature upon the nerve, by injuring the brain, or by the exhibition of opium. The latter is not affected by these circumstances, but continues after the nerve is tied or cut, and even in the intestines, though taken out of the body ; it also exists in animals destitute of brain : parts of the body possess motion, which are destitute of sensation, while others possess sensation, which are destitute of motion. The will excites and removes the nervous action, but has no power over the vis insita.

cccccv. In muscular action, whether proceeding from the vis insita, or from the nervous power, the fibres are contracted towards the middle of its belly, and expand outwards : they are varied by transverse wrinkles, and the whole muscle becomes shorter, and draws its extremities towards its centre, and therefore carries towards each other those parts with which it is connected, in the reciprocal proportion of their firmness. Muscles, during their contraction, swell, and at the same time become hard, and, as it were, increase their circumference every where. I have never observed them to turn pale. Whether, on the whole, they are increased in bulk, and acquire more in breadth than they lose in length, is difficult to be known. They draw after them the passive tendons, which of themselves are neither moveable or irritable. The whole of a muscle may be moved at once, or only a part of it : if one extremity is fixed to an immoveable part, that only is moved, which is capable of yielding.

cccccvi. Do the arteries contribute in any way to muscular motion, as indicated by the paralysis of the lower extremities, produced by tying the aorta ? Not at all, unless by preserving the integrity of the muscles, and mutual relation of the parts, by secreting vapour and fat, and by nourishing them. For

by dividing or tying its artery, a muscle does not become paralyfcd, unless after a confiderable time, when the muscles begin to be destroyed by gangrene. The irritation of the artery has no effect on the muscles. Moreover, it is impracticable to explain the motion of peculiar muscles from a cause, which, proceeding from the heart, operates with equal force on all parts of the body. Lastly, the influence of the will is confined to the nerves, and does not extend to the arteries or other solid parts of the body.

ccccvii. But the manner in which the nerves excite motion in the muscles, is so obscure, that we may almost despair of discovering it. And we do not even attempt to investigate the vis insita, which seems to be an increased attraction of the elementary parts of the fibre, by which they mutually approach each other, and accumulate contortions in the middle of the fibre. This force of attraction, which is implanted by nature in the moving fibre, is excited and increased by stimuli. The rest is mere hypothesis. As to nervous vesicles swelling by a quicker influx of the nervous fluid, they are inconsistent with anatomical truth, which demonstrates the fibres to be cylindrical, and in no part vesicular; and likewise with the celerity with which muscular motion is performed, and with the bulk of a muscle being rather diminished than increased during its action. The chains and rhombs of the inflated fibres are in the same manner repugnant to anatomical inspection, and to the celerity; they would also occasion an immense waste of power, and render the muscle but little shorter. The nerves want that irritable nature which is observed in the muscular fibre; and besides, it is by no means demonstrable, that the fibres, so numerous, can arise from nerves, so few and distributed in a different direction, almost transversely with respect to the muscular fibres. The idea of nerves being disposed round  
arterial

arterial fibres, compressing them by their elasticity, is founded upon a false structure of the fibre, which is gratuitously assumed to be filled with blood, and supposes nerves, where cellular fibres only can be demonstrated. Moreover, the phenomena of animals, which have neither brain or nerves, and are yet very capable of motion, demonstrate the fabric of the muscles to be sufficient for their motion, even without nerves. Blood globules, filled with air, and the explanations derived therefrom, suppose a false nature of that fluid; namely, that elastic air exists, where it does not (cclxxxi.) The animal spirits are not of the nature of electricity.

cccccvi. If we may add any thing to the phenomena, we may suppose the nervous liquor to be of a stimulating nature, forcing the elementary particles of the muscular fibre to approach nearer to each other. The motive cause which occasions the influx of the spirits into the muscle, so as to excite it into action, seems not to be the soul, but a law established by the Creator. For animals, newly born, or newly transformed, without any attempt, or exercise, know how to perform compound motions, very difficult to be defined by calculation. But the soul learns those things, which it performs, slowly, imperfectly, and experimentally. Muscles, therefore, contract, which in a given time receive more of the nervous fluid, whether that be occasioned by the will, or by some irritating cause arising in the brain, or applied to the nerve.

cccccix. Though the soul may be supposed to act in nervous motions, it cannot be admitted in those arising from the vis insita. The heart and intestines, also some organs of the venereal appetite, are governed by the vis insita, and by stimuli. These powers do not arise from the will; nor are they lessened, or excited, or suppressed, or changed by it. No custom or art can subject these organs of inherent motion to the will, or cause a satellite of vol-

untary motion to forget to obey the commands of the soul. It is so certain, that motion is produced by the body alone, that we cannot even suspect any motion to arise from a spiritual cause, except that which the will seems to excite in animals; and, even in the very organs of animal volition, a stimulus will occasion the most excessive actions, in direct opposition to the will.

ccccx. There seems to be this difference between the muscles obeying the will, and those which are governed by the *vis insita*, that the latter are more irritable, and are very easily excited into action by a gentle stimulus; as, for instance, the heart and intestines; which organs are most manifestly, and greatly, and constantly, irritable. On the other hand, the muscles which obey the will, are less easily, and less durably irritable. Hence, they either need the agency of the will, or of a powerful stimulus; by which, indeed, even these may be excited to action, independent of the will. Thus, it happens, that, in apoplexy, the muscles which obey the will, being deprived of all influx from the brain, languish, and become paralytic; while the vital muscles, having no occasion for the operation of the brain, continue to be excited into contraction by their stimuli; the heart by the blood, and the intestines by the air and aliments.

ccccxi. The strength of this action is very considerable in all persons, but more especially in madmen, and in some strong men; since frequently, with a few muscles only, they will raise a weight, much greater than that of the whole human body. But even in healthy people, very slender muscles have elevated 200 or 300 pounds. The muscles of the back will even sustain 3000. Notwithstanding this, much the greater part of the force or power exerted by a muscle, is always lost, without producing any visible effect. For all muscles are inserted nearer the fulcrum, than the weights are append-  
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ed; and therefore their action is lessened, in proportion as their lever is shorter than that of the weight. Moreover, most of the muscles are inserted into the bones, especially in the limbs, at very acute angles; whence, again, the effect which a muscle exerts in action, is proportionably less than the effort which it exerts, as the sine of the angle intercepted betwixt the bone and the muscle, is less than the whole sine. Again, the half of every muscular effort is lost, because it may be considered as an elevating cord, drawing an opposite weight to its fixed point. Besides, many of the muscles are seated in the angle between two bones, arising from the one, and moving the other; and therefore, on that bone being moved, they are bent, and, like inflected cords, require a new force to extend them. Many of them pass over several joints, each of which they bend in some degree, so that only a small part of their effort remains to bend their proper joint. The fleshy fibres themselves of the muscles very often form angles with their common tendon, whence a great part of their force is again lost, and only that proportion of the whole remains, which is as the sine of the angle of their insertion to the whole. Finally, the muscles move their opposed weights with very great velocity and ease, so that they not only overcome the equilibrium, but likewise add a considerable excess of velocity.

CCCCXII. All these losses of power being computed, make it evident, that the force exerted by muscles in action, is exceedingly great, and totally different from any mechanical proportion; since the effect is scarce  $\frac{1}{8}$  of the whole force exerted by the muscle, and yet a few muscles, weighing but a few pounds, are able not only to raise some thousands of pounds, but also with very great velocity. Nor is this to be reputed any defect of wisdom in the Creator: for all those losses of power were rendered necessary, on account of the symmetry

fymmetry of the body, of muscular motion, and of the requisite celerity and direction ; whereas the contrary of all these is required in the mechanism of machinery. We may, however, certainly conclude from hence, that the action of animal motion is very powerful, since, in a small organ, it can exert a force equal to some thousand pounds for a considerable time, or even for entire days ; nor does this seem to be otherwise explicable, than by the incredible celerity with which the influx of this fluid obeys the command of the will. But from whence this velocity proceeds, we are unable to say, and must rest satisfied with knowing that there exists a law, by which, at a given volition, a given celerity is produced anew in the nervous fluid.

ccccxiii. The equilibration of muscular motion is assisted by the action of antagonist powers. Namely, in all parts of the human body every muscle is counterpoised by some counteracting weight, or by elasticity, or by muscles, or by a fluid which reacts upon hollow muscles, by which it is expelled. This cause is the *vis insita*, and operates continually, even while the muscle acts ; and so soon as the additional celerity derived from the brain remits, its action restores the limb or other part immediately to its former state, in which there is an equilibrium betwixt the muscle and its opposing cause. Whenever muscles constitute the antagonist power, none of them can contract without extending their antagonists, by which the nerves being distended, and a sense of uneasiness produced, a still stronger endeavour towards restoring the equilibrium is excited. Hence, when a flexor muscle is divided, the extensor operates even in the dead body ; and the reverse.

ccccxiv. But there are accessory means, by which the motions of the muscles are rendered safe, certain and easy. The large long muscles, by which the greater flexions are performed, are included in  
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firm tendinous sheaths, which are drawn and tightened by other muscles ; for thus, while the joint is bent, the muscle, though in a state of contraction, remains pressed against the bone, and a considerable loss of power is avoided. But the long tendons, which are incurvated or extended over joints which are bent when they are moved, are received within proper braces, which have lubricated canals hollowed out in them, and which, at the same time that they do not interrupt their motion, keep the tendons steady, so that they neither can be displaced, nor get rigid under the skin, with pain and loss of motion. In these tubular braces, a proper liniment is poured around the tendons. The same office is performed in some situations by perforated muscles themselves. In other parts, the tendons are either carried round eminences of bone, in order that they may be inserted at greater angles into the bone which they move ; or they are inserted into another bone, from whence a different tendon descends under a much larger angle into the bone to be moved. In other parts, nature has carried the muscles derived from convenient situations, in a contrary direction into the part to be moved, as it were round a pulley. She has likewise furrounded the muscles on all sides with lubricating fat, both the fibrils, fibres, lacerti and muscles ; which fat, being compressed and effused amongst the tumid muscles and fibres, anoints the fibres, and preserves their flexibility.

ccccxvi. Moreover, the effect of one muscle is determined by the co-operation or opposition of others, which either hold firm the part from which the muscle arises, or bend it, or else, by the concurrence of their action, change the action of the muscle from its straight course to its diagonal. Muscles also assist each other, even though situated at a considerable distance, by the one keeping the bone steady, out of which the other arises. Therefore,

fore, the action of no muscle can be understood from considering it alone; but all the others must likewise be considered at the same time, which are either inserted into the muscle itself, or into any of the parts to which the said muscle adheres.

ccccxvii. By these muscles variously conspiring and opposing each other, are performed walking, standing, flexion, extension, deglutition, and all the other functions of human life. But the actions of the muscles are also generally useful. They accelerate the return of the venous blood, by compressing both the contiguous veins between the tumid muscles, and the veins proper to the muscles between their turgid lacerti, and by the force of that pressure being determined by the valves towards the heart only, they assist the powers of the heart: they likewise return the fat to the blood; and agitate, and triturate the arterial blood, and supply it more quickly to the lungs. They influence the secretions and excretions, retarding or accelerating them; in the liver, mesentery, womb, &c. they promote the course of the contained blood, bile, and other juices, and lessen the danger of their stagnation: they increase the strength of the stomach, by the addition of their own, whereby digestion is promoted; insomuch that all sedentary and inactive courses of life are contrary to the appointment of nature, and predispose to diseases arising from stagnation of the fluids, and crudity of the aliments. The large muscles, which are placed round the belly, propel the blood contained in that cavity, and press it towards the heart. But by much action, the muscles themselves become indurated and tendinous, and they convert the cartilaginous and membranous parts upon which they are incumbent, into a bony nature; they increase the inequalities and processes of the bones, and excavate the sides contiguous to them; they obliterate the cells feat-  
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ed in the diplœe, and bend the bones towards themselves.

ccccxviii. Muscles which are not excited by a stimulus, or for which the mind has no occasion, become relaxed and soft; their wrinkles are smoothed out, their fibres are rendered longer, receding from the middle towards the fixed extremities; and the whole muscle collapses; the accessory cause of contraction, whatever it is, is removed; while that remains without which the muscle never is, as long as it is alive. Nor is there any occasion for antagonist muscles, although they may assist. It has been asked, What becomes of the spirit that is sent from the brain? A part of it perhaps is exhaled; I suspect a part to adhere to the fibre; and that this is the reason, that by exercise the muscles grow stronger, and the limbs become thicker.

## C H A P. XII.

## TOUCH.

ccccxix. **T**HE other office of the nerves and brain is sensation; that is, to suffer changes from the impressions of external substances in the parts of the body affected by them, and to undergo analagous changes in the representations in the mind. We shall, therefore, first examine each of the senses in particular; and then consider what is common to all of them, and what happens in the mind from the changes in the organs of sense.

ccccxx. Touch is understood in a twofold manner. For, by this term, in general, we call every change of the nerves, arising from heat, cold, roughness, smoothness, weight, moisture, or dryness in external bodies, in whatever part of the body that change may arise. In this acceptation, touch is ascribed

cribed to almost all parts of the human body, in a greater or less degree; as in different places of the body the nerves are more numerous, bare, or covered with thinner membranes; and in this sense pain, pleasure, hunger, thirst, anxiety, itching, and the other sensations, belong to the sense of touch.

ccccxxi. But, in a somewhat different and more proper acceptation, the sense of touch is said to be the change from external bodies which is produced in the skin, more especially at the ends of the fingers, and is represented to the mind. For, by the fingers, we most accurately distinguish the tangible qualities of bodies.

ccccxxii. Indeed, in the skin we do not easily distinguish any particle which does not feel. But since the touch is commonly ascribed in a peculiar manner to the papillæ, the structure of the skin must be described. What is strictly called the skin, is composed of a dense web of very compact cellular substance, whose fibres are intermixed and interwoven, which renders it highly extensible, contractile, and porous. Its strata, which are exposed to the air, and next to the epidermis, are more closely compacted; as they approach the fat, they are gradually relaxed, and resolved into a softer cellular texture. It is more tender in some places, and in others firmer. It is pervaded by many small arteries, which come from the subcutaneous ones: they are neither large nor long, but are numerous in some parts where the skin is red, as in the cheeks; in other parts they are fewer in number. The veins arise in great numbers from the subcutaneous reticulations: the nerves likewise in the skin are very numerous; but they vanish so suddenly, that it is very difficult to trace their ultimate extremities. Betwixt the skin and muscles, there is cellular substance, into which the skin insensibly resolved, degenerates, in most parts replenished with

with fat, of which the little eminences form pits in the skin; but in some parts, as the penis, red part of the lips, &c. it is destitute of fat. There are very few parts in the human body where muscular fibres are immediately contiguous to the skin, without any separation by fat; for the dartos is only cellular substance, and has no muscular fibres. There are some places where tendinous fibres are inserted into the skin; as in the palms of the hands, and soles of the feet.

ccccxxiii. Throughout the skin in general, in most parts of the body of man or of the larger animals, on removing the epidermis, scarcely an unevenness is perceptible, unless very minute granulations, raised hardly any visible height, and obtuse. But in the ends of the fingers, papillæ, somewhat larger, but still very difficult of demonstration to the sight, are seated in cavities of the cuticle, and receive nerves scarcely visible; they are minute projections, formed of vessels with one or more small nerves, wrapped up in cellular substance. In the lips, after maceration, they appear long and villous; in the penis they are flaky; and in the tongue they are most evident, from the fabric of which we conclude, by analogy, with respect to the other cutaneous papillæ.

ccccxxiv. The skin is surrounded by another covering, which resists completely the action of the air, and which coheres with the skin by an infinite number of small vessels, and by hairs passing through it. The outer surface of this covering, of a corneous nature, dry, insensible, not subject to putrefaction, destitute of vessels and nerves, wrinkled in a particular manner, and reticular towards the skin, is called the epidermis. It is perforated by an infinite number of pores, of which the larger ones are perspirative, and the smaller vaporiferous, and is connected with the skin by numerous minute vessels resembling down. By pressure or burning,

ing, the cuticle grows thicker, by the addition of new plates, formed between it and the skin ; and is then said to be callous. But even without disease, in negroes the two plates are distinct.

ccccxxv. The inner surface of the cuticle, more soft, pulpy, half fluid, resembling concreted mucus, is separated with difficulty in Europeans, but easily in the African negro, in whom it is truly membranaceous, solid, and separable ; and in the palate of brutes. It is incumbent on the skin, of which it receives the papillæ into soft pits. It is called the rete Malpighianum, although it be certain that it is not perforated in a conspicuous manner, as a sieve.

ccccxxvi. That this reticular body is composed by the concretion of some fluid, transfusing from the skin, seems very probable. The fabric of the cuticle is still uncertain ; for since it is destitute of vessels, is regenerated, and is insensible, it does not seem to belong to the organical parts of the body. Is it the outer part of the Malpighian mucus (ccccxxv.) coagulated and condensed by the air and by pressure ; which is perforated in many places by exhaling and inhaling ducts, the mouths of which are cemented together by the interposed condensed glue ? Is this opinion supported by the mucous expansion upon the membrane of the tympanum ; by its dissolution in water, as observed by eminent anatomists, though by others denied, in the cuticle of negroes ?

ccccxxvii. Moreover, to the history of the skin belong the simple glands, which are seated in very many places under the skin in the cellular substance, and perforate it by their excretory ducts, and pour out upon the cuticle, in the hairy scalp, and in the convex surface of the ear, a fat soft half fluid liniment. Other sebaceous glands, partly simple, and partly compound, generate in the face, though more slowly, a dry white liniment, but in  
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the groins and armpits one more oily, with which the skin being anointed, shines, and is defended both from the air and from friction. They are found in all parts of the human body that are under the necessity of being more immediately exposed to the air, as in the face, where there are a great number of the compound sort; or wherever the skin is liable to great friction, as in the breasts, armpits, groins, glans penis, nymphæ, anus and hams. They frequently send out hairs. Are follicles of this kind seated in all parts of the skin? Although anatomy does not demonstrate them, yet it seems probable that they are present every where, as appears from the fordes, collected about the whole surface of the body, seemingly of the sebaceous kind. But another sort of oily ointment (ccix.) is poured out upon the skin, through its pores, from the fat itself, without the intervention of glands, especially where the skin is clothed with hair.

ccccxxviii. The hair and nails are also appendages to the skin. The former are scattered over almost the whole surface of the body, the palms of the hands and soles of the feet excepted; in most parts short and soft; but longer upon the skin of the head, cheek, chin, and breast in men; also, upon the forepart of the limbs, in the armpits, groins, and pubis. They arise from the subcutaneous cellular substance, originating from a little bulb, which is membranous, strong, vascular, of an oval shape, and more lax towards the cellular texture, at which part it is also furnished with vessels; in which little bulb another bulb lies hid, roundish at its beginning, but afterwards cylindrical, and surrounded with blood. In this second bulb lies the hair, covered with a fatty humour. The hair, with both its cylindrical sheaths, arrives at a cutaneous pore, goes out through it, and forces the epidermis into a similar sheath; whence the very great stability of the hair: after this the sheath cannot be any longer separated from

from the cortex ; the filaments, and spongy and cellular matter, are continued throughout the whole length of the hair. The hairs grow naturally in the subcutaneous cellular substance ; but, by disease, they are sometimes formed in other situations within the fat. They grow continually ; and when cut, are renewed by the protrusion of their medullary substance from the skin outwardly, and by the prolongation of the cuticle. In old age, the hairs, destitute of this medulla, dry up, split, and fall off. Their colour is from the juice, which fills the internal cellular texture. They seem to exhale through their extremities, and possibly throughout their whole surface, as we may conclude from the constant protrusion of their medulla, which ought to have an end from the plica Polonica, and from the luminous rays that come out from the hairs of an animal electrified. The subcutaneous fat follows the course of the hairs, and is exhaled.

ccccxxix. The nails are of the nature and fabric of the cuticle, and fall off along with it, being in like manner insensible, and capable of reproduction. They are found upon the end of the fingers and toes, occupying their upper and back part, and correspond to the tactile papillary apex, which they support, and retain applied to the object felt. They arise from a square root, between an internal stratum of the skin, mixed with periosteum, and another external stratum, a little beyond the last articulation : they go out by a lunar cleft in the external plate of the skin, where the cuticle partly returns back towards the root of the nail, to which it adheres, and is partly laid over the outside of the nail, and extended forward with it, forming its outer covering. The nail itself is soft when it is first produced, and in the part covered by the skin ; but, by age, and contact with the air, it becomes harder, corneous, solid, and elastic, composed of long fibres cemented by gluten, separated by  
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fulci, fissile, and of many layers. The nail thus formed, extends itself to the extremity of the finger ; and, through its whole extent, its internal striated surface is lined by furrowed skin, blended with periosteum, of which the filaments are first short, afterwards longer, and those which adhere near the point of the nail are the longest of all. These are most intimately connected with the root of the nail. Beyond the adhering part of the nail, the skin again becomes free and unconnected with the nail, and has its own epidermis. A furrowed network is interposed betwixt the skin and nail, which is separable and soft, for the protection of the papillæ ; where the furrows are, it becomes gradually harder, so that at last it can scarcely be distinguished from the nail. The tendons do not reach so far as the nail.

ccccxxx. The subcutaneous cellular substance in very few places is without fat, on account of the necessary motion of the skin. Where it is replenished with fat, it defends the warmth of the internal parts from the air ; it renders the skin moveable upon the muscles ; it fills up the cavities between the muscles themselves ; and contributes to the whiteness and beauty of the body. The skin, Malpighian mucus and cuticle, not only cover the external surface of the body every where, but likewise, where they seem to be perforated, returning inwards they gradually change their appearance. For the cuticle is manifest in the anus, urethra, vagina, cornea of the eye, auditory passage, mouth and tongue ; nor is it wanting even in the stomach itself and intestines ; although, by the perpetual emollition, its fabric be altered, and relaxed into their villous coat. Thus the true skin, being continuous with the internal fabric of the palate, tongue, pharynx, nostrils, vagina, &c. changes every where into the white, thick, pulpy, commonly called nervous, coat of those parts.

ccccxxxi. What has been hitherto advanced, is sufficient to enable us to understand the nature of touch. The papillæ at the ends of the fingers, somewhat larger in the inside, beautifully disposed in spiral folds, probably somewhat erected by the attention of the mind, as appears from shiverings, from the nipples of women, from the prolapsus of an intestine, from the handling of tangible objects, and from gentle friction, receive the impression of the object on their nervous fabric, and transmit it to the trunks of the nerves, and to the brain. This is the sense of touch. It enables us to distinguish chiefly the roughness of objects; and has been possessed to so exquisite a degree by some persons, that they have been known to distinguish coloured surfaces by the touch alone. We perceive heat, when external bodies are warmer than our fingers; and weight likewise, when they gravitate more in comparison with their bulk than usual. Humidity we judge of by the presence of adhering water; softness, by the yielding of the object; hardness, by the yielding of the finger; figure, by the hard limits circumscribing them; distance, by an inaccurate calculation derived from experience, to which the length of the arm serves as a measure, &c. Touch corrects the errors of our other senses, although it sometimes errs itself, and though other senses, independent of touch, furnish animals with just perceptions.

ccccxxxii. The mucous body of Malpighius moderates the action of the object touched, and preserves the integrity and softness of the papillæ. The cuticle excludes the air from the destructible skin; moderates the impressions of bodies, so that they may be only sufficient to affect the touch, without causing pain: and, therefore, when thickened by use, the sense of feeling is lost; but, if it be too soft, the touch becomes painful. The hairs defend the cuticle from friction, generate and preserve the heat,

heat, conceal some parts, and render the membranes of others irritable, which require to be defended against the entrance of insects; and perhaps they excrete something excrementitious, and afford a passage to the exhaled oil. The nails are subservient to the touch, by resisting the object touched, so as to prevent the papillæ from yielding, and being bent back; they increase the power of apprehension, and assist in the handling of minute objects. In most animals, they serve as weapons of offence; and would be of the same use to man, if they were not cut.

ccccxxxiii. These are not all the uses of the skin. For a most important office of that covering is to exhale from the body a large quantity of humours, and to absorb others from the air. Accordingly, the whole surface of the skin, by an infinite number of small arteries, both prolonged into the papillæ, and seated in the skin itself, exhales a vapour which exudes through corresponding pores of the cuticle; but when the position of the vessels is changed, it is effused between the cuticle and skin. These arteries are easily demonstrated by injecting water or isinglass into the arteries; for then, from all parts of the skin, an infinite number of small drops exude, which being effused under the cuticle, rendered impervious by death, raise it up in blisters.

ccccxxxiv. During life, this exhalation is demonstrated in many ways. A bright mirror, when held near the warm and naked skin, is quickly obscured by a moist vapour. In subterraneous caverns, where the air is denser, it most evidently escapes into the air, from the whole surface of the body, in the form of visible and thick clouds.

ccccxxxv. In man, and in some, though not in all animals, whenever the motion of the blood is increased, while at the same time the skin is hot and relaxed, from the small cutaneous pores, instead of an invisible vapour, sweat exudes in the

form of minute, but visible drops, which, with others of the same kind, run together into larger drops. The hottest parts are most subject to sweat, as the head, breast, and folds of the body. The experiment before mentioned (ccccxxxiii.) together with the simplicity of nature, the visible density of the cutaneous and pulmonary exhalation (ccccxxxiv.) persuades us, that sweat is discharged through the same vessels which are the organs of perspiration, and that it differs only in its quantity and celerity, and by the admixture of the liquor of the sebaceous glands (ccccxxvii.) and the subcutaneous oil, which being diluted by the more plentifully secreted arterial fluid, exude of an oily and yellow consistence, and chiefly cause the smell and colour of the sweat. Hence, it is more fetid and yellower in the armpits and groins, where those glands are most numerous. Both blood and small sand have escaped from the skin along with the sweat.

ccccxxxvi. The nature of perspiration must be investigated by experiments, and by its analogy with the pulmonary exhalation, which, in like manner, but more frequently becomes visible in a cold air. That this exhalation is chiefly water, has been proved by experiments, in which the breath, being received into large vessels, has condensed into watery drops. This is confirmed by the tenuity of the cloud on the mirror, and its volatility, and by the familiar change of the perspired matter, when obstructed, into a diuresis or diarrhoea, and from the easy determination of warm liquors to assume the form of perspiration by heat, or of urine by cold. This water is derived from our drink, which furnishes a great part of the perspiration, and from inhalation. Frequently, even the odours of our aliments may be plainly perceived in the perspiration; there is also an admixture of the electrical matter in every person, and in some it is evidently lucid.

ccccxxxvii. That it also contains some volatile particles of an alkaline nature, is evident, both from the nature of our blood, and from the considerable evils which succeed the retention of the perspiration, most conspicuously in acute diseases, when, by being repelled inward, it renders the urine pale, and from the corruption of the air by respiration. This volatile alkaline matter arises from the particles of the blood, attenuated by perpetual heat and trituration, and changed into an acrimonious nature. Dogs trace these odours, and could not know their masters unless something of a particular nature were perspired from each person.

ccccxxxviii. The quantity of the matter perspired is very large, whether we consider the extent of the organ secreting it, the quantity of vapour exhaled by the lungs alone, or the experiments of Sanctorius, by which it would seem, that of eight pounds of food and drink, five pounds, or, according to other experiments in a colder country, from thirty to fifty-six ounces are perspired, which neither add to the weight of the body, nor escape by any visible excretion, except the saliva, sweat, and mucus of the nose. But the cutaneous exhalation is even much larger than this; since it not only throws off such a proportion of the alimentary matters, but likewise redischarges what the blood acquires by inhalation (ccccxlii.) In this, however, the different states of the air, and of the body, have great influence. In warm countries, in the summer months, and in young active persons, more goes off by transpiration, and less by the urine. But in cold climates, during the temperate and winter seasons, in aged or inactive persons, more goes off by the urine than by the insensible perspiration. In temperate countries, making a computation throughout the whole year, something more is perspired than what passes off by urine; and, by collating all the experiments made in different countries, both ex-

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cretions are almost alike. It is also somewhat affected by the difference of time after eating ; and the law which seems to obtain, is, that the perspiration is most copious at that time when the alimentary matters, being mostly digested, and received into the blood, are fitted for exhalation. It is naturally diminished during sleep, even in the warmer climates ; but it is increased by the heat of the bedclothes.

ccccxxxix. In general, a plentiful and equable perspiration, at the same time that the body is strong, are good signs of health ; for excessive perspiration, when conjoined with debility, is observed to do more mischief than its entire suppression, if what has been written on this subject is sufficiently to be depended on. It is a sign of health, because it denotes the perviousness of the vessels dispersed throughout the whole body, and the complete digestion of the aliments, of which a great part is resolved into halitus. When it is diminished, it indicates constriction of the skin, weakness of the heart, and imperfect digestion. When excessive, it perhaps wastes the nervous spirits. This discharge is, by moderate exercise, increased to six times that of a person at rest, to the extent of a pound in an hour, or even in half an hour. It is farther increased, if aided by strong and open vessels, by warm, watery, and cordial drinks, by food of easy digestion, by a dense and temperate atmosphere, and by cheerfulness. It is diminished or suppressed by the contrary causes ; as a dense skin, a moist, or a cold and dry atmosphere, rest, an increased flow of urine, the supervention of a diarrhœa ; and lastly, nervous agitation, from a disagreeable affection of the mind. However, the continuance of life does not depend so intimately on this discharge, which is so easily, and without bad consequences, increased or diminished by slight causes ; and is so inconsiderable, in many nations, anointing their skins with oil,

oil, and in many animals. When by being suppressed, it produces such bad effects in fevers of a bad kind, it hurts chiefly by the putrescent particles, which are retained by the perspiration being suppressed.

ccccxl. The sweat is evidently of a saline nature ; as appears both from its taste, and from the crystals which form upon the clothes of glass blowers ; and by distillation, which demonstrates its alkaline nature. Hence, by this discharge, the miasmata of the most pestilential diseases are frequently expelled. But, in reality, sweat is always a preternatural discharge, and ought never to exist in a healthy person, unless by violent bodily exercise, he have induced a temporary disease. It also is frequently injurious in acute diseases ; by wasting the water of the blood, so that the rest becomes thicker, and the salts more acrimonious. By violent exercise, or the heat of the climate, the sweat is rendered extremely fetid, and even sanguineous ; being electrical, it sometimes is lucid.

ccccxli. The uses of perspiration are, to free the blood of its redundant water, of its alkaline impurities, rendered more acrid by repeated circulations ; and of an extremely volatile oil, probably prepared from the same blood. The same perspiration likewise qualifies and softens the cuticle, and preserves the necessary softness of the papillæ.

ccccxlii. But the same skin, which has vessels exhaling into the air, is likewise replenished with vessels, which absorb thin vapours from the air, either perpetually, or at least in a moderate degree of cold ; in a moist atmosphere ; in the night time, when the body is at rest, the mind depressed, and under circumstances, contrary to those mentioned above, (ccccxxxviii.) which increase perspiration. These veins are demonstrated by anatomical injections, which, if thin or watery, exude through them in the same manner as through the arteries :  
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moreover, by the manifest operations of medicines, diffused in the air, or applied to the skin : of vapours, mercury, turpentine, saffron ; of baths, mercurial plasters, tobacco, coloquintida, opium, cantharides, arsenic ; by the fatal effects of poisons, absorbed by the skin ; as the venereal poison ; by the living of animals, without drink, in hot but humid islands ; by the perspiration and urine being sufficiently copious in such situations, without much drink ; and lastly, by extraordinary morbid cases, in which the quantity of urine discharged has far exceeded the drink taken in ; in which it is probable, that the inhaling pores were more open ; for that new ones were generated, is not credible. It is difficult to ascertain its quantity ; that it is very great in plants, in the night time, is proved by certain experiments.

CCCCXLIII. Both the exhaling and inhaling vessels, may be contracted and relaxed by the nervous power. This appears from the effects of the passions of the mind ; which, if lively and exhilarating, relax the exhaling vessels, by increasing the impulse of the influx of blood ; and by the remission of the nerves ; hence redness, moisture, and turgescence of the skin. Those passions which are languid and depressing, contract the exhaling vessels ; as appears from the dryness of the skin, produced by them ; from the goose skin, by terror ; and from diarrhœa, caused by fear. They also seem to dilate the inhaling vessels, whence fear facilitates the action of the smallpox and the plague.

## C H A P. XIII.

## TASTE.

CCCCXLIV. **T**HE organ of taste differs but slightly from that of touch. It appears, by certain experiments, to be seated in the tongue chiefly; for neither does sugar, applied to any other part of the mouth, excite the least sense of taste in the mind; nor any other sapid body, unless it contain something vehemently penetrating; in which case, the palate, root of the tongue, uvula, and even the œsophagus, are affected by the sapid acrimony. That sensation, which is sometimes excited in the stomach, œsophagus, and fauces, by the regurgitation of the aliments, seems also to belong to the tongue, to which the sapid vapours are applied.

CCCCXLV. Only the upper surface and lateral edges of the tongue are fitted by nature to exercise the sense of taste. By the tongue we understand a muscular body, lodged in the mouth, obtuse, very broad in man, and divided in the middle by an obscure sulcus. Its posterior and lower parts are variously connected to the adjacent bones and muscles; its anterior and upper parts are moveable. In that portion which constitutes the organ of taste, the skin continuous with that of the face and mouth, adheres to the muscular flesh, but is pulpy and soft, from the perpetual warmth and moisture. From this skin arise innumerable nervous papillæ, of a more considerable size here than in other parts. Of these there are several kinds: the first kind consists of nine or ten, at the back part of the tongue, disposed in a line on each side of the foramen cæcum. These, surrounded by a circular groove, for the most part resemble an inverted cone, and have a deep sinus in their middle; but are otherwise hard, and but indifferently adapted for tasting, although you  
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can easily trace nerves into them. There are some other papillæ of the same kind found scattered before these upon the back of the tongue.

CCCCXLVI. These degenerate into the fungiform class of papillæ, which are found distributed over the upper surface of the tongue, less and slenderer than the former, always becoming more pointed as they proceed forwards, till around the edges of the tongue they are crowded together, and disposed in diverging lines. The third sort of papillæ are conical. These are by far the most numerous; are dispersed among the former, and are spread copiously over the tongue. The most anterior of them in the apex of the tongue, are more inclined and fluctuate; they are most remarkably numerous in the edges of the tongue; there are even some behind the foramen cæcum. They are highly sensible, and constitute the true organ of taste: other papillæ are intermixed, partly conical, and partly filiform; and of the conical ones some are larger, and others successively smaller.

CCCCXLVII. These papillæ, besides numerous vessels, are supplied with nerves which may be traced into the larger papillæ, and with which the tongue is more largely supplied than almost any other part. For, besides a nerve of the eighth pair, which, with one of its principal three branches, enters deeply into the basis of the tongue, covered by the cerato-glossus, near the os hyoides; there is also a considerable nerve that goes to the muscles of the tongue, from the ninth pair; which having inosculated with the first nerve of the neck, and with the large cervical ganglion, and having sent a branch downwards, often uniting with the eighth pair, and constantly with the second and third of the neck, and supplying the muscles arising from the sternum, and frequently communicating with the phrenic nerve, proceeds with the rest of its trunk to the tongue. This communicates in the cerato-glossus,

rato-glossus, by many branches, with the fifth pair, and is chiefly spent upon the genio-glossus. Lastly, the third branch of the fifth pair having sent upwards or received the cord of the tympanum, and given other branches to the internal pterygoid, and biventer; to the maxillary gland, forming with these a ganglion; to the sublingual gland, and crossing with its principal trunk the cerato-glossus, where it is united with the ninth pair, comes to the tongue, in company with the deep seated artery, with which it penetrates to the tip of the tongue, where it becomes cutaneous. To this nerve, therefore, if there be any preference, the sense of taste is to be especially ascribed, which is even confirmed by morbid examples. Lastly, the papillæ of the tongue are of a hard texture; a firm, pulpy, cellular substance uniting the arteries, veins and nerves into masses, of which many compose one large papilla.

CCCCXLVIII. The arterial and venous villi, which run between the papillæ, are for the purposes of exhalation and inhalation, and have nothing to do with taste, farther than that they separate from the blood, a liquor proper for dissolving salts, and for keeping moist the papillæ, which they pour out on the back of the tongue. On the upper and back part of the tongue, are seated many simple muciferous glands, opening by one or more outlets, and of a round shape, formed by an hemispherical membrane, and the fleshy part of the tongue. Some of these open into an obscure blind cavity, of an uncertain figure, which is placed in the middle of the largest papillæ, (CCCCXLV.) and commonly contains some of them.

CCCCXLIX. The papillæ of the human tongue are covered only by a mucous, semipellucid membrane, which adheres closely to them, and serves them as a cuticle. But, in animals, a perforated network receives

receives the papillæ, which enter into hollow cornuted sheaths.

ccccL. Under the papillæ lies the muscular substance of the tongue, composed of various muscles, but in man hardly extricable. The lower part is in a great measure made up of the genio-glossus muscle extended outwards from the commissure of the chin, and distributed like rays upon the tongue. The upper and lateral parts are composed of the stylo-glossus, whose fibres run to the tip of the tongue. Its middle part between these is composed of the proper lingual muscle, which arising from itself before the pharynx, and from the stylo-glossus, but deeper, proceeding forwards, is terminated there, and in the genio-glossus muscle, and between that and the stylo-glossus, constitutes a considerable part of the tongue. The back part is formed by the cerato-glossus, of which the fibres ascend upwards and backwards, and which is included between the stylo-glossus and lingualis, and by the chondro-glossus, an entirely different muscle, which arises from the small bones of the os hyoides, and the nearest part of its basis, from whence passing outwards, covered by lateral layers of the genio-glossus, and joining the stylo-glossus, it disappears in the tongue. By the action of these muscles, the whole tongue is moveable in all directions, and is capable of varying its own figure, becoming concave when elevated by the stylo-glossi, being again flattened by the cerato-glossi, being rendered narrower and almost cylindrical, by the transverse fibres of the tongue; besides which, there are other orders in the human tongue inextricable and intermixed with much tenacious fat.

ccccLI. The arteries of the tongue are numerous. The largest, which is deep seated and serpentine, comes from the external carotid, and extends along the lower part to the tip of the tongue; a smaller superficial artery, incumbent on the sublingual gland,

gland, and inosculating with the preceding, arises either from it, or from the labial. Other small posterior arteries arise either from branches of the labial, or from the tonsillaris. The veins of the tongue are variously intricated, and difficult to describe; one, lying deep, accompanies the nerve of the ninth pair; another, superficial, accompanies the mental artery, and, inosculating with the former, forms the ranular vein; but all of them tend towards that large vein, which is a different branch of the internal jugular, from the cerebral one. They variously communicate with the adjacent tonsillary, thyroid, pharyngeal, and cutaneous plexuses; and on the back of the tongue, before the epiglottis, those of the right and left sides are interwoven with each other. I find lymphatic vessels rather in the neighbourhood of the tongue, than in the tongue itself.

CCCCII. The papillæ of the tongue, being larger and softer than those of the skin, and perpetually moist, perform the office of touch more exquisitely than those of the skin, which are dry and small; hence the tongue suffers more acute pain: moreover, the cutaneous papillæ receive no other sensations from salts than those of moisture or pain. But the papillæ of the tongue being erected and somewhat protuberant, to perform the office of taste, are affected in such a manner by salts dissolved in water, or saliva, and applied to their summits, that the mind distinguishes certain classes of taste, as sour, sweet, rough, bitter, salt, urinous, spirituous, aromatic, pungent of various kinds, insipid, putrid, and others partly purely saline, and partly changed, and compounded by the admixture of subtile animal or vegetable oils. All very acrid salts excite pain instead of taste. Does the diversity of flavours arise from the different figures of the salts? Does this appear from the cubical figure of sea-salt, the prismatical figure of nitre, or the particular

lar configuration of vitriol, sugar, &c.? It does not seem probable, for even insipid crystals have their particular figures; and in salts, very different in taste and other properties, the figures are too much the same, and again are inconstant in the same salt, as for example, in nitre, which may by art be rendered cubical. The cause of taste seems therefore to reside in the internal structure of the elements, not perceptible by our senses.

ccccliii. But the nature of the covering of the papillæ, of the saliva, of the fluids, and of the aliments lodged in the stomach, have great influence on the perception of tastes; insomuch, that the same flavours do not affect all ages alike, nor all temperatures; nor even the same person, according as he may be in health, diseased, or habituated to it. In general, whatever contains less salt than the saliva does, seems insipid.

ccccliv. The spirituous parts, more especially of vegetables, are received either into the papillæ themselves, or into the absorbing villi of the tongue; as appears from the speedy renovation of strength by liquors of this kind, even when they are not taken into the stomach.

cccclv. Nature designed the diversity of flavours, that animals might know those things most proper for their food: for in general, there is no aliment unhealthy, that is of an agreeable taste; nor is any thing ill tasted that is fit for the food of man. We here take no notice of excess, by which the most healthy food may become prejudicial, or of minerals, which are not furnished by nature, but prepared by art. Thus nature has invited man to take the food necessary for his subsistence, both by the pain called hunger, and by the pleasure arising from taste. But animals, which do not learn from example and the instruction of others, distinguish flavours more accurately, and, admonished by that test, abstain cautiously from unhealthy

unhealthy food; and, therefore herbivorous animals especially, to which a very great diversity of aliments mixed with noxious plants are offered, are furnished with such long papillæ, and so elegant a structure of the tongue, for which man has less occasion.

## C H A P. XIV.

## SMELL.

CCCCVI. **T**O the same use of discerning prejudicial food, the sense of smelling is subservient; by which we both perceive their noxious nature, before they be tasted, which might be dangerous; and especially avoid putridity in our victuals, which to us is exceedingly hurtful; and discover what is grateful and wholesome; although by habit, this advantage of smell is more conspicuous in animals than in man. But men who have been left to themselves, and whose sense of smell has not been corrupted by variety, have been observed most certainly to retain that sagacious faculty in distinguishing food in an eminent degree. Finally, the powers of medicinal plants are hardly to be estimated better than by the simple testimonies of taste and smell. Hence, in all animals the organ of smell is placed near the mouth; and hence the smell is stronger, and the organs larger, in those animals which have to seek their prey at a considerable distance, or to reject deleterious plants from among their food.

CCCCVII. The sense of smelling is performed by means of a soft, pulpy, vascular, papillous, porous membrane, which lines the whole internal cavity of the nostrils, and is thicker upon the septum and principal cavity of the nose, but thinner in the sinuses. It is plentifully supplied with very soft nerves,

nerves, the middle ones of which descend from the first pair, (ccclvii.) through the holes of the os cribriform to the septum narium; but in such a manner that it is very difficult to trace them to their extremities and into the septum. Other lateral nerves come from the second branch of the fifth pair and its branches, from that which crosses the pterygoid canal, and from another which descends through the canals of the palate; and in the maxillary sinus from the infra-orbital branch, from the dental branch, and from the anterior nerve of the palate. Moreover, the anterior part of the septum has a twig from the ophthalmic of the first branch of the fifth pair.

ccclviii. The nostrils are supplied with very numerous arteries; from the three nasal branches of the internal maxillary, above from both the ethmoidal branches, and the frontal and nasal branches, with lateral arteries from the smaller ophthalmic branch of the internal carotid, and from branches of the palatine artery, and in the sinuses from the infra-orbital, and from the superior dental one. These arteries have the property of exuding blood easily, and in great quantity, without any lesion of consequence. The correspondent veins form a very large plexus upon the external pterygoid muscle; then communicate with the sinuses of the dura mater; and, lastly, meet in the external branch of the internal jugular. The arteries supply nourishment, warmth, and mucus.

ccclix. The head, especially in man, being of a spherical figure, confines the organ of smell within a small space. That it may be extended internally, the nostrils have been made complicated and cavernous in a surprising manner. In the first place, the nostrils are that multiform cavity which begins at the anterior openings of the nose, and, extending transversely backwards over the roof of the palate under the ethmoid bone, terminates at  
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the cavity of the fauces. This cavity is divided by a septum, often unequally, which is bony in the upper part, and descends from the plate of the ethmoid; below, it is formed by the vomer, and in its forepart it consists of a triangular cartilage, whose surface is large and very sensible.

CCCCCLX. Moreover, the lateral surfaces of the nares are increased by the spiral convolutions of the ossa turbinata; the uppermost of which are the small superior and posterior convolutions of the ethmoid bone. The middle ones belong to the same bone, are of a long conchoid form, convex inwards, externally concave, pointed at both ends, covered all over with pits, and internally filled with spongy cells suspended transversely, and supported by particular eminences of the palate and maxillary bones. The lowest turbinata are similar to the middle ones; like them resemble in figure a limpet shell, but longer; are for the most part divided from the former, but sometimes conjoined by a bony plate which is most frequently of a membranous nature. This appendix, being extended upwards in a square form, completes the maxillary sinus.

CCCCCLXI. The cavity of the nostrils is still further enlarged, by means of the various sinuses, which are recesses or a kind of appendages to the nostrils. The uppermost of these are the frontal sinuses, which are inconstant and irregular, seated in the superciliary ridge, and situated betwixt the anterior and posterior plates of the frontal bone. They are not found in the foetus, and seem to arise from the action of the corrugator and other muscles, which draw the anterior plate outwards, and increase the diploë into cells, in the same manner as in the mastoid process. These open in the upper part of the nostrils into the anterior cell of the os papyraceum. There are instances of their being totally wanting, and growing after birth.

CCCCCLXII.

cccclxii. The second in order are the ethmoidal sinuses ; of which four or more on each side are found in the outer part of the os cribosum, like the cells of an honey comb ; above, they are completed by the cellular diploë of the os frontis, before by the os unguis, and behind by the palate and sphenoidal bone ; they open into the upper part of the nostrils in a transverse line, by many small tubes, even placed one above another. With these are continuous the cells in the bottom of the orbit, and those excavated in the os planum and maxillare are outwardly continued from them. In the third place, the large cavity of the multiform bone on each side is also contiguous, and in some measure belongs to the ethmoid and palate bones. By the drying up of the cartilage, which is here of large extent in the fœtus, it gradually is formed in the solid bone, under the sella turcica, is capacious, either single or divided, and opens forwards by its aperture into the upper passage of the nostrils.

cccclxiii. The last, lowest, and largest of the sinuses, which in the fœtus exists in some degree, but in the adult, by the attenuation of the bony laminæ, becomes very large, is chiefly excavated in the upper maxillary bone. Its opening into the nostrils is bounded by the os unguis, bone of the palate, proper lamella of the lowest os turbinatum, and by membranes, so that it enters by a round aperture between the middle and lowest spongy bones. But it likewise sends forth an hollow appendix, stretching forwards under the orbits, which is formed by the os planum, unguis, and papyraceum, communicating likewise with the ethmoidal cells, and opening behind the ostium lachrymale.

cccclxiv. The nerves of the nose, being almost naked, require a defence from the air, which is continually inspired and expired through the nostrils, for the purposes of respiration. Nature has therefore

therefore supplied the nostrils, in place of a thicker cuticle, with a viscid, bland, insipid mucus, fluid at its first separation, but by the air condensing into thick dry crusts, and more consistent here than in other parts of the body. By this mucus the nerves are defended from drying and from pain. It is poured out from the very numerous small arteries of the nostrils; and is deposited partly into numerous cylindrical ducts, and partly into round visible cryptæ, scattered throughout the nostrils. The same mucus exudes over the surface of the whole olfactory membrane, and every where anoints it. In the septum, a long sinus, common to many muciferous pores, runs forwards a considerable way. The mucus accumulated in the night time, in too great quantity, is expelled during the day by compressing the nostrils, and forcing the breath through them; or by its dryness and acrimony, it irritates the very sensible nerves, and is then expelled by the sneezing excited. But the sinuses which abound with mucus, evacuate it according to the different postures of the body; by some of them always being at liberty to discharge it, whether the head be erect or inclined forwards, or to the side; yet so, that generally the maxillary and sphenoidal sinuses are more difficultly emptied than the rest. Moreover, the tears descend through a proper duct into the nostrils, and moisten them, and dilute the mucus.

CCCCCLXV. The extremities of the nostrils are covered by the nose, which is lined inwardly with a membrane of the same nature, and is composed of two bones, and usually six cartilages, two of which are continuous with the middle septum (CCCCCLIX.) The nose may be moved by its muscles, so as to be raised and dilated by a muscle common to it and the upper lip, and to be contracted by its proper depressor and compressor, and depressor of the septum. Thus the organ of smell is prominent, and exposed to the action of odours, and may be dilated

for taking in a larger quantity of air, and again be contracted, when the superabundance is expelled.

CCCCCLXVI. The air, therefore, filled with the very subtile, invifible, pungent, oily, faline, and volatile effluvia, which exhale from almost every known body, being received into the noſtrils, by the action of refpiration, (CCLXV.) and by a peculiar effort for drawing the air into them, carries theſe particles to the nerves, widely naked, and conſtantly ſoft. By theſe there is excited in theſe nerves a kind of ſenſation which we call ſmell, by which we diſtinguiſh the ſeveral kinds of oils and ſalts, in a manner ſomewhat indiftinct, difficultly reducible to claſſes, difficultly recalled to the memory, nevertheless ſufficiently for our purpoſes. This ſenſe informs us of unwholeſome putridity, of exceſſive acrimony, and of the bland and uſeful nature of ſubſtances. And as ſalt, united with oil, is an object of taſte, and as oils, combined with ſalts, conſtitute odours, the affinity of the two ſenſes, which was neceſſary to derive utility from either, is apparent. But volatile particles chiefly are diſtinguiſhed by ſmell, and fixed ones by the taſte; perhaps becauſe the thick mucous cuticle, ſpread over the tongue, intercepts the action of the more ſubtile ſalts, which eaſily affect the ſofter and leſs covered nerves of the noſtrils. We are ignorant of the reaſons why ſome ſmells pleaſe, and others diſpleaſe; perhaps cuſtom may have ſome influence in this reſpect.

CCCCCLXVII. The action of ſmells is ſtrong, but of ſhort continuance; becauſe particles in a very minute ſtate are applied to naked nerves, in the immediate vicinity of the brain. Hence the deleterious and reſreſhing actions of odours, by which people are reſuſcitated from faintings, and even from drowning. Hence the violent ſneezing, excited by acrid particles, the evacuation of the bowels, by the ſmell of purgatives, and the power of antipathies.

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Hence the pernicious effects of excessive sneezing, more especially blindness, from the great sympathy of the nerves. Amongst the various parts of the nostrils, the septum, and the ossa turbinata, and their anterior portions, especially form the organ of smell: since these parts are multiplied in quick scented animals, forming beautiful spires in quadrupeds; and in fish, being distributed in parallel laminae elegantly toothed.

## C H A P. XV.

## HEARING.

CCCCLXVIII. **A**S the sense of smelling distinguishes the small bodies which float in the air, hearing perceives the tremors of the elastic air itself. Therefore, the sensitive organ of the ear is composed in a different manner from that of any of the other senses; as it is in a great part made up, either of elastic cartilages, or hard bones, that it may communicate with accuracy the tremors received.

CCCCLXIX. The external organ of this sense is the ear, or that cartilage which is connected before and behind to the bones of the temple, by strong cellular substance and proper ligaments, with some degree of mobility, which is diminished by habit. This cartilage is of a compound figure; in its general shape, oval, but divided by projecting convolutions and intermediate grooves, to which other hollows and ridges correspond in the opposite surface. The outer eminence, called helix, arises above the loose lobe, and surrounding the ear, terminates in a projecting line dividing the concha. Below it, lies the anthelix, a bifurcated eminence, forming a ridge contained within the former, and terminating in a short tongue called the antitragus. The remaining  
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part of the ear hollow before, and convex behind, growing gradually deeper, having a projecting line running through its middle, is called the concha, and is joined with the meatus auditorius, which is protected by a nearly round moveable appendix, called the tragus.

ccccclxx. All this part of the ear is only covered by a thin skin, and lean cellular substance; and is replenished with many sebaceous glands, supplying an ointment. It is moved by certain muscles, which generally become useless, from habit and the custom of binding them, which, however, it is probable were appointed by nature to perform certain offices. The uppermost of these muscles arises thin from the frontal and from the aponeurosis of the cranium; whence it is broadly spread over the aponeurosis of the temporal muscle, and is inserted into the anthelix, or neighbouring helix, at the anonymous cavity. The posterior muscles, which are two or three, or more or less, are more robust than the former, almost transverse, and arising from the aponeurosis of the cervical muscles, and from the membranes adhering to the mastoid process, are inserted into the convex part of the concha, and without doubt dilate it. The anterior muscle is the least; this also is spread upon the aponeurosis of the temporal muscle, and is inserted almost transversely into the origin of the helix and into the neighbouring concha. But smaller, short muscles, hardly distinguishable, though somewhat red, probably make some change in the ear itself. The transverse muscle of the ear, joining the concha with the concave back part of the anthelix, opens the ear. The antitragicus, descending from the root of the anthelix to the upper part of the antitragus, widens the entrance of the concha. The tragicus, which lies upon the tragus, and is almost square, dilates the aperture; the musculus incisuræ majoris, lies between the middle and third cartilages of the auditory

tory passage, brings them nearer together, and renders the meatus itself more elastic. The remaining muscles, the longer or larger, and the lesser of the helix, have hardly any great use; perhaps they have some influence when we wish to hear weak sounds more accurately, and tighten the organ of hearing, and render the meatus auditorious firmer by drawing together the cartilages.

CCCCCLXXI. With the concha is connected the meatus auditorious, of a round compressed figure, inclined inwards, lessening as it proceeds, about the middle bent forwards, and for a considerable part bony. But, in its anterior and outer part, it is partly formed of three imperfect rings, the first arising from the tragus, the second from the concha, and the third from the other two, connected with each other by intermediate muscle, membrane, and cartilage, and finally adhering to the bone itself. The upper and back parts of the meatus are formed by mere membrane. This is the state of it in adults; for, in the fœtus and new born infant, the meatus is wholly cartilaginous, and its osseous part is gradually formed.

CCCCCLXXII. Into this auditory passage are continued the cuticle and true skin, which are gradually extenuated and exactly stretched over the bone, and are therefore very sensible of any irritation, pleasure or pain; and by the irritable hairs with which it is furnished, intimation is given of the accumulation of any fordes, and of the entrance of insects. In the cellular substance, which is somewhat indurated and reticulated, especially in the membranous portion, (CCCCCLXXI.) there are numerous yellow round follicles, which, by short ducts, deposite into the cavity of the auditory passage a liquid, at first oily, but afterwards becoming gradually thick, bitter, and inflammable, which lines the sensible skin and membrane of the tympanum, and defends them from the air, and drives  
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away or keeps back insects; but, when accumulated in slothful or uncleanly persons, it causes deafness.

CCCCCLXXIII. Into the ear the sonorous waves of the air flow, which, from the principles of mechanics, it collects. The elastic air receives sonorous vibrations; and particularly transmits them, although some other bodies also propagate sonorous vibrations, either alone, or at least in the greatest degree, if indeed water deprived of air be capable of vibrating. Hence, sound is increased in air that is condensed, and is lost in vacuo. The air receives these tremors, either from some body striking against it, or from some body against which it rushes, or lastly from the mutual collision of bodies. But a body which produces sound, must vibrate and oscillate in all, even in the least of its particles, so as to form alternate arches rising up from the former straight surface, and returning beyond the same. This species of curved line is called the *excedens* of the sounding body. The tremor impels the nearest wave of air, and thus the anterior portion of air being compressed, as soon as its elasticity overcomes the impelled tremor, rebounds and repels the air towards the sounding body, where the air is now more rarefied and thin, and compresses it. The same portion of air, struck by the sounding body, in like manner impels the portion of air contiguous to it, which also reacting in due time, repels the tremulous air backwards towards the body, and forwards to produce a new wave. These oscillations must thus succeed each other quickly, to render them audible, and must not be fewer than 30 in a second.

CCCCCLXXIV. Acute sounds are, in general, emitted from bodies that are hard, brittle, and very tense: grave sounds are connected with the contrary properties. Those sounds in general are called  
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acute, which are produced by more frequent vibrations in a given time; and those obtuse, which are produced by less frequent vibrations. There is no limit between acute and grave sounds, but what is arbitrary. Cords, or other bodies, that yield the same number of vibrations in a given time, are said to be in unison. Octaves are produced when the one makes double the number of oscillations that the other does; other proportions have different names assigned to them. The shorter cords produce the sharpest tones, and the reverse, in the inverse proportion of their lengths; they are also more acute as they are tenser in the subduplicate proportion of their tension, or the weights by which they are stretched. Experiments to this purpose are very easily made with a monocord, or a series of cords stretched by weights.

CCCCCLXXV. Sound, however produced, whether acute or grave, strong or weak, is carried through the air with a velocity equal to about 1038 Paris feet in a second, and that with an uniform velocity, without being diminished by great distances. But a contrary wind, although much slower, retards in some degree the progress of sound, and takes away about  $\frac{1}{2}$  of its velocity. So likewise density and dryness of the air increase sound; rarefaction and moisture diminish it. The heat of summer augments its velocity; in Guinea, it has been transmitted at the rate of 1098 Parisian feet in a second.

CCCCCLXXVI. Every sound meets with particles in all adjacent bodies, even in water and mercury, in which it excites similar vibrations, not only in such as are in unison, which yield a more evident sound, but also in other particles, which vibrate in a different ratio. Hence every sound which we hear, is a mixture of the primitive tone, produced by the vibrating body, and of the secondary tones generated by the elastic tremors of the surrounding bodies. The strength of sound is increased, if the secondary

condary sounds succeed the primary one so quickly, that they cannot be discriminated by the ear ; but if so slowly as to be distinguishable by the ear, they produce an echo ; but this requires an interval of six thirds of time, or the distance of 55 feet betwixt the body returning the sound and the ear.

CCCCCLXXVII. Sound is reflected from hard bodies in angles equal to those of its incidence. But sound emitted into the open air, being diffused through an immense sphere, grows weaker : when sent through a cylinder, it retains its strength, and when collected into the focus of an ellipse, as in the speaking trumpet, it is increased, as it issues from the focus of the parabola in parallel, not in diverging lines.

CCCCCLXXVIII. Therefore the sonorous undulations, propagated through the air, strike upon our ear, placed in an elevated situation, and naturally inclined forwards and outwards. As that is elastic, they are reverberated ; and by alternate reflections, they are collected into the concha, and into the meatus auditorious, where they become as much stronger, as the surface of the ear is larger than the caliber of the meatus. Through that passage, in some measure cylindrical, they proceed inwards undiminished, and increased by new resonances, excited by the percussion of the elastic cartilages and hard bones, and blended with the primitive sound.

CCCCCLXXIX. The internal end of the meatus auditorious is terminated by the membrana tympani ; in adults it is obliquely applied, of a roundish figure but having an appendix above, projects inwards like a shield, so that the lower half, concave towards the meatus, projects as the boss into the cavity of the tympanum, and the upper half is concave towards the tympanum, and convex towards the meatus. This membrane is composed of several plates ; the first is white and mucous, not a perfect

fect membrane, and in the foetus only ; then the epidermis ; and then the true skin, continuous with the membrane of the meatus, and vascular ; the third is dry, rattling, shining, pellucid, and without blood-vessels. It is formed from the periosteum of the meatus, and of the tympanum. Some tender cellular texture intervenes between these. This membrane is not naturally perforated with any opening, so far as I have been able to discover, and the transmission of smoke is fabulous. It is constantly stretched in the groove of the ring in which it is contained, which is proper to the foetus, but after the birth coalesces with the rest of the os petrosum, so that there is no part of the human body more tense or more tremulous than this. Upon the surface of this membrane, and more especially upon its conical cavity pointing inwards, the sonorous waves strike, after their last reflection in the auditory passage, and on account of its elasticity, force it to vibrate.

CCCCCLXXX. This membrane is stretched over a cavity of the os petrosum, called the tympanum ; which is in general of an irregularly roundish figure. It is divided in its middle by a promontory, and in the adult it is increased backwards by the cells of the mastoid bone, which in the foetus are wanting. The tympanum is cellular also before, above and behind. It is lined with a vascular membrane, receiving small branches from the internal carotid, from the branch of the artery of the dura mater, which passes through the fissure in the aqueduct, and from the external arteries of the tympanum, and from the stylo-mastoidea. It is commonly full of mucus, poured into it from the Eustachian tube, and is divided into a kind of cells by different membranes, which are productions of the periosteum to the ossicula auditus.

CCCCCLXXXI. Within this cavity, the little bones of hearing are situated, three of them being larger,  
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ger, and the fourth lefs. The round head of the malleus, its upper part, is fituted in the roof of the tympanum, from whence its long handle descends between the laminæ of the membrane of the tympanum, as far as its middle, accurately tied to it, with a broad extremity a little incurvated outwards. It is also connected with the long crus of the incus by a peculiar ligament ; another membrane, near its long process, fastens the malleus. A short and conical process above its handle, presses the membrane of the tympanum outwards. From the same place, a process, very long, compressed, and somewhat broad, but of a variable figure, extends forwards into a fulcus of the tube. The head of the malleus is articulated with the incus by two protuberant lines, and an intervening fulcus, all of them oblique.

CCCCCLXXXII. Three muscles are commonly described, as belonging to the malleus ; the first and largest, the tensor tympani, is internal, and is lodged in a particular canal of the tube, to which it runs parallel, arising from a process of the multiform bone between the passage of the cerebral carotid and the hole of the artery of the dura mater ; it is inserted by its tendon reflected downwards and outwards, around a pulley, into the beginning of the handle. The second muscle arises from a fulcus, connected with the same tube, but external to it, shorter than the former ; and carried backwards almost in the same manner, but without being reflected, it adheres by a considerable extent to the longer process ; its muscularity is doubted, not being remarkably different from red pulpy membrane. The third, which is said to arise from the auditory passage, to enter the tympanum, through a notch in the imperfect ring, to be inserted just by the shorter process into the malleus, and to relax the membrane, has never been seen with sufficient certainty, either by myself, or by the most eminent anatomists. The tensor, by means of the malleus, adapts

adapts the membrane of the tympanum for the hearing of weak sounds; the second muscle, if it exist, moderates those that are too powerful, by drawing the malleus from the incus, and in that way, interrupting the propagation of the sonorous tremors. If the membrane of the tympanum be broken, or the small bones displaced, the hearing first becomes dull, and afterwards perfect deafness ensues; that part of hearing only being left, which is propagated through the bones of the skull.

CCCCCLXXXIII. The malleus imparts the tremors which it receives from the membrane of the tympanum, to the incus, which is a short thick little bone, articulated with it behind by a broad surface, with two fulci and a middle eminence. The shorter leg of this bone, whose little body is bifurcated, is notched, suspended by a ligament, and is held firm in a peculiar fulcus of bone. The other leg descends farther, parallel to the malleus; and, by its extremity bent inwards, is adapted to the fourth bone, which it receives, being convex on that side, and flat on the other, and rests upon the stapes, to which it communicates its vibrations.

CCCCCLXXXIV. The stapes, aptly so called from its figure, lies in an inclined position, with a hollow head which receives the incus, with curved crura, especially the posterior one, and with an oval basis, but flatter below, with which it fills a hole corresponding to it, commonly called the fenestra ovalis. The crura, which are fulcated inwardly, are joined by a dense membrane affixed to the slightly hollow basis. The stapes is governed by its own muscle, which being included in a bony papilla, sends out a small tendon, which proceeds forwards, and is inserted under the incus into the head of the stapes. It seems to draw the stapes so that its posterior part may enter deeper into the fenestra ovalis, and its anterior part advance outwards. Thus the nervous pulp of the vestibulum

vestibulum is compressed, both by the basis of the stapes, and by the air of the tympanum. The whole seat of the stapes is separated from the rest of the tympanum by a peculiar membrane.

CCCCCLXXXV. A small roundish oval bone, slightly excavated on both sides, is connected by one side with the longer leg of the incus, and by the other with the head of the stapes.

CCCCCLXXXVI. Various canals pass out from the cavity of the tympanum. Above the two larger bones, behind the posterior leg of the incus, is a small cell, a kind of appendix to the tympanum, of the figure of a gnomon. Behind it, the cells in the os petrosum begin above the mamillary process. Below these, that process is excavated in the adult with various cells.

CCCCCLXXXVII. Besides, a peculiar canal, proceeding forwards from the anterior extremity of the tympanum, emerges from the bones between the sphenoid and temporal bones, and corresponds with an elliptical diverging cone, partly cartilaginous, of uncertain structure, and partly membranous, which opens behind the nostrils into the cavity of the fauces, by a very large elliptical aperture, turned inwards and forwards: it is lined with a porous membrane, full of cryptæ, continuous, and similar to the membrane of the nares. This forms the Eustachian tube, which by the action of the circumjacent muscles, may be compressed, and probably a little relaxed and opened again, by the circumflex muscle of the moveable palate. By this canal, the air, during inspiration, enters into the tympanum to be changed, and the mucus is poured around the little bones to defend them: nor is it improbable, that the air issues out of this tube, when the tympanum is pressed inwards by powerful sounds; likewise, sounds received into the mouth, are conveyed by it to the organ of hearing. In inspiration, the air presses the membrane of the tympanum outwards; hence

hence the humming and dulness of hearing in yawning; for then the air entering in greater quantity into the tube and tympanum, resists the tremors of the external air.

CCCCCLXXXVIII. Two other passages lead from the tympanum to the labyrinth, or innermost part of the ear. The fenestra ovalis, (CCCCCLXXXIV.) not covered by any membrane, leads into the vestibulum; which is a round cavity, excavated in the very hard petrous bone, and lies near the inner part of the tympanum. In that cavity there is a superior elliptical recess, an inferior circular one, and a third resembling a groove. There is a nervous pulp in the vestibulum, separated from its bony sides by vapour furrounding it. Into this the five mouths of the three semicircular canals, the foramen ovale, and the passages of the nerves and arteries open.

CCCCCLXXXIX. In the foetus, the canals are formed of a distinct hard shell, which is furrounded with spongy bone; in adults, they are excavated in the excessively hard petrous bone, something larger than semicircles, and have ample openings. The larger posterior and lower of these is perpendicular; also the middle and upper one is placed perpendicularly; but the outermost and least is horizontal. The inner mouth of the uppermost unites with the upper opening of the posterior.

CCCCXC. But the cochlea is still more wonderful. It is seated in an inclined position in the anterior portion of the os petrosum. Into its one cavity the vestibulum opens, and into the other the fenestra rotunda of the tympanum, which being covered by the promontory, lies hid in the bottom of the tympanum. The cochlea itself is composed of a nucleus of bone, of a conical figure, with its apex inclined inwards; divided into tubes, which are called *scalæ*, by a middle *fulcus*, which is perforated, both in its basis, and through its whole length, by  
innumerable

innumerable small foramina, and terminates in the middle of the second spiral. About this nucleus are wrapt two turns and a half of a canal; which, in the foetus, is distinct, and has its own shell; but, in the adult, is united with the adjacent bone, and diminishes conically from the two openings mentioned above, towards the apex of the nucleus. This canal is bilocular, and divided by a partition called lamina spiralis, of which the greatest part is bony, and arises from the nucleus, projecting from it at right angles into the hollow canal, is striated, and included on both sides in the internal periotum as in a capsule. The remaining and exterior portion is membranous, which completes the division of the canal: thus there are formed two distinct semicanals, called *scalæ*. The interior and posterior of these begins from the fenestra rotunda, where it is shut by a membrane, and is called the *scala tympani*; the other anterior one arises from the vestibulum, from which it has its name. From the apex of the nucleus a third cavity originates, shaped like a funnel. Into this the spiral lamina terminates by a membranaceous extremity, but so that the funnel communicates with each *scala*, by one small hole on each side, and by many with the cavity of the modiolus, which is filled with nerve.

ccccxci. The blood-vessels of the outer ear come from the temporal, and proper auricular branches; those of the membrane of the tympanum from the temporal, from the stylo-mastoideal, or from both; those of the meatus auditorius come from the same; those of the tympanum were described (ccccclxxx.) and the vessels belonging to the vestibulum, cochlea, and semicircular canals, are from the vertebralis and stylo-mastoideal and meningeal. The industry of late anatomists has traced absorbent vessels of a particular kind, from the vestibulum into the transverse sinus, from the cochlea into the cavity of the skull.

ccccxcii. It now remains that we describe the nerves subservient to the sense of hearing, of which the principal is that called the seventh, (ccclvii.) This nerve enters into the internal auditory sinus of the os petrosum, in the blind end of which it divides. The smaller part of the nerve enters through the upper opening in the sinus, into a canal, which is at first transverse, and afterwards reflected behind the tympanum. While it descends there, it gives off a branch through a peculiar canal to the tympanum, which ascends betwixt the malleus and incus, goes out of the tympanum, through a fissure behind the articulation of the lower jaw, and inserts itself into the nerve of the tongue, (ccclvii.) the reason of which secret communication is obscure, but serves to explain the sympathy between the teeth and sharp sounds, and burning of the ear, &c. The rest of the nerve, escaping by the side of the styloid process, is distributed on the external ear, the parotid gland, a large part of the face, and upper part of the neck, both cutaneous and muscular; and in the face, forms numerous inosculation, both betwixt its own branches, and with those of the first, second, and third of the fifth pair; with the eighth pair, and with the third cervical pair. To the organs of hearing, it sends either no branches, or very small ones. The anterior part of the outer ear receives other nerves from the third branch of the fifth pair, and the posterior part, from the second and third cervicals.

ccccxciii. But the soft portion, which is larger, but more obscure, arises by very minute filaments, from the fourth ventricle of the brain itself, (ccclvii.) and enters through exceeding small holes of the inner auditory sinus, in part with from three to five branches, into the vestibulum, and in part into the fulcus of the cochlea. These branches in the vestibulum form three pulpy masses, which combine

bine to form the membrane suspended in the vestibulum, and which is continued through the whole of the semicircular canals. The other part, which enters the sulcus of the cochlea, has an obscure termination.

ccccxciv. With respect to the nerve which is distributed upon the vestibulum and semicircular canals, there is no doubt that it is affected by the tremors of the external air, propagated to the stapes; which reach the pulp of the naked nerve, through the fenestra ovalis. That part of the nerve, which enters the cochlea, is altogether less understood. It is probable, that small branches from thence pass through the little foramina, (ccccxc.) to the peristeme of the cochlea, and to the membranous part of the lamina spiralis. Do transverse nervous filaments, successively shorter, pass out from the nucleus of the cochlea, along the lamina spiralis? Is it the organ of hearing? These are questions, which we are yet hardly able to resolve from anatomy; though the example of birds and fishes, which hear exquisitely without a cochlea, seems to negative them. However this may be, it is probable, that the spiral plate, full of nerves, is excited to vibration by the oscillations of the membrane of the tympanum, which agitate the air in the cavity of the tympanum, so that it impinges on the membrane of the round fenestra, which again agitates the air contained in the cochlea.

ccccxcv. It is an elegant conjecture, that since the lamina spiralis forms a true triangle, of which the apex is a very acute angle, it may be supposed to contain an infinite number of cords, successively shorter, which correspond harmonically, (ccccclxxiv.) with the various acute and grave tones, so that they vibrate in unison with the greatest number of sounds; the longest cords in the basis of the cochlea, with the gravest sounds; and the shortest

est cords nearest the apex, with the sharpest sounds. Are sounds perceived in the middle semicircular canals, since these alone are found in all classes of animals? Or are they perceived in these canals, in the cochlea, and in the membrane suspended in the vestibulum? This seems probable.

ccccxcvi. It appears that the audible elastic undulations of the air, pass through the outer ear and auditory passage, to the membrane of the tympanum; for when it is injured, and not repaired, the hearing is totally destroyed. It seems to be stretched, for hearing weak sounds, by the muscles of the malleus. From this membrane, the sound is propagated through the small bones to the vestibulum; for these bones being destroyed, the hearing is again abolished. The bony sides of the vestibulum vibrate, and agitate the aqueous fluid surrounding the nervous pulp. By it, the nervous pulp suspended in the vestibulum, seems to be affected, and that tremor to be continued through the continuous pulp of the cochlea and semicircular canals. Nothing farther is known: but, by undoubted experiments, elastic sonorous tremors affect the auditory nerve, through the intervention of the Eustachian tube, of the teeth, and of all the bones of the skull.

ccccxcvii. The distinction of sounds, without doubt, proceeds from the velocity of the tremors excited in the auditory nerve, according as they succeed each other more swiftly or slowly; it is not necessary the mind should number them; it is sufficient that the different numbers excite different changes in the mind. Does the gratefulness of sounds arise from the number of consonances? Does the mind, unconsciously, number the degrees of consonance, and derive pleasure from their facility and frequency? These are denied by the most expert musicians, who prove, that much pleasure proceeds

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from

from sounds having very little concordance, and related in very difficult proportions. Why are too acute sounds intolerable? They seem to stretch our nerves in the lamina spiralis to such a degree, that they are even ruptured, as glasses are broken by acute sounds, and the shrill whistling of canary birds almost destroys the power of hearing.

## C H A P. XVI.

## SIGHT.

ccccxcviii. **H**EARING is the perception of the vibrations of the air; sight perceives those of light: the organ of hearing is bony, that it may admit of resonance; the organ of vision chiefly consists of humours, which refract: the complex nature of this organ was rendered necessary for the defence of parts, so very tender, and by the diversity of the humours, to be contained each in its proper integuments.

ccccxcix. The most external defence of the eye is afforded by the eyebrow, which is a protuberance of the skin, sustained by muscles, at the bottom of the forehead, full of thick imbricated hairs, and along with the frontal muscle, capable of being pulled down by the action of the corrugator, and orbicular muscles, so as to afford a shade to the eye in too strong a light. After the eyebrow has completed its functions, it is again raised by the frontal muscle, which is inserted into it, thin and fleshy, immediately under the continuous skin, fastened to the cellular membrane of the skull, which is shining, not very unlike an aponeurosis, and is drawn backwards by the rectangular occipital muscle. The depression of the eyebrow denotes care, its elevation, tranquillity and serenity of mind. It also turns  
aside

aside the course of the sweat, and keeps off insects from the eye.

D. The eyelids furnish a nearer protection to the eye. These are folds of the skin, proceeding from that of the face, extenuated, lengthened out into an edge, as if divided, reflected upon itself, and retracing the course of the former lamina, from which it is separated by some cellular substance; then having become membranous, vascular, and therefore red, and thin, it is carried over the ball of the eye, under the denomination of conjunctiva tunica, and covers the anterior portion of the sclerotica, and finally the cornea. The epidermis accompanies it in its whole course, even where it adheres to the cornea. The upper eyelid is larger, and more moveable: the lower is smaller; and rather passive, than moved by any power of its own. The nerves, which give sensibility to the eyelids, are numerous, from the first and second branches of the fifth pair, and from the portio dura of the seventh; they abound with arteries from the ophthalmics, temporals, branches of the internal maxillaries, infra orbitals, and facials.

DI. That the eyelids may shut together more exactly, each of them has a cartilaginous arch, called tarsus, upon that margin which touches the other. It is slender, of a lunar figure, extenuated outwards, and stretches the eyelid, preventing the formation of folds while it is elevated or depressed. The elevation of the upper eyelid is performed by a peculiar muscle, arising from the involucrum of the optic nerve gradually spreading, and continued by its expansion to the tarsus. This is considerably assisted in its action by the frontalis, which is variously connected with the orbicularis, and draws it upwards. The upper eyelid is depressed by the orbicularis, as it is called; a broad muscle, both widely expanded around the orbit, and contained in the eyelids, carried as far as both angles of the

eye,

eye, and having, as fixed points, the ligament adhering to the process of the maxillary bone, and some fibres inserted into the frontal and upper jaw bone. The same muscle elevates the lower eyelid, and covers the eye in such a manner that no dust or light can enter it during sleep. The lower eyelid is depressed by two bundles of fibres, inserted into the upper lip.

DII. Finally, that the tumid margins of the eyelids may not shut too closely, they are provided with eyelashes, or fringes of hair spreading outwards, proceeding in many rows from the edges of the eyelids, which, by decussating each other, increase the shade and obscurity. These are of use in more distinct vision, by excluding the extraneous rays, when we require a distinct representation of any object.

DIII. The eyelids are prevented from hurting each other by the sebaceous glands of Meibomius, consisting of thirty or more follicles in each eyelid, which are simple, bifid or trifid; placed in general according to the length of the lid, and composed of peculiar blind roundish cavities, which unite into one larger serpentine duct, of which the orifice is in the margin of the eyelid itself. These discharge a soft unctuous liniment, which mixes and washes off with the tears.

DIV. But the perpetual attrition caused by the eyelids ascending and descending against the globe of the eye is prevented, the delicacy of the cornea is preserved, and any insects or other irritating substances which may have got into the eye, are washed away by the tears; a saline, pellucid, and evaporable liquor, which never ceases to be poured over the anterior surface of the eye, but never runs over the cheeks, unless accumulated from some cause. This liquor is exhaled partly from the arteries of the conjunctiva, as we see from an imitation of nature by injecting water; and in part it is believed

believed to proceed from a gland seated in a hollow recess of the os frontis, somewhat hard, and of the conglomerate kind : divided into many lobes, intermixed with fat, and supplied with many blood-vessels from the ophthalmics and internal maxillaries ; and pervaded by many nerves arising from a peculiar branch of the first trunk of the fifth pair.

DV. From this lachrymal gland, six or more visible ducts descend, which open on the inner side of the conjunctiva of the eyelid. In man these ducts have been lately discovered by credible authors. The secretion of the tears is increased by the repeated contractions of the orbicular muscle, either from irritation, or some depressing passion, by which means the tears are conveyed over the whole eye, and the surface of the conjunctiva is washed.

DVI. After the tears have performed their office, some part of them being evaporated by the air, the rest, that they may not prove injurious by their accumulation, are propelled by the orbicular muscle, towards its origin next the nose, and to the innermost part of the commissure of the eyelids ; which from not having any tarsus, does not meet exactly together. There a caruncle, full of sebaceous, hairy follicles, oblong, and conical outwards, interposes itself between the eyelids, and prevents them from meeting, and anoints with its liniment those parts of the eyelids which have no Meibomian ducts. Before it, a small third eyelid descends perpendicularly, and joins the true eyelids ; it is larger in beasts. At the beginning of this space interposed between the eyelids, in which the tears are collected, in each margin a little papilla projects, having one orifice, surrounded by callous cellular substance, and perpetually open, unless when convulsively closed. This orifice, which is called the punctum lachrymale, absorbs the tears from the sinus in which they are collected, partly by attraction, and partly by the impulse of the orbicular muscle. If  
these

these points are obstructed, the tears run over and excoriate the cheek.

DVII. From each point, a peculiar duct, much wider, thin, and included in the skin, proceeds, the one downwards above the caruncle, and the other more transversely inwards, and under it; which approach each other, and are inserted by two mouths into the lachrymal sac, not quite at the top; which name is given to a cavity formed in the groove of the os unguis and upper jaw, lined first with a hard cellular, and as it were aponeurotic membrane; then by another, red and pulpy, continued from the membrane of the nares, pervious to the exhaling moisture, and somewhat of an oval figure. From this vesicle the nasal duct descends a little backwards into the nares, and opens by an obliquely oblong aperture, covered by the lower os spongiosum, into their lowest meatus. Through this the superfluous tears descend into the nose, which they in part moisten, (ccclxiv.) A muscle is by some ascribed to this sac; but it is not yet sufficiently ascertained.

DVIII. The eye, of a globular shape, compressed before, though not always in the same manner, longer from the brain to the cornea than from the right side to the left, is situated in the orbit, which is an osseous cavity, almost conical, composed of seven bones, interrupted in the back and outer sides by larger fissures, and widening forwards, and by which it is defended on all sides. But as this is larger than the eye, it is filled by much very soft fat, surrounding the globe of the eye, and allowing it free motion.

DIX. The eye begins from a nerve, by the expansion of whose coats those of the eye are formed. Its origin we have already described, (ccclvii.) Having passed across the crus of the brain, it joins with its fellow from the other side, and coheres with it for a considerable way, by much medullary substance; yet so that the right goes to the right eye, and the left to the left, though not without some

some reciprocal intermixture of medulla. The nerve then enters the orbit, a little inflected, and of a round form, somewhat compressed; and is inserted, not into the middle of the globe of the eye, but a little nearer to the nose.

DX. The nerve having reached the eye, the inner plate of its dura mater, which it received in the opening of the sphenoidal bone, is detached: or having become thicker, is extended around the eye, as its first coat, called the sclerotic, or adheres to the sclerotic, which perfectly resembles it, and always arises from it. The other plate of the dura mater, the external, recedes and forms the periorbitum of the orbit; the pia mater, which is in this nerve very distinct and full of vessels, having become entirely dark coloured and thin, lines the inside of the sclerotic. The remaining medullary central part of the nerve, continued from the brain, but divided by cellular plates, contracts into a depressed white conical papilla; which entering through the holes in the white circle of the choroid coat, and again expanding, produces the most internal membrane of the eye, the retina.

DXI. The sclerotica is in general white, furnished with few vessels, tough and compact, resembling the nature of skin, of a figure very nearly globular, but compressed before, and is thicker at the back part. Before this coat, which is perforated by circular holes in its forepart, is placed, and obliquely connected with it, a more convex portion of a sphere; pellucid, composed of many plates, whose vessels are filled with pellucid water, and are difficult of demonstration, insensible, and almost circular, circular towards the nose, and oval towards the temples: it is termed the cornea, and through it the light passes into the inside of the eye. It readily imbibes and exudes water. Before the anterior and flatter part of the sclerotica, and before the cornea, the conjunctiva is detached from each of  
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the eyelids, and is joined to the sclerotica by proper cellular substance, which may be inflated, (D.) and is replenished, partly with red vessels, and partly with their pellucid continuations.

DXII. The origin of the choroid coat, is from the circumference of the white cellular circle, terminating the substance of the optic nerve, and through whose numerous foramina, and from which the retina and arteria centralis retinae proceeds. At that place the choroides adheres to the sclerotic, and to the circle above described. Then it is expanded concentrically, within the sclerotic, with which it is united, perhaps by some cellular substance, and by many vessels, which come from it to the choroides. Outwardly it is of a brown colour, but inwardly of a deep russet or almost black, and at the same time villous; the two surfaces are separable by maceration; and the innermost may be distinguished by the name of Ruyfch; but it grows white through age. When it has reached the beginning of the pellucid cornea, it there becomes closely connected with the sclerotica, by much cellular substance, having the appearance of a white circle, called orbiculus ciliaris, and then turns off in another direction; namely, the coat, which was before spherically expanded, is now stretched under the arch of the cornea, in the form of a circle, a little convex forwards, and incomplete, having in its centre a circular foramen called the pupil, which is seated nearer to the nose, and is larger towards the temple. The anterior part of this ring is called the iris; and the back part, separable from the former in the human body, by maceration, in some animals even by the knife, is, from the black pigment with which it is covered, called the uvea. On the anterior surface of the iris appear numerous radiated and branching streaks, of various colours in different people, and entirely covered with flocculi. These terminate  
on

on this side of the pupil in a serrated circle, from which other similar streaks extend, even to the edge of the iris. They are serpentine when the pupil is dilated, and straight when it is contracted. On the posterior surface of the uvea is much black pigment; which being washed off, straight radiated streaks appear, extending to the pupil, and not flocculent. Orbicular fibres, concentric with the pupil, I have not been able to observe, either with the naked eye, or with the microscope, even in the ox; but only in the uvea, an internal circle distinguished by obscurer rays, and less villous. In the human foetus, the pupil is shut up, and the iris being continued, makes a complete circle. That part of it which extends across the pupil is of a vascular texture.

DXIII. Though the iris has little sensibility, and is not endowed with any mechanical irritability; yet during life, in man, quadrupeds, and birds, the pupil is contracted by every greater degree of light, and is dilated by every smaller one; hence it is also rendered broader for viewing distant objects, and narrower for viewing such as are near. The cause of this dilatation seems to be a remission of the powers resisting the aqueous humour; as proved by the dilatation of the pupil, from debility, syncope and death. The contraction is less understood, and perhaps only depends on the stronger afflux of humours into the colourless vessels of the iris, by which these vessels are extended; and, at the same time, the iris is rendered longer, and shuts up the greater part of the pupil: so that this motion has something in common with inflammation, as agreeing in their cause. In young people, the pupil is more evidently moved and contracted; as the eye gradually grows callous in old people, it becomes almost immoveable. In an animal twenty-three hours after death, I have seen the iris extended by heat so as to shut the pupil.

DXIV. Behind the uvea, from the same circle in which the choroides unites with the sclerotica, more externally than the cornea, thick striæ, elegantly plaited, arising from the choroides, white, with parallel vessels running under them, with plumes, pendulous extremities, joined to the loose and thin retina, and every where covered with a good deal of black pigment, depart, in the form of a perforated ring, inwards from the tunica choroidæ, and proceed forwards behind the ciliary circle, and rest upon the vitreous humour; and, lastly, upon the capsule of the crystalline lens, but do not adhere to them. They are denominated the ciliary ligaments. The origin of the pigment is not known; nor have the secreting glands, which some have supposed, been found. Among its uses, one seems to be, to keep the crystalline lens firm. In infants, this same mucus, behind the ciliary processes, expresses the figure of a radiated flower.

DXV. The retina, which is a true continuation of the medulla of the optic nerve, and therefore very tender, mucous, and evaporable, is expanded within the choroides into a similar sphere, concentric with it; and immediately incloses the vitreous humour. But when the retina has reached the ciliary processes, it follows their course, supporting their arteries and striæ, and proceeds to the crystalline lens, adhering to and covering its capsule, if the observations of some other anatomists, as well as my own are to be relied on; for in quadrupeds this termination of it is not perfectly certain, although in birds the internal lamina of the retina, covered with the ciliary body, is evidently continued to the crystalline lens; to the circumference of which it also adheres in man. The fabric of the retina is such, that externally its soft and medullary globules form a thick and pulpy membrane, within which radiated fibres proceeding from the lamina cribrosa, and continued forwards, constitute a thinner

a thinner involucrum, very readily observed in fishes, and also in some birds and quadrupeds, but not in man. Arterial and venous vessels with red trunks, form a net in the internal surface of the retina, which when accurately filled with coloured water compose a membrane.

DXVI. These coats, resembling the coats of a bulbous root, are supported, and the spherical figure of the eye is preserved by its humours: of which one is a solid, another a soft body, and a third truly a liquor. First, then, the concave surface of the retina is every where filled by the principal or vitreous humour, of which the structure consists of a peculiar thin, pellucid, cellular membrane, in whose cellular intervals is contained a very pellucid liquid, very rarely altering even in old age, completely evaporable by heat, nearly allied to the aqueous humour, and somewhat denser than water. Its vessels, which are most manifest in fish, lie in the back part, most beautifully radiated from the central trunk of the retina, embracing the convexity of the vitreous humour; and inserted into a circle formed not far from the lens by other arteries coming from the choroides, and which I have seen in the sheep. The vitreous membrane, which is tender considering its body, adheres to the lens in two places, before and behind; so that a hollow space is intercepted in the middle between the two insertions, around the crystalline lens. This space is divided in different places by some fibres. On its anterior surface the striæ of the ciliary body imprint their marks.

DXVII. But, in the forepart of the vitreous body, behind the uvea, there is an orbicular depression of considerable depth, into the cavity of which the crystalline lens, (also, though improperly, ranked amongst the humours,) is received. The figure of this lens, resembling frozen jelly, is composed of  
two

two elliptical convex segments, the anterior of which is flatter, and the posterior more gibbous. It is constructed of concentric laminæ, connected by cellular fibres, which themselves are composed of fibres elegantly disposed through fine cellular membrane. Betwixt the plates of the crystalline lens, is also contained a pellucid liquor, but which, in old age, naturally acquires a yellow colour. The innermost scales are more closely compacted; and form as it were a harder nucleus; externally it adheres so very loosely to the capsule, that when that is broken, it very readily springs out; and some even say, that a little water is effused around it. It is supplied with an artery from the retina, which perforates the middle of the vitreous humour, and enters behind; for vessels have not yet been discovered on the anterior surface. The whole lens is contained in a strong, thick, elastic capsule of a pellucid membrane, more firm in the forepart, and which is lined posteriorly by the vitreous tunic.

DXVIII. Lastly, the aqueous humour, which is extremely pellucid and fluid, and which is renewed again if it be let out, swims in the small triangular curvilinear space betwixt the uvea and crystalline lens, and in that larger segment of a hollow sphere which lies betwixt the iris and the cornea. This humour seems to exhale from the small arteries of the iris, uvea, and ciliary processes; being again absorbed by the corresponding veins, while some portion of it is absorbed by and exhaled through the cornea. This humour also moistens the uvea and capsule of the lens. About the beginning of the present century, the spaces filled with this liquor were called the chambers of the eye; that between the cornea and iris the anterior one, and that small one between the surface of the crystalline lens and the uvea the posterior.

DXIX.

DXIX. The eye, thus constructed, is provided with muscles externally inserted into it, by which it is governed. Namely, into the circle of the sclerotica, which is contiguous to the cornea, are inserted four straight muscles, arising almost in one circle from the dura mater of the optic nerve; where, departing from the nerve, it coheres with the periosteum of the orbit, and proceeding forwards with their bellies round the bulb of the eye, they terminate again by their aponeuroses, meeting together in another circle. Of these, the elevator is the least, and the abductor rather the longest. The office of each of these muscles appears very plainly; since, being bent round the convex bulb of the eye, as about a pulley, they must, of course, elevate, depress, or turn the eye either to the nose or to the temples. Moreover, two of them acting together may move the eye diagonally; as upwards and outwards, upwards and inwards, &c. Lastly, when all the four straight muscles contract together, there is scarcely a doubt that they draw back the whole eye within the head towards their origin, and thus bring the crystalline lens nearer to the retina.

DXIX. But the fabric of the two oblique muscles of the eye is more compound. The upper of these, arising together with the recti, is long and slender, ascending forwards to a notch in the os frontis, which is completed into a hole by a double ligament, which on each side sustains a cartilage, excavated in the middle, and almost quadrangular. Through this canal passes the tendon of the obliquus, which being reflected backwards and outwards, included in a capsule of its own, is inserted into the globe of the eye behind the straight muscles. This draws the globe forwards, as if out of the orbit, and inwards, and turns the pupil inwards and downwards. The other, the obliquus minor from the sinus of the lachrymal foramen in  
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the upper jaw, ascends immediately outwards from the os unguis round the globe of the eye, and is inserted by its tendon into the sclerotica behind the external rectus : whence it appears to turn the point of its insertion into the eye downwards and outwards ; and, therefore, the opposite pupil upwards and inwards.

DXXI. But there are other minute muscular motions performed in the eye, which presuppose a knowledge of its nerves. Of the optic nerve we have already treated (DIX. DX.) The fourth pair goes only to the larger oblique muscle, and the sixth pair to the rectus externus. The third and fifth pair produce the principal nerves in the eye ; the first or ophthalmic branch of the fifth sends off a nerve at its entrance into the orbit, to the eyelid and lachrymal gland, which joins with the second branch of the fifth pair, and with the temporal branch of the third of the fifth pair. On entering the orbit, its trunk divides into two. The upper branch, larger and bifid, is expended on the forehead and eyelids : but the lower, penetrating inwards above the optic nerve, sends off a long slender filament at the outer part of that nerve, which, joining with another filament of the third pair forms the ophthalmic ganglion, and sends off one or two ciliary nerves. Finally, after having given off the recurrent nerve of the nose (CCCCLVII.) it is then spent upon different parts in the internal angle of the eye.

DXXII. But the third pair is of most importance. After giving off a branch upwards to the straight muscles of the eye, and to the eyelids, it proceeds with its trunk under the optic nerve, and at the same time sends out three branches to the inferior, obliquus minor and internus ; after this, or before, from its trunk, or sometimes from the branch of the obliquus minor, it sends off another short nerve, much thicker than the root from the fifth,  
(DXXI.)

(DXXI.) which, under the abductor muscle upon the optic nerve, forms the ophthalmic ganglion, which is oval and constant, and sometimes arises from the third alone. From that ganglion, and sometimes from the trunk of the third or fifth, four or five ciliary nerves playing around the optic nerve in a flexuous course, go to the globe of the eye, perforate the sclerotica almost in its middle, in company with its longer small arteries or veins, run straight forwards along the choroides, and visibly proceed to the iris, and seemingly to the ciliary processes. Other very small nerves, originating from the same ganglion, remain in the tunica sclerotica.

DXXIII. The motion of the ciliary processes is obscure and difficult of demonstration, (DXXIV.) lying incumbent upon the furrows of the vitreous membrane, by their action they are believed to press back that body, so as to bring the lens forwards, and remove it farther from the retina. But I have never seen, in all the animals I have dissected, any thing like a muscle in this ciliary body, but only a membrane which supports small vessels. The sphincter of the pupil and constrictor of the cornea, mentioned by some writers of eminence, and the moving fibres, which others have imagined proper to the crystalline lens, are not confirmed by anatomy, nor are they consistent with the constant hardness of the lens and cornea in most animals.

DXXIV. The history of the eye also comprehends its vessels, which have a most beautiful fabric. All those which belong properly to the eye itself come from the ophthalmic artery, a branch of the internal carotid, (CCCXVI.) This, creeping under the optic nerve, sends off, as principal branches, the upper ciliary, one or more inferior ciliaries; the lachrymalis, from whence the nasalis recurrens posterior, and internal part of the arch of the tarsus; afterwards the muscularis inferior, the nasalis recurrens,

currens, anterior and posterior, the musculares superiores, and the palpebralis, which, with the former branch, forms the arch of the tarsus. Lastly, it goes to the face, nose and adjacent parts. But the ophthalmic branches, belonging to the inner parts of the eye, are called the ciliaries; which, arising from the trunks now mentioned, and playing around the optic nerve, in four or more branches, in a serpentine course, partly close by the entrance of the optic nerve, go to the choroides with forty or more branches, and make upon its external surface, ramifications divided at acute angles, which proceed forwards to the circle of the uvea.

DXXV. But most of the small arteries of the tunica choroides gradually incline towards the interior parts of the eye; and, being covered with a kind of cellular down, go to the ciliary processes, along each of which two small arteries run, giving off on every side, vascular flocculi, and inosculating at their apex.

DXXVI. Other small arteries also, likewise arising from the ciliary ones, but few in number, most commonly two, go to the place, from which the uvea originates. There, spreading in various directions, they surround the root of the uvea with their branches, and join to form a circle, into which the anterior ciliaries inosculate; which are small arteries arising from the muscular branches of the ophthalmic; and are inserted into the circle generally by twelve small trunks, near the origin of the cornea. From that circle, and likewise from the above mentioned anterior ciliary arteries, without the intervention of the circle, straight, branched vessels, are distributed, both on the iris, and on the uvea; the former full of a blue or dark coloured fluid; and the latter naturally white, but covered with a good deal of a black paint. In the uvea, at some distance from the pupil, they frequently form an imperfect circle.

DXXVII.

DXXVII. But from the same ophthalmic artery, from its trunk, or from the lachrymal branch, or from one of the ciliaries, one or more branches enter into the optic nerve; the principal, the central artery of the retina, penetrates into the medulla of the nerve, and passing through the apex of the papilla, (DX.) enters the centre of the retina; from thence it spreads every way through the retina itself, by so many branches, when traced by a skilful anatomist, that that vascular network has been taken for a peculiar membrane. Sometimes a small branch goes along the centre of the nerve to the retina, and is in like manner ramified through it. From comparative anatomy, it is certain, that from these branches the vascular branches of the vitreous tunica are produced, as well as the posterior artery of the lens. The most internal of these arteries, is the celebrated porus opticus of the ancients.

DXXVIII. The veins of the eye, in general, arise from the ophthalmic vein, which on the one side comes from the facial vein, entering the orbit; and on the other, is inserted into the cavernous sinus. The internal veins of the eye perforate the middle of the sclerotica, with fewer and larger trunks than the arteries, and form larger and more anterior reticulations, of a roundish figure, which commonly occupy the middle of the tunica chorioidea: some, which are long, are continued to the origin of the uvea: others anterior, similar to the arteries; and another, the centralis nervi optici, corresponding with the artery, goes to the retina. The pellucid vessels do not differ from the sanguiferous. Lymphatic vessels are said to have been seen in the retina; but the observation has not been sufficiently repeated.

DXXIX. So far with respect to the anatomy; but the action of the eye is entirely elucidated by physical experiments, from which it has been ascertained, in the most incontrovertible manner, except  
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a few doubtful points. Light is the same matter with heat, or very nearly the same, possessing extreme fluidity and subtilty, penetrating through all bodies, very rigid, not exhausted by any distance of its passage, and moving with excessive velocity, so as to arrive at the earth from the sun in eight minutes and thirteen seconds. Light in our planet proceeds either from the sun, which seems to have the power of arranging in straight lines, the matter of light, otherwise confusedly scattered; or from some other lucid point. From it, as from a centre, the light is distributed like rays, to all parts of the sphere, so as to fall upon the surfaces of all bodies; from whence again it is reflected, and impinges on the eye, at angles equal to the angle of incidence, and renders the bodies, from which it comes, coloured and visible.

DXXX. It is ascertained, from experiments, that light is composed of rays in right lines, almost without any physical breadth; and yet, each of which may be separated into seven more minute, permanent and immutable rays. The known properties of these rays are, that all of them, conjoined together, constitute a white beam; but when refracted, and separated by the minute surfaces of bodies, they are subdivided into red rays, which are the most constant, hard, and least refrangible; and afterwards into orange, yellow, green, blue, indigo, and violet; which are always weaker and more refrangible, as they are farther distant in order from the red rays. Shade arises from a deficiency of reflected rays. Colours are compounded of shade united with various rays.

DXXXI. The peculiar colours of bodies arise from the minute surfaces of their solid particles, by which their pores are limited, which refract the rays of light, according to the difference of their thickness, reflecting one kind of rays most copiously, and in a great measure suffocating by repeated internal refractions, the others admitted into their substance: so that  
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the thickest and densest particles reflect a white colour; the next red; and the thinnest violet. Bodies are opaque, which retain all the rays, and transmit none, from the largeness of their pores, to the sides of which the light is attracted; and which are filled with some matter that has a power of refraction, different from that of the particles of the body. These principles we embrace, till a new theory, which ascribes the diversity of colours to vibrations of different celerities, shall be better established; for it is not our business to ascertain these matters.

DXXXII. These rays, when they fall obliquely upon liquors of various densities, in passing through them, variously recede from, or incline towards the perpendicular: this is called refraction. In general, the denser the medium, the more are the rays bent towards the perpendicular; excepting only inflammable liquors, which, by a peculiar property, attract the rays more to the perpendicular, than in proportion to their density. The proportions of the angles of incidence to those of refraction, are constant; so that the sine of the angle of refraction of rays passing from air into water, is to the sine of the angle of incidence, as 3 to 4: and of rays, passing from air into glass, the sine of the incidence is to that of refraction, as 17 to 11; and from water into glass, as 51 to 44.

DXXXIII. Rays, which come through the air with but little divergency, as those of the sun on account of its immense distance; or as, in general, any rays that come from a distance of above 100 feet, when they fall upon a body, spherically convex, and denser than the air, at a large angle, as at  $48\frac{1}{2}$  degrees, are reflected, and do not penetrate it. If the angles are smaller, they penetrate the refracting medium, and are refracted in it, so as to meet together in one point, which is called their focus. This point lies in the axis, or in the ray, falling perpendicularly

perpendicularly on the surface, and therefore not inflected; and in a spherical globule of water, the focus of rays coming from the atmosphere, is at the distance of one semidiameter from the sphere; and in a sphere of glass, a fourth part of the diameter, and in a convex lens of glass, that is, a part of a sphere not less than thirty degrees, and equally convex, it is also one semidiameter; but so that the rays meet, not in a point, but in a little circle.

DXXXIV. Therefore the rays of light, whether direct or reflected, fall in such a manner upon the cornea of the eye, as to form a very acute cone, from the lucid point to the surface of the membrane: the basis of which is the surface of the cornea, and the apex the radiant point; yet so, that the rays of the cone may be considered parallel, without any sensible error. Of these rays, all those which fall upon the cornea at a greater angle than forty degrees, are reflected from the cornea without penetrating its surface. Others which enter the cornea, but still at large angles, fall in betwixt the uvea and sides of the crystalline lens, and are suffocated in the black paint that lines the uvea, (DXII.) and the ciliary processes, (DXIV.) and those rays only fall upon the surface of the lens, which enter the cornea at small angles, not much distant from the perpendicular, or at about twenty-eight degrees. By this means, all those rays are excluded, which the refracting power of the humours in the eye could not have been able to collect into one point of the retina; and which, therefore, would have painted the image on the retina too broad and confused.

DXXXV. Those rays, therefore, coming from the air, which is so thin, and passing through the cornea, which is the segment of a sphere, thick, denser than water, and therefore almost a fourth part more refracting, are remarkably inclined towards the perpendicular. By the aqueous humour, which is  
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small in quantity, and almost like water, but rather lighter, they are not altered, and fall upon the surface of the transparent lens, before they have formed a focus, because of its nearness, nearly parallel, or rather converging; because their divergency was abundantly corrected by the refracting power of the cornea. Moreover, the cornea being convex, and more prominent than the hemisphere of the sclerotica, receives and collects a greater number of rays than if its surface were flatter, and therefore smaller.

DXXXVI. That the refracting power of the crystalline lens, exceeds that of water, may be understood from its hardness and weight, although we have no sufficiently certain measure. In this lens, therefore, and more especially in its posterior very convex surface, the rays converge very much, and pass thence into the vitreous body.

DXXXVIII. This substance is denser than water, since it sinks in it; but rarer than the crystalline lens; bends the rays a little more gently towards the perpendicular, till at length the rays, coming from a point of distinct vision, are concentrated into the smallest possible point of the retina, where they paint an image of the object from which they come; but inverted, on account of the necessary decussations. The manner in which the images of objects are thus painted, may be seen in an artificial eye, or in a natural eye, when the back part of the sclerotica is removed. But the image is painted on the outer side of the entrance of the optic nerve, at the termination of the axis of vision, which is not limited to a mere point, but has some breadth; since we see many objects at once, whose images must be represented in different points. Vision is there most distinct, because the rays arrive thither nearly perpendicular. But frequently it does not fall on the same place in both eyes of the same individual. When the lens is destroyed,  
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the vitreous humour alone collects the rays, though less powerfully.

DXXXIX. Is it entirely false that the object is painted on the retina? Is the picture represented on the choroides? Is this new opinion confirmed by the experiment, by which it appears, that the place where the optic nerve enters is insensible? and which is thus explained, that there is in that place no choroides but only the bare retina, and that therefore, it does not possess vision. But this is repugnant to a very well known observation, that the retina is a most sensible nervous medulla; and that the choroides almost entirely consists of a few small nerves, and of vessels which are most certainly blind. This is likewise contradicted by the very great variety of the choroides in animals; by the equally great uniformity of the retina; and by the black spots, which, even in man, obscure the exterior surface of the retina. But, by this experiment, we perceive the reason why the optic nerve is not inserted into the axis of the eye, but towards one side. For thus, except only in the single case, where an impediment is situated in the point of intersection of lines drawn through the centre of the optic nerves, the one eye sees and assists that whose blind portion is directed to the object.

DXL. But since the necessary functions of human life require that a distinct object be painted upon the retina, not only by the rays which come from one certain distance, but likewise that rays which come from various and very different situations, more or less distant, should excite a distinct idea of the object from which they come: therefore, it is believed, that the necessary change is produced in the eye by proper means. Some celebrated anatomists have supposed the lens moveable by the powers before mentioned, (DXIX. DXXIII.) They assert this art of changing the eye is learned by experience,

ence, and is not possessed by those on whom the operation of couching the cataract has been lately performed. Also in an artificial eye, the advantages and necessity of this motion, it is said, may be plainly perceived. Therefore, too great a divergency of the rays, as in those which come from objects very close to the eye, is corrected by the removal of the lens farther from the retina, by which means the focus, which is more distant, on account of the divergence of the rays, falls upon the retina itself, which would otherwise have fallen behind the retina; for the refracting power of the eye being supposed to be such, as will cause the focus of rays coming from the distance of three feet, to fall exactly upon the retina, it will not be able to collect together into the same point, rays which come from the distance of three inches; and the more diverging rays, when not collected by more powerful means, will be too late of uniting.

DXLI. But those rays, which come from very remote situations, and may be therefore reckoned parallel, would meet in the vitreous humour before they reached the retina; and would again separate as rays from the point of concourse, as if from a lucid point: it is therefore believed, that the powers, (DXXIII.) remove the crystalline lens from the cornea, and carry it nearer to the retina, that the rays may meet at a greater distance from the lens, and that that distance may be accommodated so as to fall upon the retina. For an eye, that will collect the rays coming from a distance of seven inches, on the retina, will collect those which come from a distance of three feet too soon, and before they reach the retina. So that it seems perfectly necessary for the eye to be made thus changeable, since we see distinctly at various distances. The point of distinct vision is that in which the given object is painted on the retina in the least space possible. The powers collecting the rays, are often very different

ferent in the two eyes of the same person, so that the one eye is rather long sighted, and the other short sighted.

DXLII. These and other similar opinions, commonly received, are taught, more especially by the mathematical physicians, who more obviously perceive the necessity of these changes. Yet there is no power in the human eye which can either move the crystalline humour from its place, or compress it. And we do not perceive this faculty in ourselves: for we move a book, which by being too far off we see confusedly, nearer to our eyes, which we would not do, if by an internal change in the eye we could correct the fault of the distance: and, through a small hole, we perceive an object only single in the point of distinct vision, but double in every other. Perhaps the contraction of the pupil may have some effect in enabling us to see near objects more distinctly.

DXLIII. But this adaptation is not sufficient in all persons: for there are, and now more commonly than formerly, persons leading a sedentary life, and occupied with the observation of very minute objects, in whom the cornea is more convex and dense; the crystalline lens more convex and solid; the eye itself, by the weight of the humours, more elongated; and the rest of the humours themselves probably more dense; and in whose eyes one, or several, or all of these diseases occur. In these persons, the iris is sensible in a small light; and therefore from their winking, they are denominated myopes. In these, the point of distinct vision is very near to the eye, from one to seven inches from the eye; they see remoter objects obscurely, without being able to distinguish their parts. The reason of this is evident; since, from the causes just mentioned, the too great refracting power of the humours, causes the distant and consequently parallel rays to meet before the retina;

retina ; and therefore diverging again from their focus, they fall upon the retina in many points. Thus also to a sound eye, the perception of near objects is confused ; because the rays coming from these are spread all over the retina, without being collected.

DXLIV. The remedy, in the commencement of this disease, is to view distant places, to abstain from minute objects, and concave glasses, and to look through a small aperture, by which the light is weakened. When the disorder is confirmed, it is alleviated by the use of a concave lens, which diminishes the refracting power in the humours, cornea, and crystalline lens, in proportion to its concavity ; and thus removes the focus of distant objects farther from the cornea, so as to fall upon the retina. This glass ought to be a portion of a sphere, whose diameter is equal to the distance of distinct vision by the naked eye, squared by the distance of distinct vision in the eye furnished with a glass, and divided by the difference betwixt them. Short sighted people may hope for some relief from the progress of life ; for children are almost all myopes : but, as they grow older, the eye becomes flatter from the strength of the solids, it becomes shorter, and the converging powers of the lens and cornea are diminished.

DXLV. Another defect, the opposite of the former, troubles people who are in the habit of looking much at very distant objects, and is especially frequent and incurable in old people. In it, the cornea and crystalline lens are flatter, and the humours of the eye have a less refracting power. Hence near objects, whose rays fall very diverging upon the cornea, appear to them confused ; because the converging powers of the eye are not sufficient to collect the rays into a focus upon the retina, and the rays arrive at it scattered, and have their focus behind the eye ; hence their vision is confused,  
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The point of distinct vision among presbyopi, is from fifteen inches to three feet.

DXLVI. Such persons are, in some measure, relieved by looking through black tubes, by the use of which the retina grows tenderer, and the rays come to the eye in a parallel direction. The remedy here is a convex lens of glass, which may cause the rays to converge, so as to meet sooner in a focus, and upon the retina. The diameter of the sphere, of which such a lens ought to be a portion, is exactly as before (DXLIV.) There is no hope from age, which increases the malady.

DXLVII. The medium betwixt the short and long sighted eye is the best, with which a person can see distinctly objects that are both tolerably near and tolerably remote, and therefore may assume the properties both of the myopes and presbyopi; of this kind we reckon an eye that is able to read distinctly at the distance of one foot. But other conditions are necessary, such as perfect clearness of the humours; great mobility of the eyes; sensibility of the pupil; and a retina, neither too sensible nor callous.

DXLVIII. But by means of the eye, the mind does not receive a simple representation of the image of the object on the retina, which is transferred to the seat of the soul; but many things are added from experience, which the eye does not really see, and other things are interpreted differently by the mind, from what they are represented by the eyes. And, first, the magnitude of an object is judged of by the optical angle intercepted between the radiating object as the vertical point, and the cornea as the base. From hence, things very near seem large, and remote objects small. To this may be referred the power of the microscope, by which objects are made to appear to us so much larger, as the distance of the focus of the glass lens is less than the distance of distinct vision; and,

and, in reality, they do not appear larger, but only more distinct and lucid ; whence the mind judges them to be nearer.

DXLIX. In the same external light, the strength of illumination depends upon the same angle, and upon the number of rays, joined with the smallness of the point which they affect in the retina ; near objects therefore appear brighter, and distant objects more obscure ; or if remote objects appear bright by their own light, the mind represents them as large, or near, or both.

DL. The place of a visible object is estimated by one eye, to be in a line comprehended by two other straight lines drawn to the extremities of the body. If the same body is beheld with both eyes, it will then seem to be in the concurrence of two lines drawn through the axis of each eye to the object.

DLI. We do not see distance ; and a blind man, who has never seen, on acquiring the use of sight, imagines every thing he sees to touch him. After much experience, we at last make conjectures about distances, though always fallacious : but we judge of them both from the diminution of the known bulk of the body, and from the diminished strength of the light, and faint image of the object whose parts we distinguish less evidently, and from the number of bodies interposed, whose distance is known to us.

DLII. Convexity is not seen ; but from experience, a body is reckoned convex, after we have learned, that a body, which is convex to the feeling, causes light and shadow to be disposed in a certain manner. It is convex if the shade be in the side corresponding to the left hand, and concave if in the right. Hence it is, that microscopes frequently pervert the judgment, by transposing or changing the shadows. The same also happens in that phenomenon which is not yet sufficiently understood,

derstood, by which the concave parts of a seal are made to seem convex, and the contrary.

DLIII. The parts of a visible object are judged by the mind to have the same situation which they have in the object, and not inverted as they are on the retina. The mind possesses this power of correction, previous to experience in men who have been born blind, and in animals at birth, as appears by indubitable experiments upon men, who had been blind from birth, and acquired the power of vision suddenly by the operation of couching.

DLIV. Another false perception of the mind arises from this circumstance, that external sensations conveyed to the seat of the soul by the eyes, are represented during almost the space of a second of a minute, to the mind as objects really present. Hence proceeds the idea of a fiery circle from the circumrotation of a lucid body; and hence the continuance of the image of the sun, and sometimes also of opaque bodies.

DLV. Do we perceive only that object distinctly which is directly before that part of the retina which sees most distinctly? And does the mind persuade itself, that it sees many objects at a time, partly from the duration of the ideas, and partly from the quickness of the motions in the eye? Concerning perfectly distinct vision, this is most certain; but we can hardly affirm it of that which is less distinct. Why do we see only one object with two eyes? Because the sensation is single, and without difference, when we have similar impressions of two objects. For, even without the decussation of the optic nerves, insects who have numerous eyes perceive objects single. Hence the images of two objects excite only one sensation in the mind, when they fall upon the same point of the retina; but two sensations arise from one object, when the images fall upon different parts of the retina of each eye. Whence proceed diurnal and nocturnal blindness?

blindness? The latter is common to many nations living in the very warm climates, and under the vertical sun, and to old men. The former happens in inflamed eyes, and in young men of a hot temperament, and hence furnished with eyes vastly sensible. For great sensibility of the retina produces diurnal blindness; insensibility produces nocturnal blindness. How do animals see in the dark? From a large dilatable pupil, tender retina, and refulgent and very lucid choroides. Why do we become blind when brought out of a strong light into a weak one? Because the optic nerve, having suffered the action of stronger causes, is not affected by weaker ones. Why is the sudden translation from a dark place into the light painful? Because the pupil, being widely dilated, suddenly admits unawares too great a quantity of light, and the retina having been but slightly affected by the weak light, now feels the stronger impressions very acutely. Do we see with one eye, or with both? Most frequently with one, especially and generally the right eye: but by the assistance of the other, we see more objects, and more plainly; and we also distinguish more points of the same object, and judge better of distances.

## C H A P. XVII.

## INTERNAL SENSES.

DLVI. **W**E have considered the senses apart. It is common to them all, that the medulla of the tender and pulpy nerve, being affected by external objects, transmits some change by the nervous spirits, to that part of the brain where the fibres of the nerve affected first arise from the arteries of the brain (CCCLXXXII.) We know nothing more, than that new thoughts are  
excited

excited in the mind, as often as a change of this kind, originating in any organ of sense, is transmitted to the origin of the nerve affected. For this perception is not an actual representation of the object, by which the sentient nerve is affected: The idea of redness has nothing in common with rays little refrangible, and separated from the seven portions of the total ray; and much less is it consistent with optical principles, for an image painted by rays upon a soft white nerve, to be conveyed for a long way, in perfect darkness, through a completely opaque body, to the origin of the thalami optici. There is nothing in the pain of burning that can represent to the mind the violent motion of a swift and subtile matter, by which the particles of the nerves are removed from mutual contact. There is nothing in the idea of a sharp sound from a cord of a certain length, that can inform the mind that the said cord vibrates 5000 times in the space of a second. Neither does the taste teach us that the crystals of sea salt are of a cubical figure. Lastly, motion imparted by a body perceived by the senses, is indeed propagated to the brain, but the mind neither perceives this motion, nor the tremors of sound, nor the percussion of the rays of light, but something perfectly distinct from motion. It is established as a reciprocal law by the Creator, that with certain changes, produced first in the nerve, and then in the sensorium commune, new and definite thoughts shall arise in the mind, invariably connected; and that our perceptions of external objects are arbitrary, yet that they are not false, appears plainly from the perpetual agreement of similar ideas with similar affections of the sentient nerves, in all persons at the same time, and in one person at different times.

DLVII. Therefore, when we feel, five very different existences are conjoined: the thing which we perceive; the affection of the organ of sense by that body;

body; the affection of the brain, arising from the percussion of that sensory; the change produced in the mind; and, lastly, the consciousness of the mind, and perception of the sensation.

DLVIII. It appears from certain experiments, that the first origin of every sentient nerve is always distinct from all the others; and that the change which is first excited by external objects in that nerve (DLVI.) continues long in its origin; and that those changes are generally so arranged in the said part of the brain, that, being disposed according to the order of time, those are nearest together, which were either cotemporary, or occurred in immediate succession; or, lastly, those which have a relation to the same subject, or were excited by similar objects; insomuch, that it is certain, that new ideas are conveyed to the same part of the brain where others of the like kind are reserved: for otherwise, neither would the arbitrary signs of words and letters recall to the memory past ideas; or disagreeable ideas, returning into the mind, without the assistance of external objects, reproduce the same effects, as objects themselves; nor, otherwise, could there be so constant and manifest a connection of analogous ideas, which supervene most remarkably in dreaming, to the corporeal impressions, acting at that time most powerfully. Imagination and memory depend on this conservation of ideas. Those changes conserved in the sensorium, which many term ideas, are, for the sake of distinction, by us called the impressions of things, as they do not exist in the mind, but are impressed in the body itself, and indeed in the medulla of the brain, in an incomprehensible manner, by certain characters, incredible in their minuteness, and infinite in their number. Amongst these the impressions received by the sight are the most remarkable, and most distinctly preserved, and next, those of hearing; those of the other organs are more confused, and less revocable

vocable by the will. Both the impressions and their signs are preserved; the latter more easily; the former, however, so far, that a painter can express with his pencil upon canvas, a face similar to the image of a familiar face, impressed upon his mind.

DLIX. We are said to imagine, when, by means of any image preserved in the sensorial part of the brain, the same ideas are excited in the mind which would arise if the sentient nerve that first produced the said image itself suffered that change. This we term recalling an image. This definition is confirmed by the example of the great strength of fancy in certain persons, and in those who are delirious, and in every person, in the instance of dreams, in which thoughts arise in the mind, occasioned by the images preserved in the brain, not at all weaker than those which are primarily produced by the change in the sentient nerve, from the external objects, and in which the perfect resemblances of persons and things with which we are occupied, are represented to the mind. Attention, quiet, and the absence of other objects, even obtain a stronger assent of the mind to these traces impressed on the brain, than to those perceptions which are excited in the mind by external objects: for the will is much more powerfully determined in those who dream, than in those who are awake; and some voluntary muscles perform, during sleep, functions, which, while awake, they never could perform, even when their nerves were most strongly affected by the same object. From hence we may understand, how it is possible, that a very vivid internal impression in delirium, may so impose upon the mind, as to be mistaken for the perception of an external object; which is evident in the sparks which are excited by rubbing the optic nerve; in the redness seen by the eye when shut; in the vertigo that arises from a motion of the retina, which we ascribe to the external objects themselves; in double vision, &c.

DLX. Memory is said to be exercised, when any thought of the mind, or image of an external object preserved in the sentient part of the brain, (CCCLXXII.) excites any perception in the mind. This is commonly weaker than in imagination, and almost confined to certain arbitrary signs, which the mind conjoined with that idea at its first perception. For memory hardly represents the images and pictures of things to the mind, but almost only words, and certain attributes, and abstract ideas; for which reason, it excites volition less powerfully. But it appears from the observation of the phenomena of memory, that those changes which arise from the external senses, remain long in the brain; and sometimes, if they made a strong impression, are represented to the mind for a long period, almost forever; but that they are gradually weakened and impaired; unless they be renewed, either by the object being represented again to the mind, or by the mind itself recalling the same change again into memory; and that at last the change will be in a manner erased, and entirely lost, and the idea which was connected with that change by the law of nature, will never again recur to the mind. This annihilation is gradually effected by new and different impressions made on the sensorium, and not from time only, or the circulation of the blood, as in cataleptic patients, who sometimes, after a considerable interval of time, return to the same train of thought which the disease had interrupted. But sometimes all of them will be suddenly destroyed by some disease, in which the brain is in some way compressed, either by the blood or any other cause. Such a cause, acting on part of the common sensory, blots out a part of the impressions from the memory, such as certain words, or all of them, the characters by which we express words, or our friends, and even the necessities of life: yet all these impressions may often be renewed by removing the

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compressing

compressing cause. But the strength and duration of an idea depend upon its being unusual, excessive, or greatly conducing either to increase or lessen our felicity; and, lastly, upon our attention to it, and repetition; which last renders the impressions so vivid, that their perception is at length mistaken by the mind for the perception of external objects, as in the case of maniacs.

DLXI. Moreover, if we review the history of human life, it appears, that in early infancy, we have hardly any memory; only simple perceptions, that soon vanish: which, nevertheless, excite strong ideas in the mind, as we see from the crying of infants. The memory is perfected by degrees; and the ideas received from favorite objects, and familiar persons, remain impressed in the mind of the infant; while, at the same time, the imagination likewise increases, which is often very powerful in young children; as, for example, in terror, which in no age produces more violent or deplorable effects. Afterwards, as the number of our ideas increases, the facility of preserving past ideas is impaired, and, at the same time, the power of the imagination becomes torpid: till at last the former almost perishes, and the ideas which are received escape from the brain in a short time; while, at the same time, the imagination, which is a kind of memory, languishes.

DLXII. But since these perceptions produce various changes in the mind itself, which are perfectly distinct from any corporeal faculty, we shall briefly add something concerning them, so far as may suffice for the purposes of medicine. Thought resides in the soul, it attends to the sensations which are either brought by the senses, or recalled by the imagination; frequently also to the mere signs which recur into the mind. Attention is when one idea occupies the mind principally or solely for any length of time. The comparison of two ideas, instituted by the mind, is called judgment or genius, when

when the mind, by comparing them, discovers them to be alike or dissimilar. Genius consists in a vivid sensation conjoined with rapidity of thought, so as instantly to abstract from notions their points of similitude and dissimilitude. The principal source of judgment, invention, and wisdom, consists in the slow examination of ideas, by which they are considered by the mind in every point of view, and in the attention of the mind being confined to one object, to the exclusion of all other ideas. Hence the efficacy of darkness in making difficult calculations; the exquisite attention of blind people to the nature of sounds; and of those who are deaf, to colours. The sources of error, are negligence in contemplating the whole idea, the estimating it from a partial view, and the connection of ideas with others that are distinct, and only related by accident, or external causes.

DLXIII. The integrity of the judgment depends upon a healthy constitution of the brain. For when that is compressed, irritated, exhausted of blood, or changed in its fabric, the use of reason is totally disturbed; the strong internal impressions on the brain are represented to the mind as external or real objects; the chain of ideas is broken, so that the mind does not compare them, or perceive their resemblance or diversity, but passes abruptly from one idea to another totally different; or, lastly, the actions of the senses being impaired or interrupted, and all impressions being in a manner erased from the brain, man is reduced to a state of imbecility or vegetation. But external causes also have considerable influence in changing the relation of the mind to the impressions of the senses; the air, way of life, food, and habit, either assist or diminish the soundness of the judgment, the force of the imagination, and the strength of the memory.

DLXIV. Finally, as these ideas are either indifferent, or have some relation to our happiness, they produce different determinations in the will. Some of the causes by which the felicity of our mind is either increased or diminished, proceed entirely from the body, and are purely mechanical; amongst these are pain, disagreeable sensations, which seem to be produced by every sensation in a nerve that is too strong, and pleasure, in which the nerve is irritated beyond what is usual, but in a moderate degree. Itching is akin to pleasure, and in both the flow of blood is increased into the part in which either pleasure or titillation is perceived; but, when farther increased, it degenerates into pain, or excessive sensation in the nerve. Anxiety is from the blood being retarded in its passage through the lungs. Other ideas which affect the mind, are either entirely unconnected with the properties of matter, or certainly less simple, understood, or mechanical, than the foregoing. The presence of good constitutes joy; the desire of good, love; the expectation of good, hope: the presence of evil, sorrow, terror, or despair; the dislike of evil, hatred; and the expectation of evil, fear. Hope, curiosity, and glory, seem to be affections of the human mind, which neither belong to the body, nor exist in beasts.

DLXV. From these affections of the mind, not only the pure will appears to direct the actions of the body to a foreseen purpose, in order to attain good, and avoid evil, but also in the body itself, neither willing them nor capable of opposing them, various changes happen in the pulse, respiration, appetite, strength, and other functions of the heart, nerves, stomach, and other parts, which both immediately follow and indicate the passions of the mind. Thus anger violently excites the motion of the spirits, increases the motion of the heart, the frequency of the pulse, and the strength of the muscles;

muscles ; forces the blood into the ultimate and pellucid vessels, and even out of the vessels ; accelerates the excretion of bile, terminates chronic diseases, and removes obstructions. Grief weakens the strength of the nerves, and action of the heart ; retards the pulse ; destroys the appetite ; and produces paleness, cachexy, diarrhoea, jaundice, scirrhoties, and diseases arising from a stagnation of the humours. Fear diminishes the force of the heart, so as to occasion polypuses, and paleness weakens the muscular motions, relaxes the sphincters, increases inhalation, and diminishes exhalation. Excessive terror increases the strength even to convulsion ; excites the pulse ; removes obstructions, palsies ; interrupts the course of the blood, and produces sudden death. Love, hope, and joy, promote perspiration, quicken the pulse, promote the circulation, increase the appetite, and facilitate the cure of diseases. Excessive and sudden joy often kills, by increasing the motion of the blood, and exciting a true apoplexy. Shame, in a peculiar manner, retains the blood in the face, as if the veins were tied ; and also suppresses the menses, and has been even known to kill.

DLXVI. In what manner are these changes produced by the respective passions of the mind ? Do nervous sphincters regulate the vessels, and at one time compress them subfultorily, and increase the motion of the blood, and at another relax them and destroy their tone ? That something like this obtains in the smaller vessels, appears evidently from the very similar effects produced by fear and cold upon the nerves of the skin. In the genital parts, we manifestly see the veins, under particular circumstances, constricted, and a consequent accumulation of blood : and it seemed probable, that in the larger vessels, the nervous nooses surrounding many of them produced the same effects : for, in  
various

various parts, they surround and include the meningeal, temporal, vertebral, carotid, subclavian, coeliac, mesenteric, renal, and other arteries. But after it was shewn by our experiments, that the nerves are at rest during the action of the muscles, and cannot be rendered shorter by any irritation, we were obliged to desert this elegant theory. Nor would it seem far from the truth, that the arteries are rendered more or less irritable from the various sensibility of the nerves, and thus may be contracted more vehemently or languidly by the same quantity of blood, and that thus the motion of the blood is either quickened or retarded, if it were at all certain that the smaller arteries have the same irritable nature with the large ones. Thus the appetite and peristaltic motion of the stomach and intestines, are manifestly destroyed by the affections of the mind.

DLXVII. It cannot be denied that the Creator has affixed characteristic marks to the passions of the mind, that in social life man might not easily impose on man. For the respective muscles, more especially of the voice, face, and eyes, express the several passions of the mind so faithfully, that they may be even represented in painting. To investigate each of them, would indeed be an elegant task, but too long for this compendium. From the action of these muscles being often repeated, physiognomy arises, so that the constant expression of the face retains something of the action of the prevailing muscles; and some character of frequent anger often remains in the countenance, after the passion itself is gone off.

DLXVIII. Whence proceeds the sympathy of parts, so famous in the practice of physic? In some of them it appears to depend upon the connection of the blood-vessels; by which the blood, being repelled from one part, presses more heavily upon another, which has its vessels from the same common trunk.

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This comprehends revulsions made by blood letting; headach, from cold feet, &c. In other parts, the sympathy arises from a similitude in their fabric, by which they suffer like effects from the same causes arising in the body, such as the sympathy betwixt the womb and the breasts. Another cause is, the continuity of membranes, from hence the itching in the glans of the penis from calculus, the cure of deafness by diarrhœa. Another cause exists in the nerves themselves, and their anastomoses, as satisfactorily appears from the teeth being set on edge by certain sounds, a disagreeable sensation being produced in the maxillary nerve, on account of its various communications with the portio dura. Thus the sympathy of the eyes, which is not observable in like manner in the ears, proceeds from the decussation of the optic nerves; and vomiting is excited by nephritis. Lastly, another cause is referred to the common sensory, and beginnings of the nerves, which is demonstrated from general convulsions being produced by the irritation of a single nerve, and universal epilepsy by a local disorder, &c. Some sympathies in diseases arise from a translocation of the matter to other parts through the cellular substance, or by the action of the muscles, arteries, or gravity.

DLXIX. But that important sympathy remains to be explained, which subsists betwixt the body and the mind. For that the nature of the mind is different from that of the body, is proved by an infinity of circumstances, especially by ideas and affections of the mind, to which nothing in sensation is analogous. For what is the colour of pride? or what the magnitude of envy or curiosity? to which there is nothing similar in animals; neither can that good which is desired by it, glory and the acquisition as it were of new ideas, be referred to any corporeal pleasure. Is it possible that the body can possess two kinds of forces, so that its infinite particles

particles should unite into one mass, which do not preserve their own affections only, and represent them to themselves, but also join together into one common thinking whole, differing from the attributes of all, and yet capable both of receiving and comparing these attributes? Is there any instance of a body, which, without an external cause, passes from rest to motion, changes or reverses the direction of motion, without the action of some other cause, as is very easily observed with regard to the mind?

DLXX. Yet this mind, so different from the body, is connected with it by the most intimate ties, being both obliged to think upon those impressions which the body presents to it, and not seeming to possess memory or judgment, independent of the corporeal impressions on the brain; and, lastly, by means of volition being the cause or occasion of the greatest and swiftest motions of the body.

DLXXI. Those have acted circumspectly who, confessing themselves ignorant of the manner in which the body and mind are united, have contented themselves with the laws established by the Creator, which they have ascertained, and not conjectured. They are manifestly excused by the observation, (DLVI.) that even in optics, it is very certain that the affections of the body are connected with the thoughts of the mind, by an arbitrary relation, and that other ideas would have been suggested, if the Creator had altered the figure, the refracting power, or colours of the parts of the eye. As there is a law, which establishes a perpetual connection between the least refrangible rays and the idea of a red colour; there is also a law which constitutes the connection betwixt the impression of those rays upon the retina, and the corresponding idea. Nor need we be more ashamed of our ignorance of the mechanism of the latter law, than of our ignorance of the nature of the former.

DLXXII.

DLXXII. Does the mind govern the body? Do all the motions and actions in the body arise from the mind, as the immediate source and origin of motion? Do the motions of the heart, arteries, and respiration, arise from the mind, willing them and solicitous for the common good of the whole system? Is this power of the mind demonstrated by the structure of polypi formed in wounds, by the passions of the mind, and by the *nævi materni*? Is the absence of consciousness accounted for by the well known example of the obscure perceptions we have in respiration, winking, and muscular motion, all of which are effected by the will, although we do not know the organs, or attend, that we will, when we breathe, wink, or walk, when occupied in thought? Is it therefore certain, that all motions arise from the mind, because there is no other evident cause perpetually connected with the body, to which they can be referred?

DLXXIII. There are many reasons which do not yet permit us to adopt this opinion. And, first, the construction and government of the body itself appear greatly to exceed the wisdom of the mind. Our mind sees one point distinctly, (DLV.) and thinks one thought distinctly; but if it endeavours to see two objects at the same time, to contemplate two ideas at the same time, or to read two letters at once, it always becomes confused, commits mistakes, and comprehends neither rightly; and conscious of its own powers, whenever it applies seriously and diligently to any object, it withdraws itself as it were from the impressions of sense, and neither sees, nor hears, nor smells, nor performs muscular actions. But the mind ought to be capable of infinite and distinct thoughts, in order to be able to govern such an infinite variety of muscles, vessels, and fibres, in a manner accommodated to the most exact geometry; and to resolve and construct occasional problems in the direction of the muscles,

cles, scarcely soluble by the highest geometry : and yet we must conclude the mind ignorant of this immense task, and at the same time, over and above all those works, capable of contemplating the most difficult and abstract ideas ; so that neither the care of the body disturbs its meditations, nor its meditations interfere with the necessary motions of the body.

DLXXIV. Moreover, if, without being conscious of volition, we can will to respire, or wink, and with effect ; we nevertheless retain our control, and can suspend respiration, and keep the eyelids firm, and alternately excite their actions, and therefore we never lose either the consciousness of our control, or the use of it. But we are not able to perform any thing of this kind in the heart or intestines ; we cannot restrain their motion, when too quick, or excite them when languid. Amongst all mankind, why does every one govern his respiration ? why in all ages no one his heart ? If custom only is the cause of our unconsciousness of this power, why is not the mind sensible of its action, in moving the heart, or in exercising the peristaltic motion, after being suspended for hours, or even whole days, in swoons, in hysteric fits, and in asphyxia ?

DLXXV. But it is evidently false, that all motions arise from the mind, and that without it matter would be an immoveable inert mass : for the contractility excitable by every stimulus, to which the motion of the heart, intestines, and perhaps all the other motions in the human body, belong, (ccccxci.) does not require the presence of the mind ; it continues in the dead body ; it is excited by mechanical causes, heat, and inflation ; and it does not desert the fibres, until they become stiff and cold, although the mind, which perceives and wills, may have been a long time expelled by the destruction of the brain and heart, and even  
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although the muscle, by being taken out of the body, has been separated from every imaginable connection with the mind.

DLXXVI. Little, if any, reliance is to be put in the *nævi materni*, as is noticed in another place. That the direction of the vital motions, in diseases, is not regulated by prudence, but almost entirely by the power of stimulus; we are explicitly taught by the most ancient and only certain practice, which restrains the excessive motions in acute and intermitting febrile diseases, by the use of blood letting, opium, nitre, Peruvian bark, &c. The sage has no prerogative in the government of his body, over the merest idiot; and that the foetus, which even at birth is ignorant of the motions of its muscles, and learns by experience to walk, to swallow and to see, constructs its body, fabricated with such incredible art, is an affirmation so repugnant to probability, and so absurd, that of itself alone it is sufficient to refute the hypothesis.

DLXXVII. The state of aptitude for exercising the senses and voluntary motion, in healthy organs, is called wakefulness. Indisposition to such exercise, and their perfect rest, with healthy organs, is called sleep.

DLXXVIII. In sleep, the mind either thinks not at all of what she knows or retains in memory; or only attends to the traces of past objects repositied in the common sensory, (DLVIII.) the vivid representations of which excite altogether the same perceptions in the mind as are made by the impression of external objects upon the organs of sense. These representations are called dreams; and have the effect, that while the rest of the emporium of the senses and muscular motion is at rest, some part remains open, is pervaded by the spirits and watches. Sometimes certain voluntary motions are conjoined with these perceptions of the mind, so that the organs of speech, many, or all of the limbs,

limbs, are directed by these perceptions, as in somnambulists.

DLXXIX. But, during sleep, the motion of the heart proceeds, and also the distribution and circulation of all the humours in the body, the peristaltic motion of the stomach and intestines, and the action of the sphincters. Lastly, the respiration itself continues to be performed in like manner. This conjunction of the quiescence of certain organs with the motion of others, renders a knowledge of the mechanical cause of sleep difficult.

DLXXX. Therefore, in order to investigate it, we shall consider all the causes, and all the phenomena, both of sleep and vigilance, and trace them in all kinds of animals. For that condition, which is produced alike by all those causes, will be the true cause of sleep. Sleep naturally follows vigilance and the labours of human life. For when awake, there is almost a continual motion of the voluntary muscles, and of the organs of the senses, and the affections of the mind continually impart new stimuli to the nerves, blood-vessels, and heart. Thus the blood, by continual motion and trituration, is altered from a bland nature to an alkaline putridity; while the more subtile spirits are dissipated faster than they are replaced, and gradually not only debility and lassitude of the body are induced; and, if the want of sleep be protracted too long, also feverish heat, acrimony of the humours, and loss of strength. On the return of night, torpor is perceived in all the long muscles; the mind becomes unfit for deep thought, and the desire of rest pervades both mind and body. At this time, the powers which hold the body erect, suffer particularly; the eyelids close involuntarily, the lower jaw falls down, the necessity of yawning increases, the head nods forwards, the circumstances of external objects affect us less; and lastly, the ideas and thoughts become disturbed, and a delirium

rium ensues ; from which the transition to sleep is not perfectly known ; but which invariably precedes sleep. In this natural sleep, which is common to all animals, the cause seems to be a deficiency of the nervous spirits, which have been in some manner consumed by muscular motion, and the exercise of the senses, and of which probably a great quantity is exhaled.

DLXXXI. The absence of every irritation of the head, and other parts of the body, the perfect rest of the mind and external senses, and darkness, have great influence in promoting sleep.

DLXXXII. Again, a variety of causes which debilitate, induce, and increase sleep ; such as great losses of blood, venesection, cooling medicines, opiates, and coldness of the atmosphere, and also applications which derive the blood from the head, as warm bathing of the feet, and a plentiful meal, which always produces sleep in all kinds of animals.

DLXXXIII. On the contrary, again, various hot medicines induce sleep, by accelerating the flow of blood to the brain ; such as wine, spirits of all sorts, but more especially when resolved into vapour, opium, hyoscyamus, the indigestible particles of our aliments, acute and malignant fevers of various kinds ; or by retarding the return of the venous blood, as fatness. All these causes seem to concur in this, that the blood being collected in the head, compresses the brain and intercepts the course of the spirits into the nerves.

DLXXXIV. But likewise mechanical causes produce sleep ; for example, every compression of the dura mater and brain, whether from extravasated blood, a depressed bone, or a collection of water in the ventricles.

DLXXXV. Sleep, therefore, arises either from a simple absence, deficiency and immobility of the spirits, or from compression of the nerves ; and always

ways from the motion of the spirits through the brain being impeded.

DLXXXVI. This theory is confirmed by the causes of vigilance: for all those things prevent sleep which produce plenty of spirits; more especially warm aromatic drinks, which send minute stimulating particles to the head; by which the motion of the blood is moderately quickened through the brain, and, being at the same time more diluted, it secretes more spirits in a given time.

DLXXXVII. Sleep, again, is prevented by cares of the mind, attentive and interesting meditation, and pain of body and mind; all of which prevent the spirits in the sensorium commune from resting, and the nerves from collapsing. Therefore, the former causes increase the quantity of the spirits, these increase their motion. And, therefore, we return to our former conclusion (DLXXXV.) namely, that the nature of sleep consists in the collapse of the nerves, proceeding from the sensorium commune.

DLXXXVIII. Is the region of sleep, therefore, in the ventricles of the brain? It is inconsistent with the universality of sleep, which extends to animals which have no ventricles in their brain. Do the vital actions continue during sleep, because it is an affection peculiar to the brain, and independent of the cerebellum? And what is the cause of this diversity, which occasions the animal functions to rest during sleep, and the vital functions to continue? It is that already mentioned, that vital motions are prevented from resting by perpetual stimuli, and perpetually exciting causes, (CCCXCII.)

DLXXXIX. The effect of sleep is the abatement of all the motions in the human body. For now the action of the heart alone remains to propel all the humours, while all the motions of the muscles and sentient nerves, and those originating from the passions of the mind and volition, are removed; by which, while awake, the course of the blood and  
spirits

spirits was promoted, as well as by the heart (DLXV. ccccxvii.) The heart gradually returns from its quick and almost feverish pulsation, to its morning slowness; the breathing becomes less and slower, the peristaltic motion of the stomach and intestines, hunger, digestion, and the progression of the feces, are all diminished; the thinner juices move more slowly, while the more sluggish are collected together, and the effused fat is accumulated; the nourishing jelly adheres more plentifully to its fibres and cavities; the consumption of the spirits, the attrition of the blood, and the quantity of perspiration, are all diminished. Thus, while the nervous fluid continues to be secreted, and its consumption to be diminished, it is by degrees accumulated in the brain, so as to distend and fill the collapsed nerves, and from the accession of the slightest stimulus, both the internal and external senses are excited to action, and the system is awakened. Sleep, continued for too great a length of time, disposes to all the disorders that attend slowness of circulation, to fatness, drowsiness, and cachexies; and is highly detrimental to the memory.

DXC. Whence the yawning of those about to sleep? To promote the passage of the blood through the lungs, which is now slower. Whence the stretching of the limbs? To overbalance, by the influx of the spirits, the natural contraction of the muscles, by which all the limbs are put in a moderate degree of flexion, and so to restore strength to the extensor muscles. Whence the opinion, that, during sleep, the motion of the heart becomes stronger, and the perspiration more plentiful? From the heat of the bedclothes, by which the perspirable matter being confined, softens and relaxes the skin. But any one that sleeps in his usual garments, grows colder; and animals which sleep through the winter, become excessively cold, as dormice and hedge-hogs. Why do all animals grow sleepy after taking food?

Not

Not from pressure upon the aorta, or congestion of blood in the brain; for even animals which have scarcely any brain, sleep after food. Do the indigestible particles of our aliments, by passing less easily through the brain, and compressing its medulla, render the sleep less refreshing? Is dreaming perpetual and inseparable from sleep? Is it so far natural, and a kind of substitute for sensation to the mind, that it may never be without thought? This does not seem probable. We rather ascribe dreams to some morbid state, or to some stimulating cause, interrupting the perfect rest of the sensorium. Hence that sleep refreshes most which is without dreams, or at least without the remembrance of them. Hence they are generally wanting in the first sleep, at which time the spirits are most exhausted, and return in the morning when these are in some measure repaired. Hence care, the strong impression of some idea upon the memory, indigestible food, excess, or any uneasy posture of the body, occasion dreams; for they are usually generated by some sensation, with which, according to the laws of the association of ideas, the whole collection of similar impressions connect themselves.

## C H A P. XVIII.

### OF MASTICATION, SALIVA, AND DEGLUTITION.

DXCI. **H**ARD and tough articles of food, consisting of long parallel fibres, or covered with a bony shell or cartilaginous integuments, and friable substances, generally require mastication, to divide them into smaller and less cohering parts, that they may the more easily yield to the dissolving powers of the stomach. The more completely they are subdivided in the mouth, they become

come the more sapid, approach the nearer to the nature of a fluid, and are digested the more easily.

DXCII. Therefore most animals are provided with extremely hard teeth, each having a bony, hollow root receiving, through a small hole in the apex of its cone, little blood-vessels, and a nerve, which go to its internal periosteum; fixed by the whole root into the alveolus adapted to it, and, in the upper part of its crown, strongly tied down by the adhering gum. But the upper part of the teeth placed above the gums, is not bony, but of a peculiar structure, much harder and denser, resisting putrefaction in the dead body, and almost vitreous, composed of straight fibres vertical towards the root, and running together in the middle. This portion has neither periosteum nor vessels, and being perpetually wasted, seems to be as often repaired by some fluid which ascends from the follicle of the root. The teeth are therefore well adapted for overcoming the hardness of other bodies, and for comminuting the food.

DXCIII. As the materials of our food are various in their texture and firmness, nature has accordingly diversified the structure of the teeth. In man, the anterior teeth, four in each jaw, are weaker than the rest, have a single root, and a crown inwardly concave, outwardly convex, extenuated like a wedge, and terminated by a rectilineal edge. They are destined for dividing, into smaller portions, the softer foods, which are merely tough, and for comminuting the fibres and membranes of animals and vegetables, and the kernels of fruits.

DXCIV. The second species is the canine teeth, of which there are two in each jaw, fixed by a longer and stronger, but single root, with a crown of a conical shape. These lacerate tough aliments, and hold fast those which require much trituration.

DXCV. The third order is the grinders, which in general have several roots, and a quadrangular crown, with a flat surface, but divided by chequered asperities. The two anterior ones are weaker, have one or two roots, with the surface of their crown parted into two; the three posterior grinders are larger, fixed by three, four, and sometimes five roots, but generally by one less in the lower jaw, with a flat surface, quadrangular, and commonly divided into as many eminences as there are roots. Betwixt these teeth, the bony articles of food are interposed and broken, the hard are bruised, while the lower teeth, being moved obliquely and laterally, are rubbed against the immoveable upper ones: by these the functions of the teeth are principally performed.

DXCVI. That the teeth might possess mobility combined with strength and firmness, the upper ones are fixed into the sockets of the immoveable upper jaw, the lower ones into the lower moveable jaw, which is a single bone, and articulated with the temporals, in such a manner that it may be drawn down from the upper jaw, and raised up against them with great force; and may be moved laterally to the right and left, and forwards beyond the upper jaw, and backwards to its first situation. These motions depend upon the articulation of its condyles, (in which the lateral parts of the lower jaw terminate, and which are broadest transversely, and convex in the middle,) with the oblique tubercles of the temporal bones, which are hollowed at the root of the jugal process, deeper in the middle, and increased by a little flat surface of the same kind, before the auditory passage, from which it is separated by a peculiar fissure. This joint has greater liberty in moving, and a durable cartilaginous crust, from a cartilage interposed between the condyle of the lower jaw and the tubercle of the temporal bone, on both sides  
concave

concave in its middle, with raised edges, corresponding by the former to the tubercle of the temporal bone, and by the latter to the adjacent depressions.

DXCVII. The muscles moving the lower jaw, which in man are weaker, but very strong in brutes, are the temporalis, an elevator, arising from a large part of the side of the skull, and from its aponeurosis, collecting its tendinous fibres, intermixed with muscular fibres, in a stellated manner, into the sharp process of the jaw; the masseter, an elevator, descending double or triple from the jugum and margin of the cheek bone backwards into the coronoid process. These act in concert; but the temporal muscle carries the jaw more backwards, the masseter more forwards. The pterygoideus internus descends from the pterygoid fossa, and from the palate bone and root of the little pterygoid process, and its internal wing, into the angle of the lower jaw, which it elevates when depressed by its antagonists, or draws to one side. The pterygoideus externus has a double origin; the one transverse from the inner wing and adjacent bone of the palate, and posterior convexity of the upper jaw: the other, descending, arises from the hollow temporal part of the great wing of the sphenoides; thence it proceeds backwards and downwards into the outer part of the condyle of the lower jaw, which it draws forwards before the upper jaw, and to one side.

DXCVIII. The lower jaw is depressed, and the mouth opened by the digastric muscle, arising from a hollow of the mamillary process, tied by its middle tendon with much firm cellular substance, of a tendinous nature, to the os hyoides; likewise connected to the mylohyoideus, and passing through the descending fibres of the stylohyoideus, increased by another fleshy belly, and inserted at the symphysis of the two halves of the lower jaw. More-

over, the mouth may be opened by all the other muscles, inserted into the inferior maxilla, os hyoides and larynx, as the geniohyoideus, mylohyoideus, genioglossus, sternohyoides, sternothyroideus, coracohyoides, and latissimus colli; although the latter rather draws the skin of the neck and face downwards. The geniohyoideus and digastric muscles draw the jaw backwards.

DXCIX. The lower jaw is elevated with great force, and the lower teeth being carried up against the upper teeth, divide the food, by the action of the temporal, masseter, and internal pterygoid muscles; which appears by undoubted experiments to be very powerful, and sufficient to raise several hundred weight. The lateral motions of the jaw, and its circular motion around one condyle as a fixed point, are performed by the external and internal pterygoidei, and by the former muscles acting singly and alternately. Thus the food is cut, broken and bruised; and if the mastication be rightly performed, it is reduced into a kind of pulp.

DC. Before the teeth there is placed a cutaneous and fleshy sack, which is every where produced from the integuments of the face; and incloses a hollow space with both rows of teeth when shut. The lateral parts are called the cheeks, the middle the lips. From this cavity there is a passage, betwixt the teeth, into the mouth, which on the upper part is bounded by the bony and soft palate, underneath by the muscles lying under the tongue, and on the forepart by the teeth. On the back part it opens between the soft palate and tongue into the fauces. The tongue divides the cavity of the mouth in the middle, and is easily moveable to every part of it.

DCI. During the trituration of the food in the mouth, there is continually poured to it a large quantity of a watery clear liquor, evaporable, insipid,

pid, or very little saline, containing a very small quantity of earth, and neither acid nor alkaline, although from it a very small portion of lixivial salt may be obtained; of which all around are numerous sources. A large quantity of this saliva is secreted by innumerable oval glands in the lips and cheeks, and by some larger ones which are placed round the mouth of the parotid duct; and lastly, by the pores of the hard palate, pouring out the liquor, which they secrete, through a little short duct and hole. The fluid effused by the exhaling vessels of the cheeks, and back of the tongue, is similar, or more watery. It is now ascertained, that the ductus incisivus is impervious, and transmits nothing but the artery, which goes from the palate to the nostrils.

DCII. The saliva is a watery liquor, with a small quantity of salt, partly lixivial, and partly culinary; with some oil and earth, evaporable by the fire; with scarcely any taste, unless when sharpened by disease or hunger. The quantity produced is considerable, as twelve ounces have been known to flow out from wounds in the space of an hour. By well bred people, it is for the most part swallowed; and usefully, as it cannot be thrown away without hurting the digestion.

DCIII. The salivary glands especially supply the saliva. Of these, the principal is the parotid, extensively filling up the interval between the auditory passage and the lower jaw, and covering the jaw-bone where naked, and part of the masseter. It is a conglomerate gland, with round acini, connected by cellular substance; which more densely compacted, forms a kind of involucrum, almost tendinous, to the whole gland. Its duct is white, vascular, and capacious, ascending from the bottom of the gland to the jugum, from whence it is transversely inclined, and receives the duct of a gland, seated on the top of the masseter, which is either  
continuous

continuous with the parotid, or distinct from it, and rarely double; after this, bending round the tumid edge of the masseter, it opens with an abrupt termination, without a papilla, through the separating fibres of the buccinator, surrounded by many little glands of the cheek. The bulk of this gland, and the number of its arteries, render it the chief source of the saliva.

DCIV. Another small gland, adjacent to the parotid, but twice as small, composed of softer and larger acini, connected by a similar membrane, is contiguous to the corner of the lower jaw-bone, and being in part subcutaneous, terminates upon it, and in part sends off an appendix over the mylohyoideus muscle, which running along the long concave side of the lower jaw, of a granular fabric, and spread under the membrane of the mouth, is called the sublingual gland. From the larger maxillary gland, a duct passes out along with this appendix, covered by the middle part of the sublingualis, from which it receives one, two, or three branches; by whose insertion being increased, it opens into a projecting membranous cylinder, seated on the bridle of the tongue. But other small and short ducts from the sublingual gland, three, four, or more, even to the number of twenty, perforate the edge of the tongue in the line continued backwards from the frenum, with short little ducts and points, and secrete saliva. There are instances where the larger anterior branch of this gland, which usually joins itself to the duct of the maxillary gland, goes on single, and parallel to it, and opens by itself. Some other glands also, similar to those of the cheeks, which however may be reckoned among the sublinguals, by their proper ducts perforate the membrane of the mouth where it departs from the tongue. Various other salival ducts have been intimated by different persons, but they are not confirmed by anatomy.

DCV. The Creator has wisely provided, that mastication cannot be performed, without the salival glands being compressed by mechanical necessity, so as to discharge their fluids in an increased quantity. For, when the mouth is opened, the maxillary gland, being pressed by the digastric and mylohyoides, throws forth a fountain of saliva; the parotid gland is compressed by the masseter, when swelled, and by the cutaneous muscle of the neck which lies over it: hunger has the same effects with muscular pressure, and causes a flow of saliva into the mouth.

DCVI. The food, therefore, being ground between the teeth, with the watery saliva and air, is broken down into a soft succulent, figurable pulp, replete with elastic air, which being heated by its situation, on account of its elasticity, perpetually tends to the dissolution of the particles of the food between which it is included. By this process, the oily and aqueous parts of the food are intermixed; the smell and taste of different ingredients are blended together; and, at the same time that the saliva dilutes the saline parts, the food becomes sapid. Such particles as are volatile, are directly absorbed by the bibulous vessels of the tongue and cheeks, and recruit the strength, by being restored to the blood-vessels and nerves.

DCVII. But the motions which are necessary for turning round the food in the cavity of the mouth that it may be introduced between the teeth, are effected by the tongue, cheeks, and lips. And especially, the tongue being at one time expanded, receives the food into the small concavity in its surface; and being moved by its proper powers, (CCCCCL.) conveys its load to the part designed. At another time, the tongue contracted, and narrow, searches every part of the mouth with its tip, and collects together the food into one heap. At another time, by applying itself to the teeth, it draws from

from the cavity of the cheeks the fluids or chewed aliments, and conveys them to the posterior cavity of the mouth, situated behind the teeth.

DCVIII. But these motions of the tongue are likewise governed by the os hyoides, which is extensively connected with it by muscles and membranes, and is composed of a basis, concave inwardly, of horns extending outwardly, and terminated by a thicker knob, and of oval cornicles. When drawn down by its respective muscles, it carries back the tongue at the same time, and also depresses the lower jaw, if the muscles of that be relaxed. These powers are the sternohyoideus, but arising also in part from the clavicle, which is extenuated upwards, and striped with tendinous lines: the sternothyroideus, which is broader, and arises from the same place, and also from the upper rib; on depressing the cartilage, into which it is inserted, it necessarily forces the os hyoides connected with it, to descend: it is intermixed with the hyothyroideus and thyreo-pharyngeus, and every where intermixed with the sternohyoideus: the coracohyoideus, but which arises obliquely from the upper and shorter side of the scapula, near its notch; where crossed by the jugular vein, it becomes tendinous; with its upper belly, it is straight, and pulls the os hyoides directly downwards; it is every where blended with the sternohyoideus, and the hyothyroideus, which is governed by the former muscles.

DCIX. Other powers elevate the os hyoides, together with the tongue. The styloglossus muscle, sustained by a peculiar ligament from the upper jaw, which is sometimes fleshy. The stylohyoideus, a weak muscle, often split for the passage of the biventer, and again collected into two portions, adhering to the tendinous expansion of the biventer, and inserted by the one portion into the basis of the os hyoides, and by the other portion into the horn, and mixed with the tendinous expansion of the

the mylohyoideus. The stylohyoideus alter, when it is present, resembles the former, behind which it is placed; arising from the tip of the styloid process, and inserted into the ossa triticea, it answers the purpose of a ligament to sustain the os hyoides. All these muscles draw the tongue back, and elevate its sides. The mylohyoideus, arising from the whole length of the jaw, combining into one with its companion, elevates the tongue, and gives it firmness for various motions, or else it depresses the jaw. The geniohyoideus, accompanying the genioglossus, pulls the tongue forwards out of the mouth.

DCX. But, moreover, the muscles of the cheeks variously move and compress the food in the mouth. Some carry it from the cavity of the cheeks into the cavity of the mouth behind the teeth, as the buccinator when the mouth is shut. Others open the mouth for receiving the food; such as the double headed proper elevator of the upper lip, and the elevator communis in part, the nasalis labii superioris, both zygomatici, the risorius, triangulus menti, and the depressor proprius anguli oris, which, arising on each side from an excavation near the socket of the canine tooth, is inserted into the orbicularis. Others, again, shut the mouth, that the food received may not fall out; such as the orbicularis of each lip, the proper depressor of the upper lip, and the proper elevator of the lower lip, and the elevator communis in part. Of these, more particular descriptions may be had from professed systems of anatomy.

DCXI. By these means the food, mixed with and softened by the saliva, is collected from all sides, behind the teeth, and is committed to the tongue, expanded by the ceratoglossi and genioglossi, and rendered a little concave by the styloglossus, from thence it is next conveyed to the fauces.

DCXII. The tongue being raised by the styloglossi, and extensively applied to the palate, first  
with

with its apex, then gradually with its posterior extremity, presses the food towards the fauces, at that time the only open passage. After this, the thick root of the tongue itself resists the larynx, which is drawn upwards, and presses down the approaching epiglottis, which stands up behind the tongue, and is connected with it by numerous membranes, and perhaps by some muscular fibres. At the same time, all the muscles elevating the pharynx act together; the biventer, geniohyoideus, genioglossus, stylohyoideus, styloglossus, stylopharyngeus, and others, and draw the larynx upwards and forwards, so that the epiglottis presents itself opposite to the tongue, and is more easily inclined. Hence it is necessary for deglutition, that the jaws be closed, or at least that the lower one be raised, and fixed in that position, that the biventer, and the other muscles already mentioned, may derive stability, from it, and elevate the os hyoides. Thus the epiglottis, being turned down, shuts up the passage to the larynx sufficiently and largely, and over it, as over a bridge, the food passes into the fauces.

DCXIII. By the pharynx we understand an ample shapeless cavity, bounded behind by all the vertebrae of the neck, and the occipital bone before the foramen magnum, in the middle by the cuneiform bone, and before by the opening of the nares, the moveable velum of the palate, the mouth, the tongue, and the larynx: below it is continued into the œsophagus. Its sides are formed by the lower jaw, the cheeks, the velum of the palate, the pterygoid process, the stiliform appendix, the tongue, os hyoides, and larger cartilages of the larynx. It forms one soft membranous bag, outwardly surrounded on all sides by muscular fibres. Its internal membrane is continuous with the cuticle, and renewable, but more moist. Outwardly the pharynx is covered by a good deal of cellular substance, more especially in its posterior and lateral parts. Therefore it is lax  
and

and dilatable, and fitted for receiving all bodies that are pressed by the tongue over the larynx.

DCXIV. It is dilated in the action (DCXII.) by the powers elevating it, by the stylopharyngeus, which descends sometimes double into the membrane of the larynx, under the os hyoides, and into the margin of the thyroid cartilage, and is largely distributed over the internal surface of the pharynx, together with the following muscle; the thyreopalatinus, spread in the form of an arch round the moveable palate, and forming two columns, which descend along the sides of the pharynx, and form a considerable part of that bag, being also connected by broad fibres to the thyroid cartilage. That the salpingopharyngeus is a true muscle, I am ready to believe, rather from the observations of eminent anatomists than from my own. Of the cephalopharyngeus, I am doubtful, unless you reckon the strong white cellular substance, which occupies the upper part of the pharynx, as a muscle. Drink passes round the larynx on each side of the epiglottis, and falls into the œsophagus.

DCXV. The aliments are prevented from regurgitating into the nostrils when they arrive at the dilated pharynx (DCXIV.) by the palatum mobile, which is interposed. Anteriorly from the bony palate, and laterally from the pterygoid wings, is continued a moveable velum, composed of the membranes of the mouth and nostrils, with intervening muscles and glands, almost of a square figure, and hanging betwixt the cavity of the nares and mouth, into the hollow fauces, in such a manner that it naturally leaves the former open, and is concave towards the mouth: the middle lower portion of this, extended into a conical shape, pendulous, before the epiglottis, and replete with many glands, from its appearance in a diseased state, is called the uvula. At each side of the velum, two arches descend from the velum palati, of which the smaller and thinner goes  
to

to the tongue, the larger to the pharynx. The elevator of this velum, which is strong, arises from the asperities and plane surface of the os petrosum, behind the spinal foramen, and also from the cartilage of the Eustachian tube, descends inwards with its companion, forms an arch in the velum mobile, between the two plates of the thyreopalatinus muscle. It may therefore draw that velum to the nares and tubes, that the food may not enter either of them. But, during deglutition, it does not seem to have any considerable action. At this time regurgitation into the nostrils is prevented by the constriction of the muscles of the pharynx, together with the depression of the thyreopalatinus, which manifestly draws the moveable velum downwards, and applies it to the tongue and pharynx, and of the circumflexus palati mollis, which arising a little more forwards from the same petrous bone, and from the sharp process of the cuneiform wing, and from the interval between the wings and innermost wing, and from the cartilage of the Eustachian tube, descends broader; and, passing through the notch of the pterygoid hook, it changes its direction, and ascends with a radiated tendon, dispersed through the upper membrane of the velum palati, and, joining with its fellow, forms the basis of the other muscles, and adheres to the smooth edge of the palate bone. This is able both to open the tube, and depress the velum mobile. Thus the pharynx being contracted like a sphincter, forces down the food, without permitting any part to regurgitate into the nares. Hence, when the velum of the palate is injured, the aliments regurgitate into the nostrils, and deafness ensues.

DCXVI. During the effort to depress the food (DCXVII.) the velum being placed upon it, and depressed, is drawn down towards the tongue by the palatopharyngei, and by the circumflexus palati mollis. These muscles, together with the glos-  
fopalatinus,

fopalatinus, (which last is indeed weak, is received into the lesser arch of the fauces, and on the one side is united with its companion into an arch in the velum of the palate, and on the other is inserted into the tongue,) press the velum against the protuberant root of the tongue, and intercept any return to the mouth. After the danger of any part falling into the windpipe is over, the epiglottis is raised up again, both by its own elasticity, and by the tongue itself being again drawn forwards. Lastly, the depressed uvula is raised by the azygos, which arises from the tendons of the circumflexus, and by the levator of the soft palate.

DCXVII. A little after this, follows an effort to urge the food downwards, which is exerted by the constrictors of the pharynx, which draw the back part forwards; these muscles are partly transverse, and partly ascend into the posterior surface of the pharynx. The principal is the pterygopharyngeus, arising from the whole hook, and from the edge of the internal wing, and from the tendon of the circumflex muscle; from whence forming an arch, it is extended upwards and backwards, and, largely surrounding the upper part of the pharynx, it unites with its cognominal companion. The mylopharyngeus is partly continuous with the fibres of the buccinator, in the middle betwixt its two adhesions to the bones, and partly arises from an origin of its own, above the last of the grinders in the lower jaw. These being almost transverse, and surrounding the pharynx, draw its back part forwards. Next follow the ascending muscles in two strata, the geniopharyngei, of which the obscure and confused fibres originate from the tongue; the chondropharyngei, of a triangular figure, arising from the officula triticea; the ceratopharyngei, which ascend radiated from half of the horn; the syndesmopharyngei, arising from the horn of the thyroid cartilage, and distinct from the following; the double

double thyreopharyngei, increased by fibres of the sternothyroideus and cricothyroideus, and the transverse, the ascending, and the descending crycopharyngei. These muscles act successively, the uppermost first, and then according to their situation, and force the food into the œsophagus. At the same time, the depressing muscles of the larynx, the coracohyoideus, sternohyoideus, and sternothyroideus, draw down the larynx backwards, compress the pharynx and urge the food downwards. The arytenoidæi contract the perpendicular chink of the larynx as the food passes near it.

DCXVIII. As various dry and rough bodies are sometimes swallowed, and as it was necessary for the pharynx to be dilatable and indolent, the great quantity of mucus, which is collected in all parts of the fauces, is of great importance. Therefore, in general, betwixt the nervous and innermost coat of the pharynx, are placed a very great number of simple oval follicles, which pour out through short mouths a bland, aqueous, but viscid and ropy mucus, having a greater quantity of oil, volatile salt and earth, than the saliva. They are most plentiful in that part of the pharynx which is extended under the occipital bone, where they are disposed in a sort of radiated right lines; and about the tonsil towards the Eustachian tube, where commonly the second tonsil lies on each side adjacent to the large one, and in that portion of muscle which is called salpingopharyngeus. But likewise many flat and circular follicles of this kind are seated on the back part of the tongue, as far as the foramen cæcum (CCCCXLVIII.) Other pores from the pulpy flesh of the palate, and from the numerous glands situated there, discharge a similar mucus. Moreover, the whole moveable palate is of a glandular nature like the pharynx; only composed of more numerous and thickly distributed follicles. Nor, lastly,

lastly, are lacunæ wanting, into each of which many simple glands unite.

DCXIX. Where the pharynx descends from the pterygoid hook betwixt the two arches of the fauces, that is between the glossopalatinus and pharyngopalatinus, are seated the tonsils, one on each side, of an oval figure, convex behind, and thicker on the upper part, perforated inwardly with ten or more large sinuses, which open through the membranous velum, and by the pressure of the adjacent muscles discharge a great quantity of a very viscid mucus from their sinuses. In like manner, the adjacent parts of the nares, and tumid ring of the tubes, and the surface of the epiglottis next to the larynx, and the back of the arytenoid cartilages, are replenished with mucous organs. Lastly, the œsophagus itself, on all sides, abounds with simple follicles, from which a mucus more fluid is poured. The glandulæ œsophageæ are of the conglobate kind, and contribute nothing to this mucus. The blood-vessels of the tonsils come from those of the tongue and lips; those of the pharynx from these and from the pharyngea; those of the œsophagus from the pharyngeals, upper and lower thyreoidals, the bronchials and aorta. The numerous veins of the palate and tonsils, after forming plexuses, meet in the superficial branch of the internal jugular.

DCXIX. The œsophagus is a double tube, of which the interior is separated from the exterior, by much inflatable cellular substance. The interior is nervous and strong, continuous with the membranes of the mouth and nares, and separated from the innermost, (which is the epidermis, plaited and porous, but not villous, exhaling a thin fluid and pulpy,) by peculiar short cellular substance, in which vessels are reticulated, and glands are interspersed, which are continuous, and similar to those of the pharynx. The exterior tube, the muscular, is also strong,

strong, with fibres continued backwards and downwards from the cricoid cartilage, changing from annular into external longitudinal fibres, raising the œsophagus against the food, and dilating it that the mouthful may be received. But other internal circular fibres, which are also strong, arise in like manner from the cricoid cartilage, and by their successive contraction, force the food down through the long tube of the œsophagus, which descends first in a direct course, a little to the left side of the windpipe; in the breast, it passes behind the heart, through the posterior interval between the two bags of the pleura (LXXVII.) from whence it inclines by degrees a little to the right, and then forwards, that it may pass through the appointed opening in the diaphragm (CCLXII.) in the interval between expiration and inspiration. The whole œsophagus is surrounded externally by cellular substance, by which it is loosely tied to the neighbouring parts.

DCXX. The aliments are moved through the œsophagus as through an intestine. The longitudinal fibres, ascending to the cartilages of the larynx, dilate the gullet, to receive the descending morsel. But when it is received into the gullet, the longitudinal fibres in like manner dilate and elevate the gullet to that place which has received it. Then that part of the œsophagus, where the morsel is seated, being irritated, contracts, and propels the food downwards. Its muscularity is strong, and very irritable.

DCXXI. This upper opening of the stomach is contracted, by the action of both the lower muscles of the diaphragm, in inspiration, and the food is confined within the stomach, so that every pressure of the diaphragm sends it naturally towards the pylorus. By this means, the stomach is so closely shut, that in perfect health, even vapours are confined

finied within the stomach; and do not ascend but from a morbid affection.

## C H A P. XIX.

## ACTION OF THE STOMACH ON THE FOOD.

DCXXII. **T**HE stomach is a membranous bag, destined for the reception of the food; placed within the abdomen, behind the liver, diaphragm and left false ribs; of a figure somewhat oval, or like a cask; longest transversely, and the more so the more aged the person is. In the foetus, it is altogether round and short. But if we consider its figure more accurately, every section of it is circular; but so, that, in its left extremity, there is an an impervious cavity obtusely conical, from whence the stomach gradually grows wider, and its sections increase towards the oesophagus, at whose insertion is its largest section; from thence it diminishes slowly, till being reflected towards itself, it ends in the pylorus. Its bulk depends in a great measure on the quantity of food, by which the cavity of the stomach is augmented; and, on the contrary, it is diminished by fasting. Its situation in general is transverse; yet so that the entrance of the oesophagus is posterior, and its right termination anterior. The middle of the human body, or ensiform cartilage, corresponds nearly to the centre of the stomach; but also to its right side, and lastly to the pylorus: to the latter the umbilical fissure corresponds. Since its figure is round, but incurvated; when empty, its larger convex arch is pendulous; but when full, it appears prominent forwards within the peritonæum. At that time, the lesser arch, interposed between the two orifices, is directed perfectly backwards, and includes the

small lobe of the liver. The insertion of the œsophagus in the full stomach is more horizontal; but in the empty stomach, more perpendicular: the right extremity of the stomach, when empty, is bent upwards to the pylorus; in the full stomach, it is bent backwards, and therefore descends in persons lying on their back. In man, when alive, the situation of the stomach, approaches nearer to that which we have attributed to the full one.

DCXXIII. The viscera, contiguous to the stomach, are the spleen, contiguous to its left imperforated extremity, and connected with it by much omentum; the lobule of Spigelius, filling up its lesser curvature; the left lobe of the liver, largely interposing itself betwixt the stomach and the diaphragm, and compressing the anterior part of the stomach; after which, below the liver, a moderate portion of the stomach is immediately contiguous to the diaphragm, which there lies under the false ribs, or it is entirely covered: behind, the pancreas lies under it; below it when empty, the transverse portion of the colon is contiguous for a considerable way; lastly, from the lesser curvature, arises the little omentum, from which a continuous, but stronger membrane, connects the œsophagus with the diaphragm: and the larger omentum is not connected to the whole length of the stomach, but is wanting on the right side near the pylorus; and on the left, it is continued, into a ligament, which connects the spleen and also the diaphragm with the stomach. The ligaments are productions of the peritonæum, receding from the diaphragm, thrown over the stomach, and forming its outermost coat. Of the orifices, the pylorus lies farther forwards, more to the right side, and a little lower.

DCXXIV. The fabric of the stomach, in general, is the same with that of the œsophagus; of which, it is a kind of expansion; and, in some animals, perfectly similar. The outermost coat is from the peritonæum;

peritonæum; is strong, limits the rest, and affords support to the subjacent muscular fibres: it is expanded into both omenta; and in that place, the stomach is without its outermost coat. Then follows the first cellular coat, more abundant at the origin of the little omentum, where it contains conglomerate and lymphatic glands, and also in the region of the great omentum; it is thinner and shorter in the intermediate planes, so that the outer and muscular tunic in them cohere together: in this substance, the large branches of the vessels are distributed.

DCXXV. The muscular coat is next in order, which is complex and difficult to describe or prepare. The longitudinal fibres of the œsophagus, when they arrive at the stomach, distribute themselves along all the sides of the stomach. Some of them, of considerable strength, run on to the pylorus, along the smaller curvature; part of which, by degrees declining, and following the length of the stomach, descend into the planes of each side, and part of them proceed along the pylorus into the duodenum itself, and gradually disappear. Other similar fibres, which are less strong, descend to the blind sack on the left side of the stomach. Besides, other fibres surround that blind sack, which being gradually increased, are continued with the circular fibres of the rest of the stomach. This second stratum of fibres is the most considerable. Lastly, the sphincter of the œsophagus, is the most internal, and is a continuation of the annular fibres of the œsophagus. It is composed of fibres, arising from the left of the œsophagus, and running to the right, on each side of the gullet, which they nearly surround; and gradually becoming longitudinal, they terminate, covered by the second stratum, near the pylorus. The ligaments of the pylorus are two bands, lying betwixt the two curvatures, which contract the pylorus. They are formed of longitudinal

tudinal fibres, and run from the stomach to the pylorus, intimately connected with the external membrane.

DCXXVI. Next to the muscular fibres, there is the second cellular coat, larger than the first, easily inflatable, softer, and consisting of larger cells than is common in the intestines. Into it, the vessels, which perforate the muscular coat, enter with large trunks, and are divided into an angular network. Under this, lies the nervous coat, which is thick, white, and firm; and, like other nervous coats, properly constitutes the true substance of the stomach. Then the third cellular stratum, which is sufficiently evident, and whose vascular network is composed of smaller vessels than the former reticulation. Then the villous coat, continuous with the external cuticle, reparable; mucous and soft, with very short villi, but folded into large wrinkles, stellated under the œsophagus, and in the middle of the stomach almost parallel with the stomach itself. But, at the extremity of the pylorus, there is a more considerable fold, commonly called its valve, formed of transverse fibres, and of a reduplication of the nervous coat thickened, and of the villous, so that a kind of tumid ring is produced, slippery and fleshy, which is surrounded by the duodenum for a considerable length. The large wrinkles of the villous membrane are finally subdivided into smaller ones, resembling a reticulation, of a quadrangular figure, shallow, easily disappearing, and more obscure than those in the biliary ducts. Throughout the whole of this villous coat, but more especially towards the pylorus, I have certainly observed some pores, not always to be perceived, which terminate in simple follicles, seated in the third cellular stratum.

DCXXVII. The vessels of the stomach are numerous, and derived from many trunks, that the afflux of the blood might not be intercepted by any pressure,

ture, which might easily have happened if there had been a single trunk. The common source of all these is the *cœliaca*; from its tripod, or above the said division, arises its first and largest artery, the upper coronary, with one branch surrounding the *œsophagus*; to which, and to the diaphragm, and also to the liver, it gives branches; with another following the smaller curvature, it inosculates, by an anterior and posterior trunk, with the lesser coronary on the right side, which arises from the right branch of the *cœliac* in the *vena portarum* itself, and returns along the smaller curvature. But the same right branch of the *cœliac*, after descending behind the origin of the duodenum, gives off a considerable artery to the great arch of the stomach, the right *gastro-epiploica*, which being suspended in the omentum, supplies both surfaces of the stomach, and surrounding the greater part of it, it is inserted into the left *gastro-epiploica*. Namely, the left trunk of the *cœliac*, as it passes along the duct of the pancreas and sinuosity of the spleen, successively sends off many branches to the stomach: of which the first are commonly nameless; and of the following, one branch, called the left *gastro-epiploica*, sends off one considerable branch, and other smaller branches, to the omentum, and returns round the stomach to the right side, to inosculate with its companion of the right side. Other smaller twigs, coming from those of the spleen, are spread upon the remaining part of the greater curve of the stomach, as far as the diaphragm, and are called the *vasa brevia*. Frequently, also, one or two arteries come from the splenic one, to the posterior surface of the stomach under the *œsophagus*, in a different direction from the *gastro-epiploics*. The other arteries are smaller, the upper pylorics from the hepatics, and the lower from the *gastro-epiploics*, and those of the lowest part of the *œsophagus* from the phrenic arteries.

DCXXVIII. Those arteries are distributed in the following manner: the external and muscular membranes receive short branches; the trunks are arranged in the first cellular stratum, and with little diminution penetrate the muscular coat; and between that and the nervous membrane, they compose a larger and true network; in which all the small arteries of the different trunks are united, by an infinity of inosculations. From this reticulation, again, other short, but numerous and small ramifications, go to the third cellular and villous coat of the stomach.

DCXXIX. The branches of the veins accompany the arteries. The greater coronary generally goes to the left trunk of the porta, together with the brevia and left gastro-epiploic; while the right vein of the same denomination joins with the middle vena colica, and is inserted along with it into the mesenteric branch of the vena portarum. Finally, the right coronary vein belongs to the trunk of the vena portarum itself. All these veins are without valves; and the upper coronary veins inosculate with the branches of the vena sine pari, in like manner as the arteries inosculate with the thoracic œsophagei.

DCXXX. The nerves of the stomach are large and numerous, produced from the eighth pair, which forms two plexuses on the œsophagus, of which the anterior and smaller goes from the œsophagus to the greater curvature and anterior surface; and the posterior and larger to the smaller curvature, and along with the arteries to the liver, and to the pancreas and diaphragm itself. These nerves may be traced into the second cellular stratum. Beyond this, especially the papillæ, are more obscure. From their very great number, the stomach is extremely sensible, especially about the entrance of the gullet, insomuch, that acrimonies, which are not perceived by the tongue, turn the stomach; the intestines are  
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also known, by certain morbid observations, to be much more indolent ; even the naked skin itself is less sensible than the stomach. By making a ligature upon the nerves of the eighth pair, the action of the stomach and the digestion of food are destroyed.

DCXXXI. I have seen considerable lymphatic vessels in the smaller curvature of the stomach, arising from its glands, and inserted by a very large trunk into the thoracic duct. Others, without doubt, arise from the glands of the same kind in the greater curve ; and eminent anatomists have observed lymphatic glands over the whole stomach. Other lacteal vessels, I have not seen, and will not readily admit those lately described, which are said to pass from the stomach through the omentum to the liver, filled with true chyle.

DCXXXII. All bags in man are perforated by inorganic pores : through these, water poured into the stomach exudes through it when shut, and, on the contrary, penetrates into the cavity of the stomach when put under water. But we cannot for this reason conclude, that during life this passage is pervious to moisture.

DCXXXIII. Within the human stomach, we first meet with a great quantity of mucus, anointing its villous coat, derived from the pores before described (DCXXVI.) which mucus is not unfrequently tinged by regurgitated bile. Besides, from the stomach, after fasting, upon bending the body, a limpid humour will frequently flow, possessing all the properties of the saliva, but more mucous, which it is very difficult to obtain pure in the stomach. It is entirely without any acidity, when it can be had unmixed with food. When separated from the acid impregnations of the food, and left to itself, it changes, both in man and brutes, rather to an alkaline nature, more especially in a fasting animal. This liquor distils from the arteries of the stomach, through

through its villous coat, as is proved by anatomical injections; by which water, glue, and oil, may be thrown into the stomach, through numberless pores.

DCXXXIV. Then it must be remembered, that the stomach is compressed as in a press in the abdomen, which is perfectly full, between the diaphragm, of which the concave left wing lies before and above the liver, and therefore over the stomach, and the resisting muscles of the abdomen, the rectus and obliqui, but chiefly the transverse. The more the stomach is filled, the more it experiences this pressure of the abdominal muscles; because, at that time, it is in contact with the peritonæum at a right angle.

DCXXXV. Now we must explain what is received into the stomach, and why it is received. The Creator has given to man pain (DLXIV.) and pleasure, for his preservation; the one to incite him to avoid evil, the other to invite him to useful actions. But the taking of aliment is of the greatest necessity to man. For since every day there is much perspired, much wasted of his real substance, he also stands in need of reparation; as the body is manifestly wasted by fasting. But the necessity of taking food is promoted by the natural tendency of the blood to an alkaline disposition, making it always approach more nearly to a putrid acrimony, by the natural and necessary motions of the heart and arteries, and by the heat which very much promotes the putrefaction of animal humours. Moreover, the coagulable disposition of the blood, continually losing a great part of its water by insensible perspiration, requires a supply of its aqueous element to separate the globules and prevent it from coagulation.

DCXXXVI. These truths are proved not only from their causes, but likewise by the appearances exhibited in men and other animals killed by hunger. For it is common for these to have an acrid fetid breath,  
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for their teeth to become loose from the saline acrimony corroding them, and to suffer violent pains in the stomach, acute fever, and actual madness. These disorders are the more rapid in their progress, the more violently the body is exercised, and the more robust and younger it is. They ensue very slowly in people who are phlegmatic and unactive, who perspire little, and whose blood circulates feebly. Finally, those who have lived without food, have also lived without bodily exercise, and for the most part laboured under a disease of the nerves,

DCXXXVII. The fresh chyle, composed, for the most part, of the acescent class of vegetables, and always thinner than the blood, being received into the circulation, temperates its putrescent acrimony, dilutes its impending coagulation, and reduces the whole mass to that moderate degree of saltiness which is natural to man: and finally, the chyle, but more especially that derived from the flesh of animals, and from the farinaceous grains, furnishes a new gelatinous lymph, which being applied by proper causes (DCCCLIX.) to the vacuities of the wasted solids, repairs that waste. The drink dilutes the coagulable blood, and hinders its putrefaction, by separating its putrescent particles. Hence a person may live for a long time without food, if supplied with drink; but without drink, life subsists but a few days.

DCXXXVIII. We are induced to take food, both from the sense of pain which we call hunger, and from that of the pleasure imparted by the sense of taste (CCCLV.) The first of these proceeds undoubtedly from the folds of the stomach, which possess great sensibility, being rubbed against each other, by the peristaltic motion, and by the pressure of the diaphragm and abdominal muscles, so that naked nerves being rubbed against naked nerves excite an intolerable degree of pain. Thus man  
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is both effectually admonished of the dangers of abstinence, and excited to procure food by his labours. It is perhaps increased by the gastric juice having become more acrid, unless it putrefies.

DCXXXIX. Thirst is seated in the tongue, fauces, œsophagus, and stomach. For whenever these parts, which are very sensible, and naturally are moistened by their mucous and salival juices, grow dry from a deficiency in the secretion of those humours, or from muriatic or alkalescent salts adhering to them, a much more intolerable sensation is produced, as thirst is attended by much greater danger, and does not abate until the abundance of water, being restored to the blood, and the obstruction removed from the secreting vessels in the parts mentioned, they are again moistened. From hence we learn, why thirst attends labour, which exhales the water by perspiration; and why it is a symptom of fevers, where the exhaling vessels belonging to the tongue and fauces are obstructed; why simple water is less efficacious in allaying thirst; why subacid liquors are more efficacious, which not only moisten by their fluidity, but also, by a mild irritation of the tongue and mouth, excite a flow of the retained humours, and at the same time correct putrescency.

DCXL. From these causes, mankind being compelled to take food, has in all ages selected these supports of life from the vegetable and animal kingdoms, so that of the third, water and salt alone are added. It is probable, that the original choice of our foods was made by experiments, as suggested by the smell and flavour of certain vegetables, and as their utility was confirmed by the renewal of strength. By degrees, as animals became incommodious to husbandmen, and vegetables alone were not sufficient for supporting them under their labours, the flesh of animals was afterwards added. At present, the number of substances is almost infinite,

infinite, which we take either as food or seasoning.

DCXLI. Although there are instances of particular persons, and even of nations, who have lived entirely upon food taken from one class, as upon vegetables alone, or animals alone, and sometimes upon a few individuals of one class; and lastly, upon milk alone or its whey; yet it seems to be necessary, both from the nature of the human body, and to be indispensable according to certain experiments, that we ought to support life especially by two kinds of food, so intermixed, that neither may exceed; which mediocrity we are taught from the loathing itself, which is excited by any one kind of food that has been continued too long.

DCXLII. The flesh of animals appears necessary, from the teeth in both jaws, and from the fabric of the human stomach itself resembling that of carnivorous animals; from the smallness and shortness of the intestinum cæcum, and from the strength which we require. For the flesh of animals alone contains the gelatinous lymph ready prepared, which, being extracted from the broken vessels, passes easily and in great abundance into the blood. Abstinence from animal food causes great weakness both in the body and stomach, and is usually attended by a troublesome diarrhoea. Man agrees with the herbivorous animals in the size and length of the large intestines.

DCXLIII. Esculent vegetables are generally of the acescent kind; a few of them only are either alkaliescent or aromatic. Few of them have that gluten which is spontaneously changeable into blood, and they only nourish by means of their farina, a small part of which, after repeated circulations, is at last converted into the natural juices. Yet they are necessary to avoid over repletion with blood, and of too putrescent a kind, from the use of animal food alone, such as most certainly occurs in the anthropophagi,

pophagi, and produces scurvy, ferocity, fetor, leprosy, and every kind of alkaline corruption, all which evils are cured by change of diet, and the exclusive use of acid vegetables. Hence we are furnished with few canine teeth; and our appetite in health, but more especially in disease, is stronger for acidulous vegetables, in proportion to the warmth of our temperament, of the season of the year, and of the country. Hence, in the hottest climates, people live almost altogether upon vegetables, and use flesh very rarely, and with danger; while, in the colder countries, it is eaten freely with less danger. Hence bread, or a farinaceous aliment similar to it, is eaten in every part of the world.

DCXLIV. The best drink is pure water, free from every kind of salt, and not impregnated with air, which excites fermentations. That from a mountainous spring, which runs through a sandy bed, and is cold, clear, light, and insipid, is justly preferred. Whenever there is a deficiency of pure water, as is frequently the case in flat countries, or when any power stimulating the stomach to contraction, or any aromatic is required, it is supplied by vinous liquors, especially those prepared from grapes, but also from apples and pears; which, after fermentation, become clear, and contain alcohol and an acid salt diluted with water. Liquors of the same kind, not destitute of alcohol, but more flatulent, vapid and colder, are prepared by fermentation from grain toasted, and boiled in water, in those countries where the grape does not ripen.

DCXLV. Men have invented various condiments. They have added salt, vinegar, and acids of various kinds, to correct the putrescence of flesh; pepper, hot spices, and alliaceous substances, to strengthen the stomach, which is weakened by the constant use of vegetables; and sugar, salt and aromatics, for the sake of flavouring or preserving our food.

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But none of these nourish, being destitute of gelatinous lymph, and nourishing farina. The spirits of wine and of corn may be of some use as medicines, but are unfit for drinking.

DCXLVI. According to the difference of country, climate, or season, the aliments undergo various preparations, by which crudity is removed, solid fibres softened, excessive air expelled, disagreeable acrimony diminished, or a pleasant flavour imparted. But many vegetable foods, and more especially flesh meats, require some trituration, particularly in man, whose stomach is but little fleshy, nor ought the articles of food to become putrid by remaining too long in the stomach.

DCXLVII. The measure of our food is determined by the ceasing of our hunger, which is different according to the difference of aliments. Animal and farinaceous food nourishes most : other aliments ought to supply by their quantity, what they want in powers of nourishment. In general, we are nourished best by a somewhat spare diet, unless subjected to much labour.

DCXLVIII. Into the stomach, therefore, the aliments are let down, often almost crude, and little chewed ; of various kinds, as alkalescent flesh, rancid fat, or acescent vegetables, bread and milk, and glutinous substances. Here they are digested in an heat equal to that of incubation, imparted by the contiguous heart, liver, and spleen ; and in a cavity shut above (DCXXI.) and also below by the ascent of the pylorus, the narrowness of the valve placed there, and the action of the fibres, constricting the pylorus, so that even milk itself remains entirely in the stomach of healthy animals several hours after meals, without passing into the intestines. Besides, the aliments are macerated in a moist place with much air, either swallowed during deglutition, or mixed with the aliments. This air, therefore, expanding by the force of heat, putrefaction, or fermentation,

mentation, bursts the cells in which it is included, divides the viscid liquors, weakens the solid fibres; prepares space for the fluid which is to enter into them. But this air also, which is the principal cement of animal solids, emerges from their substance, and leaves the other elements without a vinculum, as we see from the phenomena in Papin's digester, in the stomachs of animals, and even in that of man. This air, set at liberty, distends the stomach more than the food itself, and is termed flatus. At the same time, the aliments begin to corrupt into a nauseous liquid, often acedent; at other times putrescent, but less so in man from the influence of bread and salt; or rancescent, as appears from the flatus and eructations, variously fetid, and even inflammable. This is the sole cause of digestion in fish and serpents, and almost in carnivorous birds. Hence, in man, metals themselves, by long stay in the stomach, grow soft, and are eroded. At the same time hunger is removed, the nervous folds of the stomach being removed from mutual contact by the aliments interposed, the acrid gastric fluid being neutralized, and perhaps from the very presence of this nauseous liquid being disagreeable to the nerves.

DCXLIX. But they are prevented from degenerating into complete acidity, by the heat inducing putrefaction, by the action of the gastric juice, and of the saliva, which is swallowed to the amount of half an ounce in an hour, both inclined to alkalescency, and by the bile which certainly regurgitates frequently into the stomach. These fluids, being incorporated with the aliment, macerate and soften it, divide the membranes, resolve the cellular bands, liquefy the pulps, as warm water and time do in other situations, extract their juice, and mingle it with themselves. There is, therefore, no kind of fermentation in the stomach, from which the nature of the fluid, and the design of nature, are

are distinct. And yet the juice of the stomach alone, by a continuance of its action, in fishes, dissolves the bones which they devour.

DCL. For, the fleshy fibres in the stomach being now irritated by the flatus, weight, and acrimony of the food, begin to contract themselves more powerfully than when the stomach is empty, and with greater force in proportion as it is more full, its round swelling stretching the fibres. And, first, the plane of the smaller curvature draws the pylorus to the œsophagus; and, being inserted only into its left surface, it draws that to the right. The principal stratum of the circular fibres, diminishes the cavity of the stomach, incorporates the aliments with the juices, (DCXXXIII.) and compresses them slightly as if between the hands on opposite sides and gradually determines them towards the pylorus: but it is not immediately permitted to escape, both on account of the reason before assigned, (DCXXVI.) and also because this motion begins from the part that is most irritated; and, therefore, impels the aliment upwards, as at other times it forces it downwards. The contracted portion of the stomach propels the food into the neighbouring dilated part, and is in its turn relaxed when that other is contracted. These alternate contractions at last terminate in complete evacuation. In this action, there is nothing which resembles the trituration made by the strong gizzards of granivorous fowls, which some anatomists have ascribed to the human stomach; yet it has a considerable degree of strength, and affords an example of fibres contracted to more than a third part of their length; for the stomach is frequently reduced to much less than a third of its diameter, even to the breadth of an inch; and, lastly, is capable of discharging needles. Yet it neither bruises berries, nor the softest worms.

DCLI. The action exerted by the diaphragm and muscles of the abdomen, is stronger than the peristaltic force of the stomach; for, by this, it is capable

pable of perfectly evacuating the stomach, and of bringing its anterior and posterior sides into actual contact. For this force, principally, expels the fluids immediately, but the solids only when they are softened, and rendered small enough for the valve of the pylorus, through that pylorus into the duodenum, which is inclined when the stomach is full; for the aliments do not seem to leave the stomach, before they have lost their fibrous or other texture, and are resolved into a mucous, yellowish, cineritious, somewhat fetid, pultaceous liquid. That which is first prepared and liquefied, goes first, and, therefore, water and milk, first of all; then pot herbs; and, lastly, flesh. The harder, tougher, and longer skins or fibres, pass at the same time unchanged: and such things as are hard and too large to pass the pylorus, are retained in the stomach for a long time.

DCLII. But the most considerable portion of the drink is absorbed by the pendulous patulent veins of the stomach itself, corresponding to the exhaling arteries (DCXXXIII.) and is carried by a shorter way to the blood, as plainly appears from injections. Does any thing enter the lymphatic vessels (DCXXXI.)?

DCLIII. The stomach, being irritated by too great a quantity or acrimony of the food, or else by nausea from regurgitation of the bile, or other cause, with an antiperistaltic motion repels its contents upwards, and discharges them through the open and relaxed œsophagus, by vomiting. But this is assisted by the action of the abdominal muscles, which compress the belly, draw in the ribs, and, as the descending diaphragm acts against them, they evacuate the stomach with very great force, squeezed as if in a press.

DCLIV. But the aliments transmitted in their natural course to the duodenum, meet there with the bile which frequently regurgitates into the stomach itself, and with the pancreatic juice. The nature

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of the former of these, the principal fluid of digestion, requires a previous history of the viscera, which transmit their blood to the vena portarum.

## C H A P. XX.

## THE OMENTUM.

DCLV. **T**HE peritonæum is a strong simple membrane, by which all the viscera of the abdomen are surrounded. It has an exceedingly smooth, exhaling, and moist internal surface; outwardly, it is every where surrounded by cellular substance; which, towards the kidneys, is very loose and very fat; but is extremely short at the lower tendon of the transverse muscles. It begins from the diaphragm, which it completely lines; and at the last fleshy fibres of the ribs, and the external lumbar fibres, it completes the septum, in conjunction with the pleura, with which it is continuous through the various intervals of the diaphragm. It descends behind, before the kidneys; before, behind the abdominal muscles; it dips into the pelvis; from the bones of the pubes, passes over the bladder, and descends behind it; and being again carried backwards at the entrance of the ureters in two lunar folds, it rejoins upon the intestinum rectum, that part of itself which invests the loins, and in this situation lies before the rectum.

DCLVI. The cellular texture, which covers the peritonæum on the outside, is continued into sheaths in very many places; of which one receives the testicle, on each side; another the iliac vessels; others the intestinum rectum, the large vessels of the pelvis, the obturatoria, penis, bladder, and aorta, and ascending into the breast, accompany the gullet and vertebræ; by means of which, there is a communication

nication between the whole body and the peritonæum, well known in dropfical people.

DCLVII. It has various prolongations for covering the viscera. The shorter productions of this membrane are called ligaments; and are formed by a continuous reduplication of the peritonæum, receding from its inner surface, inclosing cellular substance, and extending to some viscus, where its plates separate; and having diverged, embrace the viscus; but the intermediate cellular substance always accompanies this membranous coat, and joins it with the true substance of the viscus. Of this short kind of production, three belong to the liver, one or two to the spleen, and others to the kidneys and to the sides of the uterus and vagina. By this means, the tender substance of the viscera is defended from injury by any motion or concussion, and their whole mass is prevented from being misplaced by their own weight, and from injuring themselves, being securely connected with the firm sides of the peritonæum.

DCLVIII. But the most important of all these productions of the peritonæum, are those called the mesentery and mesocolon; and the description of which, although very difficult, ought not to be separated. We shall, therefore, begin first with the mesocolon, as being the most simple. In the pelvis, the peritonæum spreads itself shortly before the rectum. But where that intestine becomes loose, and forms the semilunar curve, the peritonæum there rises considerably from the middle iliac vessels and region of the psoas muscle, double (DCLVII.) and with a figure adapted for receiving the hollow colon. But above, on the left side, the colon is connected with almost no intermediate loose production to the peritonæum, spread upon the psoas muscle, as high as the spleen, where this part of the peritonæum, which gave a coat to the colon, being extended under the spleen, receives  
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and sustains that viscus, in a hollow superior recess:

DCLIX. Afterwards the peritonæum, from the left kidney, from the interval between the kidneys, from the large vessels, and from the right kidney, emerges forwards, under the pancreas; and forms the broad and sufficiently long continuous production, called the transverse mesocolon, which, like a partition, divides the upper part of the abdomen, containing the stomach, liver, spleen, and pancreas, from the lower part. The lower plate of this transverse production, is continued singly from the right mesocolon to the left, and serves as an external coat to a pretty large portion of the lower and descending part of the duodenum. But the upper plate, less simple in its course, departs from the lumbar peritonæum at the kidney and region of the vena cava; farther to the right than the duodenum, to which it gives an external membrane, not quite to the valve of the pylorus; and, beyond this intestine, and beyond the colon, it is joined with the lower plate, so that a large part of the duodenum lies within the cavity of the mesocolon. Afterwards, in the region of the liver, the mesocolon is inflected, and descending over the kidney of the same side, much shorter, it includes the right of the colon; as far as the intestinum cæcum, which rests upon the iliac muscle; and the appendix, which is provided with a peculiar, long, curved mesentery. There the mesocolon terminates, almost at the bifurcation of the aorta.

DCLX. The whole of the mesocolon, and of the mesentery, is hollow; so that air may be forced in between its two similar plates, in such a manner as to expand it into a bag. At the place where it sustains the colon, and also from part of the intestinum rectum, the mesocolon, continuous with the outer membrane of the intestine, forms itself into small slender bags, resembling the omentum, for the most

part in pairs, with their loose extremities thicker and bifid, and capable of admitting air, blown in between the plates of the mesocolon.

DCLXI. In the next place, we come to the mesentery, a very large, folded production of the peritonæum, continuous with the transverse and right mesocolon, at the right side of the emerging duodenum; and then proceeding for a long way with both mesocolons, even as low as the pelvis. The mesentery, under the right portion of the transverse mesocolon, descending from that part of the peritonæum, which lies upon the aorta, under the pancreas, and having numberless folds in its edge, contains the very long series of the small intestines.

DCLXII. Every part of the mesentery and mesocolon contains fat, collected in the necessary interval of the plates; generally in greater quantity, where they are longer; and interposed vessels distributed around the fat, which the arteries secrete, and the veins, as already mentioned, absorb; and also very numerous glands, which are most conspicuous in a young subject.

DCLXIII. The nature of the omentum is very analogous to that of the mesentery. But there are many membranes that come under this general denomination, of the same structure and utility, all composed of a tender membrane, very easily lacerated, through which reticulated vessels are distributed, with fat deposited in streaks along their course. This membrane is always double; and between its lamellæ, closely connected by very tender cellular substance, the vessels are distributed, and the fat collected. And, first, where the top of the right kidney, and the lobulus caudatus of the liver, with the subjacent large vessels, form an angle with the duodenum, there the external membrane of the colon which comes from the peritonæum, joining with the membrane of the duodenum, which also arises immediately from the peritonæum,

tonæum lying upon the kidney, enters backwards into the transverse fissure of the liver for a considerable space, is continuous with its external coat, contains the gall bladder, supports the hepatic vessels, and is very yellow and slippery. Behind this membranous production, betwixt the right lobe of the liver, hepatic vessels, vena portarum, biliary ducts, aorta, and adjacent duodenum, there is a natural opening, by which air may be blown extensively into all that cavity of the omentum, which we shall presently describe; and, lastly, into the bags of the rest of the omentum.

DCLXIV. From thence, in a course continuous with this membrane (DCLXIII.) from the pylorus and the smaller curvature of the stomach, the external membrane of the liver joins in such a manner with that of the stomach, that the thin membrane of the liver is continued out of the fossa of the venal duct, across the little lobe, into the stomach, stretched before the lobe and before the pancreas. This is the little omentum or hepatico gastricum; which, when inflated, resembles a cone; and gradually becoming harder, and emaciated, it changes into a true ligament, by which the œsophagus is connected to the diaphragm (DCXXIII.)

DCLXV. But the larger omentum, the gastrocolicum, is of a much greater extent. It begins at the first accession of the right gastro-epiploic artery to the stomach, being continued there from the upper plate of the transverse mesocolon (DCLIX.); and then from the whole great curve of the stomach, as far as the spleen, and also from the right convex end of the stomach towards the spleen, until it also terminates in a ligament that ties the upper and back part of the spleen to the stomach. This is the anterior lamina.

DCLXVI. Being continued downwards, sometimes to the navel, sometimes to the pelvis, it hangs before the intestines, and behind the muscles of the abdomen,

abdomen, until, from its lower edge being reflected upon itself, it ascends, leaving an intermediate cavity between it and the anterior lamina, and is continued for a very great extent into the external membrane of the transverse colon, and lastly into the sinus of the spleen, by which the large blood-vessels are received, and it ends finally on the œsophagus, under the diaphragm. Behind the stomach, and before the pancreas, its cavity is continuous with that of the smaller omentum.

DCLXVII. To this the omentum colicum is connected, which arises farther to the right than the first origin of the omentum gastrocolicum from the mesocolon, with the cavity of which it is continuous, but produced solely from the colon and its external membrane, which departs double from the intestine; it is prolonged, and terminates by a conical extremity, sometimes of longer, sometimes of shorter extent, above the intestinum cæcum.

DCLXVIII. The uses of the omentum are many. In common with the mesentery, it forms loose spaces, into which the fat may be poured, and preserved during sleep and inactivity, that it may be afterwards dissolved by increase of motion, restored by the absorbent veins, and constitute a principal ingredient of the bile. Hence it is sometimes found very thick, even an inch thick, and at others thin, and more transparent than paper. For that the fat returns again into the veins, is demonstrated from human omenta being found of very different bulks and fatness, according as they belonged to indolent, laborious, or diseased subjects; from the phenomena in animals; from the analogy of all the rest of the fat of the human body (xx.); from experiments in frogs, where this reabsorption of the fat may be made evident to the eye; and, lastly, from the evidently inflammable nature of the bile. Hither I also refer the disorders of digestion, the crudities  
and

and coldness of the stomach, observed from cutting out the omentum.

DCLXIX. For all the blood which returns from the omentum and mesocolon, goes into the vena portarum, and by that into the liver itself. The omentum gastrocolicum is furnished with blood from each of the gastro-epiploic arteries, by many descending reticulated branches: of which the most lateral are the longest, and the lowest anastomose by minute twigs with those of the colon. It also has branches from the splenic, duodenal, and adipose arteries. The omentum colicum has its arteries from the colon, as also the smaller appendices, (DCLX.) and from the duodenal and right epiploic. The arteries of the smaller omentum come from the hepatics, and from the right and left coronaries.

DCLXX. The omentum, being fat and indolent, has very small nerves. They arise from the nerves of the eighth pair, both in the greater and in the lesser curvatures of the stomach.

DCLXXI. The arteries of the mesentery are, in general, the same with those which go to the intestines, and of which the smaller branches remain in the glands and fat of the mesentery. Various small accessory arteries go to both mesocolons, from the intercostals, spermatics, lumbar and capsular, to the transverse portion, from the splenic artery and pancreatico duodenalis, and to the left mesocolon, from the branches of the aorta going to the lumbar glands.

DCLXXII. The veins of the omentum, in general, accompany the arteries, and unite into similar trunks: those of the left part of the gastrocolic omentum into the splenic, and also those of the hepaticogastric, which likewise sends its blood to the trunk of the vena portarum: those from the larger and right part of the gastrocolic omentum, from the omentum colicum, and from the appendices epiploides, into the mesenteric trunk. All the veins of the mesentery

mesentery meet together in one, which is the true trunk of the vena portarum : being collected first into two large branches ; of which the one, the mesenteric, receives the gastro-epiploic vein, the colicæ mediæ, the iliocolica, and all those of the small intestines as far as the duodenum ; the other, which going transversely inserts itself into the former, above the origin of the duodenum, carries back the blood of the left colic veins, and those of the rectum, except the lowermost, which belong partly to those of the bladder, and partly to the hypogastric branches of the pelvis. The vein which is called hæmorrhoidalis interna, is sometimes inserted rather into the splenic than into the mesenteric vein. Has the omentum also lymphatic vessels ? Certainly there are conglobate glands, both in the little omentum and in the gastrocolicum ; and ancient anatomists have observed pellucid vessels in the omentum ; and a modern has described them for lacteals of the stomach.

DCLXXIII. The other uses of the omentum are, to interpose itself betwixt the intestines and peritonæum, which are very apt to adhere ; to preserve the mobility of the former entire, both among themselves and upon the peritonæum ; to lessen friction ; and to lubricate the muscular fibres with a very bland oil. Therefore, even in insects, there is a great deal of fat around the intestines. In the large intestines, there are a great many appendices, because they have larger lacerti, and cannot be altogether covered by the omentum. The omentum also arranges the vessels, conducts and supports them, connects the contiguous viscera, and exhales a soft vapour, which, mixing with watery abdominal exhalations, anoints and lubricates all the viscera.

DCLXXIV. The mesentery sustains the intestines in such a manner, that they possess both mobility and firmness : it supports and conducts with safety the blood-vessels, lacteals and nerves ; it fixes the glands,

glands, as shall be noticed hereafter, gives an external coat to the intestines, and forms most of the omenta.

DCLXXV. But besides, the blood, returning through the mesenteric and mesocolic veins, brings with it to the liver a second principal constituent of the bile; namely, a copious subalkaline humour, which is absorbed from all the small intestines, as will be demonstrated in its proper place. Moreover, from the large intestines, it conveys to the liver another fluid, but more putrid, fetid, and nearly approaching to the nature of volatile alkali, absorbed from the alvine fæces, that now begin to smell strong; which is easily proved, both from proper experiments, and from the induration of the fæces when too long retained in the bowels. For this water is naturally fluid, and rendered more so by incipient putrefaction; it moderates the tenacity of the oil from the omentum and mesentery, and keeps it from coagulation. But it especially imparts to the bile that alkaline rancidity with which it abounds, and on which the great tenuity, and dyeing and saponaceous powers of the bile almost solely depend.

## C H A P. XXI.

### SPLEEN.

DCLXXVI. **T**HE spleen is also one of those viscera, which send their blood to the liver. It is pulpy, bloody, livid, and somewhat thick; of an oval circumference, often notched on the margin, or even divided into lobes; on one side, towards the ribs, convex, on the other concave; with two surfaces, one anterior towards the stomach, and another posterior towards the diaphragm; divided by the entrance of its vessels; and with two extremities, of which the inferior and anterior is the sharpest.

sharpest. It is connected to the stomach by the little omentum and upper ligament, supported from the adjacent colon by the ligament (DCLVIII.) behind, it is contiguous to the renal capsule; and it is connected to the kidney by the peritonæum. It also receives the peritonæum from the diaphragm, under the denomination of a ligament, in the back part of its hollow sinus, behind its vessels. Its situation is variable, and depends on the stomach. When that is empty, the spleen is placed more perpendicularly, and its extremities become superior and inferior: but when the stomach is full, and its middle curvature arises forwards (DCXXII.) then the spleen at the same time changes its situation, and its extremities become anterior and posterior, so as to lie almost transversely. Also, being of a very soft texture, it is more spongy and larger when the stomach is empty; and when the stomach is full, being pressed by it against the ribs, it is emptied. Hence, in weak subjects, it is large; but in those who die suddenly, and in full health, it is small. It also descends with the diaphragm in inspiration, and ascends with it in expiration; and besides, it frequently varies its situation with the colon. Frequently there is a second accessory spleen, or even several.

DCLXXVII. The blood-vessels of the spleen are large, in proportion to its weight. The arterial trunk comes from the cœliac; the left branch of which proceeds in a serpentine course, above and behind the pancreas, to which it gives branches, and to the mesocolon, stomach, and omentum, incurvated along the fulcus of the spleen, and being supported by the right end of the gastrocolic omentum, it in a manner perforates the spleen by many branches. The thickness of this artery is greater than that of the aorta. The splenic vein is remarkably soft, almost more so than any other vein of the body; it forms the principal left branch of the vena portarum,

portarum, and, besides the branches accompanying the arteries, it receives the great coronary, descending behind the pancreas, and sometimes the internal hæmorrhoidal. The *vasa brevia*, arising from those of the spleen, we have mentioned elsewhere; and lastly, small twigs from the lumbar, phrenics, intercostals, and those of the renal capsules, go to the ligaments and membranes. In like manner, the splenic and short veins communicate with the renal capsular, renal and phrenics.

DCLXXVIII. The lymphatic vessels which are described in the duplicature of the membrane of the spleen, which, however, does not exist, and are said to proceed on to the receptacle of the chyle, are very evident in the calf; and in mankind are rendered conspicuous by blowing air under the membrane, or by maceration, or by injecting water into the artery.

DCLXXIX. The nerves of the spleen are small; so that it is little susceptible of pain, and is very rarely inflamed. They arise from a particular plexus of the posterior branches of the eighth pair, (DCXXX.) and of peculiar branches from the large gangliform plexus, which the splenic trunk of the intercostal nerve produces; and they surround the splenic artery with branches.

DCLXXX. The fabric of the spleen appears to be much more simple than is commonly believed. For it is composed, both in man and in calves, entirely of arteries and of veins; the former of which are remarkably branchy, and subdivided into fewer large branches, but into very numerous minute ones, terminating finally in very tender twigs, very difficult of injection, and arising very crowded together; from which there is a ready passage into the corresponding veins. Various authors have considered these pencils, with their parallel branches, being somewhat round, as glands. Injection, rightly managed, never escapes into any intervals;  
nor

nor have hollow glands ever been demonstrated with certainty. Each little arterial trunk, with the smaller twigs that proceed from it, is surrounded by a very fine cellular web, in the same manner as in all the viscera, but here rather softer. The whole body of the spleen is externally surrounded by a single membrane, simple and not very firm, continued from the peritonæum, and joined to the substance of the spleen by thicker cellular substance.

DCLXXXI. Observation also teaches us, that the spleen contains more blood, in proportion, than any other viscus; since it has no muscles, fat, air vessels, or excretory ducts, interposed between its blood-vessels. Its blood is scarcely ever coagulated, has a somewhat dark colour, and from its dilution, colour, and greater proportion of water, may be almost compared to the foetal blood. It abounds with water and volatile salt, but has less oil.

DCLXXXII. The want of an excretory duct to the spleen, has occasioned, in all ages, inquiries, doubts, and controversies, about its use. The following seems to us to correspond with its fabric; although, perhaps, all the uses of the spleen are not comprehended by it. A great quantity of blood is carried to the spleen, (DCLXXVII.) and, from the density and serpentine course of the artery, its motion is slow; but, when the stomach is empty, at which time it arrives in greater quantity, and being less compressed, is retained in the spleen, it in some measure stagnates, from the very great proportion of branches to the trunks in this part; and the difficult circulation of the blood of the spleen through the straits of the liver. Hence the very frequent schirrosities of the spleen; hence that immense quantity of blood with which the whole spleen is distended, and which is not found in any other viscus in such quantity. Therefore the blood, in this warm situation, and fomented by the putrid fæces of  
of

of the adjacent colon, is resolved, and afterwards advances, in a certain degree, towards putrefaction, as appears from its colour and fluidity. But it is the more fluid, because the spleen has no secretory vessels, and therefore the whole quantity of water enters the vein, which was brought by the artery.

DCLXXXIII. Then, when the stomach is filled with food or flatus, the spleen is compressed into a narrower compass, against the resisting ribs and superincumbent diaphragm, and the blood which was returning through the splenic vein, slowly and in small quantity, is suddenly pressed out of the spleen, returns with celerity to the liver; mixes with the sluggish blood loaded with the fat of the omentum and mesentery, (DCLXIX.) dilutes it, preserves it from coagulation and stagnation; and, at the same time, it conduces to increase the secretion of bile, at the time when it is most wanted, for the process of digestion which is then going on. The spleen, therefore, seems to supply to the bile some aqueous principle, but probably of a subalkaline nature, and acrid from its stagnation.

DCLXXXIV. Is the fabric of the spleen cellular? Does the blood poured out into those cells stagnate? Is it diluted with some juice secreted by peculiar glands? Nothing of this is demonstrated by anatomy; nor do liquids or wax ever escape from the arteries, unless injected with too great violence. Is an acid juice prepared in the spleen for the stomach? That opinion is discarded, as repugnant to the nature of all the animal juices, and inadmissible, from the want of a passage. Is the spleen useless? Is this proved, by the little injury animals sustain from its extirpation? The loss even of a considerable part does not injure a robust animal; and yet there are examples, where, from its extirpation, the liver became swelled and diseased, the bile more scanty and darker, and troublesome flatulencies succeeded, which are referable

ferable to the vitiated nature of the bile, the obstruction of the liver, and diminished powers of digestion ; if they were confirmed by repeated experiments.

## C H A P. XXII.

## PANCREAS.

DCLXXXV. **T**HE pancreatic juice, which is watery, insipid, thin, neither acrid nor alkaline, is excreted at the same place into which the bile is discharged.

DCLXXXVI. The pancreas, the largest of the salivary glands, is of great length, is situated before the left renal capsule and the aorta, above the inferior lamina of the transverse mesocolon ; (which beyond the pancreas, behind its superior lamina, behind the stomach, before the spleen, under and behind the liver, joins with the inferior lamina ; ) is of a flattish triangular shape, with a light depression on the upper part, and is covered with the peritonæum. Upon it, being posterior and inferior, the posterior side of the empty stomach rests. The pancreas begins at the spleen itself ; extends almost transversely towards the right side, across the vertebræ, at the right of which it grows broader, being received betwixt the superior and inferior plates of the transverse mesocolon (DCLIX.) and is, finally, so connected by its round head to the duodenum, as to serve it for a mesentery. It is like the salivary glands, composed of round, hardish acini, connected by a good deal of cellular substance. Its vessels are rather numerous than large, and are derived chiefly from the splenics : but on the right side it is supplied by the first artery of the duodenum, and from another which is inferior, and is common to the

the duodenum and pancreas ; both of which arise from the hepatic artery, and of which the former inosculates with the latter, and both with the mesenteric artery, which also supplies considerable twigs to this gland ; and minute branches come from the phrenic and capsular arteries. The nerves are not considerable, whence it is little sensible ; they are derived from the posterior gastric, the hepatic and splenic plexuses, &c.

DCLXXXVII. The duct runs through the middle of this gland, white and tender, arising every where from an infinite number of roots, by which, being gradually increased, it emerges before the vena portarum and mesenteric artery, having received a larger branch from the larger part of the pancreas ; following the course of the duodenum, it arrives at the same part of the duodenum into which the biliary duct proceeds ; where, changing its course, it descends, and being extended into a sinus, betwixt the coats of the intestine, internally smooth ; and, being continued, after having received the ductus choledochus, it opens in a particular fold in the bottom of the descending part of the duodenum. But it not unfrequently happens, that it opens by an orifice distinct from that of the biliary duct ; and sometimes by two, of which the one, the lower, is distinct and less ; but in man, and in most other animals, it always opens near the biliary duct. In its orifice there is no valve.

DCLXXXVIII. The quantity of fluid secreted is uncertain : but it must be very considerable, if we compare it with the weight of the saliva, the pancreas being three times larger, and seated in a warmer place. It is expelled by the force of the circulating blood, and of the incumbent viscera in the full abdomen ; as the liver, stomach, spleen, mesenteric and splenic arteries, and the aorta. Its great utility appears from its constancy, being found in almost all animals : nor is it refuted by  
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the few experiments, in which a part of it was cut out from a robust animal without occasioning death; because the whole pancreas cannot be removed without the duodenum: for even a part of the lungs may be cut out, without producing death, but they are not therefore useless. Its effervescence with the bile arises from the effect of the ligature, and of air mixed with the intestinal humour.

DCLXXXVIII. It seems principally to dilute the viscid cystic bile, to mitigate its acrimony, and to mix it with the food. Hence it is poured into a place remote from the cystic duct as often as there is no gall bladder. Like the rest of the intestinal humour, it dilutes and resolves the mass of aliments, and performs every other office of the saliva.

## C H A P. XXIII.

### LIVER, GALL BLADDER, AND BILE.

DCLXXXIX. **T**HE liver, the largest of all the viscera, occupies a large part of the abdomen, above the mesocolon; and in the foetus one still larger. Both above, and behind, and before, and to the right, it is covered by the diaphragm, from which it receives the peritonæum, under the denomination of ligaments, chiefly in three places. For on the convex part of the liver, from the passage of the vena cava to the transverse furrow of the liver, the peritonæum descends double, growing broader anteriorly, under the name of ligamentum suspensorium, which divides the greater right lobe from the smaller left lobe; and diverging, it expands into a membrane of the liver, (DCXXIII.) white, simple, thin, like the external coat of the stomach, having cellular substance under it, by which it is joined to the substance

stance of the liver. To the lower margin of this, the umbilical vein is united; which, in the adult, having almost disappeared, leaves a fibrous appearance, with much fat. In the extremity of the left lobe, and on the convex part, and not unfrequently at its edge, a membrane goes to the liver from the diaphragm; which in children, and in other instances, is frequently to the left side of the œsophagus, but in adults to the right side; and always conjoined both to the gullet and to the spleen, when the liver is large. This is the left ligament. The right ligament ties the diaphragm very far back to the very thick right lobe. Besides, but without any apparent length, the membrane of the right lobe of the liver is often conjoined with the diaphragm by cellular substance in the right lobe, behind and to the right of the oval lobule, more especially in old subjects, for in the fœtus it is easily separated; and betwixt the suspensory and left ligament, there intervenes a production of peritonæum, in like manner continuous, resembling a ligament. But also from the kidney, the peritonæum going to the liver makes a reduplication like a ligament; and the smaller omentum, and the continuous loose productions of the mesocolon (DCLXIII.) unite the liver with the stomach, duodenum and colon; and the mesocolon also unites it to the pancreas. Thus the liver is suspended in the body with firmness, and yet with considerable mobility, so that it may be variously agitated and depressed by the diaphragm. The same ligaments form the common membrane, which covers the liver as well as other viscera.

DCXC. Moreover, the inner concave surface of the right lobe of the liver, corresponds with its forepart to the colon; and with its back part to the right kidney and renal capsule, to which it is connected by cellular substance. The middle sinus is contiguous to the duodenum, which touches the

gall bladder, and that part which conducts the great blood-vessels. The left lobe extends largely over the stomach; and frequently, especially in younger subjects, is extended beyond the œsophagus into the left hypochondrium. The lobule adapts itself to the smaller curvature of the stomach. But, moreover, the pancreas lies under the liver, and the right venal capsule is tied to the part of the liver farthest to the right by much cellular texture.

DCXCI. The figure of the liver is difficult to describe. It begins in the cavity of the right hypochondrium, by a very thick solid protuberance, convex towards the diaphragm, and hollow towards the colon and kidney; having a protuberant line dividing these concave surfaces, which is continued into the longer appendix of the lobule. After this, the liver grows gradually slenderer and thinner, and is extenuated, with an almost triangular shape, into a tip, which passes into the left hypochondrium, across the œsophagus, in young subjects, as far as the spleen; but in adults, it is often shorter, and ends at the œsophagus. The edge, in which the convex part of the liver meets with the concave one, is wholly in the anterior and lower part. The whole obtuse margin lies backwards. The upper and back part of the liver is every where convex; sustains the diaphragm; and with a large portion, which is somewhat flatter towards the left side, it lies under the heart: but the lower surface, variously figured, rests upon the duodenum, colon, stomach, pancreas, and right renal capsule. For there are several fissures which divide the surface into different regions, which did not escape the notice of the ancients.

DCXCII. The principal of these, the transverse, extends from right to left, and divides a third part of the liver, beginning slender in the right lobe, and growing broader towards the left. Before this transverse fissure, there is an excavation in the right lobe

lobe for the gall bladder ; then there is the convex anonymous lobe ; and then the fossa of the umbilical vein, extending transversely backwards, often covered with the bridge that joins the anonymous to the left lobe. Behind the great sulcus in the right side, there is a transverse eminence, slender at its commencement, growing broader towards the right and moderately hollow, by which the great blood-vessels are conducted into the liver : the hollow was by the ancients denominated the portæ. This joins the lobe, which I shall next describe, with the right lobe. Then the posterior lobule, papillary, obtusely conical, projects into the little curvature of the stomach. The thick root of this and of the former excavated eminence, begins from the convex part of the liver, at the diaphragm ; and in the right side, is impressed with an oblique furrow, inclined to the right side, for the trunk of the vena cava, descending from the heart to the lumbar vertebræ, and frequently covered by a considerable portion of the substance of the liver, as by a bridge, so as to form a tube. The left end of the lobule is terminated by another fossa almost straight backwards, but also inclined to the left ; which beginning at the extremity of the transverse one, terminates at the passage of the vena cava through the diaphragm. In this was lodged the ductus venosus in the foetus, of which there are still some remains to be perceived in the adult. All that lies beyond this is the left lobe, which is simple, uniformly concave below, so as to lie upon the stomach, and extenuated to an edge.

DCXCHII. This very large viscus is proportionably supplied with vessels, and of various kinds. The artery, which is indeed considerable, being the greater and right portion of the cæliac, emerging forwards and to the right, goes transversely before the vena portarum ; and after giving off the small coronary and the pancreatico duodenalis, the latter

of which is pretty large, the rest enters the liver, commonly by two branches; of which the left supplies the umbilical fossa, the venal duct, posterior lobule, with the left and the anonymous lobes, and the suspensory ligament; this branch inosculates with the phrenic and epigastric arteries. The right lies deeper, covered by the biliary ducts; goes to the right and anonymous lobes, and sends off, in one small trunk, the cystic artery, which immediately dividing into two, is spread both under and over the gall bladder, covered by its external coat, and supplies branches to the gall bladder and biliary ducts, and likewise many to the liver. From the left branch, or sometimes from the trunk, a superficial artery goes to the biliary ducts, anonymous lobe, and glands of the portæ. Besides the cæliac artery, not very rarely, a large right branch is produced from the mesenterica major, creeping behind the pancreas; this serves instead of the right hepatic branch of the cæliac. But, likewise, the greater coronary, which is the first twig of the cæliac, always gives some ramifications to the left lobe, and to the fossa of the ductus venosus; which is often very considerable. Those sent to the liver from the phrenic, mammaries, renal and capsular arteries are smaller. They communicate also with the epigastrics.

DCXCIV. In the foetus, the umbilical vein brings a great deal of blood to the liver, at which time the vein going to the portæ is but small. It sends forth, while it stretches backwards through its fossa, numerous and very large branches, each of them equalling the vena portarum in bigness; at this place it is dilated into a tumor, which unites with the left branch of the vena portarum. But it sends a single branch through the posterior part of the horizontal fossa into the vena cava, or into some of its hepatic branches: this is called the ductus venosus. In the adult, indeed, this duct is obliterated,  
and

and the vena portarum, which has now grown larger, supplies the hepatic branches.

DCXCV. The vena portarum receives all the blood of the stomach (DCXXIX.) of the intestines and mesentery (DCXXXI.) of the spleen (DCLXXVII.) omentum (DCLXIX.) and, lastly, of the pancreas, at first into two trunks, the transverse splenic and ascending mesenteric, and then into one, which is continued with the mesenterics. It is large, composed of strong membranes, stronger than those of the vena cava, ascends behind the first flexure of the duodenum, receives the veins from the right side of the duodenum, and the smaller coronary, ascends to the right in the sinus of the lobule of the liver (DCXCII.) and is afterwards again divided into two large trunks. The right, which is shorter, larger, and bifurcated, having received the cystic vein, goes to its own lobe. The left proceeds through the remaining part of the transverse furrow of the liver, and supplies the lobule, the anonymous and left lobe, and being reflected, enters the umbilical fossa, about the middle of which, it penetrates branchy into the liver. There are instances in which the branch of the posterior lobule rather proceeds from the trunk of the vena portarum.

DCXCVI. The vena portarum is surrounded on every side with a good deal of cellular substance, which it brings with it from the mesentery and spleen; and which being dense and short, strengthens the membranes, which are firmer than those of the aorta itself. Intermixed with this cellular substance, are also many small vessels and the hepatic nerves, which are all comprehended under the denomination of capsule, which is nothing more than the cellular substance, and never has a single truly fleshy fibre. The vena portarum carries this along with it, through the liver, and is sustained by it; insomuch, that the branches, when cut, being supported, preserve the roundness of their section.

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Each branch of the vena portarum is divided into many others, again divided and subdivided, even to the smallest capillaries, as arteries commonly are. Every branch of the vena portarum is accompanied by a branch of the hepatic artery, creeping upon its surface, and upon the hepatic ducts, almost in the same manner as the bronchial arteries usually creep along the bronchia; and by a branch of the biliary duct, which are both connected by thin cellular substance. Some go out of the liver, being divided on the ligaments, and inosculating with the surrounding veins. The sum of the branches in the vena portarum is always greater than the trunk; hence the calibers of all the branches together, greatly exceed that of the trunk (XXXVII.) Hence there is a great degree of friction, (CLXXX. and CLXII.) exactly as in the arteries.

DCXCVII. But as the blood is conveyed to the liver by the vena portarum, as well as by the hepatic artery, it must of course be conveyed away by some other vein. Therefore, the extreme branches of the vena portarum and hepatic artery inosculate ultimately with other veins, which are branches of the cava; arising from the whole circumference of the liver, they run towards the posterior gibbous part of the liver, unite into branches and trunks, which at last terminate in ten or more large vessels. The smaller and more numerous of these, arise from the posterior lobule and liver, and go to the cava, where it ascends towards the left, to the diaphragm, through the fulcus, that lies on the right side of the lobule, and is often included by a bridge thrown over it. The remaining two or three, which are much larger, are inserted into the same cava, close to the diaphragm, whose veins they often receive. The branches of the vena cava are, in the adult, on the whole, fewer than those of the vena portarum; which is an argument that the blood moves more quickly through these branches, on account of the  
diminution

diminution of the friction, (CLXX.) and of the very collection of the blood into a less caliber, which always accelerates its course, when there is a sufficient compressing force (CLXX.) I know not of any valves in the mouth of these veins, which deserve to be remembered. The trunk of the vena cava ascends through a foramen of the diaphragm, obtusely quadrangular, included by mere tendons surrounding it; and therefore (CCLXII.) not easily variable; and immediately expands into the right auricle. The smaller veins of the liver, creeping upon its surface, are sent from the phrenica, renalis and azygos; or at least there is a communication betwixt these and the hepatic veins coming from the portæ.

DCXCVIII. That the blood comes from all parts (DCXCV.) by the vena portarum to the portæ, is proved by ligatures, by which the veins swell betwixt these parts and the ligatures; while the vena portarum itself grows flaccid and empty. But that it afterwards goes through the liver to the cava, is proved by anatomical injections, which show the anastomoses, and open communication betwixt the vena portarum and the cava, and by the common nature of the veins going to the cava. Again, the difficulty of the arterial distribution of the vena portarum, as being remote from the heart, and the oily nature of its blood, occasion it to stagnate, accumulate and form scirrhus swellings in the liver oftener than in any other part. But this danger is diminished by muscular action, and respiration; and is increased by rest, indolence, and four and viscid aliments. Hitherto, we have been speaking of the adult liver, in which both the umbilical vein and the ductus venosus are empty, although they cohere with the left branch of the vena portarum.

DCXCIX. The nerves of the liver are rather numerous than large; hence, when wounded or inflamed,

flamed, it causes a moderate degree of pain. They have a twofold origin. Most of them arise from the large gangliform plexus of the splenic branch of the intercostal nerve, with the addition of a branch from the posterior plexus of the eighth pair; they accompany the hepatic artery, and, playing around its trunk, go to the liver, with that and the branches of the vena portarum. Another fasciculus of nerves usually enters with the ductus venosus, and arises from the posterior plexus of the eighth pair, but sometimes, from the great plexus.

DCC. The lymphatic vessels of the liver are numerous, and may be constantly and easily seen about the portæ. They arise from the whole concave surface of the liver, and from the surface of the gall bladder, run together into a plexus, surrounding the vena portarum, and go to the conglobate glands, seated before and behind the said vein; from whence they meet together in one large trunk, which is one of the roots of the thoracic duct. Upon the convex part of the liver, are described other lymphatics, whose insertion is not well known; for it is hardly probable that they enter the cava, nor have they been sufficiently often traced to the receptacle of the chyle.

DCCI. The interior fabric of the liver is more obscure. Through the whole liver, bundles of biliary vessels, of branches of the vena portarum, and of the hepatic artery, are distributed. Each vessel has both its proper cellular texture surrounding it, and ligaments of the same substance, by which it is tied to its fellow vessels; and, lastly, the whole bundle is surrounded by cellular texture. The branches of the vena cava lie on the outside of the others, being less accurately received into the same bundle. Lastly, the ultimate branches of the vena portarum, cava, and hepatic artery, and of the biliary ducts, which we shall soon describe, are united

ted together by means of cellular substance (DCXCVI.) into a sort of acini of a somewhat hexagonal shape, surrounded with lax cellular substance. In these bunches, likewise, there are mutual anastomoses of the branches of the vena portarum, and of the hepatic artery, with the roots of the vena cava, and of the branches of the vena portarum, with the first origins of the pori biliarii; which last connection is demonstrated by anatomical injections; for liquors injected into the vena portarum, at last return through the porus choledochus.

DCCII. Many eminent anatomists have taught, that these acini are hollow, having arteries and veins spread upon their external surface, and that the bile, secreted from the branches of the vena portarum, is deposited into their cavities. They derive their arguments from the anatomy of brutes, in whose liver the acini are round, and more defined than in man; and from diseases, which exhibit cells and round tubercles, filled with lymph, chalk, and various kinds of concreted matter. To this, they might have added the lentor of the bile, by which it resembles mucus, and the analogy of the follicles of the gall bladder.

DCCIII. But greater accuracy in anatomy does not admit these follicles into which the small secretory vessels are said to open; for such would intercept the course of wax injections, and would occasion intermediate knots betwixt these vessels and the biliary pores, which have never yet been seen: for the wax flows in one continued thread, without any retardation, effusion into a cavity, or diminution of its impetus, from the vena portarum into the biliary ducts. Nor could the great length of the biliary ducts admit of a glandular fabric. For all follicles deposite, at no great distance, their fluid, which is not fitted for a long course, as they destroy so great a part of the velocity received from the arteries.

Lastly,

Lastly, the very common pressure, would so crush these bundles of acini, which we must suppose, that the motion of the excretory duct could derive no assistance from thence. The concretions and hydatids are formed in the cellular substance; and, lastly, the bile, when first secreted, is sufficiently fluid.

DCCIV. Again, we are convinced, that no bile is separated from the hepatic artery, by the peculiar structure of the vena portarum, which would be useless if it secreted nothing; by the continuity of its branches with the biliary ducts, which is much more evident than in the arteries; by the experiment, in which it appears that the biliary secretion continues after the hepatic artery is tied; by the great size of the biliary ducts, in proportion to so small an artery, and by the peculiar nature of the blood collected in the vena portarum, which is perfectly adapted for the secretion of bile. For it contains both oil, which abounds more in the bile than in any other humour of the body; and a saponaceous fluid, absorbed from the stomach, and the alkalescent subfetid vapour of the abdomen, brought back from the whole surface of the intestines, stomach, omentum, liver, spleen, and mesentery, as we know by evident anatomical experiments; and, finally, the alkalescent semiputrid, acrimonious humidity, absorbed from the alvine faeces themselves, while they are indurated in the large intestines, and brought thither by the internal hæmorrhoidal veins, from whence that bitterness, alkalescent and putrescent disposition of the bile is derived. But in the blood of the hepatic artery, there is nothing which renders it peculiarly fitted for the secretion of bile, or analogous to it.

DCCV. Since, therefore, the vena portarum conveys the blood, in its fittest state, for the secretion of bile, to the ultimate acini of the liver, (DCCIV.) as there the passage, from each branch of the  
vena

vena portarum, into the beginning of the biliary ducts, is direct without any intermediate follicle, and as fluids injected into the vena portarum readily take this course, the bile will be propelled that way by the force of the blood surrounding it, and urging it from behind, and also by the accessory force of the diaphragm pressing the liver against the rest of the viscera in the very full abdomen, (DCI.XXXIX.) and again of the thorax, contracted in expiration, it will be forced into the larger branches, and lastly into the two trunks of the hepatic biliary duct; which trunks meet together in one on the vena portarum, and in the transverse fossa of the liver, near the anonymous lobe.

DCCVI. This duct is composed of a strong nervous membrane, like that of the intestines, and of an external and internal cellular coat, and of a villous coat, loose, elegantly reticulated, but asperated with many small pores and sinuses, and continuous with that of the intestine. There is no certainty of any muscularity. From experiments, it appears to have a moderate degree of irritability. That it is vastly dilatable, is shown from diseases. They seem also to show that this duct is possessed of great sensibility.

DCCVII. The hepatic duct, thus formed, goes along the vena portarum, more to the right than the artery, towards the pancreas; and then descending obliquely, covered by some part of that gland, it comes in contact with the back and lower part of the second flexure of the duodenum, about six inches from the pylorus; passes through an interval in its fleshy fibres; meets with an oblique oblong sinus, made by the pancreatic duct, and opens into it by a narrow orifice. This sinus descends obliquely a long way through the second cellular coat, of the duodenum, perforates the nervous coat, and again runs obliquely between it and the villous tunica; and, lastly, opens into a protuberant long tail-  
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ed wrinkle of the duodenum. Between the first arrival of this duct at the duodenum and its orifice, a sinus, almost an inch long, which receives the ductus choledochus, is inclosed between the membranes of the intestines, so that when this intestine is filled, or distended by flatus, or closely contracted by a violent peristaltic motion, it must be consequently compressed and shut; but when the duodenum is relaxed, and moderately empty, it discharges itself. Any regurgitation from the duodenum is hindered by this obliquity, and by the wrinkle, which is easily pressed together, or closed, and by the very easy descent of fresh bile through the duct. Even air does not find its way from the intestine into the duct.

DCCVIII. But in the very portæ, this duct receives the addition of another less canal of the same kind, for a good way parallel, and adhering to it, and inserted into it in a very acute angle. This is called the cystic duct, from its origin, and is sometimes first increased by another duct from the liver. It arises from the gall bladder, which is found in most animals; but is absent in some, especially the swift footed, and perhaps only the herbivorous. It is contained in an excavation of the right lobe of the liver, (DCCXCII.) to the right of the anonymous lobule, in such a manner, that in young people, it lies entirely within the edge of the liver, but in adults projects considerably beyond it, lying upon the colon. Its situation is transverse, from before backwards; its neck ascends a little.

DCCIX. The figure of the gall bladder is variable, but in general like that of a pear; it is terminated before by an obtuse, hemispherical, impervious end; and gradually diminishes backwards; the neck or tip of this truncated cone being reflected against itself once or twice, and tied together by proper cellular substance; and having made another flexure upwards, ends in the cystic duct; which from  
thence

thence goes towards the left side of the hepatic duct. But this duct, being also contracted by many cellular bands, is internally marked with many protuberant wrinkles, which, conjunctly in the dried gall bladder, represent a kind of spiral valve; but being soft and alternate in the living body, they retard, but do not entirely obstruct, the course of the bile either way, as is proved by experiments, made with air and pressure. Besides, it is reticulated like the gall bladder itself.

DCCX. The outermost coat of the gall bladder covers only its lower side, being the common covering of the liver itself, stretched over the gall bladder, and retaining it in its situation. The second is a loose cellular coat. The third coat has sometimes splendid longitudinal fibres, in different directions, so as obliquely to intersect each other. At other times, it has none; so that we may doubt of its muscular nature, especially as the irritability of the gall bladder is slow and obscure. The nervous, second cellular, and villous coats, are found as in the intestines, except that the last, as in the biliary ducts, is reticulated and full of cells. In the gall bladder, especially about its neck, but even as far as its middle, we observe muciferous pores, capable of receiving a bristle; and arteries, as in other places, discharge some watery humour into the cavity of the gall bladder, and bile easily transudes through inorganic pores to the surface of the gall bladder, and neighbouring membranes.

DCCXI. All animals, between their gall bladder and liver, or between their ducts, have also some peculiar openings into the gall bladder; into which some ducts, originating from the liver, or from the hepatic biliary duct, open. In man, similar ducts have not been shown by any certain experiment, and the gall bladder, when full of bile, is easily separated from the liver, without a drop of bile escaping either from it or from the liver. There is also a  
thin

thin water in the bladder as often as the cystic duct is obstructed.

DCCXI. The bile naturally flows both out of the bladder and liver, whenever there is no impediment in its course; so that both ducts swell when the passage is obstructed, and the cystic lies in a straight line with the choledochus. Nor is it probable that the whole of the bile is sent into the gall bladder before it flows into the duodenum. There is not a perpetual obstacle which hinders its efflux, and peculiarly obstructs the hepatic bile, and admits the cystic; the passage into the ductus choledochus is larger and straighter, the ductus cysticus much less than the hepatic, and therefore not formed for receiving all the bile; the choledochus, much larger than the cystic, and therefore not appointed for the reception of its bile only. There are many animals in which the hepatic duct enters the intestine without any communication with the cystic. In living animals, even when the cystic duct is free, the bile appears to descend into the duodenum with a perpetual current. That the quantity is very considerable, appears from the magnitude of the secretory organ, and of the excretory duct, which is so many times larger than the salivary ones; from diseases, in which four ounces of cystic bile only have flowed out daily through an ulcer of the side. But the hepatic bile goes into the gall bladder, as often as there is any obstruction in the duodenal sinus, from flatus, or any other cause compressing the orifice of the ductus choledochus. Accordingly, it is found extremely full, whenever the common biliary duct is compressed by any scirrhoty or tumour, and it is sometimes enlarged beyond all belief; if the cystic duct be tied, it swells betwixt the ligature and its union with the hepatic duct; and in living animals, the hepatic bile has been seen to distil into the wounded gall bladder. This is not inconsistent with the retrograde angle,  
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for a very slight pressure urges the bile from the liver into the gall bladder; and air easily takes the same way, more especially if the duodenum be first inflated. Nor does there seem to be any other bile secreted by the gall bladder. Whenever the cystic duct is obstructed by a calculus, or by a ligature made upon it, we find nothing in the gall bladder, except a small quantity of insipid mucus, secreted from the follicles, (DCCX.) or some watery exhalation. In many animals, we meet with no appearance of a gall bladder, when, nevertheless, plenty of acrid and salutary bile is discharged into the intestines. It does not seem probable, that any bile is secreted in the gall bladder from the cystic branch of the vena portarum, for that is a mere returning vessel; nor from the hepatic artery, for it is scarcely probable, that the very acrid cystic bile should be separated from a milder blood than milder hepatic bile prepared from appropriated blood (DCCIV.)

DCCXII. Lastly, the bile flows also from the gall bladder to the liver, and at length returns into the blood, when its passage into the intestines is totally intercepted, sometimes also from a latent cause existing in the nerves. This course is morbid, and produces the jaundice; which, therefore, is cured by the passage of the calculi, and by restoring its free course.

DCCXIII. Therefore, a portion of the hepatic bile being received into the gall bladder, stagnates, being only gently agitated by respiration, and there exhales its thinner parts, which we see extensively diffused over the adjacent membranes. The remainder, being oily and subalkaline, from its warm situation, grows acrid and rancid, and its thickness, bitterness, and colour are increased; nor is there any other difference betwixt the cystic and hepatic bile, which last we find in the ducts, less bitter, less dark coloured, and less viscid. That this difference proceeds only from stagnation, appears from such animals

animals as have only a larger porus hepaticus, instead of a gall bladder; for the bile which stagnates there, is remarkably more bitter than that in the liver; as, for example, in the elephant. But the gall bladder gives this particular advantage, that it receives the bile, when, the stomach being empty, it is of no use, and supplies it more quickly when we principally want it for the digestion of the aliments, now flowing in great quantity into the duodenum. This quickness is greater in proportion as the cystic duct is smaller than the gall bladder.

DCCXIV. The gall bladder, indeed, does not touch the stomach, but the beginning of the descending duodenum. But when the stomach is distended, and occupies a considerable space in the very full abdomen, it both presses the liver and duodenum, and compresses the gall bladder, and empties it. Thus the bile flows through a free passage, from the gall bladder into the biliary duct, and into the duodenum; most easily in persons lying on their back, for then the bottom of the gall bladder is uppermost. Hence the gall bladder becomes turgid after fasting. There is scarcely any other evacuating power than the stomach and diaphragm; for that residing in the proper muscular and contractile membrane of the gall bladder, is very inconsiderable.

DCCXV. The hepatic bile is always bitter, but the cystic more so; always viscid; of a full yellow colour, with a tincture of green; miscible, by trituration, with water and oil, and with vinous spirits; coagulable by the mineral acids; soluble in the alkalies, especially the volatile alkali; well adapted for dissolving oily, resinous, or gummy substances; of a lixivial and saponaceous nature; quickly putrefying, and by putrefaction spontaneously acquiring the odour of musk. Its chemical analysis, and experiments of mixture with various substances, demonstrate, that it contains a large portion of water,  
and

and a considerable quantity of the inflammable oil, which is so evident in cystic calculi. It therefore, is a soap ; but of that sort which is composed of a volatile alkaline salt, mixed with oil, and retains its water. Therefore, being intermixed with the aliment, reduced to a pulp and expressed from the stomach by the peristaltic motion of the duodenum, and pressure of the abdominal muscles, it in a great measure overcomes the aciescent qualities of the food ; it dissolves the coagulum of milk, and disposes the aliment more to putrescency ; it dissolves the oily matters, so that, by freely incorporating with the watery parts, they may form chyle, and enter the lacteals ; it absterges and attenuates the mucus ; and, lastly, excites the peristaltic motion by its acrimony ; all which offices are confirmed, by observing the opposite diseases to arise from a want of bile. Nor is the hepatic bile sufficient to evacuate the intestines, if the cystic is wanting. So great is its utility, that perfectly robust animals have been found to die in a few days, by preventing the afflux of bile to the intestines, or destroying the gall bladder.

DCCXVI. The bile gradually descends along with the food, and is evacuated along with the fæces, somewhat changed, its bitterness being destroyed by putridity. Perhaps some of the watery, least bitter, and thinnest parts, are again taken up by the vena portarum. Its regurgitation into the stomach is impeded by the ascent of the duodenum, at the bottom of which it enters, by the valve of the pylorus, and by the access of new chyle which the stomach adds to the former : in man, however, it frequently happens, and in birds always. The bile in the foetus is bland and sweet ; for in them no fetid fæces supply acrid alkaline vapours, nor is there any oil absorbed. As the bile is viscid in sluggish and fat animals, and in man from the same causes, and from grief, it readily forms hard coagulums,

either calcareous or resinous, and much more frequently than the urine, according to our experiments. Its use is manifest, as, by trituration with the aliments, it dissolves oil, resists acidity, and stimulates the intestines to contraction.

DCCXVII. In the foetus, besides secreting the bile, the use of the liver is evidently to transmit the blood returning from the placenta, and, as it seems, to moderate its impetus. Even in the adult, it has the same use, though less manifestly, in retarding the return of the blood coming back from the chylo-poëtic viscera.

## C H A P. XXIV.

### SMALL INTESTINES.

DCCXVIII. **B**Y the small intestines, anatomists understand one continued, and almost cylindrical tube, whose transverse section is nearly oval, the obtuse end being towards the unconnected side of the intestine. This tube being continued for a long way from the end of the stomach, the right orifice of which it embraces, (DCXXV.) terminates by expanding into a larger intestine. Anatomists have usually reckoned three small intestines, though nature has formed but one. However, the duodenum has a tolerable fixed limit, at the bottom of that part of the abdomen which is above the transverse mesocolon (DCLIX.) But that small intestine which lies below this mesocolon, has no certain mark of distinction, by which the jejunum, commonly so called, is separated from the ileum : for although the former abounds more with valves and blood-vessels, and is furnished with longer villi, and therefore appears somewhat redder ; and the ileum again rather contains glands, and has fewer vascular ramifications ; these differences insensibly occur, without

out any certain limits, being great in their extreme, and obscure in their contiguous terminations.

DCCXIX. The duodenum is denominated from its length. It is lax and large, especially in its first flexures, because in part it has no external membrane, and in part is not completely furrounded by it. It is florid and tender, and has fleshy fibres of considerable thickness. It begins by adhering round the annular orifice of the pylorus; then it proceeds undulating, but on the whole transverse, to the right and backwards in the empty stomach, to the gall bladder, to the neck of which it becomes contiguous (DCCXIV.) From thence it descends obliquely to the right, and backwards as far as the lower plate of the mesocolon, and the entrance of the biliary duct, and in that course is received betwixt the upper and lower plates of the mesocolon. From thence it again returns, transversely, but at the same time ascending, behind the pancreas and large mesenteric vessels, to the left, along with the left renal vein; it goes out from the duplicature of the plates of the mesocolon; and making a turn, it descends on the right of the said vessels, through a peculiar foramen, in which the mesentery, left and transverse mesocolon, adhere to it, to the lower part of the abdomen, which it enters, and becomes the jejunum. The largeness of this intestine, its ascent from the insertion of the biliary duct, its succeeding flexure around the root of the mesentery, cause some delay, by which the bile and pancreatic juice are here especially mixed with the alimentary mass.

DCCXX. In the rest of the small intestine there is no certain point; but with uncertain and infinite convolutions, not to be described, it fills the lower part of the abdomen and the pelvis, furrounded by the colon, and also lies between the bladder and uterus.

DCCXXI. The fabric of the small intestine is almost the same with that of the stomach and œsophagus.

phagus. Excepting part of the duodenum, it receives an external coat from the peritonæum, or mesentery, applied to the acute vertex of the intestine, double, and separated there by some cellular substance, often by fat, but closely embracing the rest of the intestine, so that its muscular fibres adhere to the external membrane, which does not at all differ from that of the stomach. By this external membrane, and by the mesentery (DCLXI.) the intestines are supported as firmly as is necessary, and with very great mobility.

DCCXXII. But the muscular coat is different, from the difference of figure. The most considerable stratum of fibres in the intestines is circular; they surround the tube on every side, and are uniform, parallel, formed of imperfect arches, cemented into circles, pale, and yet remarkably contractile. The longitudinal fibres are, in the small intestines, few in number, and scattered round their whole extent, but especially laid over the others on the obtuse vertex of the intestine.

DCCXXIII. Within the muscular coat, is seated the second cellular, larger, as in the stomach, spread on all sides round the nervous coat, and in man rarely fat. But the nervous coat, as in the stomach, serves as the foundation for the whole intestinal tube; it is composed of compacted fibres, which, by inflation, may be separated and disunited, so as to assume a cellular appearance. Next follows the third cellular coat, which is almost like the second. The innermost, the villous, differs from that which we described in the stomach: for, first, it is every where folded into wrinkles, generally semicircular, but also into others joining the semicircular ones obliquely, and into others variously irregular, into which the nervous coat slightly enters, but the third cellular enters deeply, lying between the doubled villous coat, and filling up the duplicature. These folds begin within one inch of the pylorus, and are  
most

most numerous in the first half of the intestines, but gradually diminish in number. In each of these a small artery and vein lie upon the convex surface of its second cellular coat. The first plicæ in the duodenum are confused, and lie nearly in the direction of the intestine. They are changed into acute circles and valves by anatomical preparation. They are indeed soft, and easily inverted, and yield to the passage of the alimentary pulp either way, but by their number they retard it, and enlarge the surface of the villous membrane.

DCCXXIV. Lastly, the membrane is here truly villous, which in other parts is so named from analogy. Namely, the whole internal surface of the intestine, both the valves, and the intervening hollows, send out every where innumerable pendulous flocculi, resembling silk velvet, which are conical, but somewhat obtuse, productions of the inner coat of the intestine, containing cellular substance between the duplicature, and vessels and nerves wrapped up in that substance, and likewise a lacteal vessel, such as we shall afterwards describe, so as very much to resemble the papillæ of the tongue, except in being softer.

DCCXXV. The chief vessel of each of the villi is an oval vessel, opening by a slender duct in the surface of the villous coat, often filled with a milky fluid, and surrounded by neighbouring vessels.

DCCXXVI. In the internal surface of this villous coat, open an infinite number of pores; some larger, others smaller. The former lead to conspicuous simple mucous glands, seated in the third cellular stratum, similar to those seated in the mouth and pharynx, having a very vascular follicle, and an orifice opening into the intestine. In the duodenum there are several of them which are contiguous, but do not run together, and cannot always be demonstrated; in the ileum they are very numerous, both solitary, a few joined together, and in considerable numbers

numbers collected into an elliptical figure. They are furrounded by villous membrane.

DCCXXVII. The smaller pores are found throughout the whole intestines, and surround the basis of the villi; they are most conspicuous in the large intestines, where they have been long known, but have been lately discovered in the small intestines likewise. These also seem to deposite a liquor of the mucous kind.

DCCXXVIII. The vessels of the small intestines are very numerous. The common larger trunk belonging to that part of the intestine that lies below the mesocolon, is called the mesenteric artery, which is the largest of those produced by the aorta, and situated above the renal arteries. Descending behind the pancreas, to the right of the beginning of the jejunum, and besides the colic branches, being especially produced in a long trunk towards the right, to the bottom of the mesentery and termination of the ileum, it sends numerous branches from its left side, the first and last being shorter, the middle ones longer. These, subdividing into smaller, join with those adjacent into convex arches; which again send out other branches, united in like manner, forming almost five series of arches, until the last send, from their convexities, straight and very numerous branches to the intestine.

DCCXXIX. The division of these branches on the intestine, is very uniform; so that from the mesentery, through the first cellular coat, there is sent one anterior, and another posterior, which, having given small branches to the outermost and fleshy coats, penetrate to the second cellular one: there the anterior trunk, running out towards the obtuse vertex of the intestinal ellipsis, is continued straight into the corresponding posterior branch; and, according to its size, gradually sends off smaller arbuscular branches, inosculating with the contiguous and opposite branches, by innumerable twigs. From  
this

this reticulation, branches penetrate through the nervous tunic into the third cellular stratum, and lastly into the cavities of the villi, which finally, with open orifices, exhale their contents into the intestine. This course is easily imitated, by injections of water, size, or mercury. From recent observations, it has been added, that the arterial extremities open into an hollow vesicle, and there deposit their liquor, which exudes through the common orifice of the vesicle. Besides, the reticular disposition of the arteries, and their numerous anastomoses, have the effect, that the intestines are as little subject to obstructions as possible, and that any obstructing matter may easily return, by means of so many inosculation, into the larger arterial trunks.

DCCXXX. The last trunk of the mesenteric artery inosculationates with the ileo-colic. The duodenum has various arteries. The first, the uppermost from the hepatic, on the right, goes round the convexity of the curvature of this intestine, in the pancreas, and supplies this intestine, and inosculationates with another on the left, and inferior, the pancreatico duodenalis which makes a similar arch in the pancreas, in the hollow of the curvature of the duodenum, and is at last inserted into the lower duodenal arteries, produced by the mesenteric in its passage before this intestine. I willingly pass over the small arteries, which go from the spermatics to the duodenum, and from those of the renal capsule.

DCCXXXI. The veins, exactly corresponding with the arteries, meet all together, into the mesenteric trunk of the vena portarum; except the right duodenal vein, which goes immediately into the trunk of the vena portarum itself; and those small veins which accompany the small arteries, (DCCXXX.) and are inserted into the spermatics and lumbals. Nor have I hitherto been able to discover any other veins of the mesentery, arising from the cava. It is a property

perty common to all these veins to be without valves, and to communicate freely with the arteries. In the villous coat, which is for the most part composed of veins, as the venous trunks are fewer and larger, they absorb from the intestines a thin humour; as appears from the injection of watery liquors, which readily take that course; and, from analogy, in aged persons, in whom the mesenteric glands, and consequently the passage of the lacteals, are frequently obliterated, and from the analogy of birds, which have no lacteals, and from the celerity with which watery liquors pass to the blood and through the kidneys, compared with the smallness of the thoracic duct, and chiefly from those experiments which have confirmed by ocular demonstration the passage of water from the cavity of the intestine into the vena portarum.

DCCXXXII. The nerves, numerous and small, impart to the intestines a considerable degree of sensibility; they arise from the middle plexus of the splenic nerves, which embraces the mesenteric artery, and play round it in great numbers, wrapped up in a very dense cellular substance. The duodenum has likewise nerves from the posterior hepatic plexus of the eighth pair. From the acute sensibility of the intestines, it is probable, that the ultimate branches of the nerves penetrate into the third cellular coat.

DCCXXXIII. From the exhaling arteries, a thin aqueous liquor distils into the cavity of the intestines, resembling the gastric juice, not acrid, but saltish. The very great quantity of this liquor is computed from the great size of the excretory orifices, and of the secreting arteries, which are not larger in any part of the body; and from the laxity of parts perpetually kept warm and moist, and from the copious diarrhoeas or watery discharges that often follow the use of purgative medicines.

But

But the mucus arising from the sources, DCCXXVI, DCCXXVII. lubricates the internal surface of the villous membrane, and defends the sensible nerves from acrid or spirituous alimentary matters. Hence, it is more abundant at the beginning of the large intestines, because there the mass of aliment begins to be feculent, acrid, and tenacious.

DCCXXXIV. This liquor is mixed with the pulpy mass of the aliment, with the bile, and with the pancreatic juice, by the external motion of the muscles surrounding the abdomen; but this force is quite small, and unfit for moving forwards the aliments. And in the first place, the peristaltic motion is not any where stronger, or more evident, than in the small intestines. For any part of the intestine, irritated by flatus, or any sharp or rough body, contracts itself, even after death, very violently in that part where the stimulus is applied, frees itself from the offending or distending body, and expels it into the contiguous part of the lax intestine; which also contracting from the same stimulus, repels what it received, either way. This motion occurs in various parts of the intestines, without any certain order, wherever flatus or alimentary matter act as stimuli. So great, however, is the aptitude of the intestines, for motion, that they emulate, and even exceed, the irritability of the heart, or at least are scarcely exceeded by it. When not irritated, they remain at rest, as I have often observed; and we may suppose this to be the cause why fat retards the belly. The air is the principal stimulus of the intestines, next the aliment, and lastly the bile. This motion is performed by a wonderful sort of alternate creeping and revolution of the intestines, which dissection easily demonstrates in living animals, and unfortunate cases of wounds in the abdomen, and ruptures, have shown in the human species. And since, here, among so many inflexions, gravity can have no effect, the intestine

testine when irritated, evacuates itself equally upwards and downwards. From this, the antiperistaltic motion is understood, by which the pulp of the alimentary mass is longer exposed to the gentle trituration of the intestine, and to the action of the diluent liquor, and of the absorbing veins. All the contents of the intestines are at last determined to the large intestines, because every stimulus begins in the left orifice of the stomach; and the constant succession of food excites a new contraction in the parts above, by irritating them, while no contraction of the colon propagates a stimulus backwards to the lower part of the ileum; hence the loose colon receives what descends into it, and unloads itself into the large unactive cæcum more easily, than it can repel upwards the aliments it has received, and which are resisted by the pressure of the intestine propelling fresh matter. Anatomists observe, that this motion acts more strongly downwards than upwards, and that the superior parts of the intestines are more irritable. But as often as any insuperable obstacle resists the passage of the aliment, the seat of the principal contraction will be there, and the aliment will be repelled upwards, even from the valve of the colon, through the whole length of the intestines, into the stomach, and lastly into the mouth itself.

DCCXXXV. This peristaltic motion, in which the intestine is constricted, is performed by the circular fibres, which are capable of most exactly emptying the tube, so as to propel downwards the most minute bodies, such as needles or powders. But the revolutions of the intestines, drawn upwards or downwards, and the bending of the straight, and the straightening of the crooked portions, which are so conspicuous in animals, are performed by the long fibres, and which, moreover, when they contract themselves towards the seat of the present, stimulating

ting food, we see dilate the succeeding portion of intestine, and fit it for receiving. The same contraction, forces the villous membrane into the cavity of the intestines, and renders the folds longer; and expresses the mucus, so that such a quantity is applied to the alimentary mass, as is required by the irritation and degree of the stimulus. They also produce frequent, and generally harmless, introfusions, by drawing up the succeeding portion of intestine, against that which is contracted, in such a manner, that the former is received within the latter, which is relaxed.

DCCXXXVI. The alimentary pulp, therefore, diluted with the pancreatic juice and that of the intestines, intimately mixed with the saponaceous bile, and covered with mucus, is accurately triturated, and more efficaciously than in the stomach, in proportion as the sides of the small intestines approach nearer together, and to the length of the series of the peristaltic motion acting, and to the quantity of animal juices affused. The viscid pulp, intermixed with air, becomes frothy, without fermentation, and the air continues to have the same effects as in the stomach, but so that every acid tendency within the intestines is counteracted. But the oily or fat parts of the food, dissolved by the bile, (DCCXV.) and mixed with the watery juices, acquire usually a bright white colour, like an emulsion, first visible in the duodenum, below the entrance of the biliary duct; and afterwards adhering closely to the villous coat, throughout the whole length of the small intestines. But the gelatinous juices of flesh meats, diluted by copious affusion of water, and being of themselves of a subviscid nature, adhere to the villous coat, and are prepared for absorption. The water and watery liquors are all very greedily absorbed by the veins: and yet the fæces never grow thick in the small intestines, as far as I have observed, because the water absorbed is repaired

repaired by the arterial vapour and the mucus ; nor do they become fetid in any considerable degree, both on account of the great quantity of diluting juices, and because their quick progression does not allow them time for putrefaction. In the beginning of the jejunum, the white mass is coloured with bile ; in the end of the ileum, it is entirely mucous. Those remains, which are more earthy, gross, coarse, and acrid, and were excluded by the absorbing orifices, either by their own weight, or by some power acting as a sphincter, descend into the large intestines, being gradually, forced down, so as to complete their whole course in the space of about twenty-four hours. But within three or four hours, or a little more, almost all the chyle is extracted.

DCCXXXVII. The considerable length of the small intestine, which is five times longer than the body, or more, the great surface of the villous membrane increased by folds, the incredible number of exhaling and absorbing vessels, the slow progress of the food through the large intestines, and the great quantity of the intestinal juice, poured to the alimentary mass, have the effect of providing abundantly, in the small intestines, every requisite for diluting the food with our juices ; for their absorption into the lacteals and the mesenteric veins ; for the absterfion of viscidities from the intestine ; for preventing adhesions and coagulations ; for the suppression of any acidity, not yet subdued ; and for the destruction of the deleterious qualities in many juices, which, being directly mixed with the blood, instantly kill, but are without injury received by the mouth. Hence the intestines are long in animals that feed upon any hard food, but shorter in carnivorous ones, and shortest in those that live upon juices alone ; and, in man, an uncommon shortness of the intestines has been attended with hunger, and fetid and fluid fæces.

DCCXXXVIII.

DCCXXXVIII. The heat, by which the aliment is fomented, and which is well fitted for the solution of the gelatinous matter, and for exciting the beginning of putrefaction, is therefore the principal cause of the feter, which is gradually produced in the aliment; and also of that thinness by which the useful part of the aliment is fitted for absorption. But the air also, inclosed in the viscid aliment, operates, as in the stomach, by breaking the cohesion of the aliments, if any yet remain entire. The intestinal water dilutes the masses of aliment; and if any hard part remains, softens it by maceration. The bile being intimately mixed with oil, dissolves it, and renders it miscible with water.

## CHAP. XXV.

## LARGE INTESTINES.

DCCXXXIX. **W**HAT remains, after the chyle has been abstracted, consists of some portion of the bile, but mucous and degenerate; some part of the human mucilage; most of the earthy parts that were in the food; all those parts, which by their acrimony were rejected by the absorbing mouths, changed, however, by putrefaction, (DCCXXXVI.) with all the solid fibres and membranes, which resisted the powers of maceration and the peristaltic motion.

DCCXL. All these remains pass from the extremity of the ileum into the cæcum, in which they stagnate; namely, the extremity of the small intestine applies itself obliquely to the right side of the colon, resting upon the right ileum and iliac muscle, so that, upon the whole, it ascends, but more with its lower side, and less with its upper, which is almost transverse. But the extremity of  
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the nervous and villous coats, and transverse fleshy fibres of the ileum, are so extended betwixt the departing fleshy fibres and nervous coat of the colon, that there hangs within the cavity of this large intestine, a moveable, soft, double projecting fold, composed of the villous and nervous coats of the large intestine, and of the villous and nervous coats of the small intestine, and of the interposed fleshy fibres of the ileum and colon, connected by much cellular substance. The upper fold is transverse and shorter, the lower is larger, longer, and ascending. They are conjoined by a small production of the same kind, more especially where they approach in the right side. Betwixt these two folds, the mouth of the ileum opens, like a transverse slit. By inflation, this structure is much altered, assuming the appearance of membranes and hard valves. After the cellular substance is entirely removed, and the interposed fleshy fibres are cut, the ileum, comes out from the colon, and the valvular appearance disappears; but if a large part of it only be removed, so that it still remains inserted by some, it resembles a sphincter.

DECELI. Below the entrance of the ileum, at the distance of some inches, the great intestine descends and rests with an impervious extremity, upon the ileum. From the lower part of this, towards the right side, a very acutely conical small intestine extends, in adults slender, in the foetus proportionally larger, variously incurvated upwards, sometimes downwards, and full of small mucous glands, which pour out a glutinous matter to the faeces; in the foetus, the colon itself is continued with a conical termination into the appendix. But the weight of the superincumbent scybalæ, depressing the space on the right side of the appendix; the strength of the cellular texture uniting the left part of the cæcum with the ileum; the strength of the fleshy fibres uniting both intestines; the very contractile

contractile force of the ligaments ; the fitness of the anterior sac of the cæcum, for easily receiving the fæces from the ileum ; all contribute to remove the appendix from the middle, so that it arises from the left side of the extremity of the colon : and to form the thick and pendulous bag of the colon lying farthest to the right side, and which is peculiar to adults. When, therefore, the remains of the alimentary mass come from the ileum into the colon, they fall by their weight into this impervious bag, and stagnate there, and become putrid, both from the warmth of the place and their own nature ; and here, especially, the fætor of the excrements begins.

DCCXLII. The intestine which is continuous with the cæcum, and indeed the same, is named the colon. This thick and very large intestine, which is much stronger than the small intestines, begins in the right ileum, (DCCXL.) ascends along the kidney, lies in the angle of the right hypochondrium under the liver, and is connected to both viscera by the peritonæum. Then it passes under the liver and stomach, for the most part transversely, to the spleen, under which it lies, (DCLXXVI.) and in a deep recess under the left ribs, it is often reflected upon itself. Then it descends again, and having made a large flexure to the left ileum, (DCLVIII.) it is continued with the lower part of this flexure into the pelvis, and becomes the rectum.

DCCXLIII. The structure is, on the whole, the same with that of the small intestines, but it differs in several particulars. And first, all the longitudinal fibres are collected into three bundles, which run through the whole extent of the intestine ; and of these one, and that the largest, lies naked ; another, at its origin, is concealed by the omentum, and the third by the mesocolon. These are shorter than the intestine, and contract it so that the nervous and villous membranes (DCXLIV.) project inwardly.

wardly. These fibres are connected most accurately with the external coat of the intestine; but in the intermediate places, and chiefly at the mesocolon, is seated the first cellular coat replenished with fat. Being dilated at their origin, they adhere to the vermiform appendix. In the extremity of the colon, there are often only two ligaments, the two smaller joining into one. They diffuse themselves upon the rectum so as to cover it entirely.

DCCXLIV. Again, the fleshy and nervous coat, third cellular and villous tunics of the colon, are extended into much larger wrinkles in the parts betwixt the ligaments, often projecting in a three-fold rank, which being sustained by the ligaments, are able to support a little the scybalæ, and resist their relapse. In the beginning of the colon, they are very exactly threefold; but in its progress, they vary more and more, being less, and double, and solitary, and small and large intermixed, and entirely absent. Where the ligaments which contract the colon, disappear, these valves disappear almost entirely. Lastly, the villous coat is thinner, and without villi, but wrinkled and porous, furnished both with large pores leading to proper, large, round, solitary follicles, and with innumerable small pores leading to smaller follicles. Both kinds supply a great quantity of mucus.

DCCXLV. The blood-vessels of the large intestines are partly from the greater and left mesenterics, and partly from the hypogastrics. The middle colic artery arises from the large mesenteric trunk, as that descends behind the transverse mesocolon. It rises upwards with one, two, and sometimes three branches to the transverse mesocolon, and unites on the right side with the ileo-colic; and on the left, with the lower mesenteric, in a very large arch, which is the largest of all the arterial anastomoses in the human body. Again, under the mesocolon, from the same large mesenteric artery, a  
larger

larger branch goes directly to the valve of the ileum with the colon, and inosculates upwards at the right of the colon with the middle colic; and to the left with the mesenteric; but from the middle of the mesentery it gives a branch that runs along the mesocolon of the appendix vermiformis, and terminates with two branches in the two folds of the ileum and colon, both the anterior and posterior. Lastly, the lower mesenteric, arises by its proper trunk from the aorta, betwixt its bifurcation and the renal arteries, and goes to the left part of the colon: upwards it forms a large arch, with the middle colic; downwards in three or four trunks, it spreads over the iliac flexure of the colon, and descends even into the rectum. There the rectum receives various branches from the middle hemorrhoidal, arising from the last trunk of the hypogastrics, and conjoined with the former. The ultimate arteries are from the same trunk, but arise without the pelvis. I pass over the smaller colics, arising from the spermatics, intercostal, omental, capsular, and lumbar arteries. The veins, like the arteries, run together into the gastrocolic, and the internal hemorrhoidal, and thence into the vena portarum; and into the middle and external hemorrhoidals, and the trunks of the iliacs.

DECCXLVI. The division of the vessels to the large intestines, differs much from that of the small intestines. Their arches are less frequent and less often subdivided; the trunks follow the course of the intestines a long way; the glands seated on them are fewer; the branches on the intestines less arbuscular, divided at less angles, and more tortuous; and the reticulation in the cellular substance is looser. An exhaling moisture distils into the cavity of the intestines, and the veins likewise absorb a thin fetid vapour from the fæces. The external, and perhaps also the internal veins, swelling into varices, pour out the hemorrhoidal blood; which

is always unnatural, although sometimes infractions of the vessels of the porta are relieved by that evacuation.

DCCXLVII. But there are also lymphatic vessels, arising from the whole tract of the colon, and from the rectum, which unite with those of the loins. We are not without examples of chyle having been found instead of lymph, in these lymphatics, arising from the colon; a proof, that even in this place something still remains, which may be added to the blood with advantage.

DCCXLVIII. The nerves proceed from the left colic plexus composed by the descending branches of each renal plexus, and others arising from the intercostal trunk in the thorax and loins, and others from the large mesenteric plexus. These accompany the lower mesenteric artery, and go to the colon. The lowermost nerves arise from the plexus just mentioned, and go to the rectum, within the pelvis; others go to the same intestine from the lower intercostals, and from the nerves of the sacrum. These nerves are not numerous, and the intestine is not very sensible, that it may endure the hard and acrid fæces.

DCCXLIX. The intestinal fæces, therefore, retained in the blind beginning of the large intestines, (DCCXL.) become dry by the absorption of their fluid parts, shaped by the round and contracted colon, ascend from the bottom of the cæcum, being elevated by the long ligaments, which unite in the worm like appendix. And here the manner in which the fæces are propelled by the contraction of the circular fibres, appears better than in the small intestines. The longitudinal fibres being drawn towards the contracted portion of the intestine, as to a fixed point, draw the lower part of the intestine upwards, and dilate it; then the next part of the intestine, to which the fæces are brought, being irritated in like manner, contracts the long fibres towards

towards it ; by a successive repetition of which action, the fæces finish their course through the whole large intestine ; for the most part within twenty-four hours in a healthy person. For this peristaltic motion of the large intestines may be seen in living animals, and in the human body from wounds ; it is also confirmed by the antiperistaltic motion, and by the phenomenon of glysters being discharged through the mouth. The same fibres resist the air contained in the intestines ; and flatulence is said to be generated as often as they are overcome and yield, and the intestine is dilated.

DCCCL. While the gross fæces ascend from the cæcum along the folds (DCCXL.) or valves, at the entrance of the ileum, they incline the lower fold to the left, and backwards, and draw down the ligament common to both valves, and thus depress the upper fold downwards : thus the passage is accurately shut, so that nothing may return into the ileum ; which, however, cannot be done so accurately in a fluid state of the fæces. The fæces, when falling down from the upper parts, depress the upper valve, and thus accurately exclude themselves. This happens very exactly with hardened fæces, but not so accurately with fluid fæces. From thence, becoming more and more dry and figured, they continue to move slowly forwards by the same causes (DCCXLIX.) through the whole colon, which is repeatedly bent, and of five or seven feet in length, in such a space of time as is sufficient to give no interruption to the affairs of human life ; and which is less than twenty-four hours, by the time the alimentary mass remained in the small intestines.

DCCCLI. At length the hardened excrement falls into the rectum, which is at first inclined downwards, and then also forwards, of a broad and flat figure, at first contiguous to, and afterwards spread under the bladder, or vagina, but connected more with the latter than with the former. Here the fæces

are collected for a great while, and often to a great quantity, being a part which is loose, or surrounded with soft viscera and muscles, and much fat.

DCCLII. The structure of the rectum differs very much from that of the other intestines. The external membrane or peritonæum covers it only before, while behind it is connected to the region of the os sacrum, by a very broad stratum of cellular substance, replenished with fat, and many conglobate glands. The muscular fibres are much stronger than in the other intestines, especially the longitudinal ones, which being composed of the three ligaments, expanded and separated, first occupy the anterior face, and then the whole intestine: they dilate it against the advancing fæces, and draw it back after they are excluded. But the transverse fibres are also strong, and their last oval, tumid ring, is the internal sphincter by which the opening of the anus is accurately closed.

DCCLIII. Moreover, the villous tunic, which is extremely full of pores, and rough with polygonous and tender wrinkles, has likewise some sinuses peculiar to itself. Namely, the part of the intestine next to the skin and inferior orifice, forms a white firm valvular circle, into which descend longitudinal folds, but incurvated and approaching to each other on the circle itself. Betwixt those folds, therefore, sinuses are interposed, hollow upwards, and of a greater depth towards the bottom. Into their cavities open mouths from large mucous glands; while the margin of the anus itself is defended by sebaceous glands, that it may not be excoriated by the hard and acrid fæces.

DCCLIV. There are also proper muscles which govern the anus. The external sphincter is broad and fleshy, and consists of two plates of semi-elliptic fibres, which cross each other towards the coccyx, and towards the genital parts. And, in the former place, they are inserted by fleshy bundles into a  
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callous cellular fabric descending from the coccyx. In the latter, in like manner, they are attached by similar bundles to the skin of the perinæum; but by three stronger than the others, one middle, and two lateral into the accelerator and bulb of the urethra, the lateral ones partaking both of the nature of a sphincter and levator. The fibres, therefore, of the sphincter, approaching to a straight line between their anterior and posterior fixed extremities, close the opening of the anus, which lies between them. With the internal sphincter, the external one is conjoined by a fleshy portion, that they may operate together. Their action is voluntary and not perpetual; for the anus seems to be closed naturally, by the narrowness of its orifice, compared with the largeness of the intestine, by the wrinkles corresponding to the other (DCCLIII.) by the strength of the transverse fibres of the internal sphincter, and by the incumbent bladder.

DCCLV. But the office of the levators is different. They are large and complicated muscles. They descend betwixt the opposite ossa ischia, are placed under the rectum and bladder, and sustain both, and prevent the rectum from descending and gaping disgustingly. Moreover, by their fibres spreading extensively in the manner of a sphincter, and being joined to that muscle, they can dilate its fibres, and open the anus; but, at the same time, they elevate and sustain the intestine from prolapsing while the fæces are passing. They arise, as is well known, from the spine of the ischium, os ileum, and synchondrosis of the ossa pubis, terminating the margin of the great foramen of the pubes, and from that part of the ischium, which is above the tubercle. Finally, they meet together under the coccyx, into which they are inserted by numerous fibres.

DCCLVI. Therefore, whenever the fæces are collected within the rectum in any great quantity,  
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and become troublesome by the irritation of their weight, or acrimony, even to the adjacent viscera; they are forced by the power of the will through the straits of the collapsed intestine (DCCLIV.) by the force of the incumbent diaphragm, exerting an effort; which being drawn downwards with great force, presses downwards the viscera of the abdomen, which are also resisted by the contraction of the abdominal muscles, and forces the contents of the bladder or rectum through the inferior opening between the bones of the pelvis, where the resistance is least. When the resistance of the anus is thus overcome, the force of the diaphragm abates, and the fæces are discharged from the body, by the peristaltic motion of the intestine itself. After the fæces are expelled, the intestine is drawn back by its longitudinal fibres; and the anus being contracted by both its sphincters, shuts its orifice as before.

DCCLVII. These fæces in man, and carnivorous animals, are very fetid, almost putrid, subalkaline, soft, and contain much oil mixed with saline matter, which are the remains both of the aliments and of the bile and other humours of the human body. An acrid and fetid water returns from the fæces into the blood; hence, costiveness in fevers is hurtful, as by its addition it promotes putrescency.

## C H A P. XXV.\*

### CHYLIFEROUS VESSELS.

DCCLVIII. **T**HE chyle is a white juice (DCCXXXVI.) extracted from the aliments, which is poured into the blood. It seems to be composed of water and oil, as appears from its taste, being sweet with some mixture of saltness, from its acerb  
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cent nature, from the whiteness of its colour, from its spontaneous separation and coagulability, and from its lightness, by which it swims on the blood: in all which properties it very much resembles an emulsion. It is composed of vegetable farina, with lymph and animal oil. It every where retains the properties of the volatile and oily aliments. It changes into milk with very little alteration. But then, the glutinous pellucid serum which it contains, becomes more manifest, being coagulable into a kind of a jelly, by exposure to a high temperature, or by evaporating its water:

DCCLIX. That the chyle is absorbed into the lacteal vessels from the villous coat of the intestines, to which it adheres, has been long known, by experiments with coloured liquids, which described the same course; from the similitude of the white liquor, as seen in the lacteals, and out of them and from the venous nature of lacteal vessels. But late experiments have given us better information on many particulars. The chyle is absorbed by the patent orifice in the extremity of each of the villi, by a force similar to that of capillary tubes; is received into the hollow villi, which are relaxed when the intestine itself is relaxed; but the vesicle, being compressed by the succeeding constriction of the muscular fibres of the intestine, the chyle is pressed on into the duct, which begins to appear in the second cellular stratum. But there is a double series of these trunks, one anterior, the other posterior, as we observed of the blood-vessels, (DCCXXIX.) From thence the lacteal vessel, already united into a larger canal, passes into the first cellular stratum, and, in general, follows the course of the arteries, and likewise accompanies their arches, being conjoined with others of the same kind into a very obliquely angled network. This kind of vessels hitherto has been observed only in quadrupeds. In the large intestine they arise without the vesicle.

vesicle. Very many arise from the first part of the small intestines under the mesocolon ; some from the duodenum, and a few from the large intestines themselves.

DCCLX. The lacteal vessels are valvular in the very first cellular texture of the intestine, being provided, like the lymphatics, with very frequent, double, lunated valves, (LVII.) which admit the chyle passing from the intestines but prevent its return. Through this whole course, the chyle is propelled by the peristaltic motion of the intestines ; by the peristaltic action of the vessels themselves, which are certainly irritable, even after death propelling the chyle ; and by the considerable pressure of the abdominal muscles, directed by the valves.

DCCLXI. But betwixt the plates of the mesentery, at the divisions of the vessels, are found an infinite number of glands, of the conglobate kind, but softer and spongy, consisting of cellular texture full of juices, covered with an external membrane, less hard than in other parts, and variegated with numberless small blood-vessels. Some lacteal vessels seem to pass by these glands : the greatest number enter them ; and, being divided and subdivided through their cellular fabric, compose the greatest part of the gland. On the other hand, other lacteal vessels originate in every gland ; and, being mutually joined, compose trunks, of which the ultimate and largest go out from the gland. In the same manner the chyle enters two, three, or four glands, in succession ; nor does any lacteal vessel arrive at the thoracic duct without entering some of these glands, although it may occasionally pass by some without entering them. That this is the true course of the chyle, and that it passes from the intestines to the mesenteric glands, appears from tying them, by the vessels growing turgid betwixt the ligature and the intestine ; from schirrosities in the glands, by which they are rendered conspicuous ; and from the nature  
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ture of the valves preventing any return to the intestines.

DCCLXII. What happens to the chyle in these cellular spaces is not sufficiently known; but it appears that some thin liquor is secreted from the arteries in these glands, by the affusion of which the chyle is diluted. For it is observed, that after the chyle has passed all the glands, it appears more watery; and thin liquors, injected through the arteries, exude into the cells of the glands, and mix with the chyle, since the lacteal vessels may be filled through the arteries. Lastly, this milky fluid appears manifestly in the glands of infants.

DCCLXIII. From the last glands, which are collected together in the centre of the mesentery, a few very large lacteal vessels go out, to the number of four, five, or more, which ascend with the mesenteric artery, and intermix with the lymphatic plexus, which arising from the lower parts of the body, creeps over the renal vein, and afterwards with that which comes behind the aorta from the lumbar glands, and with the hepatic. A duct is thus produced, subject to great varieties, but which most frequently expands into a vesicle of considerable breadth at the side of the aorta, lying between that and the right appendix of the diaphragm, two or more inches long; and most commonly continued above the diaphragm into the thorax, conical both ways: it is called the receptacle of the chyle. In this the gelatinous lymph of the limbs, and of the abdomen, mixes with the chyle, and dilutes its white colour; so that sometimes it appears filled with a pellucid or reddish humour, but frequently also with a white milk. But there are some instances where there are two or three small and narrow ducts, instead of this receptacle. This, however, is most frequent, and being compressed by the diaphragm and aorta, propels the chyle with greater velocity, in proportion

as its caliber is larger than that of the duct into which it empties itself. This receptacle is rarely so short, that it may be compared with an egg; but for the most part it is broadest in the middle, and decreases conically towards each end.

DCCLXIV. That the chyle comes from the intestines into this duct, is shewn from injections, by which quicksilver has sometimes been pushed from the first lacteal vessels into the thoracic duct; from ligatures made on the duct itself, or the red veins which receive it, by which the first and second lacteal vessels swell; and from the manifest flux of the chyle into the thoracic duct when the ligatures are removed.

DCCLXV. The thoracic duct, as it is called from its course, is generally single; or, if double for some part of its course, it soon unites into one, which ascends in a waving course behind the pleura, betwixt the vena azygos and the aorta; and receives in its way the lymphatic vessels of the stomach, œsophagus, and lungs, passing through the conglomerate glands, of which there are many incumbent on it, and collected into large bunches. It is, on the whole, cylindrical; and often forms islands, by splitting and uniting again, more especially in its upper part. It has few valves, and those less conspicuous. About the fifth vertebra of the back, it generally goes to the left, behind the œsophagus, and then ascends along the left side of the thorax, behind the subclavian vessels, till it arrives near the sixth vertebra of the neck.

DCCLXVI. Then, being reflected and often divided, it descends with each branch dilated into a sort of vesicle, and enters, either with distinct or united openings, into the junction of the subclavian and internal jugular vein, by an oblique course from the upper, posterior, and right side, downwards, to the left, and forwards; or going on with one or other branch, it enters the subclavian, on the outside of  
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that junction. It is guarded by a true, moveable, and almost circular valve; also by its descent the blood is prevented from entering it. It is rarely otherwise disposed; and very rarely split into two, with one branch entering each subclavian; and yet more rarely does it send a branch into the vena azygos. Near its insertion it receives a large lymphatic vessel, coming transversely from the arm; and another descending from the head, in one or more trunks.

DCCLXVII. It appears that the chyle flows through the thoracic duct into the blood; because, on tying the red veins, both the thoracic duct and lacteal vessels which are inserted into it swell.

DCCLXVIII. I have attributed the first cause of motion in the chyle, and of its absorption, to the attraction of the capillary vessels, alternated with the peristaltic contraction of the intestines. The attraction fills the villi; the peristaltic force empties them, and moves the chyle farther forwards. The rest of its motion seems to depend on the force of the membrane of the lacteal vessel itself, which, even after death, expels the chyle, so that the vessels become pellucid, which before were milky. The alternate compressing force of the diaphragm also has some effect; and the motion of the chyle through the thorax is somewhat accelerated by the receptacle, which, being compressed, propels the chyle so much the more quickly, as it is larger than the thoracic duct.

DCCLXIX. The chyle, mixed with the blood, does not immediately change its nature; as is proved from the milk produced from it. But five hours or more after a meal, almost to twelve, during all which time a woman can afford milk; having circulated near 80,000 times through the body, fomented with the heat of the body, and mixed with the animal juices, it is changed, so that its fat seems to be partly deposited in the cellular substance,  
partly

partly figured into the red globules, (CXLVII.) the gelatinous part changes into the serum of the blood ; and the watery parts go off, partly by urine and perspiration, and in part dilute the blood. Nor is it uncommon for a pellucid liquor to be in place of the chyle in the lacteals in a dying animal, or for a white liquor to be in one part of the mesentery, and limpid liquor in another, in vessels which perfectly agree in their fabric. There are not, therefore, two kinds of vessels from the intestines ; of which the one carries chyle only, and the other lymph.

DCCLXX. When digestion is not going on, the lacteal vessels absorb water from the intestines, and are transparent, and the thoracic duct conveys the lymph of the abdomen, and of most parts of the body, to the blood (LIII.)

## C H A P. XXVI.

### KIDNEYS, BLADDER, AND URINE.

DCCLXXI. **T**HE chyle, when taken into the blood, contains a great deal of water ; the proportion of which in the blood would be too great, and its separation into the cellular substance too easy, if it were not excreted. A part of it exhales through the skin, (CCCCXXXVI.) and another part, as large, or often larger, is strained through the kidneys, and ejected from the body.

DCCLXXII. The kidneys are two viscera, placed behind the peritonæum, one on each side of the spine, incumbent upon the diaphragm, and upon the psoas and quadratus muscles of the loins, but so that the right kidney is commonly placed lower and more backwards. Before the right kidney are placed the liver upon its upper part, (DCXC.) and then the colon and intestines ; before the left kidney are the spleen, stomach, pancreas, and also the colon. They are

are tied by reduplications of the peritonæum to the colon, duodenum, liver, and spleen. Their figure externally is convex, and semi-elliptical; laterally they are flat, and inwardly concave; they are unequally divided into an upper, longer and thicker extremity, and into a lower, flat, slender extremity. They are firmly invested by a strong external dense membrane, which does not come from the peritonæum. Betwixt that membrane and the peritonæum of the loins, there is always interposed a great quantity of fat, by which the whole surface of the kidney is surrounded on all sides, and the nidus is completed, which, though prepared for it, the kidneys would not totally fill. From the kidney the peritonæum ascends to the liver, spleen, colon, and diaphragm, and forms as it were ligaments for the kidney.

DCCLXXIII. The vessels of the kidneys are very large, both the arteries, which together exceed the mesenterica, and the veins. The arteries arise from the aorta under that of the mesentery, not always in the same manner, yet so that the left is commonly shorter than the right, and each of them frequently in two, three, or four trunks. From these arise the lower capsular arteries, and the adipose ones belonging to the fat cortex of the kidney (DCCLXXII.) and not unfrequently the spermatics. The fat, rather than the kidneys, receives smaller branches from the spermatic and lumbar arteries. The arteries are thick, so that the proportion of their coats to their caliber is great; that they are among the strongest of the body; and that they exceed the strength of the aorta by one third.

DCCLXXIV. The veins are large, especially the left, and less inconstant than the arteries: the right, which is often without a branch, is short and concealed; the left always receives one of the spermatics, and the capsular, and the last branch on that side of the vena sine pari. It is a very large vein,  
and

and accompanies the duodenum, being extended transversely a considerable way to the left, before the aorta. Both the arteries and veins of the kidneys arise from the great trunks in an angle, acute downwards, and both divide themselves into several branches before they enter the kidney. That the passage of the blood from the renal arteries into the veins is very quick, appears from the facility with which water, wax, or air pass that way. The uppermost veins of the fat of the kidneys come from the capsular vessels, the middle from the renal ones, and the lowermost from the spermatics.

DCCLXXV. There are lymphatic veins, of considerable size, found near the renal veins, where they form the beginning of the receptacle of the chyle (DCCLXIII.) and which are said to receive the branches that are divided under the external coat of the kidney, and are rendered manifest by putrefaction, or by the injection of a fluid into the renal arteries, or even into the ureter.

DCCLXXVI. The nerves of the kidneys are small, but numerous; arising from a considerable plexus, mixed on each side with ganglions, which is generated by branches of the great semilunar ganglion, joined with others coming from the intercostal trunk, from within the thorax itself. They enter the kidney, along with the artery, and send off the middle mesenteric, (DCCXLVIII.) and the spermatic nerves. As these nerves are small, they give but a small degree of sensibility to the kidney.

DCCLXXVII. Upon the top of each kidney is seated the renal capsule; which in the foetus is large, even larger than the kidney itself, but does not afterwards increase in the adult: it is glandular, of the conglomerate kind, divided into lobes, of an oval shape in the foetus, and triangular in the adult; that on the right side is connected to the liver; the left to the spleen and pancreas; and both to the diaphragm and kidney, by as many fides. From careful

ful observation, it seems to be hollow within, separable like a ventricle, with the internal surfaces smooth, as if cut, full of a liquor of a yellowish red colour, and fluid, almost like blood. The arteries of these capsules are many, and of three kinds; the uppermost from the phrenics, the middle ones from the aorta, and the lower ones from the renals; the veins are one on each side, the right one going to the cava, and the left to the renal vein. The said vein creeps almost naked through the very smooth ventricle, in the sulcus dividing the capsule, and sends branches through its internal surfaces. Its uses are as yet unknown; although we are led to believe, that it is subservient to the kidney, especially in the foetus, from their constant vicinity in so many animals. It has no excretory duct, nor does it discharge any juice, by visible pores, into the vein.

DCCLXXVIII. The internal fabric of the kidney is simple, and known. The vessels enter the interval between the upper and lower portions of the kidney, and penetrate into its substance, surrounded with a cellular sheath, and divide into branches, which run between the branches of what is called the pelvis, along the columns interposed betwixt the papillæ. From thence, having formed arches both in the papillæ and between them, they surround the origin of the papillæ, nearer to the periphery, sometimes joined, but by small branches: from whence proceed innumerable little twigs, of which some return by the intervals between the papillæ into the columns, and into the papillæ; and others tend towards the external surface of the kidney, and sometimes pass through the coat of the kidney, enter into its adipose covering, and are there changed into minute serpentine twigs, which being reflected towards the same portion of the kidney from whence their trunk arose, they are gradually extended, and intermixed with the uriniferous

ous tubes. But from the cortex, bundles of uriniferous tubuli arise in several rays, collected in great numbers into threads, of which each contains many tubuli. That they are continuous with the arteries, or at least that they receive their branches into them, we know, from experiments which shew that water, or even air, passes easily from the arteries of the kidneys into the ureter; and, lastly, from diseases, in which the blood itself takes the same course. Between these papillæ, and about their origin, are situated some roundish knots, which the latest anatomists consider as arterial glands, producing the proper and more narrow urinary ducts. Between these ducts many arteries run parallel. It is probable, that the cortex consists of curved vessels, which eminent anatomists have supposed to be smaller than the red ones.

DCCLXXIX. Those uriniferous vessels gradually converge, being joined together like rays, and inserted in great numbers into one blind duct, which ducts complete the rest of the papilla, and terminate singly in its convex extremity by conspicuous pores. The number of these papillæ is not altogether certain; but thirteen or more of them, simple, triple, and even quadruple, have been seen. These were in the fœtus so distinct, that the kidney then appeared to consist of as many distinct smaller kidneys, connected together by loose cellular membrane, each of which was furnished with its proper cortex of serpentine vessels, and its compages of straight uriniferous ducts; the basis of all of them lay in the circumference of the kidney, and their vertices converged towards the centre. The opposite cortices of two of these little kidneys make a column, which separates the two papillæ. In the adult, the cellular substance being condensed, draws the papillæ closer, and unites them into one kidney; however, it again almost recovers the condition which it had in the fœtus, if the cellular plates  
be

are relaxed by injecting water into the vessels. The kidney is also larger in the foetus than in the adult.

DCCLXXX. Around the protuberant surface of each papilla, a loose membranous distinct covering, of larger size, adheres; so that the papilla, or sometimes two contiguous ones, project into the hollow tube of this cylindrical funnel. Two or three of the tubes unite together, and form by that union three hollow trunks, an upper, middle, and lower, which again unite, but on the outside of the kidney, into one conical canal, called the pelvis.

DCCLXXXI. The blood of the renal artery being less moveable, as is generally believed, than that of the brain, and probably containing more water, and being brought by the serpentine arteries of the kidneys, deposits into the rectilinear tubes of the papillæ a great portion of its water, and the oil incorporated with it, and the salts, and any thin fluid it may contain. But the small diameter of each uriniferous duct at its origin, and its firm resistance seem to exclude the gross oil, and the chyle, and the coagulable lymph. Hence, the increased celerity of the blood so easily forces the red globules through these tubes, and, by morbid relaxation, they transmit the true fat and the chyle, and the salts of the meat and drink. But when the strength of the kidney is restored by astringent medicines, the urine returns to its natural state. The nerves likewise have a power of contracting or relaxing these passages; and thus the urine, which was of a yellow colour, suddenly becomes watery from violent affections of the mind. A vast quantity is prepared; equal to that of perspiration, or somewhat greater.

DCCLXXXII. The urine, by heat or putrefaction, sometimes by disease, and in some animals more easily, changes into a volatile alkaline substance, intimately mixed with oil; partly empyreumatic, yellow, and volatile; and partly very fixed, separable only by the last degrees of fire, called phosphorus,

a congealing substance, spontaneously emitting light, and taking fire in the air : and with earth in greater quantity than any other human fluid, both cretaceous and sparry ; the latter coming chiefly from the drink, the former also from the solid parts of the body themselves, dissolved and mixed with the blood. But there is also sea-salt in fresh urine, and even after long putrefaction it is found in the phosphorus, although a great part of it is changed into volatile alkali. Nor is the urine wholly destitute of an acid, similar to the vitriolic, both in man and in animals. There is also a salt obtained from urine, which is fusible by heat, cooling and analogous to nitre. In fevers, the oily and saline parts of the urine are augmented in quantity and acrimony.

DCCLXXXIII. The ureter, continuous with the pelvis, carries on the urine received from the kidney, by the pressure of the incumbent viscera, and of the abdominal and lumbar muscles, and by the blood circulating and giving impulse from behind ; and, lastly, by the weight of the urine. The ureter, covered by the peritonæum, is composed of cellular membrane ; then of a weak and obscure muscular coat, if any : then a second cellular coat ; a firm, white, nervous one ; a third cellular coat, and an innermost very smooth membrane, porous and glandular internally ; and it is in general moderately irritable. It is of different diameters in different places, and every where swells into vesicles. It descends along the psoas muscle, across the great iliac vessels, arrives into the pelvis behind the urinary bladder ; and, at the union of the descending and transverse portions of the bladder, enters obliquely betwixt the muscular fibres and nervous coat ; and descends betwixt the nervous and villous coats, for a considerable way inwardly, so that the mouths of the two ureters are near each other, and open by a truncated orifice. They have no valves, either at  
their

their orifice, or in any part of their course. From their insertion, a protuberant line of the thickened nervous coat descends towards the caput gallinaginis.

DCCLXXXIV. That the urine is separated in the kidneys, is a matter of fact, as it can be emulged from its canals by pressure. That it descends by the ureter, is shewn by the surprising swelling of the kidney, and of that part of the ureter which is above a ligature, and by the emptiness of that part which is below it. That it passes into the bladder, is also proved, by the immense swelling of the ureters and kidneys, as often as the bladder cannot receive the urine, or cannot emit it; in consequence of an obstacle in either place.

DCCLXXXV. Nor does the urine seem to come in any other way. For although it be certain, that the stomach, like all other membranes, exhales; although it be not improbable, from experiments, that the bladder also absorbs; and although the passage of acidulous waters be extremely quick; it does not follow, that there is a way, different from the ureters, to convey the water from the food to the bladder. For the bladder is, on all sides, separated from the cavity of the abdomen by the peritonæum; nor is it ascertained that vapours, either exuding from the bladder, or tending towards it, can here find open pores in the peritonæum; and membranes which are already wetted and saturated with moisture, do not imbibe much. But the urine also which is contained in the bladder, distends it even so as to occasion death; and does not find any passage through which it can escape into the pelvis; and on the other hand, when the ureters are obstructed with stones, so that the bladder receives nothing from them, it is either quite empty, or contains a very acrid and thick urine, manifestly indicating that the water can find no way from the pelvis into the bladder. And a careful attention to the manner in which

which mineral waters are discharged by urine, demonstrates, that there is no such rapidity therein as is commonly imagined ; but that the cold of the water drunk, like external cold applied to the skin, stimulates the bladder, so as to make it discharge immediately the urine it contains already secreted, and not that derived from the drink just taken. Again, the largeness of the renal vessels demonstrates, that not much less than an eighth part of the blood of the whole body is sent to the kidneys ; and, consequently, above 1000 ounces of blood in an hour ; so that it is not surprising that 20, or even 50 ounces of water, are separated from the blood in that space of time. Finally, it is certain, that both man and animals perish if the ureters be tied or obstructed ; nor, in these circumstances, is any urine found in the bladder.

DCCLXXXVI. The urinary bladder is seated in the cavity of the pelvis, which is an appendix to the abdomen, surrounded almost on all sides by bones ; but laterally, and at the bottom, only inclosed by muscles ; and in every dimension, larger in women than in men. It is so situated in it, as to cohere with the ossa pubis by much cellular substance ; then it receives from them the peritonæum, which is applied to a small part of it before ; but behind the bladder, it descends for a great way, almost as far as the insertions of the ureters ; from whence it proceeds to the rectum, or to the uterus in women. Behind the bladder, the seminal vesicles, prostate gland, rectum, and levatores ani, lie under it. In the foetus, the bladder being very long, and conical, extends above the ossa pubis ; but in adults, it hardly arises above those bones, even when inflated, because, in them, the pelvis is much larger and deeper in proportion to the body.

DCCLXXXVII. The figure of the bladder is, in general, oval, but its anterior surface is flatter, its posterior more convex, and its inferior obtuse vertex, which

which rests upon the rectum, is very flat and broad. Such is the figure of it in the male adult : in the foetus it is almost cylindrical ; and, in women, who have had many children, it is so much flattened laterally, that it resembles a roundish tetrahedral figure, of which the sections are triangular. This change seems to arise from the weight of the urine, which depresses the lower parts of the bladder, and extends it in breadth, so as to render it shorter and broader. It is of different magnitudes ; so that, in some diseases, from irritation, and habitual contraction, it becomes very small.

DCCLXXXVIII. The fabric of the bladder is much like that of all large membranous receptacles. The first membrane is cellular ; in its forepart lax, and replenished with fat ; behind, it is less so, where it also unites with the rectum. In this, there is a network of vessels, chiefly of veins. Next to this follows the muscular coat, which is very difficult to describe, consisting of pale contractile fibres, disposed in various reticulated bundles, not continuous, but with intervening spaces, in which the nervous coat lies uncovered. The principal stratum of these is longitudinal ; which, arising before from the prostate gland, and frequently, though not always, so connected to the synchondrosis of the ossa pubis, or the membranes covering it, as seemingly to arise from thence, ascend towards the conical superior extremity of the bladder ; descend over it, along the posterior surface, become at that place very broad, and again terminate at the prostate ; but at the sides they diverge, variously palmated, and are blended from the anterior and posterior planes. These fibres must depress the bladder, and consequently propel the urine towards its lower part.

DCCLXXXIX. The remaining fibres are very difficultly reduced to any order. They fill the intervals of the former ; arising from the prostate, then inflected, they ascend, and form a stratum, partly oblique,

oblique, and partly transverse, the interior ones more so than the others, both in the forepart and back part of the bladder.

DCCXC. The contractile force of the bladder is gentle, but perpetual; so that it contracts from its greatest dilatation to its smallest diameter, without any alternate relaxation, and remains long in its state of greatest contraction. The urine is its least uneasy stimulus; water injected is more so; and calculus, and every kind of irritation, the most insufferable. When immoderately distended, it loses its powers; so that either it cannot expel, or it cannot retain the urine.

DCCXCI. Within the muscular coat is spread the second cellular stratum, of an elegant fabric, inflatable, more tender, and softer than in the intestines. Next follows the nervous coat, continuous with the skin, and acutely sensible; the innermost, resembling that of the stomach, is last; more obscure; difficultly separable from the nervous one; continuous with the epidermis; and, like it, easily reparable, extremely mucous, and folded into various wrinkles, without any certain order. In it, the pores of the cryptæ sometimes appear, but not always easily, pouring out a viscid and bland gluten. The mucus itself is very manifest, and is prepared in greater quantity in proportion to the irritation of the bladder. It is of the greatest importance for diminishing the irritation of the acrid urine.

DCCXCII. The vessels and nerves of the bladder coincide with those which go to the genital parts, where we shall describe them. Those which come from the epigastrics are small. Their principal reticulation is in the first cellular stratum, and there is another in the second. Through the villous coat the exhaling arteries exhale, as we learn by experiment, from anatomical injections; and the absorbing veins open, to which are owing the greater consistence and higher colour of the urine, when retained.

retained. The lymphatic vessels in the outer cellular stratum, are easily demonstrated; but their origin is probably foreign from the adjacent intestine.

DCCXCIII. The urinary bladder is of the same nature with other membranous sacs, so that it both transmits water from its cavity through the inorganic pores of its membranes, and absorbs water when immersed in it.

DCCXCIV. Into this bladder, the urine flows, in one uniform stream, as has been proved, in morbid and uncommon cases, in which the extremities of the ureters were visible to the eye, and there remains, and becomes more acrid and higher coloured, from the absorption of its water. We are not fully acquainted with the cause, which retains the urine in the bladder. The sphincter is obscure; the depression of the bladder seems to assist, which being convex, descends upon the rectum, behind the sphincter, below its orifice, so that the urine does not reach the orifice of the urethra till collected in some quantity. It is certain, that the urine does not escape spontaneously even from the dead body.

DCCXCV. At length, the urine, by its bulk and acrimony, irritating the sensible fabric of the bladder, is expelled, first by the motion of the diaphragm and abdominal muscles, by the pressure of which, impelling the intestines against the bladder in the erect posture, the urine makes itself a way through the narrow and impeded passage; and secondly, by the peristaltic motion of the bladder itself, arising from the contraction of its muscular fabric (DCCCLXXXVIII. et seq.)

DCCXCVI. By the urine, besides the water, and part of our food, much matter, that is noxious to the human body, seems to pass off; especially calcareous earth reformed from the bones and solid parts, and which would produce bony crusts and calculi wherever it was retained; the sparry earth of waters; an acrid oil mixed with salt, so as to assume

fume a volatile nature. The urine, by its retention, disposes to the generation of calculi, and to gout : when suppressed, it produces acute fevers ; and lastly, flows back to the brain, and is deposited on it, and destroys it.

DCCXCVII. From the obtuse vertex of the bladder, not exactly from its bottom, but further forwards, a canal with a small orifice, continuous with the bladder, arises. It is denominated the urethra, and is composed of an internal membrane, which is evidently continuous with the epidermis, of surrounding cellular substance, and of a firm nervous coat. It is variable in its diameter and direction ; in women, it is straight, transverse, and short. I do not find a valve in its orifice.

DCCXCVIII. The urethra is at first surrounded on all sides, by the prostate gland ; it then proceeds naked, for a small space ; it is then embraced by the bulb immediately attached to it, first below, and then above ; it is then received in the interval between the corpora cavernosa of the penis, contiguous to it above, and laterally, and acquires strength and the state of an open tube from them. The urethra is widest where it arises from the bladder ; it contracts itself conically in the prostate ; in its naked part it is cylindrical ; it enlarges at the first accession of the bulb ; in the penis it is also cylindrical, and again dilates itself a little before its termination.

DCCXCIX. This canal is governed by various muscles, either proper or contiguous. And first, in women, there are manifestly fibres placed round the egress of the incipient urethra, which are, on the whole, transverse, but variously decussating each other ; of which the fixed point is in the vagina, and the office is evidently that of a sphincter, to depress the canal, about the opening of which they are disposed, and to close it against the resisting contracted vagina, and sphincter of the anus. In  
man,

man, similar transverse fibres, but forming an arch upwards, run into the conjunction of the bladder with the prostate; both covering a longitudinal bundle of fibres and the prostate, and covered by these fibres, they are to a certain degree fitted for contracting the orifice of the bladder.

DCCC. The first transverse muscle proceeding transversely from that branch of the ischium which sends forth the erector muscle of the penis, towards the other os ischium, partly passes into it, partly is inserted into the middle of the bulb of the urethra, and partly degenerates into the accelerator. It presses upon, shakes, and draws backwards the bulb of the urethra. The other, produced from the branch of the os ischium, is inserted into the isthmus of the urethra before the bulb, and dilates it.

DCCCI. But likewise the levator of the anus seems to raise the urethra against the os pubis, and to shut the exit from the bladder; and the constriction of the accelerator, together with the sphincter, is easily perceived in the living body, as it perfectly closes the mouth of the bladder, and checks the urine even while it is flowing; whence there is no doubt, that the moderate tension of this muscle contributes towards retaining the urine.

DCCCII. An effort being now made, (DCCXCV.) by the pressure of the diaphragm, the urine is ejected with greater celerity, as it comes from a large receptacle, through a narrow canal; and, being discharged, the body is freed from the uneasy sensation. The last drops, which remain in the lowest part of the bulb, and are retained there by their weight, are expelled by the accelerator muscle, which is a strong muscular expansion, placed round the bulb of the urethra, with pennated fibres, meeting in the bottom middle part of the bulb, fastened before by two tendons to the cavernous bodies of the penis behind, and connected by three muscular portions to the sphincter of the anus, of which two are lateral,  
and

and one central, with some accession from the transverse muscles. This muscle, when the sphincter is steady and shut, draws the bulb upwards; and, acting upon the urethra alternately, with considerable force, expels the last drops of the urine.

DCCCIII. We cannot admit, that the pyramidal muscle of the abdomen, draws the bladder downwards from the bundle of umbilical vessels, and relaxes it, and fits it for the action of the long muscular fibres, as the muscle itself is often wanting; as it cannot depress the bladder, and very rarely reaches the navel.

DCCCIV. But as the urine is acrid, and the membrane of the urethra very sensible, and as the air can be admitted into it, nature has supplied this canal with a large quantity of mucus. Besides its sources in the bladder, this mucus is generated, in the first place, by two conglomerate glands; one of which is seated on each side, in the angle betwixt the bulb of the urethra and the cavernous body of the penis, and sends out a duct, running for a considerable way obliquely along the urethra, and inserted before its bulb. I am ignorant of any gland of the isthmus different from the cellular texture. Moreover, the whole urethra is full of cylindrical mucous sinuses, most of which descend towards the glans, though some run in a contrary direction, into whose sides minute cryptæ deposite a fluid and bland mucus. The largest of these sinuses are disposed in a series along the upper side of the urethra, beginning before the bulb, and extending to the origin of the glans. The small ones are both mixed with these large ones, and disposed on the sides. In women, they are numerous and large in their short urethra, especially at its opening.

DCCCV. The necessary propriety of human life requires the detention of the urine. But this very utility is attended with the danger of disease, since  
the

the urine when at rest, immediately deposits its earthy particles, which by the accession of new strata, form calculi. But the great number of people free from calculi, show, that the very lubricous mucus of the bladder is a sufficient protection, unless the use of fabulous and tephaceous water, of wine, or of viscid aliments, excessive inactivity, preternatural retention of the urine, the presence of some viscid body to attract the calculous earth, and, finally, nephritic diseases, afford a superabundance of calculous earth, or a nucleus for its adhesion,

## C H A P. XXVII.

## MALE ORGANS OF GENERATION.

DCCCVI. **T**HE vessels belonging to the genitals arise near the kidneys, almost in every kind of animals. This is occasioned by the opportunity of deriving a double use from one organ, which might discharge both the urine and the semen, and by the relation of the genital parts to the interval between the tops of the thighs, which is subservient to cleanliness, modesty, the facility of parturition, of making water, and to the effect of the efforts employed in these.

DCCCVII. The male semen is formed in the testicle; is deposited in the seminal vesicles; is ejected from the penis; is injected into the uterus, and fecundates the ovum. Such is the arrangement we shall follow. The human testicles, small in proportion to the body, in the foetus, when very young, are lodged within the peritonæum, and gradually descend under it into the groins, and when it has arrived at maturity, they lie below the groins; their situation being changed, perhaps by the simple force of their weight, and of the influx of blood; yet sometimes they remain in the groin, even in adults.

adults. They descend by a cellular passage, which in the foetus is open, and called the process leading from the cavity of the peritonæum into the scrotum ; and the same passage, after the testicle is transmitted, is contracted and obliterated by a law of nature.

DCCCVIII. The testicles are defended by various integuments. In the first place, they are surrounded by the scrotum, which is formed of a dense cellular coat, vascular and compacted into a solid membrane, closely adhering to the skin, which possesses some elastic motion from cold and during venery, but without any muscular fabric, although when it acts it becomes corrugated, and draws up the testicles. This cellular coat, commonly called the dartos, is placed round each of the testicles separately ; therefore, at their union, they form a kind of septum, in a dry preparation ; this septum is often imperfect in its upper part, near the penis.

DCCCIX. The dartos is interiorly relaxed into cellular substance, which is inflatable as in other places, but without fat, except in the lower part of the scrotum. Next follows a muscle, from its office called cremaster ; which arises from the degenerating fibres of the less oblique muscle of the abdomen, and from the tendon of the obliquus externus, which has got the name of a ligament, and sometimes from other fibres descending from the os pubis, and being expanded into a vagina, and surrounding the testicle behind, and then on all sides, it compresses, elevates, and emulges it.

DCCCX. Next to this follows the second cellular stratum, which is continuous with the exterior spongy web, which surrounds the peritonæum ; this is called the tunica vaginalis. It is composed of longer cells than elsewhere, which may be inflated one after another. At the beginning of the testicle, above the epididymis, part of the vaginal coat, which surrounds the testicle, is so separated

rated from the rest, which lies higher than the testicle towards the ring of the abdominal muscles, as almost to prevent the transmission of air. Betwixt this membrane and the following, there is a space, into which vapour is exhaled, and sometimes a little water is collected. The innermost coat of the testicle, called the albuginea, is a strong, white, compact membrane, which immediately invests the substance of the testicle.

DCCCXI. The testicle properly so called, is of an oval figure, with an acute vertex, directed upwards and a little outwards. The epididymis is a kind of addition to the testicle; a flat thick tape, which goes round the posterior margin of the testicle, to which it is connected by cellular texture, and by vessels. Below it is flatter; on the upper part it adheres to the testicle by a thick and convex head, as it also does at the very bottom. In the middle, it is partly attached, and being partly loose, forms a shut cavity.

DCCCXII. To the testicle the spermatic arteries descend, one on each side, arising from the aorta below the renal arteries; but not unfrequently from the renals themselves, or from one of the capsularies, or from the aorta itself above the renal. This artery, the smallest in the body in proportion to its length, descends outwards before the psoas muscle, and gives small branches to the liver, the fat of the kidney, the ureter, lumbar glands, mesocolon, peritonæum, and especially a remarkable adipose branch, bent around the bottom of the kidney: and, without becoming less, it proceeds behind the peritonæum, as far as the ring of the abdomen. This ring is formed entirely of the tendinous fibres, descending from the external oblique muscle, interrupted by a long aperture, growing wider downwards; a great many of which, slender and interior, are partly inserted extensively into the middle of the os pubis, and partly decussate  
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and unite with the fibres of the muscle of the opposite side ; these are called the inner column. Other external stronger fibres, separated from the former by the aperture, are inserted in a thick bundle into the outer side of the os pubis, under the denomination of the external column : from it various fibres run off to the fascia lata and groin. The upper part of this opening is in some measure closed up by fibres, arising from the outer column, inflected and ascending along the inner and weaker column. Below these fibres, through the small opening left, which is often divided by tendinous fibres, the spermatic artery descends, along with the vein, and vas deferens, formed into a cylindrical cord, with a good deal of cellular substance, before the external column, but does not perforate the peritonæum, which lies before it through its whole extent. At this ring, the ductus deferens is joined with the rope of vessels, and the whole bundle proceeds into the groin, and afterwards into the scrotum. The spermatic artery gives many branches to the cremaster, to the cellular coat, and to the septum of the scrotum ; and descends in two plexuses to the testicle ; of which the principal passes betwixt the epididymis and origin of the vas deferens, to the middle and lower part of the testicle, and is distributed in transverse branches, through the albuginea : the other plexus goes to the testicle in company with the vas deferens, has a like termination, and is variously inosculated with the former. Other small arteries go to the coverings of the testicle from the epigastrics, and others from those of the bladder, accompanying the vas deferens ; both of which communicate with the spermatic vessels.

DCCCXIII. These very numerous arteries play about the epididymis ; but the larger of them spread transversely through the albuginea, which they perforate in several places, and enter into the innermost substance of the testicle, through which they are

are every where distributed upon the numerous membranous septula. There is no larger anastomosis or communication betwixt the spermatic artery and vein here, than in other parts, nor are the branches within the albuginea, received into the testicle, without blood. But the long course of this artery, the smallness of its diameter, the serpentine flexures, the great proportion of the branches to the trunk, and their cold situation, demonstrate, that the blood arrives at the testicle slowly, and in small quantity.

DCCCXIV. The right spermatic vein carries its blood to the cava; the left to the emulgent vein, or to both: it is enormously larger than the artery, both in its trunk and branches; and accompanies it, but more plentifully, having several trunks interwoven into a very long reticulated web within the abdomen, which surrounds the artery, and is continued into the testicle, by degrees dividing into two like the artery. There are some valves in this vein, though few.

DCCCXV. The external coverings of the testicle have their arteries from the epigastrics; the scrotum from the crural arteries, and from the internal branch of them, which is called the external pudenda; the correspondent veins go to the saphæna, and to the crural veins.

DCCCXVI. The nerves of the testicle are many, whence its sensibility is peculiarly acute, so that injuries of the testicle are immediately followed by faintings and convulsions, and particularly by locked jaw. Some of them arise deep from the renal plexus, from the great mesenteric plexus, from the trunk of the intercostal nerve, and lastly from the mesocolic plexus, and follow the course of the spermatic vessels. Others, more superficial, descend to the coverings of the testicle, from the second, third, and fourth pair of the lumbar nerves.

DCCCXVII.

DCCCXVII. I have frequently observed lymphatic vessels in the spermatic cord, which are believed to arise from the testicle itself, and which unite with those that accompany the inguinal blood-vessels. The industry of late anatomists has traced some of them even to the network of the testicle itself.

DCCCXVIII. The blood, moved slowly and in a small quantity, brought by its arteries into the inner fabric of the testicle, (DCCCXIII.) is distributed into minute vessels, which carry their fluids to the seminal vessels, although we are ignorant of the manner by which the arteries communicate with these tubes, bundles of which form the whole substance of the testicle. These are small, serpentine, somewhat firm, and have a very small caliber in proportion to their membranes; they are not, however, so impervious as to prevent them from being filled through the vas deferens. They are collected together into bundles, above twenty in number, separated by cellular partitions, which descend from the albuginea into the testicle, and conduct the arteries and veins. In each cell there is a duct which receives the semen from the seminiferous vessels. These ducts, twenty or more in number, form a network of longitudinal vessels adhering to the albuginea, and anastomose with each other; and readily permit quicksilver to escape into the surrounding cellular substance. From this net twenty or thirty ducts ascend to the upper part of the epididymis, which being wonderfully convoluted, form as many vascular cones. These, joined together by intermediate cellular substance, and lying upon each other, form the head of the epididymis, and in that head soon meet together into one duct on the outside of the testicle.

DCCCXIX. This single duct being convoluted into an infinite number of folds and serpentine flexures, in a manner not found in any other part of the body,

body, and connected together by much loose cellular substance, and being collected by one continuous membrane produced from the albuginea, constitutes the epididymis. But the duct of which the epididymis is composed, grows larger as it descends; from whence being reflected, it again ascends along the posterior surface of the testicle, and by degrees unfolding its spiral convolutions, which are now much larger, it gets the name of ductus deferens. Almost always, however, a small vessel separates somewhere from the ductus deferens, and ascends along with the chord, having an uncertain termination.

DCCCXX. This is the course described by the semen, moved forwards by the fluid successively coming from the testicle, and perhaps by the cremaster; but very slowly, as we may conclude from the numberless convolutions of the epididymis, obstructing almost every kind of injection; and from the length of time that is required to repair the semen, after the seminal vesicles have been exhausted.

DCCCXXI. The cylindric ductus deferens being composed of very thick spongy substance, included betwixt two firm membranes, perforated by a very small tube, begins at the bottom of the epididymis, ascends in the chord of the spermatic vessels, passes through the ring of the abdomen (DCCCXII.) descends into the pelvis, applies itself to the bladder between the ureters, and there meets with its subjacent receptacle, which is called the vesicula seminalis, of which there are two, one right and one left. Here the vas deferens lies on the inner side of the vesicle, as far as the prostate gland; and being dilated in its course, and bent in a serpentine direction, it appears cellular. But very near the prostate, the duct, being continued from these cellular windings, unites with a conical duct coming from the vesicle, in a very acute angle, into one

duct, also conical, which is continued rather from the vas deferens, and penetrates through the prostate gland, there forms a great flexure, diverges outwardly at right angles from its companion of the other side, and, becoming contracted, opens into the urethra in one of the two very small lateral orifices of the tumid, long beaked, hollow protuberance. By injecting a liquor into the ductus deferens of a dead subject, we perceive that it flows both into the urethra and into the seminal vesicle, but more readily into the former: but in a living person the semen never flows out but in the act of venery; and consequently the ductus deferens conveys all its semen, notwithstanding the retrograde angle, to the seminal vesicle.

DCCCXXII. By this last denomination we understand a membranaceous, firm intestine lying under the bladder, connected with it by much cellular substance: from which ten or more impervious cells proceed, some of which are also ramified and divided, but which end in impervious conical extremities. This intestine, with a great deal of firm cellular substance and intervening vessels, and peritonæum lying under it, is so contracted, as to be collected into a short serpentine mass. Besides, its external fabric is pulpy and thick, and is something analogous to the ductus deferens. Its external fabric is wrinkled like the villous and reticulated coats of the biliary vessels, villous with minute flocculi; and is said to have small pores and glands, with which I am unacquainted, though it certainly has various and hollow cells.

DCCCXXIII. The liquor deposited in it, in the testicle is yellowish, thin, and watery; and retains the same nature in the vesicle, though it becomes there more viscid and yellow; and lastly, in man it becomes white, when it is mixed with the liquor of the prostate. It has a peculiar heavy smell, in every kind of animal; and it is the heaviest fluid  
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in the body. In water, part of it forms a thin, swimming pellicle, but the greater part, which is seemingly of a pulpy nature, sinks to the bottom; and in the semen which has been long retained by continent people, shining globules mixed with a whiter liquor are easily seen with the naked eye. It agrees in many particulars with mucus.

DCCCXXIV. Without the conveyance of this into the womb, no animal which is of two sexes can be fecundated. The reason of this was unknown, till the microscope shewed, that in man, and in every other animal, the feminal liquor is full of living animalcules, resembling eels, having in man a thick head, and a long and slender but conspicuous tail; which are always found in healthy semen, from the period of puberty; but, before that time, and in those who are sterile from sickness, they are absent, and they are not found in any other animal fluid. That they are animalcules, appears evidently from their various motions, avoiding obstacles, retrogression, and change of velocity.

DCCCXXV. The real use of these animalcules has been much doubted; and we shall have another opportunity of considering the received opinion, that they are as it were the first appearance of the future animal. To me, in the mean time, the nature of the feminal animalcules seems to be the same with that of the eels in vinegar or other infusory animals.

DCCCXXVI. That the semen is produced from the lymph of the blood, and that the chyle is added to the lymph appears probable from the disposition to venery quickly supervening after eating, and being lessened by fasting. It is compounded of the liquor of the testicles, and of the feminal vesicles, which in some animals is more evident, and of the coagulable milky fluid of the prostate gland. That liquor, however, only fecundates which is generated in the testicles; as we see from castrated animals,

mals, which, though they have the seminal vesicles and prostate, are yet unprolific.

DCCCXXVII. The seminal fluid is retained in the vesicles, excepting in the venereal act and in the illusions of dreams. Being present during that whole time, according to its quantity, it stimulates the animal to venery. But a considerable part of the semen, and that the most volatile and odorous, is absorbed into the blood, and by its addition to it produces wonderful changes, impregnating the whole animal with its smell, causing the beard, and hair upon the pubes, and horns to grow, changing the voice and dispositions. For these do not happen in consequence of the age of the animal, but of the semen, and never occur in eunuchs. The growth and strength of castrated animals are diminished; but in uncut animals, the ferocity and strong smell, diffused through the whole flesh, increases. And from some examples of animals, and even of men, it has evinced a fatal irritating power, by exciting convulsions. Retention of the semen seems to proceed from the narrowness of the seminal duct, excretory duct, a scirrhus of the prostate, and other causes not sufficiently known.

DCCCXXVIII. The quantity of semen expelled at one time from the vesicles in man is but small, especially if the abstinence from venery has been short; and it is natural that it should be but slowly produced from so small, and that a subcutaneous artery. Its generation is accelerated by love, by the presence of the beloved object; so that it distends its vessels with a sense of pain. Nature herself, therefore, enjoins venery for the preservation of the human race, and likewise of the health of every sound man. That it passes from the testicle into the vesicles, is shewn by diseases, in which the ductus deferens being obstructed, a swelling of the testicle has ensued. From the vesicle it does not escape, except during the venereal act.

DCCCXXIX.

DCCCXXIX. As the semen is small in quantity, that it might be projected with greater force, and to a further distance, another humour, which is generated by the prostate, is added to it. This gland, shaped like a heart, with the small end foremost, surrounds the origin of the urethra, and contains it, though most contiguous to the upper surface of the gland. It is a very hard and compact gland, of a peculiar fabric, not evidently conglomerate; it prepares a thick, white, bland, copious fluid, which is projected at the same time and from the same causes (DCCCXL.) with the semen itself, into the excavations at each side of the openings of the seminal vesicles, through numerous ducts, and in the semen its white colour and viscosity are predominant.

The urethra, although cylindrical upon the whole, has three considerable dilatations. The first in the prostate at the caput gallinaginis, the second in the bulb, and the third in the beginning of the glans. Its course at first is generally horizontal, afterwards it ascends along the ossa pubis, and in the male it is finally pendulous, except in the time of venery. It is a continuation of the nervous coat of the bladder, and is internally lined with a very smooth epidermis; between which and the nervous coat there is cellular substance.

DCCCXXX. But it was necessary for this urethra to be firm and straight, that the semen might be thrown with some force into the distant womb; therefore it is surrounded by a triple cavernous body. The first, the proper cavernous body of the urethra, begins, as soon as that canal has passed the prostate, with a thick origin, almost like a heart; at first it lies under the urethra, but afterwards surrounds it also above, but is there thinner, and accompanies it through the whole length of the penis, till the lower part terminates in the glans, while the upper part is reflected back from the extremity  
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of the urethra, and, being dilated, returns in a contrary direction along the penis, and, being terminated by a broad, thinner, and round extremity, it rests upon the corpora cavernosa penis, and for the most part communicates with them by an imperfect septum. The fabric of this body is cellular, but lax, and composed rather of plates, interwoven like a net, than of fibres, and inclosed between two firm membranes.

DCCCXXXI. Into this cavernous body of the urethra, the blood is poured out from the deep seated arteries, which come from the external hemorrhoids (DCCCXXXVI.) This is demonstrated by the injection of any kind of fluid, which easily flows from these arteries into the cellular spaces surrounding the urethra. But they are not spontaneously turgid with blood, because there are veins equally open, sufficient to carry away the effused blood. But when these veins are compressed by the powers mentioned in DCCCXXXIX. the blood is then retained within the cellular spaces, while the arteries, being stronger, continue to pour it in. Thus the blood stagnating, distends the bulb of the urethra, together with its cavernous body, and the glans itself. But this is performed generally when the other cavernous bodies of the penis, with which this of the urethra has no communication, are previously distended.

DCCCXXXII. The cavernous bodies of the penis arise from the ossa ischii, almost from their bottom, with which they are joined by a white, cellular, but very dense and firm substance; from whence inclining inwards and towards each other, they inclose the urethra, a little before its bulb, where, changing their direction, they go on parallel, and conjoined together, with the urethra lying below and between them, and terminate in the glans with an acute end, laterally surrounded by the cavernous body of the urethra. They consist of a very firm integument,

integument, and spongy internal flesh, as in the urethra, (DCCCXXX.) like it also capable of being distended with blood. Between these cavernous bodies, there is a middle septum, composed of firm parallel tendinous fibres, growing narrower downwards, and not continuous; so that the intermediate spaces are larger and more numerous, as they are more forward; and a free communication is left between the right and left spongy body. Other fibres of this kind run through the cavernous bodies, as well as the septum, and are inserted into the very firm involucrum: they prevent overdistention and aneurisms of the penis.

DCCCXXXIII. These cavernous bodies are surrounded by much very fine cellular substance; of which the part lying next the cavernous bodies is tense and firm, like a membrane; without it the cellular substance is very tender, continuous with that of the scrotum, and included within a thin skin without any fat, and always the more tender the nearer the skin it is. By inflation, it assumes a beautiful silky texture. But the glans (DCCCXXX.) is covered in the following manner by the skin: being continued from the penis, and reflected against itself, as in the eyelids; covered on both sides with its proper cuticle, and filled with intermediate cellular substance, it is called the preputium, and may be drawn back, and lastly, it is continued forwards again to the glans penis, and is there changed into a tender, soft, spongy, flocculent body, acutely sensible, covered with its proper cuticle, and with a depressed pulpy reticulum, spread over the reflected cavernous body of the urethra, (DCCCXXX.) and, finally, continuous with the membrane of the urethra itself. The prepuce is tied by a double triangular frænulum, by which the skin is joined to the cellular involucrum of the penis, as far as the mouth of the urethra. In the hollow which lies under the crown of the glans, and in that circle itself, are seated

feated simple sebaceous follicles, which separate a liniment, which, from the nature of the place, is fetid, as in other parts of the body exposed to friction. The whole penis is sustained by a firm cellular substance, compacted into a kind of triangular ligament, which descends from the synchondrosis of the ossa pubis, and is continuous with the dense and hard cellular stratum that surrounds the cavernous bodies.

DCCCXXXIV. The whole human penis forms a cylindrical body, depressed on the upper part, of variable magnitude, whose use is to be received into the female parts of generation, and to carry thither the prolific semen.

DCCCXXXV. These cavernous bodies of the penis, during coition, by the blood impelled through the arteries, and retained in the veins, become turgid, distended and stiff, and sustain the flaccid, or if it alone were filled, the weak urethra, in such a manner that the semen may arrive at the distant womb. This is demonstrated from the dissection of animals killed in the act of venery, from artificial erection, from the injection of liquid substances into the vessels of the penis. It is produced by love, the desire of enjoyment, the friction of the glans, and various irritations of the bladder, testicles, feminal vessels, and urethra, from urine, from abundance of good semen, from the venereal poison, from cantharides, whipping with rods, or nervous convulsion. But the cause of this distention is not yet evident. The description of the distribution of the blood-vessels into the genital parts is therefore now necessary, to show how little it is adapted for promoting the cause which compresses the veins.

DCCCXXXVI. The aorta at the fourth vertebra of the loins, and the vena cava at the fifth, are divided; of these the latter is posterior, the former anterior. The common iliac branches, before they arrive at the middle interval at the beginning of  
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the thighs, send off inwards and downwards a considerable artery, called the hypogastric, which in the foetus is larger than the femoral artery, and in the adult is equal to it. This descends into the pelvis, and divides into four, five, or six principal branches; of which the first is the iliaca anterior, which also sends branches to the dura mater and cauda equina, upwards to the loins, and downwards to the os sacrum. The next, the sacra lateralis, goes to the same os sacrum and cauda equina, when it does not arise from the former. The third, the iliaca posterior, is almost confined to the glutei muscles. The fourth, the ischiadica descendens, supplies several muscles, the nerves, and the levator ani. The fifth, or the trunk, is the hæmorrhoidæ infima or pudenda communis, which, within the pelvis itself, sends considerable branches to the bladder, and to the rectum the middle hæmorrhoidal, which anastomoses with the mesenterics; after which, going out of the pelvis, it creeps by the side of the obturator, and gives off the external hæmorrhoidals to the sphincter and skin of the anus: then dividing, its internal branch supplies the bulb of the urethra and the prostate; the external is again divided, and with one branch enters deeply into the cavernous body of the penis, and runs through its whole length; while, the other branch often joined with the vessels of the bladder, runs along the back of the penis, and terminates in branches sent to its corpora, and to the skin. The sixth is the obturatrix, spent upon the joint of the femur and adjacent muscles. The last, the umbilical artery, will be described in treating of the foetus; in the adult it sends some branches to the bladder, from its thick callous vagina. Sometimes several of these arteries arise from one common trunk. The skin of the penis and scrotum have their arteries from the epigastric, from the crural, and from its internal branch. These external arteries

teries communicate in many places with the internal.

DCCCXXXVII. The veins, in general, correspond with the arteries. They often come off from the iliacs in two trunks, forming a plexus with each other; then the hæmorrhoidal vein, returning around the os pubis, forms a very large plexus upon the prostate gland, with the veins of the bladder arising in the pelvis: from which the vena penis arises, which is often single, and is furnished with valves, determining the return of the blood to the cava. The external veins of the penis and scrotum go to the saphæna and crural, and communicate in several places with the internal veins, more especially at the basis of the prepuce.

DCCCXXXVIII. The lymphatic vessels of the penis, seen by very eminent anatomists, are said to run under the skin of the penis. The nerves, which are very numerous, and very large, and accompany the arteries of the penis, arise from the great trunk of the sciatic nerve. But the bladder, rectum, and uterus, are supplied by the lower mesenteric plexus, which arises from the middle one, and descends into the pelvis.

DCCCXXXIX. To distend the penis, it is necessary that the veins (DCCCXXXVII.) carrying back the blood from the cavernous bodies of the penis or urethra, be compressed, or, at least, that a power be applied to the ultimate veins, which open every where into the cavernous bodies, hindering them from absorbing the blood brought there by the arteries. The first may be in some degree effected by the levator, drawing up the prostate and bladder; but, from the analogy of the nipples of the female breast, of the gills of the peacock, of the blushing of the face produced by the passions of the mind, and of animals, all of which copulate in the same manner, without any erector muscle; of the erection in animals totally different in their structure from man,  
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and especially of the very sudden erections in birds; from the very inaction of the erector muscles themselves during libidinous erection, and from their unsuitness for compressing the veins; it is probable, that, independently of the muscles, the absorption of the blood by the veins may be retarded, and that it is affected by the multitude of deep seated nervous nooses, which being constricted by the force of pleasure, compress the veins, so that, being rendered narrower, they return less blood to the trunks than what is imported by the arteries, which are not only free from any stricture, but at the same time, by the increase of the pulse, are bringing the blood more quickly, which is an accessory cause. But the cause of this convulsion seems to exist in the nervous sphincters, since the penis becomes erected, both from mechanical irritation of the nerves, and that more subtle irritation caused by the imagination.

DCCCXL. To a continued and violent erection, an expulsion of semen at last succeeds, which requires much greater force than simple erection. For the semen is emitted when the irritation of the nerves is arrived at its greatest height: and in natural venery, when the cellular spaces of the urethra, which are later of being filled, and the continuous glands at last become turgid with blood, so that being distended with a large quantity of warm blood, they become stiff, and therefore the nervous papillæ, being erected, are violently affected by the cause of pleasure. The seminal vesicles are evacuated by the levator muscles of the anus, which press them against the resisting bladder, being excited either by voluptuous imagination alone, or by the excessive pruritus of the nerves of the glans, especially of its lower part, in the neighbourhood of the frenum. The semen is never discharged along with the urine, in a healthy man; because the expulsion of it requires the bladder to be shut; for, while  
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lax, it affords no resistance to the seminal vesicles. The transverse muscles seem to dilate the canal of the urethra for the reception of the semen expressed from the vesicles.

DCCCXLI. Soon afterwards, the sensible urethra being irritated by the semen, the powers constricting it are called into action. This is principally effected by the accelerator, (DCCCII.) which strongly compressing the bulb and adjacent part of the urethra, propels the contents more swiftly, in proportion as the bulb exceeds in diameter the urethra. That this may act firmly, the sphincter of the anus, and therefore also that of the bladder, must be contracted. The accelerator seems also to be the principal muscle of erection, by compressing the veins of the corpus cavernosum of the urethra. At the same time, the erectores penis, as they are commonly called, arising from the above tubercles of the ischium, being strong, and inserted into the cavernous bodies, support the penis, in a direction intermediate betwixt the transverse and perpendicular. Thus the semen is projected into the vagina, and into the uterus itself, in prolific coition. This action is very violent, and comes near to a convulsion; whence it is wonderfully debilitating, and very much injures the nervous system principally, as the maladies arising from thence seem to indicate, from the affection of the nerves, without which the semen cannot be expelled.

## C H A P. XXVIII.

### VIRGIN UTERUS.

DCCCXLII. **T**HE uterus in woman is seated in the upper part of the pelvis, with the bladder before, and the rectum behind it, without adhering to either of them, and with its mouth inclining

clining a little forwards. In the female adult, it is contained within the pelvis ; but in the infant, it rises above it. In women, the peritonæum descends from the os pubis into the pelvis, and proceeds for a considerable way behind the bladder, to the bottom of the uterus. Then it ascends along the uterus ; and a second time descends on its opposite side, applied to it as far as the vagina, and the transverse portion of the uterus, from whence, including the rectum with lunated folds, it ceases to differ from the structure in man. But this same peritonæum, coming into the pelvis from the iliac vessels, and being broader than the uterus, and adhering to its sides, and to the vagina ; and being reflected along itself, divides the pelvis into two regions, the anterior and posterior, like a partition, and is called the ligamentum latum. It is accurately connected with the uterus, without any intermediate fat, so as to serve it on all sides as an external coat. It does not hinder the uterus from being totally moveable.

DCCCXLIII. The body of the uterus is usually distinguished from its neck. The figure of the body is convex before and behind, with a degree of flatness, with acute edges, where its surfaces meet, converging at the sides, and moderately convex at the top. It has a peculiar fabric, of a close compact, firm, but somewhat succulent, cellular substance, in which we perceive muscular fibres, especially in puerperal women. They are flat, and reticularly interwoven with each other, some longitudinally disposed along the uterus from the fundus to the os uteri, others arranged in various circles, and particularly in the fundus, and betwixt the tubes, and likewise in the neck near the mouth. In beasts, the uterus is manifestly muscular ; and in women, likewise, it gives evident signs of a contractile nature. Its outer coat is received from the peritonæum. After repeated examinations, I have not found any mucous sinuses, branching and variously dividing within

within the substance of the uterus, but veins surrounded with cellular substance, which do not collapse. The internal membrane of the uterus is continuous with the cuticle; within the cavity, it is pulpy, and covered with short flocculi; in the cervix, it is callous and valvular. The cavity of the uterus is small, almost triangular, but bounded by lines convex inwardly; in the remaining part, it is a compressed cylinder. This part, which is called the cervix uteri, is cylindrical, compressed, and thick, and has also a cylindric cavity within. It is entirely rough, with callous wrinkles, extenuated to an edge, and inclined towards the vagina. These recede from an anterior and posterior line towards the sides, and are joined by smaller wrinkles, in the intervals of which are mucous sinuses, as round globules are every where found in the upper part of the neck of the womb, filled with a very pellucid liquor, differing both in number and magnitude. It is not uncommon for the uterus to be divided by a middle projecting line. The cervix is terminated by the os internum uteri, having a transverse slit, surrounded with tumid lips, drawn out into the vagina, and received within its blind extremity, projecting into it obliquely and forwards. It is full of mucus, and has mucous sinuses in its tumid edges.

DECCXLIV. The triangular part of the uterus sends out, from its lateral angles, canals, folded together by means of cellular substance, growing gradually broader, and, again a little contracted towards the extremity: their direction is at first transverse towards the ovarium, and afterwards descending, but with some variation: they are termed the Fallopian tubes. Their external membrane is from the peritonæum; for they are included within the duplicature of the broad ligament: their internal membrane is wrinkled almost reticularly, mucous, and is extended to a greater length, in the form of spread fringes, folded longitudinally, which crown the orifice

fice of the ovarium, and are connected to the ovary. Betwixt the two membranes, is some spongy cellular substance, of a more slender texture than in the vas deferens. They usually contain mucus, the origin of which is not known. There are also a great number of vessels interposed, and perhaps some muscular fibres, but the latter are more obscure. They are supported by a proper fold of the peritonæum, which proceeds from the broad ligament.

DCCCXLV. The ovaries are transversely situated in the same broad ligament, included in its duplication behind the tubes, and conjoined to these tubes by a peculiar expansion of the broad ligament, which is long enough to allow them a free motion. They are of an oblong figure, compressed on each side; their unconnected edge is convex, and semi-elliptical; but that which is connected with the ligament is straight. Their peritonæal membrane is thick, and almost cartilaginous. Their fabric very much resembles that of the uterus itself; being close, white, and cellular, and without fat. The margin of the broad ligament, where it recedes from the uterus, becoming thicker, to sustain the ovary, has something of a solid substance, resembling a ligament, but is not hollow, or a true canal.

DCCCXLVI. In the ovary even of a young girl, there are round vesicles, consisting of a pretty strong pulpy membrane, and connected every where to the ovarium by cellular threads, which are filled with coagulable lymph; uncertain in their number, fifteen or more being found in one ovary; nor uniform in their size. They are remarkable bodies, being found very widely diffused through all animals, even in those which have but one sex.

DCCCXLVII. Lastly, the uterus sends forwards, from the same lateral angles of its triangular body, a fasciculus, composed of long cellular fibres and  
vessels,

vessels, which, becoming smaller in its progress, goes out of the pelvis through the ring of the abdomen (DCCCXII.) into the groin, where it splits into branches, and separates into small vessels, which communicate with the epigastrics. Has it also long fibres propagated from the uterus itself? I have not seen them sufficiently distinctly.

DCCCXLVIII. The arteries of the uterus are from the hypogastrics; a considerable branch of which the uterine, like the lowest to the bladder in men, arises from the umbilical trunk, or immediately below that trunk. It goes to the lower part of the uterus, almost at the termination of its neck, giving branches to the uterus, bladder, and rectum, and ascending upwards, it sends transverse inflected branches to the uterus, makes numerous anastomoses with the spermatics, and often gives arteries to the tube itself. Another plexus of branches tends downwards to the vagina, running along it a considerable way, although there is also a proper vaginal artery originating likewise in the pelvis, and sometimes accessory branches from the mesocolic. There are also feminal vessels which have the same origin as in men, and descend with a pampiniform plexus over the psoas muscle into the pelvis, and divide into two plexuses. The posterior goes to the ovary itself, with many twisted furculi distributed through its substance and among the ova. The anterior both supplies the tube, and descends to the uterus, in which it is divided into winding branches upwards and downwards, some going to the bladder. Another artery, the middle hæmorrhoidal, from the trunk of the pudenda communis, accompanies the vagina a considerable way forwards, to which, and to the bladder and rectum, it is distributed. Moreover, the beginning of the vagina and the clitoris, have arteries from the external hæmorrhoidal, and the clitoris, like the penis, has both deep seated  
and

and superficial arteries, also inosculating with a branch from the bladder.

DCCCXLIX. The uterine veins on the whole correspond with the arteries, originating from the trunks of the hypogastrics; they are both internal as the uterine, the vaginal, and middle hemorrhoidal, and external as the circumflex, and those of the clitoris. But they form a remarkable plexus on each side, which occupies the sides of the vagina below the clitoris. Below that, it is joined into a continued plexus with its companion on the other side. A plexus also from the external hemorrhoidal and vesical vessels, goes to the clitoris, as in men to the penis. They have no valves, except a few in the spermatics, which also, in a very large bundle, go to the ovarium, and the *alæ vesipertilionis*.

DCCCL. Within the uterus itself the arteries terminate in exhaling branches on its internal surface. In the puerperal state they are elongated into pendulous tubes. Thus the veins of the uterus become at that time very large sinuses; for they are enormously enlarged, and open with very large mouths into the cavity of the uterus.

DCCCLI. Lymphatic vessels are found in the uterus of brutes, and in women more rarely, though by very eminent anatomists.

DCCCLII. The nerves are supplied from the lowest mesocolic plexus, united with those of the sacrum, and sending large branches to the bladder, womb, and rectum; besides which, some pass through the broad ligament to the ovarium, and others from the nerve that goes with the vessels to the clitoris, arising from the sciatic trunk. But the ovary has also its proper nerves from the renal plexus, similar to those which go to the testicles of the male. Thus all these organs, from the great number of their nerves, are extremely sensible.

DCCCLIII. What we have hitherto described is common to all ages of the female ; but about the 13th year, or somewhat later, nearly at the same time when semen begins to be formed in the male, a considerable change also takes place in the female. For, at this time, the whole mass of blood in the female begins to circulate with an increased force, the breasts swell, the pubes becomes covered ; and at the same time the menses begin to flow, by a common law of nature ; although in different countries, the time and quantity of blood discharged is different.

DCCCLIV. This discharge is preceded by various symptoms in the loins, heavy pains, sometimes like colic pains, with an increased pulse, headachs and cutaneous pustules, and a white fluid commonly flows from the uterus. For now the fleecy vessels of the uterus, which have hitherto deposited into the uterus a milky fluid, of a very white colour in the fœtus, and in young girls serous, now begin to be turgid with blood ; and at last to pour out the red cruor itself into the cavity of the uterus. This continues some days, while, in the mean time, the first troublesome symptoms abate, and the orifices of the uterine vessels again gradually contracting, distil only a little serous moisture as before. But at uncertain intervals in young girls, gradually, however, shortening to the end of the fourth week, the same pains return, the same flow of blood takes place, and this period is observed to about the 50th year ; though the diet, country, and constitution, have much influence in this respect. Pregnancy commonly produces a cessation of the menstrual discharge.

DCCCLV. That this blood is discharged from the vessels of the uterus itself, is demonstrated by actual inspection of women who have died during their courses ; of living women, in whom the uterus being inverted, has distilled the blood from the os  
internum :

internum : and of others, in whom, from obstruction of the menses, the uterus has been filled with concremented blood ; and by comparing the nature of the uterus itself, replete with soft vessels, and spongy with the thin, by no means villous, and callous vagina. Observation also shews, that this is good blood in an healthy and clean woman. However, there is nothing to prevent the blood from being discharged through the vagina, when the uterus is obstructed, as in other instances it is through the intestinum rectum, and lastly through the remotest parts of the body.

DCCCLVI. Since no animal certainly menstruates in the same manner as the human species, (although some animals distil blood from their genitals, in the season of their annual venery) and since the body of the male is free from this periodical discharge, the cause of this hemorrhagy, peculiar to the female sex of the human species, has been an object of inquiry in all ages. From the remotest periods, it has been ascribed to the attraction of the moon, which is known to raise the tides ; by others, to a sharp stimulating fluid secreted in the female parts, also the cause of the venereal appetite. But its being caused by the moon is disproved, since there is not a day in which there are not many women subjected to this evacuation, and there are not fewer in the decrease than the increase of the moon. There is no such thing as any ferment near the uterus, but every thing is bland and mucous ; and venery, which expels all those juices, neither increases nor lessens the menstrual flux : and women deny, that, during the time of their menses, they have any increased desire of venery, many of them at that time being rather affected by pain and languor ; and the seat of venereal pleasure is rather in the entrance of the pudendum than in the uterus, from which last the menses flow. Lastly, that the menstrual blood is forced out by some cause exciting the motion of the blood

against the vessels, appears from hence, that, when retained, it has been known to break through all the other organs of the body, where no ferments were acting, the veins being even ruptured; nor is the effect of the retained blood confined to those parts which pour out the venereal humour.

DCCCLVII. Nature has, in general, given women a softer body, less elastic solids, smaller muscles, with a greater quantity of fat interposed betwixt their fibres, and slenderer bones, with smaller processes. Moreover, the pelvis of the female is, in all its dimensions, larger; the ossa ilia more distant from each other; and the os sacrum turned more backwards from the bones of the pubes, while the ossa ischii are separated by a longer line; but above all, the angles in which the bones of the pubes meet is much larger: which differences are confirmed by the observations of the greatest anatomists; and from necessity itself, which requires a greater space for the greater number of viscera in the pelvis. Moreover, the arteries supplying the uterus are very large, more so than in men; and their caliber is larger in proportion to their coats, and they are more lax in proportion to the veins: but the veins are, in proportion, less ample in the men, and of a more firm texture than in other parts of the body. From hence it follows, in the first place, that, in women, the blood is brought to the womb in greater quantity, and more quickly, through lax and ample arteries; and, in the second place, that, on account of the rigidity and narrowness of the veins, it returns with difficulty from the uterus, and distends its vessels.

DCCCLIX. The female infant, when first born, has small lower extremities; and the greater part of the blood of the iliac arteries goes to the umbilicals, a small portion only enters the pelvis. Hence the pelvis is small, and little concave; and the bladder and uterus itself, with the ovaries, rise above the pelvis.

pelvis. But, when the fœtus is born, and the umbilical artery is tied, all the blood of the iliac artery descends into the lower limbs and pelvis, which grow larger, and the pelvis becomes deeper and wider; so that by degrees, the womb and bladder sink into its cavity, and are not so much compressed by the intestines and peritonæum, when the abdominal muscles contract the lower parts of the belly. Then, when the growth is completed, or nearly so, the arteries of the uterus, and of the pelvis in general, which in the fœtus were very small, have become very large, and are easily injected with wax; and all things are so changed, that the hemorrhoidal artery now forms the trunk of the hypogastric (DCCCXXXVI.) as formerly the umbilical had done. More blood, therefore, at this time goes into the uterus, vagina, and clitoris, than formerly.

DCCCLX. At the time when the growth of the body has almost ceased, and a large quantity of blood is prepared in sound viscera and in healthy constitutions, plethora takes place in both sexes of the human species. In the male, it vents itself frequently by the nostrils, from the exhaling vessels of the pituitary membrane (CCCCLVIII.) being dilated to so great a degree, as to pour out the red blood, and now the semen first begins to be secreted, and the beard to grow. But in the female, the same plethora finds a more easy passage, because the very weight of the blood carries it downwards, and because the uterine vessels, now much enlarged, being placed in a lax situation in the succulent and soft cellular substance of the uterus, and being therefore very extensile and exhaling by very soft flocculi, open into the empty uterus, and the blood finds almost a more easy passage that way, than into the corresponding veins; while in the same females, the arteries of the head are firmer and smaller in proportion. The return of the blood is also retarded, both because the flexures of the  
arteries

arteries, from the increased afflux of the blood, become more serpentine and fitter for retarding the motion of the blood, and because it now returns with difficulty through the veins. The blood is, therefore, first collected in the vessels of the uterus, which at this time, according to dissections, are turgid; then in the arteries of the loins and in the aorta itself; now when the heart sends a new torrent of blood into the vessels already distended, its force is at last propagated to the serous vessels of the uterus, so that they distil at first a copious warm mucus, then red serum, and lastly pure blood. The same determination of the blood to the genital parts, forces out the hitherto latent hairs, increases the bulk of the clitoris, dilates the cavernous plexuses of the vagina, and excites the appetite towards venery. Accordingly, the quantity of the menstrual discharge is increased, and its first appearance hastened by every thing that either increases the quantity of blood in general, or determines it particularly to the uterus; such as joy, desire, pediluvia, a full diet, warm climate, and lively temperament of body. It is diminished by those things which diminish plethora and the motion of the blood, as want, grief, cold atmosphere, inactivity and preceding diseases.

DCCCLXI. When six or eight ounces of blood have been thus evacuated, the unloaded arteries now exert their elastic force as all arteries do, and their diameters being contracted, they only transmit a thin fluid as at first. But the quantity of blood which the uterus discharged, being reproduced by the same causes, it is again excreted through these same passages, rather than through any other. Nor is it necessary to inquire, why this period is nearly menstrual; for this depends upon the proportion which subsists between the quantity and momentum of the blood collected, and the resistance of the uterus, which will at last gradually yield,

yield. Therefore this discharge of blood returns sooner and does not wait for the interval of a month, whenever a greater quantity of blood is determined to the uterus in plethoric or libidinous women. They cease entirely to flow, when the uterus, like all the other solid parts of the body, has acquired so great a degree of hardness, as cannot be overcome by the force of the heart propelling the arterial blood. This hardness in the uterus, in the arteries and ovaries, is shewn by the knife and by injections. Animals in general have no menses; on account of their uteri being membranous rather than fleshy, and if the firmness of their vessels, which is so great, that in these animals no hemorrhage, either from the nostrils, or any other part, ever occurs. In men they do not occur, because in their pelvis there is no spongy organ fit for retaining the blood; and because the arteries of the pelvis are both harder and smaller in proportion than the veins, and thus the impetus of the blood is turned aside into the lower extremities, of which in men, the growth is greater, as that of the pelvis is less.

DCCCLXII. Why do the breasts swell at the same time? Their fabric in many respects is analogous to that of the uterus; as appears from the secretion of the milk in the breasts, which succeeds the birth of the foetus, and which increases or diminishes in proportion as the lochial flux diminishes or increases; from the similitude of the serous liquor, found in the uterus, to the thin whitish milk, in those, who are not lactescent, which is very apparent in animals; and from the erection of the nipples by friction, analogous to the erection of the clitoris. Therefore, the same causes which distend the vessels of the uterus, likewise determine the blood more plentifully to the breasts; the consequence of which is an increase of the conglomerate gland of the breast, and of the surrounding fat.

CHAP.

## C H A P. XXIX.

## CONCEPTION.

DCCCLXIII. **W**E now enter upon a very difficult subject ; to investigate what internal changes take place in woman, when the germination of the life of a new being begins within her, whom, in proper time, she is to bring forth. We shall relate, in the first place, therefore, those things which observation has proved ; and then shall add those hypotheses by which learned men have endeavoured to supply whatever is not learnt from experience. How few things are ascertained on this subject, and how difficult they are to be ascertained, I have learned too much by experience.

DCCCLXIV. That some light may appear amidst this darkness, we shall begin with the most simple animals, and afterwards notice what nature has added in others whose fabric is more compounded. The smallest animals then, which have very few or no limbs, very little distinction of parts, very short period of life, the vital functions both few and very similar to each other ; these animals bring forth young ones like themselves, with no distinction of sexes, all of them being fruitful, and none fecundating the rest. Some of them exclude their young whom they have conceived in their bodies, through some opening in their bodies ; from others, some limbs fall off, which are completed into animals of a kind similar to those from which they have fallen. This kind of generation is extended very widely, and comprehends the greater part of animal life.

DCCCLXV. The next, which are a little more compounded, all parturiate ; yet in such a manner, that in their bodies is generated a certain particle, dissimilar

similar to the whole animal, and contained in some involucra, within which lies the animalcule that is afterwards to become similar to that within which it is produced; these are called eggs. A great part of these animals is immoveable.

DCCCLXVI. The animals which follow, which are not indeed numerous, have both eggs and also male semen; so that both sexes are joined in the same individual. By the male semen we understand that with which it is necessary for the eggs to be sprinkled, in order to become prolific, although alone it never becomes a new animal. In this class, therefore, a juice is prepared by its own proper organs, which is poured on the eggs generated in like manner, in proper, but different organs.

DCCCLXVII. Those animals are much more numerous which have both a male juice and female eggs; and yet are not capable of fecundating themselves, but stand in need of real venery. For of this kind two individuals concur in the work of fecundation, in such a manner, that each impregnates the other with its male organs, and reciprocally has its female organs impregnated by the male parts of the other.

DCCCLXVIII. And now the nature of animals approaches nearer and nearer to that of the human race; amongst the individuals of which, though in other respects similar, some have only male organs, and these males sprinkle their semen on the female eggs of others. Many cold blooded animals effuse their seed upon the eggs after they are excluded from the body of the mother. Warm animals inject their semen into the very uterus of the female. But now, whether eggs be generated within the body of the female, and the foetuses be produced inclosed in coverings, or whether the female carry the live foetus so long in its uterus, until it produce them without any involucrum; the difference between these oviparous and viviparous animals

imals is so small, that in the same class, and in the same genus, some animals lay eggs, and others live foetuses ; and, lastly, the same animal sometimes lays eggs, and sometimes brings forth live young.

DCCCLXIX. From this review of animals it appears, that all of them are produced from an animal similar to themselves ; many of them from a part of it similar to the whole ; others from an egg of a peculiar structure ; but that all these do not stand in need of male semen. Lastly, the locomotive and more lively animals, having a compound structure, only are endowed with a double system for generation ; and the difference of sexes seems to be added for the bond of social life, and for the preservation of a less numerous progeny.

DCCCLXX. To this effusion of the male juice into the female organs, both sexes are excited by the most vehement desires : the male indeed most strongly ; the female being always ready to suffer the venereal congress, it behoves the male to be animated with a desire of venery, when he has abundance of good and prolific semen. Therefore, this circumstance itself is the greatest cause of venereal desire in him ; but in females, of the brute kind especially, it is a certain degree of inflammation in the vagina, which excites an intolerable itching.

DCCCLXXI. But nature has added, for combining the energy of both, in women and in quadrupeds, to the uterus, a vagina or round membranous canal, very dilatable, which, embracing the mouth of the uterus, (DCCCXLIII.) descends downwards, and then downwards and forwards, lying under the bladder, and resting upon the rectum to which it adheres, and, lastly, opens under the urethra with an orifice a little contracted. ( This orifice, in the foetus and in virgins, is protected from the action of the air or water, by a remarkable valvular fold, denominated the hymen, formed of the skin and cuticle of the vagina, probably for some moral purpose, as  
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amongst all the animals I have examined, it exists only in the human species. It would be circular, if it were not incomplete under the urethra and even there it is not always deficient; toward the anus it is broader. Being gradually worn away by copulation, and lacerated, it at last disappears. The caruncles, which are called myrtiformes, are partly the remains of the lacerated hymen, and partly the indurated extremities of the columnæ of the vagina; and, lastly, the valves of the mucous lacunæ hardened into a kind of flesh.

DCCCLXXII. The fabric of the vagina in women is cutaneous, and is composed of a firm callous cuticle, and a thick, white, nervous skin, in which, more especially at its extremity, fleshy fibres appear. Its internal surface is, in a great measure, rough with callous verrucæ, which, though hard, are sensible, and with inclined laminæ, terminated by a projecting edge, pointing downwards, and arranged so that they are collected into two principal columns, studded as it were with these verrucæ, of which the uppermost and largest is extended under the urethra, and the lowest is incumbent on the anus. From each of these, a valvular series of smaller papillæ, variously inflected into arches, is continued till they mutually meet on both sides. This fabric seems to be designed for the purposes of enjoyment, and for facilitating its expansion. It is furnished with a peculiar mucus, from sinuses situated all over it, but more especially in its posterior and smoother side.

DCCCLXXIII. At the entrance of the vagina are prefixed two cutaneous appendages, called nymphæ, continued from the cutis of the clitoris, and from its glans itself, full of intermediate cellular substance, of a distensible fabric, jagged and furnished on both sides with sebaceous glands, such as are also found in the folds of the prepuce of the clitoris. Their chief use, it is supposed, is to direct the urine, which

which flows betwixt them from the urethra, so as to turn it off from the body, which office is attended with a certain erection of the nymphæ. These membranes descend from a cutaneous arch surrounding the clitoris, which is a part extremely sensible, and wonderfully prurient, and, like the penis, is composed of two cavernous bodies, arising from the same bones, and joined together, but without including any urethra. It is furnished with blood-vessels, nerves, and levator muscles, and a ligament sent down from the synchondrosis of the ossa pubis, analogous to those in men: and in like manner from venery, the clitoris grows turgid and erect, but less in modest women; but from friction always.

DCCCLXXIV. The muscle, termed *ostii vaginae constrictor*, arises on each side from the sphincter of the anus, and being increased by an accession from the os ischium, covers the vascular plexus, and proceeds broadly forwards, along the beginning of the labia externa, and is inserted into the crura clitoridis; it seems to compress the lateral plexuses of the vagina, and to retard the return of the venous blood in both ways. The transverse muscle of the urethra, and the bundle from the sphincter inserted into it, have the same situation as in men.

DCCCLXXV. The female being invited either by moral love, or the desire of pleasure, admits the male, whose penis being introduced into the vagina, is rubbed against its sides, until the male semen is ejected and thrown into the uterus. Thus, as we have observed of the male, (DCCCXL.) the friction of parts so tender and exquisitely sensible, excites a convulsive constriction of all the parts surrounding the vagina. By these means, the return of the venous blood being suppressed, the clitoris, both the nymphæ, and the plexus surrounding almost all the vagina, become turgid, more especially  
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in libidinous women ; the pleasure is raised to the highest pitch : and, lastly, though not always, or in all women, there is expelled, by muscular force, (DCCCLXXIV.) a mucous lubricating liquor of various origin. The principal sources of this are, in the first place, in the entrance of the urethra, where large mucous sinuses are placed in the tumid extremity of this uriniferous canal. Then, at the sides of the urethra, in the bottom of the sinuses which are formed by the membranous valves being concave upwards, two or three large mucous sinuses penetrate into the substance of the urethra itself. Lastly, at the sides of the vagina, betwixt the bottoms of the nymphæ and the hymen, there is one opening, on each side, from a very long duct ; which, descending towards the anus receives mucus from small follicles.

DCCCLXXVI. But, by the same action which increases the pleasure to the highest degree, and, therefore, causes a conflux of blood to the whole genital system of the female, (DLXIII.) a much more important change is produced in the internal parts of the female : for, when the hot semen of the male penetrates into the sensible cavity of the uterus, which is itself turgid and heated with influent blood, the Fallopian tubes at the same time swell, being very full of distended vessels, creeping betwixt their two coats, and now filled with a very great quantity of blood. In this state, these tubes become red and rigid, and the fringed mouth of the tube ascends, and is applied to the ovarium. All these changes are confirmed by dissections of women, and other animals, and by morbid cases.

DCCCLXXVII. But, in a female of ripe years, the ovary is extremely turgid, with a lymphatic coagulable fluid, with which the vesicles are distended. In a prolific copulation, some one of the riper of these vesicles bursts, and opens with a manifest cleft, and at length effuses a clot of blood. Within this vesicle,

vesicle, after copulation, a kind of flesh is formed, at first flocculent, then granulous, and like a conglomerate gland, consisting of many acini joined together by cellular substance; which, by degrees, becoming larger and harder, fills the whole cavity of the vesicle, and is indurated till it acquire a scirrhous appearance, in which, for a long time, a cleft, or the vestige of one, remains. This is the corpus luteum, common to all warm blooded quadrupeds, in which some late anatomists have asserted, that there is a fluid before defloration; which, however experience does not admit, since there is no corpus luteum at that age. Nor is the vesicle, which becomes the human ovum, contained in the corpus as in a calyx.

DCCCLXXVIII. Moreover, in a prolific congress, the tube, compressing the ovarium, is supposed to express through a fissure in the outer membrane, a mature ovulum, and to absorb it, and then to transmit it to the uterus by a peristaltic contraction, which begins from the first point of contact, and gradually forces the ovulum towards the uterus, as is very manifest in animals. The truth of this is certainly supported by the fissure produced in the ovarium after conception; by foetuses being certainly found in quadrupeds and in women, both in the ovarium and in the tube; and by the analogy of birds, in which the descent of the ovum from the ovarium is very manifest. Yet we must acknowledge, that a true ovum was never found, with certainty, in quadrupeds, unless after a long time. It is probable, that at the time of conception, the true ovum being almost fluid, very soft and pellucid, cannot be distinguished from the mucus with which the tube is filled; likewise, that it is very small, on account of the narrowness of the tube. The vesicle itself which was in the ovary, remains fixed in it, and becomes the covering of the corpus luteum. But the accounts of ova,  
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said to have fallen from women during the first days, are not certain, and are contradicted by the smallness of the foetus observed many days after conception; by the shape which it was first observed to have, which is always oblong, and in brutes even cylindrical; and likewise by the smallness of the tube.

DCCCLXXIX. These things are performed with pleasure to the future mother, and not without a peculiar sensation of internal motion in the tube, and of a tendency to faint. Neither is the place of conception in the uterus, into which accurate experiments show that the male semen reaches. For the power of the male semen fecundates the ovum in the ovarium itself, as is proved by the foetuses being found in the ovaries and tubes; by the analogy of birds, in which, by copulation, one egg indeed falls into the uterus, but many are fecundated at once in the ovarium. Nor is this inconsistent with the small quantity of the male semen, or its sluggish nature, which, by eminent anatomists, has been thought unadapted for performing such a journey. For it is certain, that the male semen has filled the tubes themselves after recent impregnation, both in women and other animals.

DCCCLXXX. The uterus indeed, certainly in animals, and in women probably, is closed after conception, lest the very small ovum, together with the hope of the new progeny, should perish. At that time the new mother suffers many disagreeable affections, which probably arise from the absorption of the subputrid and subalkaline male semen. Conception, almost like the swallowing some rancid egg, causes nausea, especially of flesh meat, vomiting, the eruption of some pustules, and pains in the teeth. The greater inconveniences I ascribe to the swelling of the uterus, compressing the viscera  
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of the abdomen, and to the retention of the menses.

DCCCLXXXI. What we have hitherto stated, can certainly be confirmed or corrected by the testimony of our senses. What follows is more conjectural, and more difficult, on account of the paucity of experiments, and their little agreement with each other. And, in the first place, it is a difficult question, from whence do the rudiments of the new animal proceed? Are they derived from both parents, and mixed into one animal by a conjunction of seminal matter coming from the whole body; as indeed there is a resemblance of the fœtus to both parents in animals, but especially in plants, as confirmed by numerous experiments, and as the diseases of parents are propagated to their children. But no semen has ever been observed with certainty in females; and innumerable examples of animals show, that the species may be propagated without any mixture of seeds. Lastly, the resemblance to the father seems only to show, that in the male semen there is some power, which can influence the form of the soft substance of the very minute embryo, just as the same power adds length to the pelvis in the body itself, dilates the larynx, and causes the horns to grow.

DCCCLXXXII. To the father some have attributed every thing; chiefly after the seminal worms, now so well known, were first observed in the male semen by the help of the microscope, which are observed, with truth, to agree in figure with the form of the first embryos of all animals. But these animalcules are not proportionate to the number of the fœtuses, and are not perpetual in the different tribes of animals; and they have too great a resemblance to those animalcules that are every where produced in other juices, which, though always tenacious of their own genus, are never found to grow  
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up into a totally different kind of animal, possessing limbs.

DCCCLXXXIII. Again, other anatomists, not less celebrated or less worthy of credit, have taught that the foetus existed in the mother and maternal ovary; that the male semen excites it into a more active life, and likewise influences it variously, but that it finds it already existing and present. For yolks are manifestly found in the female ovary, even although they have not been subjected to any male influence. But the yolk is an appendix to the intestine of the chick; and derives its arteries from the mesenteric artery, and the membrane of the yolk is continued from the nervous membrane of the intestine, which is continuous with the skin of the animal. In the hen, therefore, the foetus seems to be present along with the yolk, which is a part of it, and receives vessels from it. Lastly, the analogy of nature shows, that many animals generate eggs without any connection with a male of the same species, but that no male animal is ever prolific without a female. There is a continued progression from the female quadruped to the oviparous, and from that to the non-oviparous. But the old animal produces the new one from part of itself. It is therefore certain, that the male is an appendage to that sex which produces the foetus from its own body; which addition is necessary in some tribes of animals, but in the greatest number, and most fruitful, may be wanted. Nor can any kind of ingrafting be admitted with any degree of probability, by which the dilated navel of the male-born animal should cohere with the vessels of the female. For this navel is much too small at the time when the yolk is of considerable size; nor could the very small umbilical arteries be applied to the very large yolk with any hope of a continuance of the circulation.

DCCCLXXXIV. Thus much concerning the materials. But there is as much difficulty concerning the means by which the rude and shapeless mass of the first embryo is fashioned into the beautiful shape of the human body. We readily reject such causes as the fortuitous concourse of atoms, the blind attractions of nutritive particles, and the action of ferments inconscious of their effects. The soul is certainly unequal to the task of producing such a beautiful fabric; and internal moulds, of which I never could conceive any clear idea, are to be referred to those hypotheses which the desire of explaining those things, of which we are unwillingly ignorant, has produced.

DCCCLXXXV. To me, indeed, the test of experiment seems to coincide with those things which the mind itself foresees will arise from their own causes. For hence, indeed, it appears to me certain, that the beautiful structure of animals, so various, that it is always perfectly adapted to the proper and distinct habits and functions and manner of life of each; calculated by rules more perfect than those of human geometry, and most evidently accommodated to foreseen purposes, in the eye, the ear, and the hand, and finally, every where; can be ascribed to no cause below the infinite wisdom of the Creator. Again, the more frequently, and the more minutely, we observe the long series of increase through which the shapeless embryo is brought to the perfection necessary for animal life, the more certainly does it appear, that those things, which are observed in the more perfect foetus, existed in the tender embryo, although the situation, figure, and composition, seem at first exceedingly different from what they appear at last; for an unwearied and laborious patience discovers the intermediate degrees by which the situation, figure, and symmetry, are insensibly corrected. Even the transparency of the primary foetus alone conceals many things, which  
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the colour afterwards added does not generate, but renders manifest to the eye. And it sufficiently appears that those parts, which eminent anatomists have supposed to be generated at a later period, and to be added to the primeval ones, were connate with these, though small, soft, and colourless.

DCCCLXXXVI. It does not seem improbable, that the embryo, lying dormant during a long period, neither increases, nor is agitated, except by a very gentle motion of the humours, which we may suppose to oscillate from the heart into the neighbouring arteries, and from these back again into the heart. But it is also probable, that the stimulus of the male semen excites the heart of the foetus to greater contractions; so that it insensibly evolves the complicated vessels of the rest of the body by the impulse of the fluid, and propagates vital motion through all the canals of the animal embryo; more quickly into some parts, and more slowly into others; and that from thence it happens, that some parts of the body of the animal seem to be produced very early, and others to supervene afterwards; and lastly, that some do not shew themselves until a long time after birth, as the vesicles of the ovaries, the vessels of the male testicles, the teeth, hairs of the beard, and horns of animals. In all animals, heat assists this evolution; in the more simple ones, whose vessels are few, and less complicated in the variety of their origin, it alone effects it.

DCCCLXXXVII. Of the objections which are usually brought, some are not true, as the difference of structure caused by *nævi*; others seem to belong to causes depending on some accident, such as most instances of monsters; some to the increase of some particular parts, occasioned by the powers of the male semen; some to the cellular texture variously relaxed, so that it seems to form new parts; some to indurated juices. Although it is not easy to explain every thing mechanically, yet we ought to remem-

ber, that if indeed the new animal actually, and according to observation, exists in the egg, those difficulties which are made cannot overturn things which have been truly demonstrated, although perhaps some things may remain, to which, in the present infancy of human knowledge, we cannot yet give a satisfactory answer.

DCCCLXXXVIII. Some days after the human ovum is brought down into the uterus, we become more sensible of its changes. The ovum itself sends out, from every part of the surface of its membrane hitherto smooth, soft branchy flocculi, which adhere to and inosculate with the exhaling and absorbing flocculi of the uterus (DCCCXLIII.) This adhesion takes place in every part of the uterus; but chiefly in that thick part which lies between the tubes, and is commonly called the fundus uteri. Thus, the thin serous humour of the uterus, proceeding from its arterial villi, is received into the slender venous vessels of the ovum, and nourishes it together with the fœtus. Before adhesion, it is either nourished by its proper fluid, or by absorption, if indeed there is a time when it does not adhere.

DCCCLXXXIX. At this time, in the ovum, there are contained a great proportion of a watery fluid, coagulable by heat or alcohol, and limpid, and the fœtus, which is long invisible, as I have never observed it before the 17th day, at first a shapeless mass, consisting of mere mucus, and then cylindrical. When now some distinction of parts succeeds, it has a very great head, a small body, no limbs, and is fixed by a flat ample navel to the obtuse end of the ovum.

DCCCXC. From this minuteness the ovum increases in size, and also the fœtus, but in unequal proportions; for while the arterial serum is conveyed by passages, gradually more open, into the vessels of the ovum, the fœtus itself grows the fastest, to which the greatest part of the nourishment seems to pass  
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through the very large umbilical vein. At the same time, the ovum itself also grows, but slower, so that the proportion of the ovum, and the waters which it includes, to the foetus, is perpetually diminishing. The flocculi of the ovum gradually diminish and occupy a smaller portion of the ovum, and are insensibly spread over with a continuous membrane, and only those which sprout out from the obtuse end of the ovum increase, and are by degrees formed into a round circumscribed placenta.

DCCCXCI. Such is the appearance of the ovum in the second month; and after that period, it changes only in bulk. That portion of the ovum, in its upper part, next the uterus, making about a third of its whole bulk, consists of a round, flat, succulent, fibrous, tuberos and perfectly vascular disc, changed into equal and similar tubercles, accurately, and often inseparably connected, generally with the uppermost part of the uterus remarkable for its large vessels, by thin cellular substance without fat collecting the vessels, both generally, but chiefly in the circumference of the greatest circle, and also by the exhaling arteries of the uterus, answering to the veins of the placenta, and by the arteries of the placenta, inosculating with the large veins of the uterus. There, in the surface common to the uterus and placenta, a communication exists, by which the uterus transmits to the foetus, both that serous liquor not unlike milk, and lastly, as it seems, blood itself. This communication of fluids between the uterus and placenta, seems to be demonstrated by the suppression of the menses in pregnant women, whose blood must be turned into another channel; from the loss of blood which follows from the separation of the placenta, especially in a miscarriage; and from the blood of the foetus being exhausted by hæmorrhagies from the mother; from hæmorrhagies that ensue from the unsecured navel-string, while the placenta remains in the uterus, killing the  
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the mother ; and, lastly, from the passage of water, quicksilver, tallow, or wax, from the uterine arteries of the mother into the vessels of the placenta, as observed, and lately confirmed by eminent anatomists. But that it is blood which is sent into the foetus, is evinced by the magnitude of the sinuses of the uterus and placenta ; the diameter of the serpentine arteries of the uterus ; the hæmorrhagy that follows the separation, even the most gentle, of the placenta, and especially by the motion of the blood, which, in a foetus destitute of a heart, could only be given to the humours of the foetus by the blood of the mother.

DCCCXCII. The remaining part of the body of the ovum, and likewise the convex surface of the placenta, are covered by an external membrane, which is villous, flocculent, reticulated, porous, easily lacerable, and vascular, resembling a fine placenta, and is called the chorion. This also is connected to the flocculent and very similar but softer surface of the uterus, by vessels smaller than those of the placenta, but manifestly inosculated from the chorion into the vessels of the uterus.

DCCCXCIII. Under the chorion lies a continuous white, opaque, and firm membrane, not vascular, which does not cover the part of the placenta contiguous to the uterus, but its concave surface contiguous to the foetus. It coheres by cellular texture both with the chorion and amnios. The most simple name we can give it, is the middle membrane.

DCCCXCIV. The innermost coat of the foetus, the amnios, is a watery pellucid membrane, very rarely having any conspicuous vessels, which, however, I have observed even in the human subject ; extremely smooth, and in all parts alike ; also extended under the placenta along with the former, and every where in contact with the waters. If there be more foetuses than one, either in woman or  
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in any other female, each of them has its proper amnios.

DCCCXCV. The nourishment of the foetus from the beginning to the end of the conception, is without doubt conveyed through the umbilical vein. This gathering its roots from the exhaling vessels of the uterus, (DCCCLIV.) and from the umbilical artery, with which it is manifestly continuous, and forming venous sinuses under the surface of the placenta, unites into a large trunk, which being twisted in various folds, but less than its corresponding arteries, and being of sufficient length to allow of a free motion; surrounded with cellular substance full of mucus; separated by three partitions, and by the membrane which is continued from the amnios, but firmer, and known by the name of the umbilical rope; and swelling into several knots, enters the navel between diverging arches of the skin and abdominal muscles, and proceeding to a proper sinus of the liver, (DCXCII.) sends the smaller portion of its blood through the ductus venosus, which is small and seated in the posterior fossa of the liver, to the vena cava; and transmits to the heart the greater part through the large hepatic branches which constantly arise from its sulcus, and remain even in the adult, (DCXCV.) and through the branches of the cava, (DCXCVII.) continuous with these. The sinus of the vena portarum, or left branch, is also a part of the umbilical vein, and its branches bring the blood from the placenta to the cava, while the right branch alone (DCXCV.) carries the mesenteric and splenic blood through the liver.

DCCCXCVI. But this is not the only use of the placenta: for the foetus sends great part of its blood to the placenta, through two very large umbilical arteries, which are the continuation of the aorta; and after giving off slender femorals, and very small arteries into the pelvis, they ascend reflected along  
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the bladder, surrounded by the cellular plate of the peritonæum, and some fibres separated from the bladder and urachus, and on the outside of the peritonæum enter into the umbilical cord, in which, alternately straight and contorted, with various windings, somewhat sharper than those of the vein around which they play, they arrive at the placenta, whose substance is entirely made up of their branches, and the corresponding veins, and lubricous cellular substance accompanying both vessels; so that the acini themselves, conspicuous in the placenta, are convolutions of vessels. This blood seems to pass out through the arterial vessels of the placenta into the bibulous veins of the uterus, so that after undergoing the action of the lungs of the mother, it returns ameliorated to the foetus: For what other reason can be assigned for such large arteries, which carry off above a third part of the blood of the foetus?

DCCCXCVII. Is the foetus also nourished by the mouth? Does it drink from the cavity of the amnios, the lymphatic lubricating liquor, which is coagulable, unless when putrid, in which the foetus swims, and whose origin is not sufficiently known? Is this opinion confirmed by the analogy of chickens, which are necessarily nourished from the contents of the egg only; by the absence of a navel-string in some foetuses; by the meconium filling the large, and part of the small intestines; by the liquor found in the stomach of the foetuses of birds, and even of the human species, similar to that which fills the amnios; by the proportionable decrease of the liquor amnii, to the growth of the foetus; by coagulated fibres, found continued from the amnios, through the mouth and gullet, into the stomach of the foetus; by hairs and true faeces being found in the stomach of the foetuses of quadrupeds; by the open mouth of the foetus, which we have certainly observed; the gaping of the chicken, swimming in this liquor, and its attempts as if to swallow it?

What

What are the sources of this lymph of the amnios? Does it transfuse through the invisible vessels of the amnios? Is it transmitted to it through certain pores from the succulent chorion, which is itself supplied from the uterus? On every point, numberless difficulties occur; but it seems more probable, that this liquor is nutritious, especially in the early stages of the foetus, and that it is derived from the uterus.

DCCCXCVIII. The excrements of the foetus are collected during that whole time in small quantity, on account of the great tenuity of the nutritious fluid, percolated through the very small vessels of the uterus. I frequently observe, that the bladder is almost empty in the foetus. However, there is generally some quantity of urine, collected in the large and very long urinary bladder. But in a great portion of the intestines, there is collected a green pulp, possibly the remains of the exhaling juices; for I have seen a similar substance in other cavities, that are filled with exhaling juices, and in the vaginal coat of the testicle.

DCCCXCIX. Is there, then, no allantois? since it is certain, that from the top of the bladder the urachus passes out, which is a tender canal, at first broad, covered by the longitudinal fibres of the bladder as with a capsule; and afterwards, when those fibres have receded from it, it is continued slender, but hollow, for some way along the umbilical cord; in which, however, it vanishes. Are not the other parts, though not yet seen in the human species, supported by the very strong analogy of brute animals, which have both an urachus and an allantois? But a proper receptacle, continuous with the hollow urachus, so large in quadrupeds, has not yet been observed in man with sufficient certainty, or not sufficiently often; and those eminent anatomists, who have observed a kind of fourth vessel, continued along the umbilical cord into a proper vesicle, do not consider that vessel to be the  
urachus,

urachus, and very lately have referred it to the omphalomesenteric genus; and in the human foetus, the urine is separated in a very small quantity: nor perhaps would it be an improbable conjecture, that some portion of the urine is conveyed from the urachus into the funiculus umbilicalis, and its spongy cellular fabric, and there effused; and therefore, that, of all animals, man has the longest umbilical cord, because he alone has no allantois. It is certainly short, and enters into the cord, but does not seem to reach the placenta. Sometimes, in the adult, it has remained open, and has contained urine even as far as the navel.

cccc. In the mean time, the foetus grows; the tubercles of the limbs gradually shoot from the trunk; and the further most beautiful evolution of the child advances to perfection, in a manner which cannot be described here, and not yet sufficiently by anatomists; of which, however, we must premise a short account.

dcccl. The embryo which we first saw in the uterus of the mother, was gelatinous, having scarcely a definite form, of which one part could not be distinguished from another. There was, however, in that gluten, a heart, the source of life and motion; there were vessels which generated the liquor of the amnios; there were therefore umbilical vessels, and the trunks of the yolk, which it receives from the foetus, are largest when they first become visible. There was both a head and spinal column, each of them very large, and larger in proportion than at any other time. There were likewise, without doubt, the rest of the viscera, but in a mucous and pellucid state; for which reason, they may be observed sooner than is to be expected naturally, by rendering them opaque.

dccclii. But in every part of the foetus, a very large proportion of water is mixed with a very little earth, so that the very cellular texture is in an intermediate

intermediate state between fluid and solid; from large drops of water being interposed between distant solid elements.

DCCCCIII. In birds, besides this living gluten, there is the albumen, which is of a lymphatic nature; and the yolk, which is oleaginous: in man, there is a lacteous fluid, not very unlike the yolk, and coagulable lymph. That the blood is prepared from the fat by the proper powers of the foetus, we are persuaded from the example of birds. From it, are gradually prepared the other humours, and all of them are at first mild, void of taste, colour and smell, and of a glutinous nature. The peculiar nature of each supervenes, at a later period, in some of them not till many years after birth, for instance in the semen.

DCCCCIV. The elementary solids, even in the adult, constitute much the smallest portion even of the harder parts of the human body; in the foetus they differ from the fluids, only by a somewhat greater degree of cohesion, resembling, as yet a gluten, at first fluid, and afterwards of greater consistence. In this, the fibres, of which none were to be distinguished in the primeval embryo, are by degrees produced, by the gluten, as it seems, being compressed between the neighbouring vessels, part of the water expressed, and the earthy elements attracting each other. These fibres variously comprehend one another, and form cellular texture, even morbidly, and intercept little spaces, in which a fluid is contained. Of this cellular substance, are formed the membranes and vessels, and almost the whole body.

DCCCCV. The vessels are prior, and exist, formed in the first appearance of the embryo. What first appears distinct, and formed in an egg during incubation, are venous circles: but these veins suppose arteries, by which they both receive their fluid, and the motion of that fluid. They are not generated  
mechanically,

mechanically, from any obstacle to the course of the arterial blood. The trunks of the veins are first visible, and afterwards the branches which lead to these trunks. If they were produced from reflected arteries, the branches would first be seen, and the trunks formed in the last place. Nor could the arterial blood, if repelled by an obstacle, form those most beautiful circles, and vessels returning into the heart; but it would rather be irregularly diffused through the cellular texture. And the primeval heart would soon lose its vitality, unless as much fluid returned to the heart by the veins, as was sufficient to maintain its pulsations.

DCCCCVI. There are, therefore, in the primeval fœtus, when it first becomes visible, some things more perfect and conspicuous; others involved, invisible, and very small. The heart is the most perfect, and the only moveable and irritable part; although it is in many respects different from what it is in the adult. The brain is large and fluid; the vessels formed, which appear in the back, next to the heart. We cannot yet distinguish the viscera, muscles, nerves, limbs; the bones themselves, of which the first appearance is mucous, or the vessels of the rest of the body. The other portion is the abdomen, of which the umbilical capsule is an immense hernia.

DCCCCVII. To this embryo is superadded motion, in man almost of the heart alone; and also in birds, whose formation does not take place without a heat rather greater than that of the human body: yet, without the heart, heat destroys, instead of forming the fœtus. The heart is proportionally largest at the very first, and afterwards decreases more and more in comparison with the rest of the body. Its pulsations are also at this time very frequent, and in the very soft fœtus extremely powerful, in impelling the humours, and distending and producing the vessels.

DCCCCVIII.

DCCCCVIII. To the force of the heart is opposed, what nevertheless is of service in the formation of the foetus, the viscidty of the vital humours which unite the earthy elements. There is therefore in the embryo both an impelling force, which increases the longitudinal growth ; and a resisting force, which moderates that increase, and increases the lateral pressure, and thus the distention. By the force of the heart all the arteries, or for easiness of expression the artery, which represents all the rest, with all the surrounding cellular texture, is lengthened out ; its folds are smoothed out. It is also dilated. And the blood by its lateral pressure makes an effort against the almost impervious branches of the arteries, fills and involves them, and sets them off at more obtuse angles : thus are produced spaces, having little resistance, into which the gluten is deposited. In the very substance of the artery, while it is every where dilated, between its imaginable solid threads, are prepared little reticulated spaces like the interstices of a distended net, which are also adapted for receiving humours. These are larger round the heart and in the head, whither the impulse of the heart is more direct, and in the placenta : they are smaller in the inferior part of the body, from which the umbilical arteries subtract the greatest part of the blood.

DCCCCIX. The foetus increases very quickly, as is most evident in the example of the chick in ovo, whose length on the twenty second day is to its length the first day at least as 1,000,000 to 1 ; and the whole increase of bulk in the bird during the remainder of its life does not exceed the fifth part of its increase in the egg during the first day. For the foetus has a larger and more irritable heart, vessels larger in proportion, and likewise more numerous and relaxed, and its solid parts are mucous and distensible. The breast is later formed, and  
surrounded

surrounded with membranes so soft, that they cannot be seen.

DCCCCX. The embryo does not only increase in bulk, but is remarkably altered in every particular, so that it is brought forth totally dissimilar from what it was, when it first became visible. And first it is probable, that from the production of the arteries of the limbs, the limbs connected to the sides by some gluten are separately evolved, and that at first they sprout out very short, but afterwards become gradually longer, and divided into distinct articulations, as the wings of a butterfly are expanded by the extension of a network of vessels. Thus likewise the right ventricle of the heart is expanded by the blood coming to it in greater quantity; and, being increased by degrees, becomes equal to the left.

DCCCCXI. On the other hand, the cellular texture, from its glutinous aqueous nature, becoming gradually harder by the addition of earthy particles; by a gentle attraction contracts the parts, which were before straight, into various flexures; and unites the auricles to the heart, from which they were hitherto separate. Thus the muscles, by their action, draw out the processes from the bones, and dilate the small cavities into large cells: and likewise incurvate the bones, and variously modify their shape.

DCCCCXII. Pressure has much influence: to it is attributed the descent of the testicles into the scrotum, after the abdominal muscles acquire irritability; to it the repulsion of the heart into the breast, when the integuments of the breast become larger: to it also the lengthening of the breast, the shortening of the abdomen, and the lessening of its viscera, when the air received into the lungs dilates the cavity of the thorax. But even the bones are variously depressed by the pressure of the muscles, blood-vessels, and even of the very soft brain itself;  
and

and by the same means flesh is changed into tendon.

DCCCCXIII. The power of derivation brings the blood into the pelvis and lower extremities, from the closed umbilical arteries : when the foramen ovale is contracted by the auricles drawn towards the heart, it evolves the right ventricle of the heart : when the vessels of the yolk have occupied the whole length of the egg, and can receive no further elongation, it dilates the umbilical arteries of the chick, and produces a new membrane with incredible celerity. On the contrary, but by the same power, after the blood has acquired a new facility of admission into any vessels, the other parts, to which its passage is not equally easy, increase less quickly. The growth of the head is slower after the lower limbs have begun to increase.

DCCCCXIV. By the evaporation of the thinner part of a fluid, a membrane may be formed, as in the example of the epidermis : or cartilage, as happens in the bones : or bone itself, or something of a stony nature, which happens very frequently in the shells of aquatic animals. The bones at first are soft, and of a mucous nature ; then they acquire the consistence of jelly ; and this afterwards becomes a cartilage, without any change of parts, as far as can be observed.

DCCCCXV. Cartilage, however, is not so imperceptibly converted into bone. It never happens, without lines and furrows having previously marked the cartilage ; without the red blood making a passage for itself into the vessels of the bones ; without these vessels manifestly penetrating from the nutritious trunks into the interior of the bone, and impinging as it were in right lines on the cartilaginous extremity of the body of the bone, which they remove farther and farther from its middle. Round these vessels are formed cellular texture and laminae, which the vessels themselves seem to compress into

into a medullary tube. Lastly, in the epiphysis, which both remains cartilaginous, and denies entrance to the blood much longer, the red vessels penetrate through the extreme crust, as also others which come from the exterior vessels of the limbs. Thus also in the epiphysis is produced a red vascular nucleus, which, being gradually increased by vessels sent out from its surface, converts the rest of the cartilage into a bony nature.

DCCCCXVI. In these long bones, it seems evident, that their growth is owing to the arteries being elongated by the force of the heart, and gradually extended to the extremities of the bones: and that the hardness is owing to grosser particles, deposited in the cartilage, after its vessels have admitted the red blood. But even a bony callus never becomes found, till newly formed red vessels have penetrated its substance.

DCCCCXVII. The flat bones originate from a kind of membrane. Over this, the fibres spread themselves, at first in a loose network, and afterwards more densely, having a membrane for their basis; the pores and intervals between these fibres being gradually contracted and filled with a bony juice, at last convert it into perfect bone. In these bones also, straight red vessels, are distributed between the fibres.

DCCCCXVIII. The phenomena of the formation of callus, prove, that, between the primeval fibres, an osseous fluid, replete with grosser particles, is deposited, as it exudes in small drops, not from the periosteum, but from the inmost substance of the bone, and gradually becomes indurated. But even chemical analysis extracts that gluten from the bones; and in ankylosis, it appears poured around in the manner of consistent fluid, and manifestly fills up the chinks of the bones and intervals of the sutures. It contains gross earthy particles, which have been discovered by various experiments; and the juice  
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of madder adhering to it, manifestly distinguishes it by its colour.

DCCCCXIX. The periosteum covers the bones, as membranes the viscera; and from it cellular productions follow the interior vessels of the bones: but the periosteum has neither straight fibres, nor the habit of alveoli or laminæ, nor red vessels, while the bone in the egg is indurating; nor does the periosteum at all adhere to the bone, except in the epiphysis, when its bony nature is spreading from the middle; and it is thinnest when the bone is in a cartilaginous state, afterwards it becomes every where complete. In the flat bones, it every where affords a basis for the bony fibres.

DCCCCXX. Therefore the head is large, every where membranaceous, and, in the first days of gestation, cartilaginous in few places, the mouth deep, and the jaws long; also, in the mature foetus, there are the rudiments of the teeth, to which a great deal of membrane is attached: the brain is at first fluid, and always soft; it is also large; and the nerves are large: the eyes are large, and the pupil is shut by a membrane: the breast is very short, but expansile, on account of the great quantity of cartilage: the belly is large, and inclosed with membranes: the liver very large: the bile is inert and mucous: the intestines are slowly irritable, and, when the foetus is ripe, are full of green soft faeces: the kidneys are divided into lobes, and large, and renal capsules very large: the pelvis is very small, so that the ovaries, the bladder, and Fallopian tubes project above it: the genital system is dense, not yet evolved, or secreting its fluids: all the glands are large, especially the conglobate glands, and full of serous fluid: the skin is at first pellucid, and afterwards covered with a soft cuticle, and sebaceous ointment: the fat is gelatinous, and afterwards grumous: and the tendons soft, succulent, and not yet shining.

DCCCCXXI. There is a great difference betwixt the circulation of the blood in the foetus and in the adult : that this may be understood, it is necessary to describe the organs by which it is preformed. The first is the thymus, a soft loose gland, consisting of many lobes, collected into two larger upper processes, and two inferior shorter ones, which are, however, joined together by a great deal of long and lax cellular texture : this gland is large in the foetus, and occupies a great part of the breast : it is seated in the cavity of the mediastinum, and in part of the neck ; and is wholly filled, in its very inmost structure, with a white serous liquor, which cannot be discovered without wounding it. In the adult, being compressed by the enlarged lungs, and by the aorta now become larger, it gradually disappears. Of the use of this gland or its liquid, we are altogether ignorant ; although all the other glands, especially the conglobate ones, are also larger in the foetus, as we have just now observed.

DCCCCXXII. We have said, that the cavity of the breast is short, being compressed by the enormous bulk of the liver ; the lungs are small in proportion to the heart, and solid so as to sink in water, when completely excluded from the air, by being surrounded with water. Since, therefore, previous to respiration, the lungs cannot transmit so great a quantity of blood as they do in the adult (CCXCII. CCXCVII.) in the foetus there are therefore other ways prepared, by which the greatest part of the blood passes from the umbilical vein and lower cava, into the aorta, without entering the lungs. In the primeval foetus there is no right ventricle of the heart ; and the communication between the right auricle and the left is so large, that all the blood which comes by the vena cava passes immediately into the aorta, a very small quantity excepted, which goes to the very small and invisible lungs. Afterwards, in the foetus, now grown bigger, the lungs are indeed

deed larger, and the passage from the right part of the auricle into the left is narrower, since the auricular canal is now taken entirely within the heart, and the auricles themselves are become much shorter. But yet the septum, which is common to the right and left auricles, is perforated with a large foramen ovale, through which the blood coming from the abdomen, and a little repelled by the valvular margin of the right auricle, (LXXXIII.) flows in a full stream into the left sinus. But by degrees the membrane of each sinus is elevated backwards, and is connected with the pulmonary sinus, above the oval foramen, by an upper fibre on each side, and then by many lower palmated ones in succession, so as to close up at first a small part, and afterwards the greater part of this foramen; so that only a transversely oval oblique passage is left, which remains free betwixt the round margin of the said oval foramen, and the increasing vessel in the mature foetus, equal to about a fifteenth part of the mouth of the vena cava.

DCCCCXXIII. That the blood takes this course, and that no part of it, on the contrary, flows from the left sinus into the right, is consistent with every fact. For, the column of blood in the right sinus is very large; for it is impossible there should be a larger, as it brings back the blood from the whole body; and the left auricle contains less blood than the right, as part of it flows through the ductus arteriosus, whence it is also much less than the right: moreover, the valve in the mature foetus is so large, and placed so much to the left of the isthmus or muscular arch (DCCCCXXII.) that when impelled from the left side, the valve, like a shutter, closes up the foramen; but being impelled from the right side, it readily gives way, and transmits either blood or flatus, and even retains flatus itself, when blown from the right, and does not suffer it to return to the right side.

DCCCCXXIV. Moreover, but a small portion of that blood which entered the right ventricle passes to the lungs: for the pulmonary artery, being in the foetus much larger than the aorta, is continued in a straight line into the ductus arteriosus; which is larger than the joint caliber of both the pulmonary branches, and greatly larger than the opening of the foramen ovale, and which enters into that part of the aorta which first comes in contact with the spine, under its subclavian branch: by which means it transfers more than half the blood of the pulmonary artery to the descending aorta, which must otherwise have passed through the left ventricle into the ascending branches of the aorta; and this is the reason why the aorta in the foetus is so small at its coming out from the heart. By this mechanism, therefore, the lungs are relieved from pressure, and a great part of the blood flows in a more direct course to the umbilical arteries, and the powers of both sides of the heart are united in propelling the blood of the aorta.

DCCCCXXV. Those who have asserted that the foetus respire in the uterus, having made very few observations, have neglected that most easy one which is derived from the water, in the middle of which the foetus swims, and likewise of the lungs, which in a foetus are constantly heavy, and sink in water; and, lastly, the evident shortness of the breast, and smallness of the lungs. Whether it can take in air during its short passage through the vagina, is more difficult to determine; and I suspect, that in a certain situation, a healthy foetus, not too much compressed, may sometimes inspire, while it is in part still impacted between the parts of the mother.

DCCCCXXVI. The uterus increases constantly along with the foetus; the serpentine arteries of which it is composed being extended, and rendered straight, by the blood impelled into them; the veins being  
unable

unable to return the blood into their trunks compressed by the great bulk of the uterus, and swelling out into immense sinuses ; and lastly, the menstrual blood, being retained in the uterus, and not entirely spent on the still small foetus. Its thickness continues the same, because the greater quantity of blood in the arteries and veins compensates for the extenuation of its solid parts. The fundus or upper part, especially, increases ; so the tubes now descend from the middle of the gravid uterus. The uterus, therefore, rises out of the pelvis, even as high as the colon and stomach itself, and compresses the abdominal viscera, and the bladder and rectum. The os uteri in the first months of gestation is drawn upwards along with the uterus, and recedes from the entrance of the vagina : after the third month, however, it again descends and immerses into the vagina. The same becoming perpetually shorter, projects into the impervious extremity of the vagina : for it is constantly becoming more tender ; and, from that cartilaginous hardness which it has in the virgin womb, it is relaxed into a mucous softness. Never perfectly closed together, it is covered and defended from the air by the mucus of the sinuses, and perhaps by that of the vesicles which are seated in the cervix uteri. Finally, the cervix, which remains long unchanged, at length, during the last months of gestation, becomes likewise short, and its opening becomes flat and broad, without length ; and towards the time of delivery, is always more open. At the same time, the foetus increasing, which in the first months had no certain situation, and about the middle of the time of gestation, was often rolled together into a globe, so that the head lay betwixt the knees, sinks its ponderous head more and more into the pelvis, and directs it towards the cervix uteri.

DCCCCXXVII. The various complaints in the uterus are now increased to the highest degree. Being distended

distended by the blood retained in it, all its nerves are irritated; for nothing is more disagreeable to man, than excessive tension, unless it occurs very gradually. From the head of the foetus, sunk into the pelvis, the rectum, bladder, and that part of the uterus next to the neck, and the most sensible, are pressed, and become painful: the foetus, having acquired its full bulk, distends the uterus every way; and with greater uneasiness, because, the waters being now taken away, the projecting limbs, and the head, press much more strongly on the uterus. It is also thought, that the placenta itself, now very large, distends the naked internal surface of the uterus. From these causes, arise at first transient efforts of the irritated uterus, to free itself; and at last, when these causes have got to their utmost height, an uneasy sensation is occasioned by the impacted head of the foetus, like that which arises from a collection of faeces in the rectum; by which pain, therefore, the mother is forced to attempt the birth of the child. The time of delivery arrives at the expiration of nine solar months, and is in the same manner defined in every species of animals, although by particular causes it may be accelerated or retarded for some weeks, provided these causes be ascertained, and their power not extended too far.

DCCCCXXVIII. Tormented by tenesmus, now become intolerable, the mother exerts the whole effort of a very deep inspiration, by which the viscera of the abdomen being forced downwards, press upon the uterus, (DCCLVI.) while, at the same time, the womb itself, being contracted by its contractile force, urges the foetus, so as sometimes to exclude it, without any efforts of the mother. The difficulties of the birth, however, are evidently overcome principally by the efforts of the mother, when the mouth of the uterus, now very soft, suffers itself to be distended by the head of the foetus. For the amnios, filled with water, protruded in the form of a cone,

by

by the head of the foetus, dilates the os internum uteri, becomes extenuated, and distended, and bursts; the waters escape, which lubricate the passage of the vagina, and relax all the parts. Then the naked head of the foetus, with the face turned towards the os sacrum on account of its weight, and being urged forwards, like a wedge, dilates the os uteri; till, by a very powerful effort of the mother, the bones of the pubes being often somewhat loosened with intolerable pain to the mother, and tremor of the whole body, the head is pressed out, and advances through the dilatable vagina, which is not very much compressed by any bone; and the foetus is brought forth, with difficulty even in quadrupeds, but most difficultly in the human race, whose foetus has the largest head.

DCCCCXXIX. It is natural for women to have but one child at a birth, which law they have in common with all the larger animals, except the carnivorous. Frequently, however, they have two, more rarely three, and never more than five. It is not to be doubted, that a second foetus may be conceived, while the first remains in the uterus; since women have frequently born children, in whose uterus a hard and ossified foetus had been long retained.

DCCCCXXX. The placenta, connected with the fundus uteri, (DCCCLXXXVIII.) is generally separated without difficulty in a mature birth, by weaker throes of the mother, and by the art of the midwife. Thus the flocculi of the placenta are drawn out from the villi of the womb, a considerable flow of blood takes place, and the mother is delivered of the secundines. At the same time, the umbilical cord is tied; for it cannot be left open in a healthy and lively child without danger; and is cut. Thus the umbilical vein is deprived of its supply of blood, and an insuperable obstacle is opposed to the arteries of the same name.

DCCCCXXXI.

DCCCCXXXI. The uterus, which hitherto had been excessively distended, now contracts itself by the power of its elastic fibres, (DCCCXLIII.) so suddenly and powerfully, as often to catch the hand of the deliverer, and the placenta, if it be not soon loosened. Thus, the vessels are compressed, also contracting to a less size by their own power; whence the large quantity of blood that was collected in the uterus, is expressed and flows out under the denomination of the lochia; at first pure blood, but afterwards, as the vessels contract themselves more closely, it becomes yellow, and afterwards white; and the extensive wound of the uterus is healed, which soon shrinks to a bulk not much exceeding that of the virgin uterus.

DCCCCXLIV. But two or three days after delivery, when the first violence of the lochial discharge has abated, the breasts swell considerably; and as in the time of gestation they yielded a little serum, they now become turgid, at first with a serous, thin fluid, which is soon followed by the chyle itself. For milk very much resembles chyle, but human milk less than that of other animals. It is white, thickish, sweet, and replete with a very sweet essential salt, grows sour spontaneously, but is tempered by the addition of oil and lymph, and is composed of an odorous volatile halitus, a good deal of fat, water, viscid cheesy matter, and an earthy substance rather alkalescent; by fasting some time, from the chyle being then converted into serum, the milk becomes salt, alkalescent, and displeasing to the infant. Like the chyle, it frequently retains the nature of some kinds of aliments and medicines. The cause of this increased secretion in the breasts, seems to depend on revulsion, and to succeed the suppression of that plentiful uterine secretion by which the foetus was nourished; as diarrhoea succeeds suppressed perspiration. For it has been observed, that true milk has been discharged from other parts,  
and

and even through wounds. And there is besides between the uterus and breasts, some kind of nervous sympathy, and a similar fitness for generating a white liquor. For the uterus in infancy, and during pregnancy, manifestly generates it. But the inosculation betwixt the mammary and epigastric arteries, though true, are so small, that in this nothing is to be ascribed to them.

DCCCCXLV. The breasts are composed of a very large quantity of very soft and very white surrounding fat; and of a conglomerate convex gland, consisting of round, hard kernels, of a reddish blue colour, surrounded externally, and connected together, by firm cellular substance, separating into smaller acini; which structure is common to men and women. To these glands many vessels are distributed from the internal mammaries, from the external thoracics, and lastly from the humeral artery, all which mutually inosculate near the nipple. The trunks of the mammary arteries, but not the mammales, inosculate with the epigastric vessels; the veins more evidently. The nerves, both large and numerous, as in cutaneous parts, are derived from the nerves placed between the upper ribs.

DCCCCXLVI. From the middle of this gland of the breast, and likewise from the surrounding fat, from an infinite number of roots, numerous, very slender, soft, white, and dilatable ducts arise, which converge on all sides to the nipple in the centre, both into the circle which subtends its base, and into the area of that circle, and emerge into the root of the nipple. This is a cavernous cellular body, into which the blood may be effused, so as to cause erection, as in the penis. This papilla is perforated by twenty or more excretory ducts from the breast, called lactiferous; between which there is not any inosculation, and which are much narrower in the nipple, than before: and in the flaccid state of the nipple, are compressed, wrinkled, collapsed,

lapsed, and shut; but when the nipple is erected by any kind of titillation, they become straight and have patulent mouths, lying betwixt the cutaneous wrinkles. This papilla is surrounded by a circle furnished with sebaceous glands, which defend the tender skin against attrition and perpetual moisture.

DCCCCXLVII. This is the first food of the infant, and at other times also is exceedingly salutary to man. This the infant knows how to take, before it has attempted to perform any other function of the body. Taking the nipple in its mouth, it causes it to swell by gentle vellications, and presses it with the lips, that no air may enter betwixt them; at the same time, it inspires and forms a space in its mouth, in which the air is rarefied; and thus, the pressure of the air, and the compressing force of the lips of the infant, emulges the milk from the nipple, from which, on account of its quantity, it is moreover disposed to flow spontaneously; and the infant sucks, and is nourished. The first serous milk, termed colostræ, loosens the bowels of the young infant, and evacuates the meconium, (DCCCXCVIII.) to the great advantage of the child. Yet, even independent of the fœtus, simple titillation erecting the nipples, and increasing the afflux of blood, has produced a flow of milk, even from virgins, old women, and men. Milk is only generated after puberty; before that time a serous humour flows from the breast; and for the most part it is first generated about the middle of pregnancy. After the menses have ceased, the breasts, as well as the uterus, being grown effete, cease to perform their office.

DCCCCXLVIII. But great changes happen to the infant when born. The first is respiration, which it attempts even within the vagina of the mother; being probably excited, by various pain and anxiety; to those cries with which it salutes the light, and perhaps

perhaps by the desire of food which is obtained from the store of the amnios: therefore, it draws air into its lungs, and dilates them, till now, small and full of serous humours, and changes them from being of a deep red colour, small, solid, and sinking even in salt water, into a substance, which is light, spongy and floating, large, full of air, and almost of a white colour: therefore, the blood enters more easily into these enlarged and loose lungs, (cclxv.) in consequence of which, a large portion of the blood of the pulmonary artery, that went through the canalis arteriosus into the aorta, now passes into the lungs by the other branches of that artery. And the duct is still more deserted, as there is a new obstacle to the descent of the blood into the abdomen; for the very large umbilical arteries are now tied, so that the blood of the descending aorta cannot now find its way, but by an effort with which it dilates all the arteries of the pelvis and lower extremities. Finally, as the lungs receive more blood, the aorta arising from the heart also receives a greater quantity, and the intermediate ductus arteriosus is compressed between the tumid aorta and the pulmonary artery, so that in the adult it is found not only empty but shortened; in other respects it is singularly red within, soft, and very apt to concrete with stagnating blood. This course of the blood, therefore, is soon abolished, commonly within a year.

DCCCCXLIX. Then the foramen ovale is, by the same causes, also gradually closed up. For as soon as the passage into the lungs is rendered easier, the passage into the right side of the heart also becomes easier; whence the blood of both cavas flows thither more plentifully, as it is invited by the lax pulmonary artery, and therefore does not need that passage excavated in the septum of sinuses. Again, the umbilical vein, being now almost destitute of any supply of blood, on account of the umbilicus being

being tied, (DCCCCXXX.) less blood will flow into the lower cava, and consequently the pressure against the foramen ovale will be diminished; into which, moreover, the blood of the upper cava, on account of the isthmus, will be scarcely able to penetrate. Lastly, as more blood is conveyed through the lungs into the left sinus, it is dilated, and, along with the whole sinus, the cornicles of the oval valve, which are fixed to it, are extended, and elevate the valve; so that, in the mature foetus, being drawn over the isthmus, it entirely shuts up the passage, and is closely applied to the isthmus, while, at the same time, the blood, within the left sinus, supports the valve against the impulse of the blood within the right sinus. Thus, by the accession of a little friction of the uppermost margin of the valve against the superior isthmus, the foramen ovale closes up by degrees, and the upper margin of the valve is agglutinated and coheres to the posterior surface of the isthmus. But this takes place very slowly; so that, very frequently, even at an advanced age, a small aperture still remains between the isthmus and upper part of the valve; and where there is no aperture, yet there are the remains of the whole foramen, hollow to the left side, and of a passage at the upper part, open towards the right side, and closed to the left, because the power of the blood in the right side is always either greater than its resistance on the left, or certainly not less, even in the advance of life.

DCCCL. The umbilical vein, being deprived of blood, soon closes up. The blood of the vena portarum, being no longer impeded by an opposite force coming from the umbilicus, occupies the left sinus and curve of the umbilical fossa, (DCXCV.) and transmits blood through those branches by which the umbilical vein formerly sent blood into the cava. The ductus venosus being neglected, closes by the new compression which the diaphragm, descending  
in

in inspiration, makes against the liver; by which the left lobe of the liver is pressed towards the lobule, and perhaps too from the obtuse angle which it makes with the left sinus of the vena portarum; for it is certainly first closed next the vena portarum.

DCCCCLI. The umbilical arteries are closed up in the same way as other arteries usually are when tied, by part of the blood being coagulated into a polypus, which fills up the impervious extremity, and by the blood, which meets with resisting membranes, diverging into the adjacent less resisting branches. Nor do I overlook the force of the abdominal muscles, by which those arteries are compressed against the full abdomen in respiration; or the very acute angle in which the umbilicalis, arising from the iliac artery, and now incurvated with it along the bladder, makes; or the straight direction in which the thighs, which in the foetus made an acute fold with the body, are now extended. Thus, these arteries are soon shut up, leaving only a very small tube, that leads to two or three arteries of the bladder. The urachus is very quickly obliterated, from its ascending directly from the bladder, being a very slender tube, having no outlet, and now neglected on account of the descent and permeability of the urethra.

DCCCCLII. From similar causes the liver is gradually diminished, and contracts itself within the ribs; and the intestina crassa, from their slender condition in the foetus, dilate to a considerable diameter, and the stomach is elongated; and the caecum is formed by the weight of the faeces pressing downwards on the right of the appendix; and the lower extremities are remarkably enlarged by the repulsion of the blood, from the umbilical arteries now tied; and the other changes take place, by which the foetus insensibly advances to the nature of a perfect adult.

## C H A P. XXX.

## NUTRITION, GROWTH, LIFE, AND DEATH.

DCCCCLIII. **E**VEN after the child is born, it continues to grow, but always more slowly in proportion to its age. There are many causes for the perpetual diminution of its growth. Many vessels seem to be obliterated, both because they are compressed by the neighbouring torrent of some large artery, and because the blood, now become more viscid, coagulates. Besides, the food being now coarser, accumulates in the blood more earth, which, being carried through the whole body with the nutritious fluid, renders every part of it harder, bones, teeth, cartilages, tendons, ligaments, vessels, muscles, membranes, and cellular substance; so that an increase of hardness may be perceived, even by the touch. Wherefore, since the blood flows from the heart through fewer canals, and since all the parts which should be lengthened or distended have become harder, it necessarily follows, that those which ought to increase in bulk, will yield less and less to the impulse of the heart.

DCCCCLIV. But the heart likewise, which is the part that is first consolidated of all the soft ones, increases less than any other part of the whole body; and while the much more tender limbs and softer viscera are distended, the heart itself grows more slowly, and continually bears a less, and at last an eight times smaller, proportion to the rest of the body in the adult. At the same time, from that very density which it has so quickly acquired, it becomes less irritable, and is contracted less frequently within a given time. Thus, while the resisting powers are augmented, the distending ones are at the same time diminished.

DCCCCLV.

DCCCCLV. There will, therefore, sooner or later, be an end of increase; and this will happen sooner, in proportion to the quickness and frequency of the contractions of the heart, and will approach when the cartilaginous crusts of all the bones are now become so thin that they cannot yield or give way to the increase of the bony part. In women, the menses seem to put an earlier stop to the growth. In cartilaginous fishes the growth is perpetual.

DCCCCLVI. There is no durable state; for, nature from the first conception, tends, by a perpetual progress, towards decrease. It is said, however, to take place, when there is neither any increase of bulk, nor yet any very visible decrease.

DCCCCLVII. For we are all perpetually consuming (CCCCXXXIV.) Nor do we only lose the fluid parts of our bodies, but even those which are reckoned the most solid. For even the bones are changed; and the teeth, which are harder than the bones, increase in bulk when the attrition of the opposite teeth ceases to wear them away, and, therefore, their elements are changed: even the fibres of ivory in the elephant's tooth have given way, and surrounded on each side, in curved lines, a leaden shot: the bony juice likewise is changed; since in some cases the bones grow soft: in others, it forms bony tumors: even cicatrices themselves have a manifest growth, for otherwise they would not be sufficient, in an adult, to fill up a wound received in infancy; and a great quantity of the earthy, certainly of the animal part of our bodies, goes off by urine, as is proved by some diseases.

DCCCCLVIII. The causes of the destruction of the solids consist in the perpetual extension and retraction, which happens at every pulsation of the heart, of which there are an hundred thousand every day, a degree of motion by which metals themselves are worn; then in the friction of the fluids against the solids; the wearing away of all the membranes, which

which terminate with a loose extremity, either on the surface or in the internal cavities of the body, which are supported solely by the rest of the canal; in the alternate swelling and collapse of the muscles; and in the attraction and pressure which our muscles exert. But the parts of our body are the sooner worn away, that they consist of a great deal of gluten combined with a small quantity of earth; and that gluten, when it is extended, if the extension has been a little superior to the force of cohesion, must of necessity fall away and be carried off from the earthy parts. Thus, deficiencies are generated, such as are visible in the arteries of old men. The cellular texture, which otherwise would be dissolved in water, into a jelly, is worn away by the friction produced by the impetus of the blood pressing against the neighbouring blood-vessels and muscles, and by the perpetual alternation of flexion and extension.

DCCCCLIX. This decrease would be very quick and indeed there would be no great distance between the end of our life and its beginning, unless these losses were repaired. The fluid parts are restored by the aliments, and that pretty quickly; as appears from the example of a chicken, in which blood is generated from its aliment within two days. The fat, however, and red globules of the blood, are formed out of the fat, as is shown elsewhere; the lymphatic juice from the jelly; the mucus, from mucus; and the rest of the humours, from these and water. The solids are repaired almost by the same means which we have described in the history of the foetus. A gelatinous juice is conveyed from the aliments, through the arteries, to all parts of the body, and exudes into the cellular texture every where. The furrows, which we imagine to be made in the inmost arterial membrane by the impetus of the blood, are filled up by a viscid matter, applied to them by the lateral pressure;

ture ; never in too great quantity, because the exuberant parts of the nutritious particles must necessarily be abraded by the current of the blood. Nor will it be deficient while there is a sufficient quantity of aliment, since there is more rest, and less resistance in the bottom of the furrow, which is farther removed from the motion of the blood through the centre of the vessel. There seem to be certain powers in the air, by which the aliment is attached to the solid parts, although we are ignorant of the manner in which they act.

DCCCCCLX. The decrease of the cellular texture arising from attraction or pressure is repaired by the viscid vapour exhaling from the artery, and applied to the wasted places by the force of the neighbouring arteries and compressing muscles, its aqueous part being expressed and absorbed. The gluten repairs most of the organic parts, tendons, and membranes ; being formed into new cellular substance, as in the fœtus.

DCCCCCLXI. The waste, which takes place in the unconnected extremities of parts adhering by their other extremity to the rest of the body, can be repaired by protrusion alone, while the lymph fills up the intervals produced.

DCCCCCLXII. When the growth of the body can proceed no further, fatness supervenes, which is a kind of imitation of real growth. This proceeds from the fat generated by the aliment ; which, from the impetus of the blood being now lessened as it enters the small vessels with more difficulty, is removed to the sides of the vessels ; enters the lateral vessels, and inorganic pores of the arteries ; exudes into the cellular texture ; and there is accumulated, in consequence of the diminution of the compressing power of the blood, and likewise of the absorption by the veins.

DCCCCCLXIII. The beginnings of decay are perceptible even in youth itself. Even in that blooming

season the solid elements of the body are augmented, the apertures through which the humours flow are lessened, the vessels are obliterated, and the greater attraction of the cellular substance has condensed the whole body. In every part of the body the induration produced by age becomes conspicuous, in the bones now wholly brittle, in the skin, in the tendons, in the conglobate glands, in the arteries, and in the weight of every part, and of the brain itself. But those parts grow soonest rigid, which are most exercised by motion; as those in every workman, which he chiefly employs in his profession.

DCCCCLXIV. Moreover, the arteries continue to become denser, narrower, and even impervious, both by the internal pressure of the blood flowing through the large arterial tube, and by the attraction of the cellular texture of which the greatest part of the artery is composed. An infinite number of parts of the cellular texture therefore cease to be nourished; to which the minute arteries hitherto conveyed nourishment; but which being now stopped up, bring none. The extending force being removed, the cellular flocculi attract each other, lessen the interstices between them, degenerate into membranes, or substances of a hard texture, which inclose, and, as it were strangulate other vessels. The gelatinous vapour likewise concretes in the interstices of the cellular texture, and forms a hard solid with its sides. The muscles, by the expulsion of their blood, and the concretion of their fibres, degenerate into hard dense tendons, destitute of irritability.

DCCCCLXV. At the same time, the nerves become more and more callous, and insensible to the impressions of the senses, and the muscles to irritation: thus the contractile force of the heart, and the frequency of its pulsations, is diminished, and therefore every force which impels the blood into the ultimate vessels.

DCCCCLXVI.

DCCCCLXVI. The quantity of humours is diminished in the denser body, as the perspiration, semen, humours of the eye, and of the conglobate glands; the vapour, which moistens the solid parts of the body, every where manifestly decreases. For this reason, nutrition now languishes, because there is more which requires nourishment, and less nutritious juice.

DCCCCLXVII. Nor is the quantity of humours only diminished: they themselves likewise become vitiated. They were mild and viscid in children: but these same humours are now acrid, salt, fetid, loaded with a great quantity of earth, in old men. This is produced by the use of salt and putrescent aliments, the bad effects of which increase, being collected through a great length of time; also, by the diminution of the cutaneous perspiration, and the costiveness of the belly, on account of the diminished irritability, and by the resorption of the putrid liquamen, thus increased. Hence the fetor of the urine, of the breath, and the difficult healing of wounds.

DCCCCLXVIII. But the greatest fault of the humours, is, that they abound with earthy particles, both collected insensibly from the aliments after the secretions have become less easy, and partly abstracted from the solids themselves, and returned into the blood: for this earth is demonstrated in some diseases, and by the nature of the gouty concretions. From this abundance of earth, the proportion of that element through the whole body, is again augmented, because the nutritious liquor brings too much of it along with it; whence the brittleness of the bones, and the hardness of all the parts increases: it is likewise every where deposited in the cellular texture, and produces every where crusts, at first callous, and then bony or stony, chiefly in the coats of the arteries.

DCCCCLXIX. The rigidity of the whole body, the decrease of the muscular powers, and the diminu-

tion of the senses, constitute old age ; which, sooner or later, oppresses mortals severely : sooner, if subjected to violent labour, or addicted to pleasure, or fed upon an unwholesome diet ; but more slowly, if they have lived quietly and temperately, or if they have removed from a cold to a warm climate.

DCCCCLXX. But as those causes incessantly continue to operate in rendering the matter of the body more dense, in diminishing its irritability, and in augmenting the quantity of earth, it is not possible but decrepit old age must succeed. In it, the senses are almost destroyed, and the vis insita of the muscles becomes exceedingly weak, so that the limbs lose their strength, and become, especially the legs, unable to direct the body ; that the callous insensibility of the nerves cannot be excited to perform the office of generation ; that the very intestines, becoming torpid, do not obey the habitual stimuli ; that, by the induration of the intervertebral cartilages, the body bends forward ; that by the falling out of the teeth, the jaws, now rendered shorter, do not support the lips sufficiently ; and lastly, that the pulsations of the heart become one half less frequent than in the infant state.

DCCCCLXXI. Thus at last, the necessity of natural death approaches, although the greatest number of mortals are carried off prematurely by diseases. One in a thousand exceeds the age of 90 ; and one or two perhaps in a century live to the age of 150. Man is long lived, when compared with other animals ; he is also more tender than any of them, has looser flesh, and less hard bones. It is not easy to say what was the cause, in long lived people, of their longevity. England seems to exceed all other nations in the number of those who live to an advanced age ; and in general, the temperate countries are remarkable in this respect. Among the classes of men, the commonalty has almost solely afforded these rare examples ; although, from its  
being

being the most numerous, we may expect a greater number of examples. Some prerogative seems to belong to sobriety, at least in a moderate degree; temperate diet; peaceable disposition; a mind not endowed with very great vivacity, but cheerful, and little subject to care. Among animals, birds are longer lived: and fishes, whose heart is very small, growth very slow, and whose bones never harden, are the longest lived.

DCCCCLXXII. Death from old age happens sometimes, but rarely. It may be said to occur, when the powers gradually decay, first of the voluntary muscles, then of the vital muscles, and lastly, of the heart itself; so that, in an advanced age, life ceases through mere weakness, rather than through the oppression of any disease. I have often observed the same kind of death in animals. The heart becomes unable to propel the blood to the extremities, the pulse and heat desert the feet and hands; yet the blood continues to be sent from the heart into those arteries nearest to it, and to be carried back from thence: the flame of life is thus supported for a little while, which soon after we perceive to be extinguished; when now the heart itself, being totally deprived of its powers, and not irritable by the blood to any effectual motion, cannot propel the blood through the lungs, that the aorta may receive its due quantity. The last efforts of respiration are now exerted to open a passage for the blood through the lungs, until even the powers given by nature for performing the action of inspiration, becoming unequal to their task, cease. Then, the left side of the heart neither receives blood nor is irritated, and therefore remains at rest; while yet, for a little time, the right ventricle, and lastly the auricle of the same side, receive the blood brought by the veins from the cold and contracted limbs, and being irritated by it, continue to beat weakly. But at last, when the rest of the body has become perfectly cold,  
and

and the fat itself congealed, even this motion ceases, and the death becomes complete.

DCCCCLXXIII. I shall call that death, when the heart has become totally deprived of irritability. For the mere quiescence of the heart is not without hope of resuscitation : neither does the putrefaction, or insensibility, or coldness of any part of the animal body, demonstrate the death of the whole animal : but all these things, when joined together, and perpetually increasing, with the rigidity produced by the congelation of the fat, in consequence of rest and cold, afford the signs of death in any doubtful case.

DCCCCLXXIV. The body after death is destroyed by putrefaction. Thus the fat, and the water, and the gluten, being resolved, are dissipated ; the earth, deprived of its bonds of union, insensibly moulders away, and mixes itself with the dust. The soul goes to that place which God hath appointed it : its indestructibility by death is proved by a very common phenomenon ; for many people, when their bodily powers are wasted and spent, give evident proofs of a highly serene, vigorous, and even cheerful mind.

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34. The strength of the arteries.  
The trunks are weaker, and the branches stronger.
35. Arteries go to all parts.  
The proportion of arteries to the parts which they supply.
36. The proportion of the solid part of the artery to its caliber.
37. The division of the arteries into branches.  
The proportion of the caliber of the branches to that of the trunk.  
The angles at which the branches go off.
- The flexions of the arteries.
38. The anastomoses and reticulations of the vessels.
39. The transition of the ultimate arteries into veins.
40. The various disposition of the arteries in the viscera.
41. The arteries terminate in vessels of a smaller denomination.
42. Or in excretory ducts.
43. Or in exhaling canals.
44. Are vessels every where produced from the red ones?
45. Are smaller orders of vessels produced by a multiplied division?
46. The veins are similar to the arteries in many respects, but in others are different.
47. The structure of the veins.
48. The size and division of the veins.  
They affect the surface of the body.
49. The valves of the veins.
50. The veins originate from arteries; from veins of inferior orders; from the absorbing veins of the whole circumference, and of every cavity of the body.
51. Other absorbing vessels from the cellular texture are little different from these.
52. There are veins as well as arteries of smaller kinds.
53. The lymphatic vessels.
54. The conglobate glands.
55. Where the lymphatic vessels are found.  
They unite in the thoracic duct.
56. The office of the conglobate glands.
57. The valves of the lymphatics.

## C H A P. III.

CIRCULATION, OR THE MOTION OF THE BLOOD  
THROUGH THE ARTERIES AND VEINS.

58. In what manner the blood fills the arteries and veins.
59. The blood moves rapidly through all the vessels.
- 60—76. The direction of the motion of the blood.
60. Proofs that all the arteries and veins communicate.
61. The blood flows through the arteries from the heart to the extremities.
62. The motion of the venous blood was doubted.  
Who have discovered their error.
63. Harvey first showed, that the venous blood every where returned from the extremities to the heart.  
This is proved by the valves which prevent the reflux of the blood into the branches.
64. The valves also sustain the weight of the blood.  
They also cause the pressure of the muscles upon the veins to direct the blood towards the heart.
- 65—70. Proofs of the course of the venous blood.
65. The valves of the right side of the heart.
66. Ligatures and compression in a living person.
67. More accurate experiments on living animals.
68. Injections into the veins.
69. Transfusion of blood.
70. Injections prove, that the blood passes from the arteries into the veins.
71. The same passage is shown by the microscope.  
There is no parenchyma between the arteries and veins.
72. The nature of that circulation of the blood, which is proved by what is already said.
73. There are instances, however, where the passage is for a little in a contrary direction.
74. In the lymphatic vessels the course of the liquor is from their roots to the thoracic duct.
75. The reformed vapours are carried towards the heart.
76. A passage must be found for the blood from the right ventricle of the heart into the left.

## C H A P. IV.

## HEART.

- 77, 78. The bags of the pleura.
77. The mediastinum.  
The pleura.
78. The situation of the pericardium.  
The mediastinum posterius.  
The ligaments of the lungs.
- 79, 80. The pericardium.
81. The arteries of the pericardium.  
Its veins.  
Nerves.
82. The structure of the pericardium.  
The water contained in it.
83. The use of the pericardium.
84. What animals have a heart.
85. In what manner the vena cava terminates in the heart.
86. The right sinus venosus.  
The right auricle.
87. The fossa ovalis.  
The anulus ovalis.
88. The valve of Eustachius.
89. By

89. By what powers the blood is forced into the right porch of the heart.
90. The contraction of the right auricle, and its effects.
91. The figure and situation of the heart.
92. The anterior or right ventricle of the heart.
93. The valvulæ triglochines.
94. Their papillary muscles.
95. The use of the triglochines.
96. The heart is stimulated to contraction, by the blood thrown into it.
97. The muscular fibres of the heart, according to the author.
98. The same described by others.
99. The nerves of the heart.
100. These nerves contribute to the motion of the heart.
101. There is, however, some other cause.
102. The irritability inherent in the heart.
103. How the contraction of the ventricle is performed.
104. By the contraction of the heart, the blood does not return into the auricle and veins.
105. By the contraction of the right ventricle the blood is driven into the pulmonary artery.
106. The origin and beginning of the pulmonary artery. Its semilunar valves.
107. The passage of the blood from the right ventricle into the pulmonary artery.
108. The passage of the blood through the lungs.
109. The blood cannot return from the pulmonary artery into the heart.
110. The pulmonary veins. The course of the blood through these.
111. The left sinus venosus. The left auricle.
112. The contraction of the left porch forces the blood into the left ventricle. The valvulæ mitrales.
113. The course of the blood from the right ventricle into the left, or the smaller circulation.
114. The left ventricle.
115. The blood is forced into the aorta by the contraction of the left ventricle.
116. The valves of the aorta.
117. The diastole of the heart.
118. In what manner the motions of the auricles and ventricles alternately follow one another.
119. Why are these motions continued so long, and so constantly.
120. This question is explained, by the stimulus of the blood driven into irritable cavities.
121. Nothing more is necessary. The reason cannot be found either in the compression of the nerves, or in the coronary arteries.
122. The powers of the heart are not assisted by the oscillation of the ultimate vessels. Or by the power of external heat. Or by the contractile force of the arteries.
123. The velocity with which the blood issues from the heart. The weight of the blood incumbent on the heart. The force of the heart.
124. Many things on this subject are uncertain. The powers of the heart are, however, very strong.
125. This is proved by the resistances which the heart overcomes.
126. The entrance of the blood into the coronary arteries. The two coronary arteries.
127. They terminate in veins. The great coronary vein.
128. The middle vein. The third vein.
129. The anterior veins.
130. The middle sized veins.
131. The minute veins.
132. At what time the coronary arteries receive the blood.
133. The blood returns from the coronary arteries into the cavities of the heart through the veins.
134. The lymphatic vessels of the heart.

## C H A P. V.

NATURE OF THE BLOOD, AND HUMOURS OF THE  
HUMAN BODY.

135. The blood in general.  
 136. The warmth of the blood.  
     The halitus issuing from blood when drawn.  
 137. The blood coagulates when the halitus is discharged.  
     The cruor is the principal part of the coagulum.  
 138. The serum of the blood.  
 139. How the blood is changed by putrefaction.  
 140. Besides these, there are in the blood, sea-salt, earth, calx of iron, and air in an inelastic state.  
 141. What changes are produced in the blood by the admixture of salts.  
 142. The chemical analysis of the blood.  
 143. Result of the information derived from it.  
 144. Red globules are distinguished in the blood by the help of the microscope.  
     Their figure.  
 145. The colour of the globules, their number, magnitude, and variable figure.  
     Do they break down into other smaller globules?  
 146. Fibres are produced from washed blood, which did not exist in the living animal.  
 147. The cruor is composed of globules, which are inflammable.  
 148. The chemical analysis of the serum.  
     The aqueous humours, the saliva and mucus, afford nearly the same products.  
 149. The quantity of blood in the whole body.  
 150. The proportions of the elements of the blood are not always the same.  
     The causes which vary their proportion.  
 151. On the different proportion of the elements, and the consideration of the structure of the solids, depend the differences of temperaments.  
 152. The use of the red cruor.  
 153. The coagulable serum, thinner liquids, saline particles, air and fire; the effects of each.  
 154. The thick blood and more thin liquids are equally necessary for health.  
 155. The difference between the arterial and venous blood.  
 156. All the rest of the humours are produced from the blood alone.

## C H A P. VI.

## COMMON FUNCTIONS OF THE ARTERIES.

157. The blood propelled from the left ventricle into the aorta.  
 158. The arteries are constantly full.  
     The pulsation of the arteries, and its cause.  
 159. The contraction of the arteries.  
 160. How is it proved that the artery is contracted, and that the blood is driven forwards by that means?  
 161. No succession can be perceived in the pulsation of different arteries, although we are

certain

- certain that it actually takes place.
162. The velocity of the blood coming from the heart must continually be diminished as it proceeds farther through the arteries.  
What circumstances seem to diminish its velocity, without actually diminishing it.
163. The blood does not seem to lose so much of its velocity as, according to calculation, it ought to do.  
The causes of this.
164. Why the pulse vanishes in the ultimate arteries.
165. The blood presses against the sides of the veins.  
Why the veins do not beat like the arteries.
166. The pulse is the measure of the powers of the heart.  
What is meant by a slow, full, hard, or quick pulse.  
Where it is best felt.
167. The pulse is slower in proportion to the bulk of the animal.  
The difference of the pulse in men, according to the time of the day.
168. A frequent pulse is different from a quick one.  
Different causes of a frequent pulse.
169. By what powers the venous blood is moved.
170. It moves more quickly in the trunks than in the branches.
171. By what means the blood is prevented from stagnating and coagulating in the veins.
172. The venous blood is propelled by the action of the muscles.
173. Other powers compressing the veins.
174. The power of derivation.  
What are the effects of anastomoses.
175. The velocity of the venous blood.  
What causes render its motion more difficult.
176. The time in which the circulation is performed.
177. The effects of the motion of the heart and arteries upon the blood, and by what means they are estimated.
- 178, 179. The means by which we understand the manner in which these effects are produced.
180. The friction which takes place in the arteries.  
Its effects, how calculated.  
Whence the redness of the blood.
181. Does the heat of the blood arise from its motion?
182. The progressive motion of the blood hinders putrefaction.
183. It is various in different particles of different natures.
184. The effects of the systole of the arteries.
185. The smallest mouths of the arteries are the moulds in which the particles of blood are formed.
186. What is the use of the reticulations of the arteries.
187. The effects of a retarded motion of the blood.

## C H A P. VII.

## SECRETION.

188. Four classes of secreted humours.  
The first consists of the coagulable ones, which for the most part exhale.
189. The second are not coagulable, and partly exhale, and partly do not.
190. The third are mucous.
191. The fourth inflammable.
192. The other humours are composed of these.
193. A description of the secretory organs is required, in order to discover the reason of the diversity

- diversity of the secreted fluids in the different organs.
194. The secretion of coagulable liquors is performed without glands.
195. What glands secrete the albuminous fluid of the joints.
196. The seat of these glands.
197. The exhaling liquors which are not coagulable are secreted without glands.
198. Such liquors as are neither coagulable nor exhaling, are secreted by conglomerate glands.  
These are composed of acini.
- 199, 200, 201. The structure of these acini.
202. Some liquors of the nature of 198 are even secreted without these kernelly glands.
203. The mucus is every where secreted by glands.  
The structure of a true gland.
204. How the secretion is performed in these glands.
205. The excretory orifices.  
The cryptæ.
206. The conglutinated glands.
207. The excretory ducts.
208. The compound glands.  
The agminated or congregate glands.
209. The various secretions of inflammable liquors.  
There are many sebaceous glands without a duct.
210. Other sebaceous ones have a duct.
211. Compound sebaceous ones.
212. The milk is secreted in conglomerate glands.
213. The organs being described, we return to the question 193.
214. The blood going to the secretories is already of a particular nature.
215. The retardation of the blood in the minute vessels separates the more dense humours from those that are lighter and more sluggish.
216. The mouths of the secretory vessels are of very different diameters.
217. This inequality may alter the secretions in many different ways.
218. Most secretions are performed by vessels arising from sanguiferous arteries.  
Others, however, by vessels which arise from an inferior order of arteries.
219. The angle at which the secretory branch goes off is perhaps of some consequence.  
What things render this probable.  
What things render it doubtful.
220. The flexions of vessels contribute to secretion.
221. The density of the arteries may do the same.  
Their irritability has nearly similar effects.
222. Various circumstances which augment or diminish the velocity of the blood have great effect on the secretions.
223. The secreted humours are varied by a variation of these conditions.
224. The largest and densest particles of the blood pass into the veins.
225. What becomes of the large, slow, and sluggish particles.  
And of the coagulable ones.
226. In what vessels the thin and aqueous liquors are secreted.  
In what vessels the light aqueous but viscid and slow humours.
227. Various hypotheses are formed concerning secretion.
228. It remains to be discovered how the pure secretions are made.  
All recent secretions have an admixture of water.
229. All of them become viscid by stagnating in follicles.
230. The fluids may be changed in their receptacle by the admixture of a new liquid.
231. The reformed humours are also of use.
232. The use of receptacles.
233. The powers by which the retained humours are at last ejected.

## C H A P. VIII.

## RESPIRATION.

234. The figure of the lungs.  
 235. The external membrane of the lungs.  
 236. The structure of the lungs.  
 237. The structure of the asperia arteria.  
 238. Its muscular fibres.  
 239. Its mucous glands.  
     The conglobate glands contiguous to it.  
 240. The vessels and nerves of the asperia arteria.  
 241. Its division into bronchia.  
 242. Their ultimate branches terminate in cellular texture.  
 243. The bronchial arteries & veins.  
 244. The pulmonary artery.  
     The pulmonary veins.  
 245. The lymphatic vessels of the lungs.  
     The nerves of the lungs.  
 246. A very large portion of the blood enters the lungs.  
     The utility of this viscus depends on the air.  
 247. The nature of atmospherical air.  
 248. In what manner it is excluded from the body.  
     We must investigate why it enters the lungs.  
 249. The reason why it enters them.  
 250. The general fabric of the thorax.  
 251. The vertebræ of the back.  
 252. The articulation of the ribs with the vertebræ.  
     The ligaments of this articulation.  
 253. How the ribs are joined with the sternum.  
 254. The length of the ribs.  
 255. The direction of the ribs.  
     Their strength various.  
 256. The sternum.  
 257. The thorax must be raised in order to dilate the seat of the lungs.  
     This is performed by the external intercostal muscles.  
 258. The internal intercostals.  
     There are doubts concerning the action of these, but it is certain that they elevate.  
 259. In what manner the thorax is enlarged by these.  
     But this dilation is not, however, sufficient.  
 260, 261. The diaphragm.  
 262. The two holes of the diaphragm.  
 263. The contraction of the septum augments the capacity of the thorax.  
     Alone, it almost performs respiration.  
 264. By what powers it is assisted in deep inspirations.  
 265. Inspiration, how performed.  
     Its effects on the air and blood-vessels.  
 266. Is air contained between the lungs and thorax?  
 267. The air is vitiated by respiration.  
 268. The inconveniencies of too long an inspiration.  
 269. The powers of expiration.  
 270. The abdominal muscles conspire to produce this effect.  
     The sternocostals and others also assist.  
 271. What powers assist the muscles in stronger respirations.  
 272. The effects of expiration.  
 273. From thence there arises a new necessity for inspiration.  
 274. Other causes for alternate respiration are scarcely ascertained.  
 275. Respiration is necessary for adults.  
 276. The utility of respiration is different from that necessity.  
 277. How that is ascertained.  
 278. Is heat generated in the lungs?  
 279. Is the blood condensed in the lungs?  
 280. Is the air itself received into the blood in the lungs?  
     What

- What circumstances render this probable.
281. What seem to prove the contrary.
282. Is the blood cooled in the lungs?
283. Does the red colour of the blood proceed from the air?
285. Is the use of the blood to absorb nitre from the air?
286. What animals live long without air.
- Why every animal dies in air that is not renewed.
287. What is the connection between the pulse and respiration.
288. Cough.
289. Laughter.  
Weeping.  
Hiccup.  
Sneezing.
290. The accessory uses of respiration.

## CHAP. IX.

### VOICE AND SPEECH.

291. The larynx is composed of cartilages.  
Its vessels and nerves.
292. The scrutiform cartilage.
293. The annular cartilage.
294. The arytenoid cartilages.
295. The glottis.
296. The epiglottis.
297. The ventricles of the larynx.
298. The mucous glands of the larynx.
299. The thyroid gland.
300. The connection of the larynx with the os hyoides.  
The elevation of the larynx, and contraction of the glottis.
301. The depression of the larynx, and dilatation of the glottis.
302. The cavity of the mouth.  
The nostrils.
303. The tongue.
304. The voice.  
Whispering.
305. The strength of the voice.  
What circumstances produce an acute tone.
306. A grave tone is produced by the opposite causes.
307. The causes of diversity of tone.
308. Singing.
309. Speech.
310. The pronunciation of letters.

## CHAP. X.

### BRAIN AND NERVES.

311. The nature of the arrangement.
- 312—319. The arteries which belong to the brain.
312. The arch of the aorta, and the branches produced from it.
313. The division of the carotid.  
The external carotid. From it proceeds,  
The superior thyroid artery.  
The lingual.  
The labial.  
The ascending pharyngea.
314. The occipital artery.  
The auricular.
315. The temporal artery.  
The internal maxillary.  
The principal branch to the dura mater.  
Other branches of the internal maxillary.
316. The internal carotid.  
Its flexures.  
Its passage through the foramen of the os petrosum.

The

- The branches produced from it in the receptacle.
317. The branches of the internal carotid on the bridge and crura of the brain.  
The branch to the plexus choroïdes, and accompanying the optic nerve.  
The anterior and posterior branch.  
The structure of the branches of the carotid artery which lie within the skull.
318. The vertebral artery.  
The basilaris.  
The profunda cerebri.
319. The conclusions which may be deduced from the history of the arteries of the brain.
- 320—324. The coverings of the brain.
320. The ossious shell of the encephalon.  
The dura mater in general.
321. The external and internal lamina of the dura mater.  
The falx and tentoria proceed from these; their use.
322. The glands.
323. The arachnoid membrane.
324. The pia mater.
- 325—339. The veins of the encephalon.
325. The fourth sinus.
326. The superior sinus of the falx.  
The transverse sinuses.
327. The inferior sinus of the falx.
328. The inferior, anterior, and posterior veins of the brain.
329. The veins of the cerebellum.  
The superior veins terminate in the fourth sinus; the inferior ones in the superior petrous and transverse sinuses.
330. Circular sinus.  
The transverse sinus joining the cavernous ones.
331. The superior sinus petrosus.  
The inferior sinus petrosus.  
The posterior occipital sinus.
332. The anterior occipital sinus.  
The cavernous sinus.  
The conjunction of the sinuses and external veins of the cranium with each other, and its effects.
333. The use of the sinuses.
334. The connection between the arteries and the sinuses.
335. The blood chiefly flows into the jugular veins.  
Their cerebral and facial branches.
336. The external jugular vein.  
The internal vertebral vein.
337. The sinuses of the medulla spinalis.
338. The uses of the venous anastomoses.
339. The lymphatic vessels of the brain.  
The resorption of what is exhaled in the brain.
340. A great number of parts are comprehended under the name of encephalon.  
The cerebrum, cerebellum, bridge, and medulla oblongata, what they are.
341. The figure of the brain.  
Its circumvolutions.  
—cortex.  
—medulla.  
—lobes.
342. The minute structure of the brain.
- 343—53. The interior anatomy of the brain.
343. The oval section of the brain.  
The corpus callosum.
344. The anterior or three-horned ventricle.
345. The corpora striata.  
The thalami of the optic nerves.  
The double semicircular centre.  
The anterior commissure.  
The mamillary eminences.
346. The pellucid septum.  
The fornix.  
The fimbriae.  
The hippocampi.  
The psalterium.
347. The choroid plexus.
348. The third ventricle.
349. The pituitary gland.
350. The posterior double commissure.
351. The separation of the third ventricle from the calamus scriptorius.  
The anterior commissure.
352. The

352. The nates.  
The testes.  
The pineal gland.
353. The crura of the brain.
354. The cerebellum.
355. The bridge.  
The medulla oblongata.  
The olive shaped and pyramidal bodies.  
The fourth ventricle.  
The great valve.  
The aqueduct.  
The calamus.
356. The common properties of the nerves of the brain.
357. The origins of each of the nerves of the brain.
358. The medulla spinalis.  
Its pia mater, arteries, and veins.
359. The arachnoid membrane of the medulla spinalis.
360. The hard membrane of the medulla spinalis.  
The denticulated ligament.
361. The common properties of the spinal nerves.
362. The anterior and posterior trunks of the spinal nerves.  
The intercostal nerve.  
The eighth pair.  
The phrenic nerve.  
The accessory nerve.
364. The extremity of the nerves.  
The straightness of the fibres of the nerves.  
The nerves are scarcely elastic, and not at all irritable.  
The number of nerves is in proportion to the parts to which they are sent.  
The anastomoses of the nerves.  
Ganglions.
365. How it is proved that sensation is owing to the nerves.  
It is the medullary part of the nerve which feels.
366. The soul perceives in the brain; not immediately by the sensoria and branches of the nerves.
367. How the muscles are affected by compressing or irritating the nerves.
368. What derangements of the animal motions happen on injuring the brain or spinal marrow.
369. From what is laid down in 367 and 368, the nerves are proved likewise to be the organs of motion.
370. Is there in the brain any principal seat in which is the origin of all motions, and the end of all sensation, where the soul resides?  
It is not in the corpus callosum.
371. Neither is it the proper province of the cerebellum to carry on the vital motions.  
Nor are the motions called animal and vital to be referred to different sources.
372. The seat of the soul is where the nerves first begin.
373. The nerves are the organs of sensation and motion, not by their membranes, but by their medullary part.
374. What the medulla is.
375. Whether the medullary fibres are solid.
376. The nerves are entirely devoid of elasticity.
377. Motion can only be propagated downwards.  
From what is said, it follows, that the medullary fibre seems to be hollow.
378. Refutation of the objections against this.
379. The nature of the nervous fluid.  
How proved not to be electrical.
380. The nature of that fluid is neither aqueous nor albuminous.
381. Of what kind the nervous fluid ought to be.
382. How it is rendered more probable that the nervous fluid passes through hollow tubes than through the spongy and solid substance of the nerve.
383. The motion of the nervous juice is twofold.
384. The same nerves most evidently serve both for senic and motion.
385. What

385. What becomes of the nervous fluid.  
Whether it nourishes.
386. Questions concerning the uses of the parts of the brain.
387. The offices of the ventricles.
388. What is known concerning the use of the tubercles.
389. The offices of the striæ and of the internal ducts.
390. The reason for the arrangement of what follows.

## C H A P. XI:

## MUSCULAR MOTION.

391. The dead power of the fibre.
392. The reason why it is called dead.  
Its effects.
393. The characters of the dead power.  
The characters which are peculiar to the red muscular fibre.  
It is necessary to examine its structure.
394. What muscular fibres and muscles are.
395. The fibres treated more fully.
396. The belly, tendon, aponeurosis, and capsule of a muscle, what.  
Whether the fibres of the tendons are of a different genus from the muscular fibres.  
Muscles which commonly have no tendons.  
The parts in which the muscles chiefly terminate in long tendons, and those to which they affix themselves.
397. The modes in which the tendons unite themselves with the flesh.  
A pennated muscle, what.
398. The arteries, veins, lymphatics, and nerves, of the muscles.
399. The structure of the ultimate fibre, which is the elementary part of the muscle.
400. There is a threefold force in the muscle.  
The vis insita of the muscle.
401. The measure of the shortening of the muscles when they contract.
402. Other things which relate to the vis insita.
403. The nervous power of the muscle.
404. In what the nervous power and vis insita differ.
405. The phenomena in the motion of the muscles arising from the nervous power and vis insita.
406. What the arteries contribute to the motion of the muscles.
407. A refutation of the manner in which the nerves are said to move the muscles.
408. The nervous fluid seems to perform the office of a stimulus; and its moving cause is not the soul, but a law derived from the Creator.
409. What things show that in the motion arising from the vis insita, the soul does not interfere.
410. The difference between the muscles obeying the will, and those which are governed by the vis insita.
411. The magnitude and loss of the powers which the muscles exert in their contractions.
412. The reason of these losses.
413. The effects of antagonists, as they are called, in muscular motion.
414. Other helps to this motion.
416. The co-operation of the muscles.
417. The effects produced by the action of the muscles.
418. The relaxation of a muscle at rest.  
What becomes of the spirit sent from the brain.

## C H A P. XII.

## TOUCH.

419. Sensation.  
Account of the arrangement.
420. Touch in general.
421. Touch in another and more proper sense.
422. The true skin.
423. The granulation and papillæ of the skin.
424. The epidermis.
425. The rete Malpighianum.
426. Of what the network and epidermis consist.
427. The glands of the skin.  
There is another source of oily liquor; what it is.
428. The hairs.
429. The nails.
430. The subcutaneous cellular texture in very few places is without fat.  
What purpose it serves after it has received the fat.  
The skin and Malpighian mucus, and epidermis, where they seem perforated, are drawn inwards, and degenerate.
431. The mode of touch, and the qualities which are known by it.
432. The Malpighian mucus, hairs and nails, what purposes they serve.
433. The vapour perspiring through infinite little arteries of the skin.
434. The ways of demonstrating this exhalation.
435. Sweat.
436. The elements of perspiration.  
Water.  
The odours of aliments.  
The electric matter.
437. Another element of perspiration, something volatile, of an alkaline nature.
438. The quantity of perspiring liquid.
439. The indication from the quantity of perspiring liquid.  
What things augment or diminish it, and what follows from thence.
440. How sweat benefits or hurts the body.
441. The use of perspiration.
442. Inhalation, by what arguments it is proved.
443. How it is proved that both the exhaling and inhaling vessels may be contracted and relaxed by the power of the nerves.

## C H A P. XIII.

## TASTE.

444. Taste is chiefly exercised by the tongue.
445. The tongue in general.  
First kind of its papillæ.
446. The fungiform papillæ.  
The conical ones.  
Others which intervene.
447. The nerves of the tongue.
448. The arterious and nervous villi which run between them.
449. The covering of the tongue.
450. The muscles of the tongue.
451. The vessels of the tongue.
452. The manner of exercising the taste.  
Flavours, and their cause.
453. What things contribute to the perception of tastes.
454. The spirits are resumed either into the papillæ or the absorbing villi of the tongue.
455. The use of the sense of taste.

## C H A P. XIV.

## SMELL.

456. The use of smell.  
 457. Smell is exercised by the help of the membrane of the nostrils.  
     The nerves of that membrane.  
 458. The arteries and veins of the membrane of the nostrils.  
 459. What the nostrils are.  
     The septum of the nostrils.  
 460. The uppermost, middle, and lowest ossa spongiosa.  
 461. The sinuses in general, what they are.  
     The frontal sinuses.  
 462. The ethmoidal sinuses.  
     The sinus of the multiform bone.  
 463. The sinus of the maxillary bone.  
 464. The mucus of the nostrils.  
     The sinuses abounding in mucus can evacuate it in the different situations of the body, so that some of them can always empty themselves.  
 465. The nose and its muscles.  
 466. The manner of exercising the sense of smell.  
     In what it agrees or disagrees with the sense of taste.  
 467. The strength of odours.  
     The parts of the nostrils which principally belong to the sense of smelling.

## C H A P. XV.

## HEARING.

468. The reason of the difference between the organ of hearing and that of the other senses.  
 469. The external ear and its parts.  
 470. The glands and muscles of the ear.  
 471. The meatus auditorius.  
 472. The skin and cuticle of the meatus.  
     The glands for separating its wax; the wax.  
 473—477. The physical properties of the air.  
 474. Tones.  
 475. The velocity of sound.  
 476. Sympathetic tremors.  
     The strength of sound.  
     Echo.  
 477. How sound rebounds from hard bodies.  
     The cause of the increase and diminution of sounds.  
 478. The collection of sounds in the meatus auditorius.  
 479. The membrane of the tympanum.  
     The sounds strike upon it after their ultimate reflection in the meatus auditorius.  
 480. The tympanum.  
 481. The four little bones of hearing are placed in the tympanum.  
     The malleus.  
 482. The muscles of the malleus.  
     The effects of the rupture of the membrane of the tympanum.  
 483. The incus.  
 484. The stapes and its muscle.  
 485. The little round bone.  
 486. Various canals go out of the cavity of the tympanum.  
     The appendix to the tympanum, of the figure of a gnomon.  
     The cells above the mamillary process, and in the process itself.

487. The

487. The tube.  
 488. Two other passages lead from the tympanum into the labyrinth.  
     The oval fenestra.  
     The vestibulum.  
 489. The semicircular canals.  
 490. The round fenestra.  
     The cochlea.  
 491. The vessels of the organ of hearing.  
 492. The nerves belonging to this organ remain to be described.
- The seventh pair of nerves, and its hard portion.  
 The nerves of the external ear.  
 493. The soft branch of the seventh pair of nerves.  
 494—5. Various remarks concerning the seat of hearing.  
 496. What things are known with more certainty concerning this matter.  
 497. The distinction and agreeableness of sounds.

## C H A P. XVI.

## SIGHT.

498. The difference between sight and hearing.  
     The organ of sight is necessarily compounded.  
 499. The eyebrow.  
 500. The eyelids.  
     The conjunctiva.  
     The nerves and arteries of the palpebræ.  
 501. The tarsus.  
     The levator muscle of the upper eyelid.  
     The orbicularis palpebrarum.  
 502. The eyelashes.  
 503. The Meibomian sebaceous glands.  
 504. The tears and their sources.  
 505. The duct of the lachrymal gland.  
     The effects of the contraction of the orbicular muscle.  
 506. What becomes of the tears.  
     The caruncula lachrymalis.  
     The third palpebra.  
     The punctum lachrymale.  
 507. The ductus lachrymalis.  
     The lachrymal sac.  
     The nasal duct.  
 508. The figure of the eye.  
     The orbit.  
     The surrounding fat.  
 509. The optic nerve.  
     Its course.  
 510. What becomes of it, after it touches the eye.  
 511. The sclerotica.
- The cornea.  
 512. The choroides.  
     The Ruyschian lamina.  
     The ciliary circle.  
     The pupil.  
     The iris.  
     The uvea.  
     The membrane shutting the pupil in the fœtus.  
 513. The motion of the iris.  
 514. The ciliary ligaments.  
 515. The retina.  
 516. The humours of the eye.  
     The vitreous humour.  
 517. The crystalline lens.  
 518. The aqueous humour.  
     The chambers of the eye.  
 519. The straight muscles of the eye.  
 520. The oblique muscles of the eye.  
 521, 522. The nerves of the eye.  
 521. The ophthalmic branch of the fifth pair.  
 522. The branches of the third pair.  
 523. The motion of the ciliary processes.  
 524—527. The arteries of the eye.  
 528. The veins of the eye.  
 529. Light in general.  
 530. Light consists of rays of different colours.  
 531. Whence the colours proper to every body arise.  
     Opaque bodies, what.  
 532. What

532. What refraction is, and its laws.
533. When rays fall on a convex spheric body, which of them are refracted, and which reflected.
- The focus of refracted rays.
534. What rays falling upon the cornea are reflected, or being refracted are suffocated, or reach the lens.
535. How the rays are refracted in their passage through the cornea and aqueous humour.
536. How they are refracted by the crystalline humour.
538. How they are refracted by the vitreous humour, and are at last collected upon the retina.
539. Whether objects are rather painted on the choroides.
- 540, 541. How the eye is thought to accommodate itself to the various distances of objects.
542. But nothing of this kind happens.
543. Myopia.
544. The cure for this disorder.
545. Presbyopia.
546. The remedy for presbyopia.
547. A medium between short and long sightedness is best.
548. In what manner we judge of the magnitude of objects.
549. The force of the light, and its effects.
550. How the place of an object is estimated.
551. Distance.
552. How we perceive objects to be gibbous.
553. In what manner we judge of the situation of the parts of objects.
554. The images of objects remain for a little time, even after the objects themselves are removed.
555. Various questions concerning vision.

## C H A P. XVII.

## INTERNAL SENSES.

556. Sensation takes place when a new perception arises in the mind by the percussion of a nerve.
- The perception is not the image of the object affecting the nerve.
- The connection between the changes in the nerves and the perceptions produced by them in the mind, is arbitrary.
- Why, notwithstanding this, what we perceive of this world is not false.
557. What things are combined when we perceive.
558. The changes produced by objects in the nerves remain a long time in their origin.
- The preservation and order of these ideas.
559. Imagination, what it is.
560. Memory.
561. At what times of life the memory and imagination flourish, and when they decay.
562. Thought; attention.
- Judgment; genius.
- The sources of error.
563. Soundness of judgment, on what it depends, and by what it is impaired.
564. What ideas mostly affect the will.
565. The affections of the mind.
- Effects of the affections of the mind.
566. The causes of these effects.
567. The passions of the mind are faithfully expressed in the countenance.
- Physiognomy, whence it arises.
568. Consent of parts, whence it arises.
569. The

569. The nature of the soul is different from the body.  
 570. The soul, however, is most intimately connected with the body.  
 571. We have no reason to be ashamed of our ignorance of the manner of this connection.  
 572. By what arguments those are chiefly persuaded who derive the origin of all the motions and actions in the body from the soul.  
 573, 576. What circumstances do not permit us yet to adopt that opinion.  
 577. Watching.  
 Sleep.  
 578. Dreams.  
 With these, some voluntary motions are sometimes conjoined.  
 579. What actions continue to be carried on during sleep.  
 580. How the mechanical cause of sleep is to be discovered.  
 The phenomena of watching and of sleep.  
 581, 584. What things contribute towards sleep, or produce it.  
 585. The proximate cause of sleep.  
 586, 587. This is confirmed by the causes of watching, and what these causes are.  
 588. The seat of sleep is not in the ventricles of the brain.  
 Why the vital actions go on in the time of sleep.  
 589. The effects of sleep.  
 590. Various questions concerning sleep.

C H A P. XVIII.

MANDUCATION, SALIVA, AND DEGLUTITION.

591. Most kinds of food need manducation.  
 592. Therefore most animals are furnished with teeth.  
 Their structure in general.  
 593. In man, on account of their diversity of food, there are different kinds of teeth.  
 The incisors.  
 594. The canine teeth.  
 595. The grinders.  
 596. The teeth are fixed in the jaw-bones.  
 The various motions and articulations of the lower jaw.  
 597. The levators of the jaw.  
 The pterygoideus externus.  
 598. How the jaw is depressed.  
 599. The powers of the levator muscles.  
 The muscles producing a lateral and circular motion of the jaw.  
 600. The cheeks.  
 The lips.  
 The mouth.  
 The situation and mobility of the tongue in the mouth.  
 601. The liquor poured upon the aliments during mastication.  
 Its sources.  
 The ductus incisivus is imperious.  
 602. The saliva.  
 603. The parotid gland.  
 The gland called the accessory gland.  
 604. The maxillary gland.  
 The sublingual gland.  
 605. These being compressed in mastication, pour out their liquor.  
 Appetite alone also produces the same effects with compression.  
 606. The aliments are triturated with saliva and air into a paste.  
 They are rendered sapid.  
 The volatile parts are reformed.  
 607. The motions of the tongue for revolving the aliment within the cavity of the mouth.  
 608. The tongue is directed by the os hyoides.  
 The

- The muscles depressing the os hyoides.
609. The muscles raising the os hyoides.
610. The muscles of the cheeks and lips.
611. The aliment being chewed is applied to the tongue, and carried towards the fauces.
612. How the food is carried from the mouth into the fauces.  
How the access into the larynx is closed.
613. The pharynx.
614. The muscles dilating the pharynx.
615. How food is prevented from falling into the larynx.  
The velum of the palate.  
The uvula.
616. How the return of the aliment into the mouth is prevented.  
How the epiglottis and uvula are erected after they have been depressed.
617. The powers which press the aliments downwards through the pharynx.  
The action of the arytenoid muscles.
618. The mucus of the pharynx, and its various sources.
619. The tonsils.  
The mucus of them is very viscid.  
The neighbouring parts are full of mucous organs.  
The mucus of the œsophagus is more fluid.  
The vessels of the tonsils, pharynx, and œsophagus.
- 619.\* The œsophagus.
620. The passage of the aliment through the œsophagus.
621. The constriction of the upper orifice of the stomach.

## C H A P. IX.

## THE ACTION OF THE STOMACH ON THE ALIMENTS.

622. The situation, figure, and size of the stomach.
623. The viscera in the neighbourhood of the stomach.
624. The external membrane of the stomach.  
The first cellular coat.
625. The muscular coat of the stomach.  
The ligaments of the pylorus.
626. The second cellular coat.  
The nervous coat of the stomach.  
The third cellular coat.  
The villous coat.  
The valve of the pylorus.  
The pores of the villous coat.
627. The arteries of the stomach.
628. The distribution of the arteries through the coats of the stomach.
629. The veins of the stomach.
630. The nerves of the stomach.
631. The lymphatic vessels of the stomach.
632. The inorganic pores.
633. The mucus anointing the villous membrane.
- The limpid humour which the arteries distil.
634. The pressure of the diaphragm and muscles of the abdomen on the stomach.
635. The necessity of meat and drink.
636. The phenomena of hunger.
637. New chyle, its uses.
638. The cause of hunger.
639. The seat of thirst.  
How it is excited.  
How quenched.
640. The pleasure of taking food.
641. Our diet ought to consist of two kinds of aliments blended together.
642. Why flesh is required.
643. Why vegetables.
644. Drink.
645. Condiments.
646. Preparations of aliments.
647. The measure of food.
648. The changes which happen to the food in the stomach.
649. What hinders the food from degenerating into complete acidity in the stomach.
- There

- There is no kind of ferment here.
650. The peristaltic motion of the stomach propelling the aliment into the intestines.
651. The more powerful force of the diaphragm and abdominal muscles.
- In what order and time the aliments go out of the stomach.
652. A certain portion of drink is absorbed in the stomach into the veins.
653. Vomiting.
654. Order of arrangement.

C H A P. XX.

THE OMENTUM.

655. The peritonæum and its extent.
656. The cellular texture placed round the peritonæum is continued into the capsules. Its connection with other parts.
657. The productions and ligaments of the peritonæum. By the separated laminæ of the peritonæum the viscera are surrounded, and kept firm and defended in motions and concussions of the body.
- 658, 659. The mesocolon.
660. The mesocolon and mesentery are hollow. The slender purses of the mesocolon.
661. The mesentery.
662. What things are found in all parts of the mesentery and mesocolon.
663. Many parts are comprehended under the name of omentum. Their nature in general. The membrane from the external membrane of the colon inserting itself into the fissure of the liver.
- The natural orifice, and common porta of the omentum.
664. The lesser hepatico-gastric omentum.
665. The anterior lamina of the greater gastro-colic omentum.
666. Its posterior lamina.
667. The omentum colicum.
668. It is common both to the omentum and mesentery to accumulate fat. How it is proved that this fat is received into the veins.
669. The arteries of the omenta.
670. The nerves of the omenta.
671. The arteries of the mesentery and mesocolon.
672. The veins of the omentum and mesentery. The lymphatic vessels of the omentum.
673. Other uses of the omentum.
674. The use of the mesentery.
675. The nature of the water absorbed by the veins of the mesentery, and what it contributes towards the bile.

C H A P. XXI.

THE SPLEEN.

676. The substance of the spleen. Its figure. Connection. Its situation, bulk, and number.
677. The arteries and veins of the spleen.
678. The lymphatic vessels of the spleen.
679. Its nerves.
680. Its

680. Its internal structure.  
 Its surrounding membrane.  
 681. The spleen contains a great deal of blood.

Its nature.

- 682—3. The use of the spleen.  
 684. Conjectures concerning it.

## C H A P. XXII.

### THE PANCREAS.

685. The pancreatic juice.  
 686. The situation and figure of the pancreas.  
 Its structure.  
 Its vessels.  
 Its nerves.  
 687. The pancreatic duct.  
 688. The quantity of pancreatic juice.

The powers by which it is expelled.

The universality of the pancreas is an argument of its utility.

Whence the effervescence with the bile arises.

- 688.\* The utility of the pancreatic juice.

## C H A P. XXIII.

### THE LIVER, GALL BLADDER, AND BILE.

689. The bulk of the liver.  
 The situation of the liver in respect to the diaphragm.  
 The ligaments from it.  
 Other ligaments.  
 How it can be moved.  
 Its common membrane.  
 690. How the liver is situated with respect to the colon, kidneys, duodenum, stomach, and pancreas.  
 691. The shape of the liver.  
 692. The furrows of the liver.  
 Its lobes.  
 693. The arteries of the liver.  
 694. The umbilical vein.  
 The ductus venosus.  
 695. The large trunks of the vena portarum.  
 696. The capsule of the vena portarum.  
 The divisions of its branches.  
 These are perpetually accompanied by branches of the hepatic artery.  
 The proportion of the branches of the vena portarum to the trunks.  
 697. The branches of the cava.  
 The proportion of its branches to those of the vena portarum.  
 The trunk of the vena cava.  
 The smaller veins creeping over the surface of the liver.  
 698. The passage of the blood through the vena portarum.  
 699. The nerves of the liver.  
 700. The lymphatic vessels of the liver.  
 701—3. The internal structure of the liver.  
 704. How it happens that the bile is not secreted from the hepatic artery, but from the vena portarum.  
 705. How the secreted bile is sent into the biliary ducts and through them.  
 706. The structure of the biliary duct.  
 Its irritability and sensibility.  
 707. The ductus choledochus.  
 708. The ductus cysticus.  
 The gall bladder.  
 Its situation.  
 709. The shape of the gall bladder.  
 The wrinkles of the ductus cysticus.

710. The

710. The coats and muciferous pores of the gall bladder.  
The exhalation of the arteries into the gall bladder.  
The bile exudes through inorganic pores.
711. In man, no ducts come from the liver into the gall bladder.
- 711.\* The bile flows into the intestine both from the liver and from the gall bladder.  
All the bile is not first conveyed to the gall bladder.  
The quantity of bile.  
How often the bile flows into the bladder.  
The gall bladder does not secrete its proper bile.
712. The return of bile into the blood is morbid.
713. The change which the bile undergoes in the cystis.  
It is directed into the gall bladder, when there is no use for it in the intestines.
714. The powers which express the bile from the gall bladder.
715. The qualities, elements, and offices of the bile.
716. Whither the bile goes.  
It sometimes comes into the stomach.  
The bile of the fœtus.  
Its coagulation and uses.
717. The proper use of the liver in the fœtus.

## C H A P. XXIV.

## THE SMALL INTESTINES.

718. The small intestines in general.  
Their division.
719. The duodenum.  
In it chiefly the bile and pancreatic juice are mixed with the aliments.
720. The situation of the rest of the small intestines in general.
- 721, 27. The structure of the small intestines.
721. The external coat.  
The first cellular coat.
722. The muscular coat.
723. The second cellular coat.  
The nervous coat.  
The third cellular coat.  
The villous coat.  
Its folds.
724. The villi of the intestines.
725. The vesicles of the villi.
726. The larger pores of the villous coat leading to the mucous glands.
727. The lesser pores likewise depositing mucus.
- 728, 730. The arteries of the small intestines.
730. The arteries of the duodenum.
731. The veins of the small intestines.  
How it is proved that these absorb a thin humour from the intestines.
732. The nerves of the small intestines.
733. The liquid flowing from the arteries into the cavity of the intestines.  
Its quantity.  
The uses of the mucus of the small intestines.
- 734—5. The peristaltic motion.
736. The changes which the food undergoes in the small intestines.
737. The office of the small intestines in general.
738. The principal causes which change the aliments in the small intestines.

## C H A P. XXV.

## THE LARGE INTESTINES.

739. The remains of the food after the chyle is extracted.
740. How the ileum applies itself to the colon.  
The valve of the colon.
741. The blind extremity of the colon.  
The appendix.  
How the change from the structure of the cæcum in the fœtus to that of the adult takes place.  
The fœtor of the intestines begins chiefly there.
742. The situation and connections of the colon.
743. The structure of the colon in general.  
Its ligaments.
744. The cells of the colon.  
The wrinkles, follicles, and pores of its villous membrane.
745. The vessels of the large intestine.
746. The division of the vessels to the large intestines.  
The exhalation and resorption from these.  
The hemorrhoids.
747. The lymphatic vessels of the large intestines.
- Chyle is sometimes observed in these.
748. The nerves of the large intestines.
749. The fæces of the intestinum colon.  
The peristaltic and antiperistaltic motion of the colon.  
Flatus.
750. How the ileum is shut.  
The passage of the fæces thro' the colon.
751. The situation and course of the rectum.
752. The external and muscular coat of the rectum.  
The internal sphincter of the anus.
753. The villous coat of the rectum.  
Its folds, and mucous glands.  
The sebaceous glands of the anus.
754. The external sphincter of the anus, and its action.  
How the anus is naturally closed.
755. The levator muscles of the anus.
756. The excretion of the fæces.
757. The fæces themselves.

## C H A P. XXV.\*

## THE CHYLIFEROUS VESSELS.

758. The nature of the chyle.
759. The absorption of the chyle, and its passage through the lacteal vessels.  
In what animals lacteal vessels are found.  
How they are disposed in the different intestines.
760. The valves of the lacteals.  
The causes of the motion of the chyle through the coats of the intestines.
761. The glands of the mesentery.
- The chyle proceeds from the intestines to these glands.
762. What happens to the chyle in the glands of the mesentery.
763. The course of the lacteals from the mesenteric glands to the receptacle of the chyle.
764. How the passage of the chyle into the receptacle is demonstrated.
- 765—6. The thoracic duct.
767. The chyle passes to the blood through the thoracic duct.
768. The

768. The causes of the motion of the chyle in general.
769. The change of the chyle during its circulation with the blood.  
In the intestines there are not lacteal and lymphatic vessels of different kinds.
770. The lacteal vessels absorb water when digestion does not go on.  
The thoracic duct brings back the lymph of the whole body.

## C H A P. XXVI.

## THE KIDNEYS, BLADDER, AND URINE.

771. A part of the water brought into the blood with the chyle is strained through the kidneys.
772. The situation and connection of the kidneys.  
Their figure.  
External membrane.  
Their fat.  
Ligaments.
773. The arteries of the kidneys.
774. The veins of the kidneys.  
The quick passage of the blood from the arteries into the veins.  
The veins of the renal fat.
775. The lymphatic veins of the kidneys.
776. The nerves of the kidneys.
777. The renal capsule.
- 778—80. The internal structure of the kidney.
778. The structure of the cortical part.  
The uriniferous vessels.  
The glands.
779. The papillæ of the kidneys.
780. The infundibula.  
The pelvis.
781. The secretion of urine.  
The quantity of the urine.
782. The elements of the urine.
783. How the ureter carries the urine forwards.  
The ureter itself.
784. How it is proved that the urine is secreted in the kidneys, and descends by the ureter into the bladder.
785. The urine cannot descend by other passages.
786. The situation of the urinary bladder.
787. The figure and magnitude of the bladder.
788. The first cellular coat of the bladder.  
Its longitudinal muscular fibres.
789. Its other muscular fibres.
790. The contractile power of the bladder.
791. The second cellular coat of the bladder.  
The nervous coat.  
The innermost coat of the bladder.  
The mucus of the bladder, and its sources.
792. The vessels and nerves of the bladder.  
The lymphatic.
793. The bladder transmits and absorbs water through its inorganic pores.
794. The urine flows through the ureter into the bladder.  
It remains there.  
The causes retaining the urine.
795. How the urine is expelled.
796. Various noxious matters are thrown off by the urine.  
The consequences of a retention or suppression of urine.
797. The urethra in general.
798. The parts receiving and supporting the urethra.  
The various capacity and figure of the urethra.
- 799—802. The muscles governing the urethra.
803. The pyramidal muscle has no effect in drawing the bladder downwards.
804. The mucus of the urethra, and its various sources.
805. The stone in the urinary bladder.

## C H A P. XXVII.

## THE MALE GENITALS.

806. The reason of the situation of the genital parts.
807. The order of the arrangement. The various situations of the testicles.
808. The scrotum. The dartos.
809. The cellular texture of the scrotum. The cremaster.
810. The vaginal coat of the testicle. The tunica albuginea.
811. The figure and situation of the epididymis.
812. The spermatic artery. The abdominal ring. The course of the spermatic cord from thence to the testicle. The small arteries to the coverings of the testicle.
813. The distribution of the small arteries through the testicle. The arteries have no anastomoses with the spermatic vein. The motion and quantity of the blood in the testicle.
814. The spermatic vein.
815. The vessels of the external coverings of the testicle.
816. The nerves of the testicle.
817. The lymphatic vessels of the testicle.
818. The internal structure of the testicle.
819. The structure of the epididymis, and the vascula aberrans.
820. The motion of the semen.
821. The vas deferens.
822. The vesicula seminalis.
823. The semen.
824. The animalcules of the semen.
825. How these seem to be in the semen.
826. Whence the semen proceeds. Of what humours it is composed. What is generated in the testicles only is prolific. How long the semen is preserved in the vesicles.
827. A part of the semen is absorbed, and its effects. How the semen is retained in the vesicles.
828. The quantity of semen. The semen proceeds from the testicle into the vesicle.
829. The prostate gland. Its liquor.
- 829.\* The three dilatations of the urethra; its various directions; its coats.
830. The cavernous body of the urethra.
831. How it is proved that the blood is poured into this body.
832. The cavernous bodies of the penis.
833. The teguments of the penis. The prepuce. The odoriferous glands. The suspensory ligament.
834. The use of the penis.
835. The erection of the penis. Its exciting causes.
836. The arteries of the genital parts.
837. The veins of the same parts.
838. The lymphatic vessels of the penis. The nerves of the genital parts.
839. The immediate cause of the erection of the penis.
840. The expulsion of the semen into the urethra.
841. Its expulsion from the urethra. This action is very violent, and almost convulsive.

## C H A P. XXVIII.

## THE VIRGIN WOMB.

842. The situation of the uterus in the pelvis.  
How the uterus is tied to the peritonæum.  
The broad ligaments.
843. The body, neck and internal mouth of the uterus.
844. The tubes of the uterus.
845. The ovaries.
846. The eggs in the ovaries.
847. The round ligament of the uterus.
848. The arteries of the uterus.
849. Its veins.
850. The internal vessels of the uterus.
851. The lymphatic vessels of the uterus.
852. The nerves of the uterus.
853. The age at which the menses begin to flow.
854. The phenomena of the menses.  
The duration of the flux.  
The periods at which they return.
855. The menstrual blood flows from the vessels of the uterus itself.  
The nature of the menstrual blood.  
The uterus being obstructed, the blood flows out through the vagina, and through other parts.
856. Whether the moon, ferments, or the venereal desire, be the causes of the menses.
857. The female body in general.
- The pelvis and its vessels, in as far as they differ from the fabric in the male.  
How the passage of the blood through the uterus is thence affected.
859. The inferior limbs, pelvis, and uterus, of a female child newly born.  
How the structure of these is changed in the adult.  
The effects of these changes.
860. Plethora is generated in both sexes when the growth of the body ceases.  
This, in males, goes off by the nostrils.  
In women it finds an easier passage by the uterine vessels.  
There are other effects of this determination of the blood.  
How the quantity of the menses is increased or diminished.
861. The quantity of the blood sent out.  
The remission and return of the period.  
Why the period is commonly fixed to a month.  
Why the menses cease to flow altogether.  
Why brute animals have no menses.  
Why men want them.
862. Why the breasts swell at the same time.

## C H A P. XXIX.

## CONCEPTION.

863. The difficulty of this subject.  
The order of treating it.
864. The most simple animals of no sex.
- How they produce their young ones.
865. Oviparous animals of a single sex.

866—7. Animals

- 866—7. Animals of two sexes existing in the same individual.
866. What animals impregnate themselves.
867. Animals of this kind which mutually stand in need of one another's assistance.
868. Animals with two sexes divided.
869. Consequences which follow from what has been said concerning the origin and sexes of animals.
870. Causes of the venereal desire.
871. The vagina, and its situation.  
The hymen.  
The carunculæ myrtiformes.
872. The structure of the vagina.
873. The nymphæ.  
The clitoris.
874. The constrictor muscle of the mouth of the vagina.
875. Coition.  
What happens to women during the time of coition.
876. The sources of the mucous liquor ejected.  
The tubes are erected in coition, and applied to the ovary.
- 877—8. What changes take place in the ovary at that time.  
The corpus luteum.
878. How it is proved that the tube presses out the egg, absorbs it, and carries it to the uterus.
879. The feelings of the future mother while these things are performed.  
How it is proved that conception takes place in the ovary.
880. Why the uterus is thought to be shut after conception.  
Whence the complaints after conception arise.
881. The original stamina of the new animal; whether they are from both parents, and the mixture of semen furnished from all parts of the body.
882. Whether they proceed only from the male and his seminal animalcules.
883. Whether the fœtus proceeds rather from the mother.
884. Hypotheses concerning the formation of the new animal.
885. What seems to be more certainly known concerning this matter.
886. The state of the embryo before conception.  
How it is changed by the male semen.
887. Objections derived from moles, of no weight.
888. The change of the egg when brought into the uterus.  
Its insemination with the uterus.
889. The contents of the egg at that time.  
The fœtus during the first days of conception.
890. The increase of the egg and of the fœtus until the placenta is completed.  
Description of the completing of the placenta.
891. The placenta, and its connection with the uterus.
892. The chorion.
893. The middle membrane.
894. The amnion.
895. The umbilical vein, by which nourishment is conveyed to the fœtus.  
The cord.
896. The umbilical arteries.  
These, with their veins and cellular texture form the placenta.  
The blood flows from the placenta into the veins of the uterus.
897. Whether the fœtus takes in the liquor of the amnion by the mouth, and is nourished by it.  
What is the source of this liquor.
898. The excrements of the fœtus.
899. Whether there is any allantois in the human race.  
They certainly have an urachus.  
The urine is perhaps deposited in the cellular texture of the cord.
900. A compendium of the formation of the fœtus must be given.
901. What parts are formed at the very first beginning of the fœtus.
902. The

902. The proportion of the fluid to the solid parts at that time.
903. The accessory nutritious juices. How the blood and rest of the humours are perfected.
904. How the solid parts in general are formed.
905. The vessels are first formed. How they are produced.
906. What parts are at first completed and become conspicuous in the primeval fœtus. What are as yet involved and lie hid.
907. The motion of the heart is appended to this kind of embryo. The heart at first bears the largest proportion to the rest of the body. Its pulsations are very powerful in distending and lengthening the vessels.
908. What is opposed to this power of the heart. How the arteries are then affected.
909. The fœtus grows very quickly. The cause of this quick increase.
910. The embryo is altered during its growth.
- 910—14. By what causes this is chiefly produced.
910. Expansion.
911. Attraction.
912. Pressure.
913. The power of derivation. Of revulsion.
914. The change of the humours.
915. How bone succeeds cartilage and epiphysis.
916. How the long bones are formed.
917. How the flat bones are formed.
918. How bone is produced from gluten. It is deposited from the inmost substance of the bone, and not from the periosteum.
919. The periosteum.
920. The fœtus during the first days of pregnancy.
921. The thymus.
- 921—24. The circulation of the blood peculiar to the fœtus, and the organs by which it is performed.
925. Whether the fœtus breathes in the womb. Whether it does so in the vagina.
926. The changes which happen to the uterus during pregnancy. The different situations of the fœtus.
927. The complaints attending pregnancy. The time of delivery.
928. Parturition.
929. The number of fœtuses. Superfetation.
930. The loosening of the placenta.—of the umbilicus.
931. The contraction of the uterus after delivery. The lochia. The swelling of the breasts.
- 944.\* The milk. Sympathy between the breasts and uterus.
945. The breasts. Their vessels. Nerves.
946. The lactiferous ducts in the breast. The nipple and its lactiferous ducts. The areola of the nipple.
947. Suction. The colostræ. Milk may be produced without a child. The breasts, after the menses have ceased, become effete.
- 948—52. The changes which happen to the child after birth.
948. Respiration. The deflexion of the course of the blood from the ductus arteriosus.
949. The shutting up of the foramen ovale.
950. The shutting up of the umbilical vein and ductus venosus.
951. The contraction of the umbilical veins, and abolition of the urachus.
952. Other changes.

## C H A P. XXX.

## NUTRITION, GROWTH, LIFE, AND DEATH.

953. The growth of a child is slower as it advances in age.  
The causes why the growth is continually lessened.
954. The heart grows less in proportion than any other part of the body.  
And becomes less irritable.
955. The end of the increase of the body.
956. When this is said to occur.
957. How it is proved that all parts, even the most solid, are continually consuming and changing.
958. The causes of the destruction of the solid parts.
959. How the waste of the solids is repaired.
960. How the waste of the cellular substance and most organic parts is repaired.
961. How the free extremities of parts are repaired.
962. Fatness.
963. The beginnings of decay.
964. The progress of decay.
965. The diminution of the vis insita and nervous power.
- 966—8. The change of the fluids.
966. The decrease of the fluids.
967. The corruption of the fluids.
968. The increase of the quantity of earth in the fluids.
969. Old age.
970. Decrepit old age.
971. Longevity.
972. Death from old age.
973. The signs of death.
974. The body is destroyed by putrefaction.  
The soul survives after death, and goes to the place appointed for it by the Almighty.

F I N I S.





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