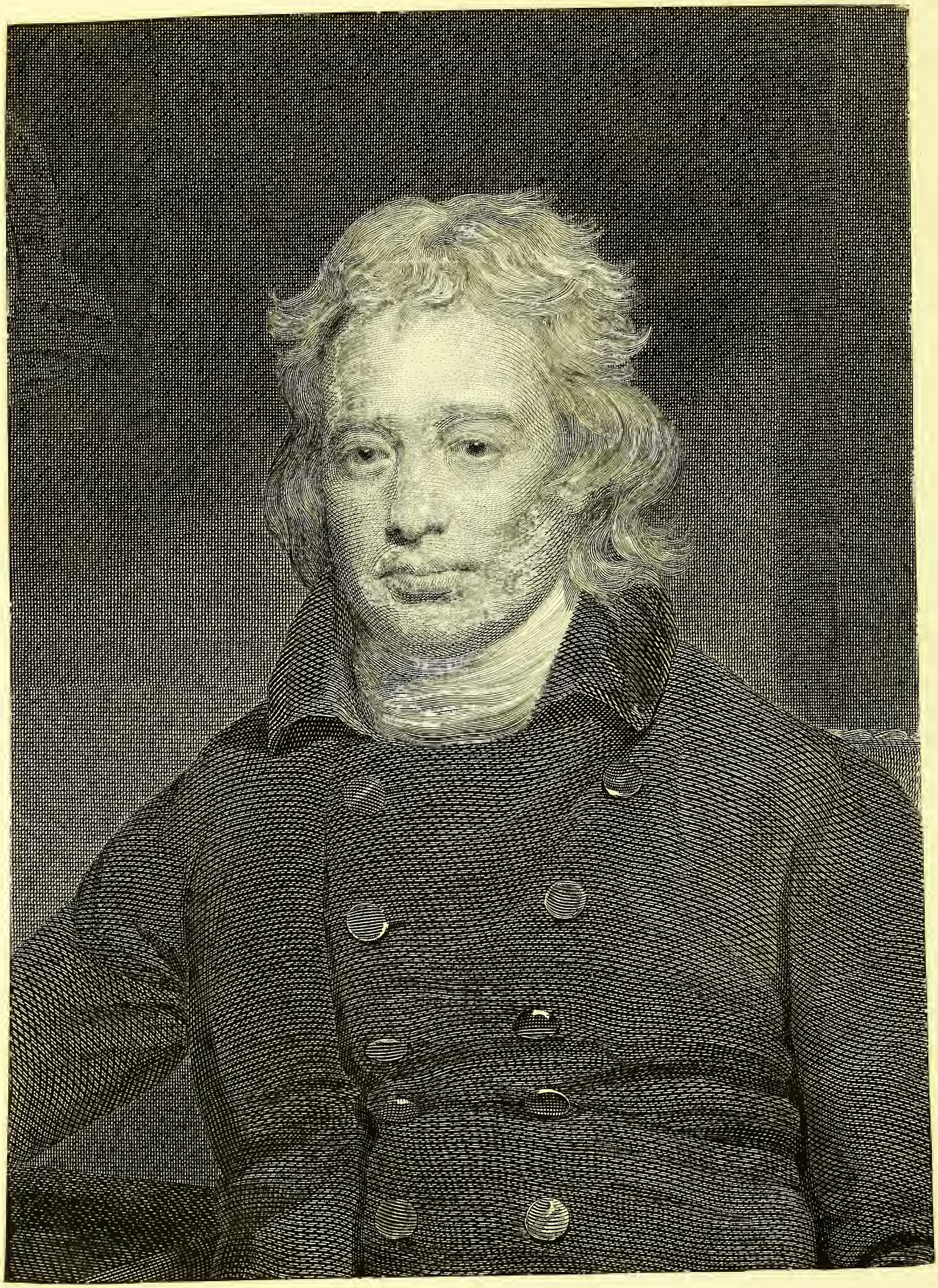
LECTURES

ON

COMPARATIVE ANATOMY.



LECTURES

ON

COMPARATIVE ANATOMY;

IN WHICH ARE EXPLAINED

THE PREPARATIONS

IN

THE HUNTERIAN COLLECTION.

ILLUSTRATED BY ENGRAVINGS.

BY

SIR EVERARD HOME, BART. F. R. S.

SERJEANT SURGEON TO THE KING; SENIOR SURGEON TO ST. GEORGE'S HOSPITAL; AND HONORARY PROFESSOR TO THE ROYAL COLLEGE OF SURGEONS.

IN TWO VOLUMES.

VOL. I.

LONDON:

PRINTED BY W. BULMER AND CO. CLEVELAND-ROW, ST. JAMES'S;

FOR G. AND W. NICOL, BOOKSELLERS TO HIS MAJESTY, PALL-MALL.

1814.

TO

HIS ROYAL HIGHNESS

THE PRINCE REGENT.

SIR,

In dedicating these Lectures to Your Royal Highness, I am desirous of making it publickly known, that the Prince Regent of these Realms has not only condescended to honour the Hunterian Collection of Comparative Anatomy with a visit, but has also been graciously pleased to permit this explanation of a small portion of its Contents to be published under His Royal Highness's auspices. Such highly honourable marks of Princely Favour, while they encourage and promote this most useful branch of knowledge, give the most unequivocal proofs to the different classes of His Majesty's Subjects, of His Royal Highness's disposition to patronize and protect all those whose labours tend, even in the smallest degree, to the advancement of Science.

I have the honour to be,

with profound veneration and respect,

SIR,

YOUR ROYAL HIGHNESS'S

most faithful and most dutiful Servant,

EVERARD HOME.

At a Quarterly Meeting of the Trustees of the Hunterian Collection, holden on the 13th day of May, 1811,

PRESENT,

The Right Hon. Lord Auckland in the Chair.

The Right Hon. the Speaker of the House of Commons,
The Right Hon. Sir Joseph Banks,
Isaac Hawkins Browne, Esq.
Sir Charles Blagden.

The Trustees strongly expressed their wish, that Mr. Home would deposit a Copy of his Lectures with this Board; and that at such time as should be most satisfactory to himself, he would cause the same to be printed.

At a Quarterly Meeting of the Trustees of the Hunterian Collection, holden on Saturday the 1st day of May, 1813,

PRESENT,

The Right Hon. Lord Auckland in the Chair.

The Right Hon. the Speaker of the House of Commons,
The Right Hon. the Chancellor of the Exchequer,
Sir Charles Blagden,
The Right Hon. George Rose,
Isaac Hawkins Browne, Esq.
Sir Francis Millman, Bart. President of the College of Physicians,
Dr. Gower, Dr. Whitter, Dr. Hue. } Censors.

The Speaker communicated to the Trustees, that he was authorised by Sir Everard Home to state, that having resigned the Professorship of Anatomy and Surgery, he no longer feels the same reasons for declining to publish his Lectures delivered in the Theatre of the College, if it should still continue to be the wish of the Trustees that the same should be published.

Resolved unanimously,

"That the Secretary do express to Sir Everard Home the acknowledgment of the Trustees for such communication; and their earnest wish that he would proceed to give to the public the benefit of his valuable labours, by publishing such Lectures."

FIRST COURSE OF LECTURES,

DELIVERED IN THE

THEATRE OF THE ROYAL COLLEGE OF SURGEONS,

IN THE SPRING, 1810.

CONTENTS.

FIRST COURSE OF LECTURES.

* The treatment of curvatures in the spine mentioned in this Lecture, was first employed by my friend Alexander Grant, Esq. surgeon at Bath. The success attending this practice is now so well established, that he permits me to mention his name, which he declined doing at the time the Lecture was given.

CONTENTS.

CONTENTS.

* In this Lecture it should have been stated, that the stomach of the craw-fish differs from that of the lobster and crab, in the teeth being fitted to divide, and not to grind; the coats being thinner, and more pliant, and having on their outer surface two hard cretaceous bodies placed opposite each other, between which the food is ground; these bodies form a species of gizzard not hitherto described. They have long been used in medicine under the name of oculi cancrorum.

Sackville-street,
November 10, 1813.

LECTURES

ON

COMPARATIVE ANATOMY.

LECTURE I.

On the general Distribution of the Preparations on Comparative Anatomy in the Hunterian Collection.

In the beginning of a Course of Lectures on Comparative Anatomy, which is to be illustrated by the Specimens contained in this Museum, the Professor, whoever he might be, must feel himself called upon, before he could enter upon his subject, to make some Observations on the Man who formed so invaluable a Collection: he must consider it as a duty to expatiate on the talents, the fortitude, the self-denial, and the labour of a Hunter, who in the course of thirty years, with unwearied perseverance, by devoting to this one object the whole of that time which could be spared from his professional avocations, and the whole of the emoluments which his profession produced, had completed a regular series of Anatomical

Preparations illustrative of the great chain of animal structures, link by link, from the most simple in their form, to the most complex and perfect of the animal creation.

The Collection he has thus formed, which in the number of Specimens, the exquisite art by which they have been displayed and the expense at which they have been made, is indisputably unrivalled in the world, so that it shews more the appearance of their having been brought together under the patronage of some munificent monarch, than of their being the workmanship of an individual member of this College, who had no inducements but his own zeal and enthusiasm, no means but the income arising from his professional labours.

This would have been the duty of any other Member of the College who had been called upon to fill this Chair; how much more then does it become incumbent upon me, who received the first rudiments of my Anatomical education in the formation of this Collection; whose hand was fashioned, whose ardour was excited, and whose mind was expanded and enlarged by living many years with the great Man who formed it. When I reflect, that it is to such an education that I am indebted for the place I now hold in my profession, as well as for this honourable office, I should be guilty of an outrage to my own feelings, were I not on the present occasion publicly to express the high estimation in which I hold this noble Collection, the great obligations I feel myself under to the late Mr. Hunter, and the grateful sense of them which I shall ever retain.

Comparative Anatomy embraces a field of such extent, that the labours of future ages will still be required before our knowledge of it can be rendered complete. If we review the steps by which it has arrived at its present state, we shall find that even many of those individuals by which it has been materially promoted, have only been able to add the anatomical and physiological account of one single species of animals; some few, indeed, have extended their labours to the different genera of the same order, but after persevering for many years, have been unable completely to accomplish even this small part; small, indeed, when compared with the whole, but of great extent when the limited powers of man are considered, in investigations of so intricate a nature.

The force of this observation will probably not be appreciated by the younger part of my audience; but it will be sufficiently felt and understood by the best informed on this subject who now hear me; they know the pains they have taken, and the time they have spent, in acquiring what must at best be called a competent knowledge of the structure of the human body alone; and none of them will venture to affirm, that they are completely satisfied with the degree of this knowledge which they have so acquired: they will ingenuously admit that there are still many parts of the human body whose structure has not been discovered, and whose particular uses, therefore, remain unknown; and man forms only one link of the chain of animated beings.

So well convinced was the late Mr. Hunter that the great field of comparative anatomy had not been sufficiently cultivated to bring the whole subject within the grasp of one man, even if his labour and perseverance were exerted to the utmost, that when a young anatomist proposed to give lectures upon comparative anatomy, Mr. Hunter told him that it was a bold undertaking, and one, which from his knowledge of the subject being too imperfect, he felt himself unable to undertake.

In so difficult and laborious an enquiry, it may be an advantage to those who are engaged in it, to be informed in what manner the late Mr. Hunter was led to form this collection, and to be made acquainted with the plan on which it is arranged. Such a history will give a general view of the subject, and form a regular introduction to the future Lectures, in which the same outline is intended to be followed. I wish it however to be clearly understood, that this is not a course of lectures comprehending every thing that belongs, or ought to belong, to a general course on comparative anatomy. I confess myself unequal to such a task, nor dare I venture further into this labyrinth of nature than I can go with safety, guided by the clue which Mr. Hunter has left me.

Mr. Hunter, from the neatness of his hands and the quickness of his eye, appears to have been fitted by nature for anatomical enquiries, and fortunately for science he was educated in human anatomy under Dr. William Hunter, who was himself an enthusiast in the art.

After Mr. Hunter had made himself familiar with the general structure of the human body, he contracted so great a fondness for anatomical investigations, and for making preparations of the parts he had dissected, that by way of recreation, when fatigued with going constantly over the same beaten track of human anatomy in his brother's dissecting room, he opened to himself a new source of information by examining the structure of other animals, and making comparative observations between them and man. By thus ascertaining the differences in the formation of the same organs in different animals, he considered that he should be best enabled to form an accurate notion of the uses for which they are intended by nature.

In this way he was enabled, in the course of his enquiries, to correct some errors in human physiology, and to come at a more accurate knowledge of the uses of some of the more complicated organs. He found that those bags in the human body which are called vesiculæ seminales, from a supposition that they contain semen, are in the hedgehog filled with a transparent bluish substance, soft near the fundus of the vesiculæ, and firmer in consistence towards the openings into the urethra, where it is as solid as new cheese; and totally different from the semen in that animal; that their excretory ducts do not communicate with the vasa deferentia, but open by distinct orifices at the verumontanum.

The discovery of these facts led him to make observations on the human vesiculæ seminales, from which it appears in the most satisfactory manner, that they are not reservoirs of semen, but secrete their own fluid, which like that of the prostate gland passes out by the canal of the urethra.

He discovered the organ of hearing in fishes, which is more simple in its structure than in those animals who hear through the medium of air, consisting in general of three semicircular canals which communicate with one another, and with a small cavity into which they all open.

As these canals form the whole organ in fishes, he was led to conclude that they are the most essential part of this organ in the quadruped, and that the others are only superadded, to render the organ more sensible to impressions through air, which are much weaker than those through water.

These discoveries not only encouraged him in such pursuits, but worked up his mind to a degree of enthusiasm which made him spare no pains in improving his knowledge in comparative anatomy, and made him redouble his labours in augmenting his collection.

Those only who feel an ambition to excel, can enter into the pleasure and delight which he received from having made a discovery, or even having succeeded in making a preparation which had not been previously accomplished by any other anatomist, whether from the nicety required, or the rarity of the animal to which the parts belonged. Such was his patience and perseverance while working upon anatomical preparations, that he never rested satisfied till every part of the object was distinctly exposed; and in this way he improved that useful art, and has raised it to a degree of excellence to which it had never before arrived.

This enthusiasm, which he possessed in so great a degree, was communicated to those whom he employed to assist him, and made them with cheerfulness and alacrity partake of his labours. It was in this school that the present Conservator of the Museum acquired those excellencies for which he is so much esteemed, and which so admirably fit him for his situation.

In the course of twenty years, Mr. Hunter formed a collection of preparations of the various structures which are met with in the same organs of different animals, and having supplied himself so amply with materials, he formed a system of his own, and arranged the preparations in the order in which they now stand. This arrangement bears no resemblance to those of other naturalists. It is little favourable to the study of natural history, but is peculiarly adapted for those who mean to prosecute comparative anatomy. It is an attempt to class animals according to their vital and other internal organs, forming the whole into one regular series of gradations, beginning with those animals that have the most simple structure and tracing them upwards as their parts become more numerous till we arrive at man, the most complex in his organs, who forms the highest link of the chain.

According to this plan, Mr. Hunter's system begins with animals that have nothing analogous to a circulation; then follow others which have some approach towards one; and afterwards animals in which it is distinct; and so on through all the complications which lead by almost imperceptible steps to man, in whom the heart is the most compounded.

All the organs of an animal body are arranged in distinct series, beginning with the most simple state in which each organ is met with in nature, and following it through all the variations in which it appears in other more complex animals.

This mode of classing animals is more rational than any which has been hitherto adopted, but can never answer one of the great purposes of classification, which is, to assist the memory of those who are learning the science in retaining the different parts of so extensive a subject.

In the year 1787, this Collection was completely arranged, and was exhibited to the public on certain days in the spring, a custom Mr. Hunter continued during the rest of his life.

In the year 1800, Mr. Cuvier, Secretary to the National Institute of Paris, an anatomist deservedly eminent in the eyes of Europe, published the two first volumes of his Leçons d'Anatomie Comparée, a most valuable work, so nearly on the same plan as Mr. Hunter's Collection, that it might be considered as a descriptive catalogue of it on a more extensive scale; the materials of this work having been compiled not only from what had come immediately under the author's observation, but what had been compiled by the best authors, who have written upon any of the subjects of which it treats.

That my audience may the better comprehend the preparations contained in the Hunterian Museum, and which are to form the materials for my future Lectures, I will endeavour to give a general description of the Collection.

As a self-moving power is the characteristic of life, by which animals and vegetables are distinguished from mineral substances, the means by which motion is produced forms the first subject which these preparations illustrate.

The series of preparations on this subject begins with specimens of such parts of plants as are capable of motion when under the influence of the sun's rays; which influence must be considered to act as a stimulus upon the parts of the plant; these preparations shew that in plants there is a structure analogous to elastic ligament.

Then follow coagula formed from the sap of plants, and from the blood of animals, to shew the varieties that are met with in the fluids out of which the moving powers, and indeed every other part of the plant or animal is formed, supported, and increased.

The different structures of muscles are next shewn, from the simple straight fibres to their most complex arrangement and the different circumstances in which muscles are placed, whether they are to move soft parts or hard ; whether inserted into ligaments, scales, shells, or bones.

Next to the preparations of muscles are those of elastic ligaments, which are employed to support parts that require being kept suspended, and are only to be occasionally moved from that situation; so that these ligaments become appendages to muscles, supplying their place at a less expense to the animal œconomy, whenever the purposes of nature can be answered by them ; as for instance, in the support of the claws of the lion and all the cat kind; for the support of the necks of animals, as in the camel.

As muscles are connected to more solid parts which serve as levers for them to act upon, the structure of the different hard substances so employed are next illustrated by preparations; also the mode in which they are formed, and the processes that are going on during their increase in size for the preservation of their shape.

The joints, by means of which the hard parts are united together for the purpose of motion, make the last part of this series ; and the mechanism employed for this purpose is found to be varied to an extent infinitely beyond what the ingenuity of man has been able to imitate. In the series which has been explained, are comprehended the different fluids out of which plants and animals are formed; the different moving powers of animal bodies; and the skeletons on which they act, so as to produce the loco-motion of the animal. These different structures constitute a distinct subject unconnected with the animal œconomy at large.

The next series is of much greater extent; it includes all the parts belonging to the animal œconomy employed for the increase and support of the animal; and as these purposes are answered by the blood, this series comprehends the organs by means of which this fluid is formed, and those by which it is distributed to the different parts of the body.

The first part of this series is the organs of digestion, in which fluids are secreted, capable of acting upon dead animal and vegetable substances, and producing a fluid which is afterwards to become blood.

It may be necessary as an introduction to this series, to mention, that there is a great difference between the processes by which the sap in vegetables, and the blood in animals, is formed.

In the first, the supplies are commonly received by the roots, and carried from thence into the plant; no common reservoir or stomach is met with; we must therefore conclude, that in the œconomy of vegetables no such part exists, and that the sap is formed by the mixture of the newly received fluids with the juices already contained in the plant; while in all animals, the most simple as well as the most compound, there is a cavity or bag into which the food is received, and in which it undergoes the change called digestion, and is converted into chyle.

The changes which the fluids undergo from the time they enter the sap-vessels, until that liquid is completely formed, are not yet wholly made out; but the great progress which my friend Mr. Andrew Knight has made in this investigation, leads me to hope that they will soon be explained in the most satisfactory manner.

The first preparation in this series is of an animal which may be said to be all stomach; for as, on the one hand, no animal exists without a stomach, so, on the other, it would appear from the preparations that that organ is all that is necessary to constitute an animal: In proof of this we have the globular hydatid, which is the most simple animal that our imagination can suggest: it is a bag, composed of a semitransparent membrane which has no external opening or mouth; it must therefore absorb its nourishment by means of small orifices on its external surface, in this respect resembling plants; but as there is a cavity to receive the nourishment, there is reason to conclude that the process of digestion is carried on in that cavity, more especially as there is another species of the same animal which has a mouth, or opening, by which food can be received.

The membrane which forms this bag is not only the digestive organ, but it has also the power of propagating the species; for the young hydatids are found attached to the internal surface.

The membranous bag of the hydatid has also the power of contracting when stimulated, and of increasing its own size by growth; from all which a fact, as extraordinary as any thing that is met with in nature, is demonstrated, which is, that a thin membrane, having no visible organs, is endowed with the three most essential properties of the compound animal, viz. muscular action, the power of increasing its own size, and of propagating the species.

When we see this membranous bag possessed of all those powers, for each of which in the more compound animals there are distinct organs of the most complicated structure, it is evident that such organs are not necessary to produce the power, but are only necessary to give it force and continuance; for although this membranous bag which lives in the brains and livers of sheep, and draws its nourishment from the living animal matter immediately surrounding it, which is connected into its own substance, a great increase of these powers will be required to act upon dead animal and vegetable matter employed for the support of a more active and powerful animal.

This simple state in which we find animal life to exist, is no less curious than instructive, since it shews that life itself, and all its powers, are less dependent upon complex organization than we should be otherwise led to imagine; and that the principle on which it acts, lies hid far beyond the reach of anatomical investigation: we must therefore satisfy ourselves in exploring the effects it produces, and the mechanism made use of for that purpose.

The globular hydatid which begins this series, is followed by the oval hydatid with a long neck, which differs from it in having an external orifice, and forms the connecting link with the polypus, which consists of a stomach with only one opening, by which the food is received and regurgitated.

Beyond these, are stomachs with two openings; in which the food as soon as digested is carried into a canal where it remains till the nutricious part is absorbed; and that which is excrementitious is voided by another passage.

The true stomach in all animals is a membranous bag of different shapes, but there are appendages to it in many animals as reservoirs for the purpose of macerating the food, or otherwise preparing it before it is received into the digesting stomach: of these there is a considerable variety.

After the stomachs, as an appendage to them, follow the teeth. In some animals, indeed, as the lobster, they are situated in the stomach. They vary exceedingly in their form, according to the kind of food the animal is intended to live upon, and in many birds the gizzard answers the purpose of teeth.

Their mode of formation is of a peculiar kind, which is illustrated by specimens in the different stages of their growth; as well as the manner in which they are shed, and a new set brought forward.

As the food, after it has undergone the process of digestion, and has been converted into chyle, is carried into the intestinal canal, and spread over the internal membrane so that the chyle may be absorbed by the lacteal vessels, the different appearances of this internal membrane, which vary exceedingly in different animals, are shewn: most of the specimens are beautifully injected, to expose the vascularity of the villi upon their surface.

After the intestines, as being closely connected with them, are shewn the glands, whose secretions are poured into their cavity for different purposes, many of which are not yet sufficiently known.

Having displayed the various parts concerned in digestion, and for carrying off the indigestible part of the aliment, as well as the surfaces from which the chyle is to be absorbed; the next preparations explain the system of vessels which perform that office. The roots of plants correspond with the lacteal or absorbent vessels of animals, and hold the first place; these are followed by different prepartions of lacteal vessels in animals injected to shew their peculiarities.

Following the regular order of those processes in nature by which animals receive their support, the next preparations are those of the most important organ of the body, the heart, and the vessels which belong to it, both arteries and veins.

In the more simple animals, it has been already mentioned that no such organ exists; and the first evident approach to it is in the caterpillar, in which the arterial system only is present, but without a heart or a circulation; as a substitute for which, the contraction and relaxation of the arterial trunk produces an undulation in the fluid contained in it.

In fishes there is a single circulation only; in the amphibia it is double, but the fluid in the two sides of the heart is allowed to mix by means of a communication between these cavities.

In the more perfect animals the two circulations are entirely distinct and separate, one carrying the blood through the lungs, and returning it to the heart, the other distributing it to the different parts of the body. The circulation of the blood, and the organization by which it is performed, forms one of the most surprising and beautiful pieces of mechanism in nature.

The discovery of the circulation of the blood was the first great step towards a correct knowledge of the structure of an animal body; it was reserved for the great Harvey, whose name it has deservedly immortalized; and it is of importance here to mention, that this discovery was the result of his expeperiments and observations in Comparative Anatomy. If the structure and uses of parts so large, and so much within the reach of examination, were not discovered till two centuries ago, can it be imagined that the smaller and more delicately formed parts of the body are readily to be investigated or easily to have their uses ascertained?

The chyle before it can become blood must be exposed to the air, from which it receives its red colour, and is rendered fit for the support of animal life. The organs, by means of which it undergoes this change, must be considered as appendages to the circulation, and therefore the preparations by which they are illustrated immediately follow those of the blood vessels.

The most simple structure by which the blood is exposed to the influence of the air, is in the egg before the chicken is hatched: the egg-shell is lined with a very vascular membrane, and the porous texture of the shell admits of the air passing through it so as to be applied to the coats of these vessels.

In fishes, this office is performed by the gills, to which the air is applied through the medium of the water in which it is contained. In quadrupeds, the air is received into the lungs, which vary considerably in their internal structure.

As there is a constant supply of fluids which are mixed with the blood, there is an apparatus for carrying off what is improper, or no longer fit for use, so that the circulating fluid may bear an uniform proportion to the blood vessels: this apparatus is the kidneys, which carry off those parts of the blood that are no longer of use, or are become superfluous.

The different structures of the kidnies form the last part of this extensive series, in which are included all the internal organs of the animal machine, connected with its nourishment.

The next series in this Collection is the most wonderful, and the least understood of all the parts of an animal body: it includes the brain, nerves, and organs of sense. These are formed and supported by the blood, and draw upon it largely for supplies. According to Mr. Hunter, they did not belong to the œconomy of the animal, but were the medium through which the animal keeps up a communication with external objects, and with other animals; but the brilliant discoveries lately made in Animal Chemistry, lead to the belief that the nerves are the agents by means of which the secretions are produced, as well as the muscles excited to action. These discoveries do not lead to any change in the arrangement of the Collection, since there can be no better order of parts than, first, to shew the organs by which the operations of the animal œconomy are performed, and then to exhibit the means by which they are animated and rendered capable of carrying on their functions, more particularly as these means are employed by the all wise Creator in connecting the internal animal with external objects through the medium of the senses.

In many of the inferior tribes there is no brain, and in others the organ is so simple as hardly to deserve the name. In the black snail it consists of a nervous circle, from which branches go off in every direction to the viscera and external coverings. This appears to be the whole nervous system.

The structure of the brain is not sufficiently known to enable us to trace its gradations with the same accuracy as in many other organs. One fact, however, appears to be sufficiently established, that in proportion to the size of the brain, is the intelligence of the animal.

The organs of sense follow the preparations of the brain. The natural order to be pursued in explaining their structure is to begin with the most simple, which is that of touch. This is illustrated by the fine villi of the skin; and as vascularity of parts seems necessary for the support of their sensibility, it is found that the one is always proportioned to the other.

The sense of taste is little more than a variation of the sense of touch; the visible structure of the organ consists therefore of similar villi; but as the tongue in most animals answers several other purposes, and in many is the only instrument by which they can procure their food, the variety in its form for these secondary uses is shewn in many beautiful specimens. As appendages to the tongue, are introduced the peculiarities met with in the fauces of different animals.

The organ of smell is more complex in its structure, and may be said to consist of a large extent of surface, so disposed that the air in its passage to the lungs may be readily applied to every part of it. This organ is less complex, and consequently the sense less acute in man, than in many animals who are destined to pursue their prey solely by the scent.

In some of the whale tribe, which from their form rank with the more perfect quadrupeds, it is an extraordinary circumstance that this organ, and the nerves by which it should be supplied, are entirely wanting. This is the case in the large and small whale-bone whales.

The organ of hearing is still more complicated than that of smell; even in fishes, in which it is more simple, it is composed of three canals; but in the quadruped it is made up of a great variety of parts, which are illustrated by preparations; many of these required great ingenuity to expose to view their more internal structure.

The organ of vision, which is the most beautiful in its form, as well as the most complex in its structure, has the last place, and this organ is made up of a great many different parts, which vary exceedingly according to the circumstances under which the animal is placed; there is one structure for seeing in strong, another for seeing in weak lights; and a different mechanism for seeing in water from what is employed to see in air. There are, therefore, a great many preparations to illustrate the several parts of this complex organ under the various forms which are given to it in different animals. The eyes are defended from external injury by different means, as the tears, the eye-lids, the membrana nictitans, and the eye-lashes, which may be considered as appendages to this organ; and with them terminates the present series.

The external coverings, by which animal bodies are defended from heat, cold, and from the effects of accidental violence, form the next series; but the cellular or reticular membrane, interposed between the different parts of the body and the animal oils which are deposited in it, being detached subjects, and these oils in the greater number of animals being situated immediately under the skin, specimens of them are placed before those of the coverings of the body.

The external coverings of animals are cuticle, rete mucosum, scales, feathers, and hair; for although shell may be in some measure thought to belong to this subject, yet, both in its structure and many of its uses, it has a great resemblance to bone, along with which it is classed, as has been already explained.

These different coverings appear to be all formed of the same materials, only varying in the appearance and in the manner of their growth; both of which are illustrated by preparations.

The parts of animals, which have been mentioned, may be called necessary parts, and are always met with; there are others which may be looked upon as peculiarities, and therefore do not belong to any of the regular series of structure: these are brought together under one head.

All weapons, offensive and defensive, come under this description, of which there is a great number. Of this kind are the horns of most animals, stings, and the electrical organs of certain fishes.

Besides offensive weapons, there are many other parts which rank among the peculiarities, as the air-bladders in fishes, and the comb of the cock: there are also powers of regeneration that some animals possess, as the shedding of the skin of the snake and of the shell of the crawfish, along with which this animal sheds the lining of the stomach, which is a crustaceous covering similar to its external shell.

There are also many glands and other parts which are only met with in particular animals, with the uses of many of these we are at present not at all acquainted.

The organs of generation form the last series in the Collection, and these are subdivided into five distinct parts. Those belonging to animals which are hermaphrodite, the same animal having both male and female organs, and capable of impregnating itself, are comprehended in the first; those in animals that have both male and female organs, but have no power of self-impregnation, constitute the second; the male organs, where they are distinct, form the third: the fourth comprehends the female organs in their unimpregnated state; and the fifth when in a state of impregnation.

The first of these includes the parts of generation of the greater number of plants, and of some of the inferior animals.

The second comprehends a tribe of animals which forms an intermediate link between the true hermaphrodite, and those with distinct sexes. These require copulation for the propagation of the species; they copulate with others of the same species; and as they are both male and female, they impregnate one another. The shell snail is of this tribe.

In the animals belonging to these two divisions, the species is multiplied in a degree much beyond those of the more perfect classes, since every individual is capable of having young.

The male organs, properly speaking, are the testicles, the other parts employed being only secondary in their uses, and frequently wanting.

In a wild state of vegetable and animal life, were these organs always fit to perform their functions, young plants and animals would be produced, equally in winter as in summer, and, consequently, the intention of nature would be frustrated; since the inclemency of the season would destroy the young: there is therefore in nature a provision against it. In plants, the flower in which these organs are contained, is only produced at the proper season of the year; and in animals the testicles are only in vigour in the spring and summer: in the winter they are so much diminished in size, as in some species almost to disappear. This is beautifully illustrated in the sparrow.

The penis is adapted in its form to the vagina of the female, in which there is great variety.

The female organs are more complex than those of the male.

In the unimpregnated state, the form of the ovarium, the oviducts, the uterus and vagina, are shewn in different animals.

In the state of impregnation, the seeds of plants are first shewn under a great variety of circumstances. These are followed by the ova of insects; and here the modes adopted by the bee and the wasp to preserve their eggs, and supply their young with nourishment, are seen: also the different external and internal changes of the silk-worm, from the egg to the moth. The formation of the egg in the pullet, and its incubation, is also traced from the first evidence of a punctum saliens till the young has arrived at a distinct form.

Those eggs, which are to be hatched out of the body, have a shell for their defence; but it is found that there is an intermediate link between the truly oviparous animals, and those that are truly viviparous, some animals having a soft egg, which is deposited in the uterus, and there hatched: of this tribe are some species of the dog-fish. In the quadruped, there is something analogous to this in the opossum tribe; so that here, as in every other part of the operations of nature, there appears to be a regular gradation from the more simple to the most complex modes of carrying on the same operations.

In the truly viviparous animals, there is an ovum originally formed. but so small that it has hitherto escaped detection, although its course from the ovarium to the uterus can be incontestibly proved; here the ovum consists of nothing but the rudiments of the young in their smallest possible form; there is nothing added for its support, as that is to be received from the uterus; and the passage is so short and so quick, that it must be a doubt whether the ovum can be ever discovered till it arrives in the uterus, and begins to acquire a certain size. As soon as it has done so, it is connected to the uterus by means of a new-formed substance called the placenta, the structure of which is shewn in a variety of preparations.

These different stages of impregnation are followed by the peculiarities met with in the structure of the fœtus, fitting it for what may be called its fœtal life, all which disappear as soon as the young animal begins to breathe and take nourishment by the mouth. The last part of this series is the structure of those glands that supply the young with nourishment, which completes the chain attempted to be formed in the arrangement of the Collection.

The parts capable of being preserved in spirits are arranged in the order I have endeavoured to explain; there are others in a dried state, and in the form of casts, distributed through the cabinets of the Museum; these, however, are all intended to illustrate the organs which have been described.

This sketch of the contents of the Hunterian Collection, and of the manner in which it is arranged, will convey to my audience an idea of the ample materials which it affords, not only for Lectures, but to assist all those who are engaged in prosecuting pursuits connected with Comparative Anatomy.

I have to lament, in common with every one who hears me, that Mr. Hunter himself was not enabled, before his death, to establish the present Course of Lectures, and instruct the public on these subjects. I have also to lament my own incompetency for this task, which I should enter upon even with less confidence than I now do, had I not the satisfaction of knowing that the plan I purpose to adopt, is the same which Mr. Hunter himself intended to pursue.

To what a degree would the spirit of that great man be gratified, could he know the high sense which his country now entertains of the value of his labours, the noble edifice which has been erected for the reception of his Collection, and the ample Theatre that has been built for the propagation of his doctrines: Could he be acquainted with the zeal which has been evinced, the exertions that have been made, and the liberal support afforded by this College, of which he was a member: Could he witness the respect shewn to his memory by my present audience, which consists not only of the most eminent in his own profession, but of some of the most distinguished statesmen, philosophers, and men of science in Europe.

LECTURE II.

On the Structure of those Parts of Animals which are formed for the Purposes of Motion.

THE object of these Lectures is to shew the preparations in Comparative Anatomy contained in the Collection, to explain the uses of the different parts, and to point out the place they hold in the general scale of animated nature; that they may form a descriptive catalogue of that portion of the preparations to which they extend.

The different structures included in the first series of preparations in the Collection, are muscles, bones, shells, and the joints, by which the two last are adapted to others of their own kind, so as to admit of motion in various directions.

In the extensive view which Mr. Hunter has taken of this subject, we find preparations to explain the nature of the fluid out of which these parts are formed, as well as to illustrate a similar investigation respecting vegetables.

This fluid in vegetables is called sap; in animals, blood; the processes by which these are prepared belong to another part of these Lectures.

The sap is not alike in all vegetables; in many it is limpid, like water, while in others it has a considerable degree of consistence. As water is known to be the principal nourishment of most plants, the limpid sap might be considered as that fluid unchanged; this, however, is not the case; for although not distinguishable from it by the eye; it is found to be in part coagulated by the aqua lythargyri acetati, which produces no such effect on water. This sap must therefore be admitted to have undergone some change, fitting it for the formation of the solids of the vegetable to which it belongs. This peculiarity of sap is illustrated by a preparation made from the sap of the willow, coagulated by the aqua lithargyri acetati. The sap of many other vegetables has a considerable degree of consistence, and when removed from the plant to which it belongs, separates spontaneously into two portions, one part coagulating, the other not: the fluid part resembles the sap of the willow.

This property of sap is illustrated by that of the onion in a coagulated state. These preparations are intended to shew the gradations from pure water to a fluid in vegetables, which resembles, in its leading characters, the blood of animals.

The blood of insects is transparent or of a white colour; when separated from the animal, and allowed to remain at rest, it forms a coagulum more compact than that of the sap of the onion. This is illustrated by the blood of the lobster in a coagulated state.

In fishes and amphibious animals, there is a red colouring matter in the form of globules; and in animals of the class mammalia, the blood, while the animal is alive, possesses a certain degree of heat at the source of the circulation, which is necessary to fit it to perform its office; and it has a power of preserving this temperature under all the common vicissitudes of climate, the life of the animal depending upon it.

The sap of vegetables and blood in animals are composed, as has been explained, of very different parts, to answer various purposes in the vegetable and animal economy. It is, however, only from that part which coagulates that the organs in which the moving powers reside are formed.

Of this, a variety of proofs might be furnished from the processes of nature for the restoration of parts that have been injured ; but by shewing the gradation from the one to the other in the similarity of their appearance, the fact will be sufficiently obvious. If, for instance, the straight muscle of a bullock's neck has the red blood washed out of it, and the fasciculi of its fibres are separated from one another, and in this state it is compared with the coagulated blood which, after death, is sometimes found in the smaller arterial branches and the red globules have been separated : the texture of the one is hardly to be distinguished from that of the other.

That vegetables, in many of their parts, have a power of motion, is fully established, although we are not acquainted with the mechanism by which these movements are performed ; we only know that they are dependent upon life ; and that they are excited by external impressions. They must be admitted to have a strong resemblance to muscular actions in animals, particularly of that class called involuntary.

In the hedysarum gyrans, the lesser foliola have an alternate motion, the use of which has not been ascertained ; but the motion itself corresponds exactly to the alternate movements of the ribs in respiration. The motion of the tendrils of the vine, the bryony, and the passion-flower, arises evidently from a mechanism, by means of which they can approach other bodies, on which they may support themselves ; for although they move otherwise, in various directions, whenever they come in contact with any body, they grasp it, and continue turning round it; some turn to the left, as the tamus, lonicera, humulus; some to the right, as the clitoria and convolvulus, directed in their course by a lateral inclination which is only on one side, there being little or no power of action on the opposite.

In the vine, the motion of the tendrils is, however, not confined to any particular direction. These exactly resemble the motion of the tentacula of polypi, and many sea animals.

The motions of plants depend upon external impressions: this is evident in the dionæa muscipula and mimosa sensitiva. The first, on being touched, shuts up its leaves and incloses the substance applied to it: the other bends down its leaves. The tragopogon and calendula pluvialis shut up the flowers towards night, and when rain comes on; while the convolvulus shuts its flowers on the approach of the sun, and opens them in the evening. Almost the whole of the winged-leaved plants shut up their foliola towards night, and do not expand them till morning.

When a plant is inverted, the footstalk of the leaf twists itself round, so as to bring the surface of the leaf to its natural position: this is remarkable in the vine, in which there is evidently an apparatus for motion, although not a joint. These actions correspond to many in the more imperfect animals, and to the involuntary ones of the more perfect, as the peristaltic motion of the bowels.

The circumstance of some plants shutting up their flowers and leaves in the day, others at night, may not unaptly be compared to the habits of different animals; thus some genera of lepidopterous insects seek their food and procreate in the day, as the common butterfly; others of the same order remain fixed to one spot all day, but on the approach of night become animated, and fly abroad in search of food, as the phalæna. The owl and hawk live upon the same kind of food, but the one feeds by day, and the other by night.

To see whether the actions of plants are affected by being quickly repeated, as in animals, Mr. Hunter instituted the following experiment upon three sensitive plants. At his desire, in the summer of 1775, I made the experiment, which was conducted in the following manner:—one leaf of each plant, which had the most extensive range of motion, was selected, and three boards were placed behind these leaves, upon which was marked the extent of its motion, and when either of the leaves moved, it became the radius of an arc described on the board. The experiment was begun at eight o'clock in the morning, while the leaves were in full expansion, and was continued till four in the afternoon. It was thought improper to go on longer, as the leaves begin to collapse of themselves between five and six o'clock in the afternoon.

From the result of this experiment, it appeared that they did not all correspond exactly in the extent of their motion, though nearly so. They were made to collapse nine times, and sometimes one, sometimes another failed in rising to the highest point; but all of them invariably collapsed to the lowest point, and in general below it, though not always so.

They moved with very different velocities, one requiring double the time that another did; but in the ninth part of the experiment they all rose equally rapidly, and in a much shorter time than before. In the first trial the times were fifty-one, twenty-four, and thirty-two minutes; in the last, fifteen minutes only, so that their velocity was evidently increased, but not regularly so.

The leaves required a much greater force to make them collapse the more frequently it was applied; and it may be remarked, that when the leaves collapse in the evening, they have nearly the same degree of flexion, as when roughly touched at noon; but if touched after they have collapsed in the evening, they fall lower than they would do from the same stroke at noon.

The falling of the footstalk at night, and the closing of the foliola, has been considered as simply the effect of relaxation, and has been called sleep; this, however, as is much an àction as the other; for if the plant is inverted, it equally takes place, although against gravity. The two actions are therefore the effects of different stimuli: light produces the one, and absence from light the other: for if a sensitive plant be kept in a dark room, its leaves will remain bent; and if one part of the plant be kept in the dark and the other in the light, the leaves of the first will continue bent, those of the second will expand.

In vegetables, action is sometimes readily communicated from one part of the plant to another; in the sensitive plant, if one foliolum is wounded at its point, that foliolum immediately collapses, and the opposite does the same, then the one next to it, and so on till the whole of the foliola of the compound leaf have collapsed; the rachis in a little time flexes also.

In the tendrils of vines which divide towards the extremity into two branches, each of which moves in a different direction; if one lays hold of any body, and twines round it, the other immediately turns in that direction, and gradually approaches the same body till it comes in contact with it, and then encircles it. This motion is, however, very slowly performed.

From what has been said of the moving powers in vegetables, it appears that they resemble very nearly those of animals, although from the nature of the materials and the smallness of the parts, they do not admit of examination so as to have their internal structure explained: they are probably composed of various modifications of elasticity dependent upon life. In the animal world, we have organs of motion formed upon a larger scale, and composed of a substance which can readily be dissected. The consideration of these becomes the next subject we are to enter upon.

Muscles.

Having already explained that the principle of muscular action is independent of the mechanism met with in large muscles, since it exists equally in the thin membranous coat of the hydatid, it will not be expected that any observations should be made upon that principle. All that is intended at present, is to state such facts and observations respecting the structure and other properties of muscles, as I have learned from Mr. Hunter, or acquired from subsequent observations.

What the real difference is between the contracted and relaxed state of a muscular fibre, perhaps may never be known. Relaxation is commonly supposed to be a cessation of action; but it appears to be an action as much as contraction; for were it simply a cessation of action, we should have those muscles become relaxed, that had contracted in the act of death, which is not the case: on the contrary, it takes as much force to overcome this contraction, as to counteract the power of a muscle under the influence of the will in the living body.

In drawing out a muscular fibre from its contracted state, there is a recoil whenever the elongating force is removed; and this is met with equally, however much or little of the contraction has been overcome: such recoil can only take place from an elastic power in the fibre. It was first taken notice of by Mr. Hunter in the body of a man who died in convulsions in St. George's hospital, in consequence of a fever with delirium, brought on by a hurt on the arm, attended with considerable inflammation. A few hours after death the muscles were found to be stiffer than usual, and extremely well marked through the skin. The rectus muscle of the thigh was laid bare, and separated from the other muscles without stretching it. By bending the knee, the muscle was stretched, and when the force was removed, a considerable degree of contraction took place. This did not arise from any remains of life, for it was tried again next day, and the same thing happened: so that every muscular fibre, besides the power of contraction peculiar to it, has also another power of contracting from elasticity.

Muscles, in all animals, are white, and the different shades of colour that are given to them, arise from the blood they contain; for if the red muscle is steeped in water, or the blood is washed out of its vessels, it becomes white. As the quantity of blood in different muscles varies exceedingly, we have some redder than others, many almost white, and others entirely so.

In the human body, the muscles of the leg are redder than those of the stomach: the temporal muscle is redder than those of the face.

The same muscles are not equally red in all animals of the same order; they have more colour in the hare than in the rabbit.

In some birds the muscles are almost wholly red, as in the black cock; but in others the red blood is so partially distributed, that the muscles are nearly all of them pale, as in the turkey.

In snakes, tortoises, frogs, &c. the muscles are generally pale, the quantity of red blood being smaller in them than in birds, and more confined to the vital parts. This is the case in a still greater degree in fishes, their muscles are therefore generally white.

In the lower orders of animals, as insects, the blood is in general colourless or white; the muscles are therefore pale: many of the vermes, however, have red blood, particularly the earth-worm and teredines.

That the quantity of red blood brought to a muscle is necessary for the continuance of its action, is plain, for those muscles, whose action is quick and frequent, are supplied with blood vessels from large trunks; but where the actions are intended by nature to be slow, the blood is carried through small branches, so as to prevent its arriving at the muscles with any velocity. In the sloth, the brachial artery has the common trunk smaller than usual, and is surrounded by a plexus formed of minute branches from the axillary artery, with the brachial artery below. This structure was discovered by Mr. Carlisle, Professor of Anatomy to the Royal Academy.

When muscles have been at rest for an unusual time, they become pale, the ordinary quantity of blood is not carried to them, it being no longer necessary.

There can be no doubt that the blood is of great use in muscular contraction, for in violent and great exertions of the muscles they swell and become much larger, and continue so when relaxed immediately after the action. This swelling does not come on till the muscle is tired of acting, and may arise either from a greater influx of blood at the time, or from the action not letting the blood pass so freely through the veins. It may be owing to this cause that the muscles of animals that use much violent exercise, and are killed during the action, are redder, fuller, and more tender than others, but do not keep so long. This explains the difference in the taste of a hare or deer that is shot, from that of one run down by dogs.

Muscles not only become larger from frequent exertion, but even swell during the time of action, and subside gradually after it is over. This increase is in proportion to the violence of their action, and appears to go on until they are tired, and is probably one cause of their being so. This fact was ascertained by the following experiment:—immediately after getting up in the morning before the parts had been used, the circumference of the right arm, over the belly of the biceps-flexor muscle, was measured while all the muscles of this part were relaxed. The circumference was ten inches and a half; the fore-arm was then bent, and when contracted the same part measured twelve inches and one eighth, so that it had gained one inch and five-eighths. The arm was then employed in working an air-pump for about ten minutes with considerable violence, till it became quite tired; after which, in the relaxed state, it measured eleven inches and two-eighths, and in the contracted, twelve inches and five-eighths; so that the muscle had acquired six-eighths of an inch in circumference in the relaxed, and four-eighths in the contracted state.

That the calf of the leg swells towards night, is a common observation, and is owing principally to its having acted so much through the day. That the swelling in such cases is in the muscles themselves, is evident, from the stiffness felt in acting with tired muscles.

It becomes a question what produces this temporary increase in the muscle. Is it an extravasation of fluids in consequence of acting for a longer time and with greater force than usual?

There is a great difference in the degree of density of the fasciculi of muscular fibres. In some tribes of animals they are very hard, while in others they are very soft. They appear most perfect in the highest, and softest in the lowest orders; and this nearly in a regular gradation. In the first rudiments of every animal they are soft, and increase in firmness as the animal arrives at its full growth.

The muscles of the male are in general more dense than those of the female; but all the muscles of the same animal are not equally dense; those employed in progressive motion, in fighting, and catching prey, are much denser than the others: the muscles of the foreleg of a lion, and those of the thigh of a fighting cock, are unusually firm. In the more imperfect animals, some particular muscles have great strength, as that which draws the snail into its shell; that which shuts the two shells of the bivalve; and those which move the boring shells of the teredines.

This greater firmness in some muscles appears to arise from their original formation, but may be considerably increased by use; as we find the heart, whose action is most constant, is in quadrupeds the strongest in the body.

In our own species we have many instances of individuals whose muscles are naturally composed of much firmer fasciculi of fibres than those of ordinary men, and therefore are capable of performing feats of strength, which no exercise could enable the same muscles of another man to perform. Mr. Millan, the bookseller, was an instance of this kind. Mr. Jackson, who teaches sparring to our young men of fashion, is another.

To ascertain whether the firm muscles really contain more matter, and therefore are specifically heavier than the soft, the following experiment was made upon two muscles of different densities: nine ounces and a half of muscle from a bull's neck, and the same quantity from that of an ox, were weighed in water; the bull's was thirty-one grains heavier, which is $\frac{1}{139}$th.

The voluntary actions of young animals are not so strong as in those of the middle age; and the strength they have, cannot be employed for any great continuance in actions where considerable force is required. Thus, we have young horses soon fatigued with the labour which, some years after, they could easily perform. This ability does not arise wholly from strength acquired by employment, which might be thought sufficient to account for it; for dealers in horses affirm that a horse of seven, and one of four years old, having equally done no work, shall not be equal in their continuance of it; in riding, they also give weight according to age.

At what period an animal has arrived at its full strength, is not easily ascertained; it is certainly after it has done growing; perhaps even some time after it has acquired its full size; but the involuntary muscles are stronger before this period: this is probably necessary for the animal's growth.

How long the muscles continue at their full size, is not easily determined; but as old age approaches, they begin to decay; not becoming pale and flabby, as in disease, but retaining their redness and sound appearance. The muscles become thinner; but in proportion to the decrease of their size, the interstices between the fasciculi of the fibres, and between the muscles themselves, are loaded with fat; and this takes place so constantly, that the muscles of an old man may be distinguished from those of a young one, by the fat intermixed with the fasciculi of muscular fibres.

Muscles in old people also have their quantity of contraction diminished so that the joints are never moved to their full extent: thus the extreme motion, which requires the greatest effort, is lost. An old man stands with all his joints bent, not being able to bring himself to the upright posture.

Muscles are improved both in strength and velocity by exercise, and obey more readily the will, by the continuance of its influence over them.

Voluntary muscles acquire from habit great readiness in taking up a particular action. The will has frequently only to make them begin it, and they go on of themselves; there are instances of people playing tunes, without attending to the notes, or even thinking of the tunes.

A man will learn one manual art much more readily if he knows another, than if he knew none at all.

The effect of exercise on muscles is well known to painters and sculptors; we have Charon and Vulcan always represented with large shoulders, brawny arms, and their lower extremities small and apparently disproportioned. This effect is still more nicely marked by the difference between the right arm and the left, the right being employed in preference, and more particularly in great exertions: people who play much at tennis, where the ball is always struck by the right hand, have that arm much stronger and thicker than the left; therefore a man originally well proportioned, loses that proportion by being employed in any action that does not require the whole body taking part in it.

I have a satisfaction in being able to confirm the observations I have made upon the great natural strength of the muscles of some individuals, as well as on the effect that an unusual swell of the muscles produces on the outline of the human figure, Mr. Jackson very obligingly having offered to exhibit himself in this Theatre to illustrate any parts of these subjects that may promote science, or tend to the improvement of physiological knowledge.

In Mr. Jackson, who is standing before you, and who is exactly of the same height with myself,* the muscles of the arms are differently formed from mine, and this difference in their form is not acquired by exercise; it is a part of their original formation. The biceps-flexor-cubiti of his arm is one inch and one-eighth shorter, the fasciculi of muscular fibres are much harder and more dense, and, as the muscle has greater breadth, the direction of the fibres is more oblique.

By these means, the quantity of contraction is diminished, and the velocity consequently increased in a very considerable

* At this time Mr. Jackson was standing on the table.

degree. By a contraction of two inches and six-eighths, the arm is bent to its utmost; while in my arm, a contraction of three inches and three-eighths is necessary for that purpose.

This shews the various purposes for which men are intended by nature. Mr. Jackson is made for the exertion of bodily strength; and in certain uncivilized states of society would have rivalled Hercules or Achilles, so much does he surpass other men in the power of his muscles; while I, unfitted for such feats of hardihood, am better qualified by my mental faculties for the investigation of physiological inquiries.

LECTURE III.

On the inherent Powers, and various Arrangements of muscular Fibres.

In the preceding Lecture the general properties of muscles were considered, and the different appearances which they put on in different animals. I shall now prosecute this subject, and endeavour to point out certain powers that are inherent in them, and explain the peculiar advantages derived from the various arrangements that are met with in the fasciculi of their fibres.

The degree of contraction of a muscular fibre is not limited to that which usually takes place: there is a power inherent in muscles, by which they can increase or diminish the ordinary extent of their contractions: this is very curious, and must arise from some change going on in the muscle itself.

The usual quantity of contraction which takes place in the fibres of the muscles in the different motions of the human body, is adapted in the nicest manner to the circumstances in which the muscle is placed, and the quantity of contraction appears to be limited, by the fibres having no power of becoming shorter. We find, however, from observation, that when the extent of motion in a joint, or the distance between the fixed points of a muscle, is accidentally altered, the muscle acquires a power of adapting its quantity of contraction to the new circumstances which have taken place.

This power in a muscle, may be considered as a proof that the principle of contraction is independent of its particular organization; since it can undergo a complete change within itself, so that its fibres shall be shortened to one half of their original length, and still have the same contractile power as in the original state.

This principle in muscles was discovered by the late Mr. Hunter, nearly half a century ago, and is now, I believe, sufficiently established. There are some, however, who now hear me, to whom it may be new; and many, whose knowledge of it cannot be rendered too correct. It is also my duty in this Theatre to trace the discoveries of the Founder of this Collection to their source, and in this instance not only make you acquainted with the circumstances that led to it, but also to show you the mode in which he was in the habit of demonstrating it. A case of fractured patella occurred, in which the two portions of that bone had been allowed to remain two inches asunder; the bone therefore united, as is usual in such cases, by ligament, instead of bone, and the muscles which straighten the leg, to produce that effect, had to contract two inches beyond the usual limits of their former action. This, Mr. Hunter was led to believe might be brought about by stimulating them through the medium of the will, and therefore he proposed that the patient should sit upon a table, with the leg hanging down, and by endeavouring to apply the mind to them, in time it would acquire an increased influence, so that a new action would take place; the former state of greatest contraction becoming the state of greatest relaxation, from which a new contraction would commence, and be continued till the full effect is produced. This plan was adopted.

The patient was unable, at first, to bring the exterior muscles of the leg under the command of the will; but after repeated trials the toes were brought a little forwards, and in time this effect was increased, as well as the power with which it was produced.

The extent of this principle is well illustrated by the following case. A Negro, about thirty years of age, having had his arm broken above the elbow joint, the two portions of the os humeri were unfortunately not reduced into their places, but remained in the state in which they were left by the accident, till the bony union had taken place; so that when the man recovered, the injured bone, from the position in which the fractured parts were left, was shortened almost one-half of its length. From this circumstance, the biceps-flexor-cubiti muscle, which bends the fore-arm, was so much longer than the distance between its origin and insertion, that in the most contracted state it could scarcely bring itself into a straight line: this muscle, however, in time, as the arm recovered strength, adapted itself to the change of circumstances, by becoming shorter, so as to correspond to the diminished length of the bone; and by acquiring a new contraction, in this shortened state it was enabled to bend the fore-arm.

Some years after this accident the person died, and the circumstance above-mentioned being known, the parts were examined with particular attention. The biceps muscles of both arms were carefully dissected out, and being measured, the one was found to be eleven inches long, the other only five; so that the muscle of the fractured arm had lost six inches, which is more than half of its original length, as is distinctly shewn in the preparation.

In such cases, however, it requires a long time for the muscle to acquire strength in this new action, and it never acquires it in the same degree as before.

If the power of contraction was limited to the quantity produced in a straight muscle, the same kind of fibres, when forming sphincter mucles, could not answer the intended purposes, as a greater power of contraction is required.

That the same length of fibre is not absolutely necessary to produce the same effect in all cases, is strongly evinced by the fibres of the gastrocnemius muscle in the Negro being shorter than in the European, and yet producing exactly the same quantity of motion in the joints which they move. This is found universally in the Africans, and now and then is met with in men of other nations.

The difference in the length of the fibres of particular muscles makes a difference in the outline of different men, and should be particularly attended to by painters and sculptors, as it is a distinguishing mark between original nations.

Muscular contraction is an operation, in whatever way performed, by which the vital powers of the animal are considerably exhausted. This exhaustion would appear to be occasioned rather by the extent of contraction, than by its frequency or force; for if we examine the mechanism of an animal body, we shall find a variety of structures evidently intended for no other purpose than diminishing, as much as possible, the necessary extent of contraction in muscular fibres, while there is no such contrivance to diminish the frequency of action.

Muscles, in general, are applied to the bones in such a way as to act with great mechanical disadvantages as to power;

but this is more than compensated by the small quantity of contraction which is required to produce the requisite quantity of motion: and in the muscles of respiration, we find frequency of action is preferred to an increased quantity of muscular contraction.

The velocity acquired by this structure is a considerable advantage; but the principal object of it is to procure the effect by means of short contractions, which admit of being frequently repeated with so much less fatigue to the muscle than long ones.

That long contractions in a muscle cannot be supported for any length of time, may be illustrated from the actions both of the voluntary and involuntary muscles.

While the voluntary muscles are under the command of the will, we cannot ascertain what would be the effects produced by the continuance of their contractions, since the influence of the brain communicated by the nerves, becomes soon weakened, and their action ceases; but when the contractions of voluntary muscles are by any circumstance rendered involuntary, the difference in the time of their continuance appears to be in the inverse proportion of the quantity of contraction; for muscles whose usual functions consist in short contractions, can go on for a longtime, while those which perform long contractions soon cease to act.

In the muscles of a paralytic arm, action to a certain extent is often continued for years (the time of sleeping excepted), without any effect being produced on the constitution, or the parts themselves; but in epileptic fits, in which the actions are equally involuntary, only requiring longer contractions, they soon cease, leaving the person greatly exhausted; an effect which must arise from the quantity, not the frequency of the contractions.

If we attend to the actions of the involuntary muscles, we find that they are continued through life, but that the quantity of contraction is very small; and if from any circumstance the quantity is increased, it cannot be continued, the parts being unable to sustain it for any length of time.

The diaphragm and intercostal muscles act constantly; but in carrying on the functions of respiration, they do not exert themselves to their full extent. In laughing, which is likewise an involuntary action, the contraction of these muscles is more extensive; therefore, if continued beyond a very short period becomes so distressing, that a cessation necessarily ensues.

In tracing the different forms of muscles, and in considering the uses for which they are employed, we observe, that the fibres are variously disposed, to obviate the necessity of great contractions; and the quantity of muscular exertion saved by this mechanism, is in proportion to the frequency of action and importance of the effect the muscle is intended to produce. This appears to be invariably the case.

Muscles only occasionally called into action have their fibres nearly straight, which gives no mechanical advantage: the sartorius is an instance of this kind.

Muscles frequently used are more complicated; as those of the fingers are half penniform in their structure: the muscle for raising the heel in walking is penniform; that which raises the shoulder, complex-penniform; and those of the ribs, cruciform.

That the two sets of intercostal muscles act at the same time, was proved by an experiment I made in the year 1776, at which period the contrary opinion prevailed. A portion of the external intercostal muscles was removed from the chest of a dog, and in that way the two sets of muscles were seen in action; the fibres of both sets contracted exactly at the same instant.

The particular structures of these different forms of muscles, and the mechanical advantages arising out of them, are now sufficiently well understood; but there is a form of muscle, in which the disposition of fibres produces a considerable saving of muscular contraction, that has not been taken notice of in this view. The muscle I allude to is the heart; the most important in the body, whether we consider the frequency of action, or the office in which that action is employed; and we shall find upon examination, that the fibres are disposed differently from those of any other muscle, which disposition of fibres appears to have a superiority in being enabled to produce their effect by a smaller quantity of contraction.

In considering the muscular structure of the heart, it is only intended at present to examine the ventricles, which may be reckoned two separate muscles: the right ventricle for sending the blood through the vessels of the lungs, called the lesser circulation; the left, to propel it through the branches of the aorta, which go to every part of the body, called the greater circulation.

If these two ventricles are superficially examined, the muscular fibres by which they are united seem to belong equally to both; one half appearing to be a portion of the right, the other of the left ventricle. Were it so, the sides of the left ventricle, although evidently more muscular and thicker than those of the right, would by no means be so strong in proportion to the effects they have to produce, as it would be natural to expect.

We find, however, upon dissection, that the septum is almost wholly a portion of the left ventricle, which gives it a great superiority over the right, and makes it capable of performing the important office of supplying the body with blood.

The muscular structure of the left ventricle, detached from the other parts, is an oviform hollow muscle, but more pointed at its apex than the small end of a common egg. It is made up of two distinct sets of fibres laid upon one another, in the form of strata; those which compose the outer set have their origin around the root of the aorta, and in a spiral manner surround the ventricle to its apex or point, where they terminate, after having made a close half turn.

The fibres of the inner set, or stratum, are similar to those of the outer in their origin, in the mode of surrounding the cavity, and in their termination; but their direction is quite the reverse; they decussate the outer set in their whole course; and where the two sets terminate, they are both blended into one mass. There is an advantage gained by this disposition of fibres over every other in the body, which adapts the ventricle so perfectly to its office, that it would almost appear impossible to construct it in any other way, so as to answer the purpose for which it is intended.

In this muscle the fibres, by their spiral direction, are nearly one-fourth part longer than the distance between the origin and termination; and the actions of the two sets being in different directions, renders only one-half the quantity of contraction in each fibre necessary, that would have been otherwise required; while the turn both sets make in opposite directions at the apex of the ventricle, fixes it, and prevents lateral motion.

In the action of the ventricle two different effects are produced; the first brings the apex nearer to the basis, by which means the *vis inertiæ* of the blood will be overcome where the resistance is least, and a direction given to its motion in the course of the aorta; the second brings the sides nearer to each other, which will accelerate the motion of the blood already begun; and the spiral direction of the fibres renders the power which is applied more uniform through the whole of that action, than it could have been made by any other known form of muscle. The spiral action will likewise readily shut the valvulæ mitrales while the apex is drawn up, which could only be effected by this particular construction.

By this beautiful mechanism, which I have endeavoured to describe, the muscular fibres of the left ventricle of the heart perform their office with a smaller quantity of contraction compared to their length, (although in themselves proportionally longer) than those of any other muscle in the body, and consequently produce a greater effect in a shorter time.

The right ventricle is situated upon the outside of the left, with which it is firmly united; it is not oviform in its shape, but triangular; nor is it uniform in its structure, being made up of two portions, whose fibres have a very different distribution.

The portion of this ventricle, which makes a part of the septum of the heart, consists of only one set of fibres, similar in their direction to those of the stratum underneath, belonging to the left ventricle, but from being considerably shorter, they are more oblique than the spiral ones; and at the edge of the cavity they are blended with the fibres of the opposite portion.

That portion which is opposite to the septum is composed of three sets of fibres; those of the external set are nearly longitudinal; the two others which lie under it, decussate each other, and are obliquely transverse in their direction, one passing a little upwards, the other downwards, and both terminate upon the edge of the septum.

In the structure of this muscle we find none of the mechanical advantages so obvious in the left ventricle: the want of these, however, is in some measure compensated by its situation; for the blood contained in its cavity will have the *vis inertiæ* overcome, and a direction given to its course by the action of the apex of the left ventricle; that motion only requiring to be continued and accelerated, for which purpose the structure of this muscle is very well calculated, and in which it will also be assisted by the lateral swell of the septum into its cavity during the contraction of the left ventricle.

So full an explanation of the muscular structure of the heart, may appear not immediately connected with the present series of preparations; but as it is the most complex in its structure, the most important in its office, and the most perfect in its kind, it seemed to me the most proper muscle, with the description of which, to terminate this subject.

The mechanical advantages which have been mentioned as peculiar to it, were shewn to me by my late ingenious friend Mr. Ramsden, whose zeal for science led him upon every occasion to promote the enquiries of his friends, whenever a knowledge of mathematics, mechanics, or optics could be applied to them.

Elastic Ligaments.

Muscular contraction is employed when parts are to be moved from a state of rest; but is not always used to bring them back to that state, or to support them in it. On many such occasions a less expensive means is adopted, by the introduction of elastic ligament.

This substance appears, as has been already observed, to be mixed with muscular fibres, so as to form a part of the muscle itself; it also forms an antagonist to many muscles. Instances of this kind are less frequent in the human body than in those of other animals: in the camel, and all quadrupeds with long necks, the head is supported by strong elastic ligaments; and when it is necessary to move the head and neck out of its more constant position, muscular action is employed.

The same substance forms a support for the abdominal viscera in large animals, and is most conspicuous in the elephant. In the lion and the whole of that tribe of animals, the claws, which are only wanted for catching prey, are raised above the level of the sole of the foot, and kept suspended by means of two strong elastic ligaments. In this way they are preserved from injury, and muscular action is only exerted to bring them down, in the act of seizing their prey.

In all the bivalves the shells are kept open, which is their usual state, by means of an elastic ligament placed at the hinge, and are closed by muscles; the last action, comparatively speaking, is rarely required; and as soon as the muscle ceases to act, the elastic power in the ligament which is constantly exerted, makes the shells fly open.

The preparations that illustrate these facts, are placed immediately after muscles, to which elastic ligaments must be considered as an appendage, or more properly a substitute; and with these observations on them, I shall conclude what I have to say on the moving powers of animals.

LECTURE IV.

On the Growth of Shell and Bone.

THE skeleton of an animal is composed of such substances as, from the hardness of their texture, can support or defend from injury the softer organs, and which being acted on by the muscles, are concerned in producing progressive motion.

This view of the subject includes the following substances: ligament, horny cuticle, shell, whether of the testaceous or crustaceous kind, cartilage, and bone.

Ligament forms the whole of the skeleton of many soft animals; of these, I shall give the earth-worm as an instance. Its body is surrounded by a number of annular ligaments: these not only defend the internal parts of the animal from injury, but become so many fixed points for the muscles to act upon, and produce progressive motion.

Horny cuticle is in its nature exactly the same as the common cuticular covering of the human body; it differs in nothing but in being more dense in its texture and thicker in its substance; it forms the skeleton as well as the covering of many land insects.

Testaceous shell, which is better known by the name of sea-shell, forms the skeleton of an immense number of sea-worms, becoming a defence for the animal which it incloses, and a fixed point on which the muscles are to act, for in these animals the progressive motion is unconnected with the shell.

Crustaceous shell forms the skeleton of all the echini, of lobsters, and that tribe of sea insects.

The skeleton of a whole tribe of fishes is formed of cartilage, and these from this peculiar character have received the appellation of cartilaginous fishes. Of this kind are the ray, and dog-fish.

Bone, it is well known, composes the skeleton of fishes in general, birds and quadrupeds.

In considering the structure and growth of these different substances, shell and bone only require a particular explanation. Cartilage is found to be composed of the same materials as bone, but in different proportions; and the mode of formation of cuticle belongs more properly to the explanation of another part of the collection, in which the external coverings of animals are exhibited.

Testaceous shells are composed of an animal and an earthy matter. In the mother-of-pearl shells, as the haliotis and turbo olearius, the part first formed is a membrane, upon which the earthy substance is deposited; and by means of a succession of membranes and subsequent deposits of earth, the shell is completed. In all shells this structure is not the same: in the river muscle, the appearance of distinct membranes is with difficulty ascertained; in the oyster it is less evident; and in the patella scarcely perceptible. In the porcellaneous shells it is entirely wanting, the earthy matter being mixed with a small portion of gelatine only, and the shell is brittle in its fracture as in the cypræa. This earth Mr. Hatchett has ascertained to be carbonate of lime. The animal and earthy matter bear very different proportions to each other in different shells.

In many, the carbonate of lime is so thinly spread as to have no distinct form, the membranes and the lime composing one compact mass; and it is only after the earthy part is separated, that the foliated membranous structure is exposed.

The difference in the hardness of shells depends entirely upon the closeness of the membranes to one another. In the pearl they are extremely close, so as to give a degree of transparency producing the beautiful lustre which distinguishes it and renders it so ornamental: but in the sepia officinalis the bone, as it is called, is of a looser texture, and the carbonate of lime is found in the form of crystals between the membranes.

When the earthy part is removed by dissolving it in an acid, the membranous plates are seen in the most satisfactory manner, and from their size are rendered very distinct. In the tubular shell of the teredo gigantea from Sumatra, the crystallized state of the carbonate of lime gives it so near a resemblance to a mineral substance, that when the shell was first sent to England in a very mutilated state, all my chemical friends were satisfied that it was a mineral, not an animal production; never having seen earthy matter forming such perfect crystals in combination with animal substance.

All testaceous shells, as they have the same component parts, have the same mode of growth, which is by a regular increase of the original shell, in proportion as the animal becomes larger. The outside of the shell, or at least such parts of it as the animal does not come in contact with, is covered with an epidermis; but all the internal or other surfaces that are immediately applied to the animal, are exceedingly smooth.

Some testaceous shells are external, forming a house for the animal; others internal, for the defence of particular parts. Those that are external have very different forms, and in relation to their growth admit of being arranged under three different heads. Such as are concave, whether there is only one two, or more shells: the spiral, and the tubular.

The concave shells of the most simple kind are the patellæ; in these the growth is readily distinguished by the simple inspection of the shell; new matter is deposited upon the internal surface of the old, rendering it thicker in its substance, and the edge is extended, increasing the circumference; so that if it were possible to separate them again, they would form a number of very thin concave shells, of which the last formed is the most internal and the largest, the number corresponding to the stages of the animal's growth.

In the multivalves the mode of growth is the same; but in the bivalves there is a new part added, which is the hinge; the mechanism of this is varied into an almost endless variety, so that in very few genera the hinges are exactly alike, as if it were to show that in the productions of nature there is no limit set to the power which formed them.

In the spiral shells the mode of growth, although it is not equally evident, is exactly the same; for if the most complex be dissected, every convolution will be found to correspond with that immediately preceding it, only being upon a larger scale, and none of the original parts of the shell have been removed. In all the bivalves the outside of the shells is rough and is covered with the epidermis; while in many of the spiral shells a part, and in some the whole of the external surface, is equally smooth and polished as the inside: this difference arises from the opening of the bivalve being sufficiently large to allow the sea water to enter the cavity, and apply itself to the respiratory organs of the animal; but in the others these organs have a very different form, and require to be expanded externally, which is best done by their being protruded on the outside of the shell; and in some genera they spread themselves out upon the whole of its external surface. This is particularly the case in the cypræa, where two portions of a membranous bag come out at the opening of the shell, and expand themselves upon it till they meet in the middle line of the back, which explains the beautiful appearance of its surface; and I understand from Lord Valentia, who, during his voyage to the Red Sea, had frequent opportunities of seeing the animal alive, that the colours and marks upon the membranes correspond exactly with those upon the surface of the shell, which is a curious circumstance.

In considering the tubular shells, in which number I include the nautili, since in many respects they resemble them, we have to regret that the animals contained both in the nautili and serpulæ are so little known, that I have never had an opportunity of seeing them. I am however induced, from what I know of the habits of the teredines and sabellæ, and the mode in which their shells are formed, to hazard some conjectures respecting the others, which must indeed remain hypothetical till physiologists shall be fortunate enough to have an opportunity of examining the animals in the recent state; but which will be useful to Natural History, if they should stimulate the exertions of those to whom such opportunities may occur.

The most simple of the tubular shells is that of the sea animal found on the coast of the island of Barbadoes, which is a thin tube, imbedded in pieces of madrepore. At first sight it would appear that the hole in the madrepore is made by other means, and that the animal takes possession of it like the soldier-crab; but on more particular examination it appears that the shell is formed upon the outer surface of the madrepore, winding along it, and becoming afterwards inclosed by it; since in tracing the course of these tubes in the substance of the madrepore, they are found to take those directions. The tube increases in length with the size of the animal, like the spiral shells; but the serpulæ and the nautili differ in a very important circumstance; the shells in their increase are divided into chambers; these in the serpulæ have no communication with each other, while in the nautili there is a small opening in the centre of each partition, forming a communication with all the chambers. In some this opening, as the shell increases, is converted into a slender canal; in others, it does not form more than an infundibular opening. It would appear therefore that these animals, as they become too large for the chamber in which they have resided, desert it altogether, and form another a size larger immediately beyond it; and in this way these shells acquire a considerable magnitude.

The shell of the teredines differs from the others in increasing from that part farthest from the external orifice, which must have also been the case with that of the animal from Barbadoes just mentioned, had it made its way into the madrepore instead of being formed upon the external surface.

As the tentacula of the teredines must be always in contact with the sea water, which is not admitted into their shells, and the animal has not the power of moving out of the shell;

to admit of its growth, a space is formed by digging out the substance in which the shell is imbedded, and on the inside of this cavity the new shell is afterwards formed.

In the progress of the life of this animal, a very curious circumstance takes place: when it has arrived at its full size the shell is closed at its termination, and after that period the animal diminishes in size: to adapt the shell to such diminution of the animal, a partition of new shell is formed, taking off a portion from the length of the tube, and leaving an empty chamber: as the diminution goes on, a second partition and second empty chamber is formed, in this respect giving it the general appearance of a camerated shell.

Each of the different shells that have been described is to be considered as the house in which the animal lives, and by which he is defended from the violence of storms, as well as from the attack of his enemies; and in those that require it, there is an operculum or door, by which the animal shuts himself in upon the approach of danger: some of these are so artfully contrived as to conceal the shell. This is the case in the tubular shell from Barbadoes; the external surface of the operculum has two small irregular projections, which entangle the sea-weed floating over the madrepore, so that the opening of the shell is completely covered.*

The habits of the animals contained in these differently formed shells vary according to the nature of the habitation. In the bivalves the animal remains intirely within the shell, which opens and admits the water, and only shuts upon the approach of danger. In the spiral shells the animal comes out in part from the shell, and has loco-motion, but the viscera

* Vide Tab. I.

remain enclosed in the shell; and in many it is the increase of the liver which fills up the smaller spirals after the animal has arrived at its full size.

The internal shells that are met with in the sepia officinalis, and in some of the mollusca, particularly the black slug, are contained in the soft parts, and therefore form no protection to the animal generally, but are intended for the defence or support of particular organs. In the black slug the shell covers the heart, and is almost fitted to it. There is a small shell in the same situation in others of this tribe.

The growth of these shells appears to be similar to that of the external shells; but is not necessarily so, since by being every where surrounded by living parts, addition can be made wherever it is required, without exhibiting a regularly laminated structure.

The paper-nautilus has a shell which, from the delicacy of its texture and the appearance of its external surface, I am much disposed to believe is an internal shell. We are unfortunately without any accurate knowledge of the animal to which it belongs; but it is admitted by every person who has written upon the subject to be nearly allied to the sepiæ, in all of which the shell is internal. This is a strong circumstance in favour of my opinion; and indeed the shell is much too weak to be any defence for an animal of that magnitude, but sufficiently strong to support and protect internal parts from injury. This shell has never been met with in any other state than as a dead shell, and is by no means rare: this can be readily accounted for, if it is inclosed in the animal to which it belongs.

The watering-pot shell I consider to belong also to those that are internal, like the paper-nautilus. It is always found without any remains of the animal; and I never heard of the animal having been met with.

The corals and coralines must be ranked among the internal shells, since they are covered by soft animal substance, although they contain cells in which the polypi conceal themselves, and some of the cells have even opercula to close up the openings.

They appear, as far as our present knowledge of them extends, to be formed by animals differing in size from those that inhabit many tubular shells, but resembling them in many of their general characters; and they are composed of the same materials, although they have not the same mode of growth.

It is curious that this most extraordinary tribe of polypi, of which each congeries may be regarded as a distinct family, has its central stem composed of different materials in different species. In madrepores, it is gelatine and carbonate of lime; in the gorgonia, it is gelatine and a small proportion of phosphate of lime; and in the pennatula, it is phosphate and carbonate of lime, being a near approach to bone.

The crustaceous shells differ from those that have been described, both in their composition and their mode of growth: they contain a larger proportion of animal matter or gelatine; and the hardening principle is carbonate of lime, with a small proportion of phosphate of lime: in this they are a nearer approach to bone; but in their mode of growth they neither resemble the testaceous shells nor bone, but are formed and shed like cuticle.

The crustaceous shells do not, like the testaceous, serve the purpose of a house in which the animal lives; they more resemble a coat of mail, in which he can travel in security: and as it is by means of these coverings that the animal is enabled to move from place to place, they may be considered as forming a skeleton in the more general acceptation of that term, only that the solid parts are placed externally for defence, as well as for progressive motion, and for catching prey.

Cuticle is another substance employed in land insects for the formation of the external skeleton; and indeed so much do the form and uses of these coverings resemble one another, that they seem only to differ in the materials of which they are composed.

In the more complex animals the soft parts are supported and defended by bone, which is a substance different in many respects from shell or horn.

Bone.

Under this term we may comprehend the permanent cartilages, as those of the ribs, since they are made up of similar materials, only in different proportions. All the varieties of bone are composed of an animal part, in which is deposited an earthy substance, the greater part of which is phosphate of lime; but there is also a small quantity of carbonate of lime.

It is to Mr. Hatchett that we are indebted for our present knowledge of the chemical analysis of these different substances, which throws so much light upon their structure, and enables us to arrange them into a beautiful series, containing first those composed of animal matter and carbonate of lime; then those in which the hardening matter is principally carbonate of lime, but to which is added a small proportion of phosphate of lime; afterwards others, in which the earth is almost wholly phosphate of lime, but still with small proportion of carbonate of lime.

To him also we are indebted for the characteristic difference between cartilage, soft and hard bones; which consists in the degree of compactness or closeness of the fibres of the animal substance. In cartilage they are very loose; in common bones less so; and in the hardest bones, as those of the fore-leg of the lion, very close to each other.

I feel much satisfaction in the part I have had in prevailing upon that able chemist to take up this investigation; and as his progress has been marked with such brilliant success, I trust that he will continue his labours in this extensive field of animal chemistry, in which there is so much to be done; and certainly no one in every respect is so eminently qualified to prosecute the enquiry.

The formation of bone is one of those processes in the animal œconomy which Mr. Hunter investigated with considerable ardour, and there are many preparations to illustrate different facts respecting it.

The soft part of a bone is the first formed, and gives the shape, as well as the dimensions, of the different portions. This has in its nature more hardness than many of the other soft parts of the body. It puts on two very different appearances according to the form of the bone: where the bone is to be flat, the base is a strong membrane; where cylindrical, it has a fibrous texture, and has a small portion of phosphate of lime mixed with it, in which state it may be called gristle, or cartilage. These two different substances may be said to be the nidus in which the new bony matter is deposited.

The process of making bone is most distinctly seen in the skull and the patella. Whenever either of these parts are minutely injected previous to their becoming bone, they are found to be exceedingly vascular; and the first evidence of a bony structure is at the termination of small arteries, which appear to have become solid at their extremities. This is first seen in the central part, and it increases in every direction; in the skull putting on a very beautifully radiated appearance. In the patella it takes a more irregular form. In neither case is the whole bone formed from one original point; but there are several different ones, which in their increase come in contact and unite into one. It appears that the arteries are the agents by which this process is carried on, since the part is extremely vascular during that period, and is not so afterwards; and the appearance of new bone can be traced in the course of their more minute branches.

To explain the formation of different bones in detail, or even of the different parts of the same bone, is foreign to the present enquiry, and this subject is so fully considered in the schools of human anatomy that it is unnecessary to enter on it here.

That the previous formation of a membrane where a flat bone is to be formed, and of a cartilage where a cylindrical bone is to be produced, is not an accidental circumstance; but that it answers some essential purpose, is evident; since it is equally found to take place when a portion of either of these kinds of bone is to be replaced or repaired. It is however deserving of remark in the restoration of parts, that although this gristle is so readily generated, that process does not usually stop there, but goes on to the formation of bone; for when any of the permanent cartilages are broken, they do not unite by cartilaginous, but by bony union.

As the bones of an animal are originally formed upon a small scale, and are to grow to a considerable size, always retaining the same shape, it becomes a question in what manner they grow, without undergoing any change in their form. Nothing satisfactory had been stated upon this subject till the year 1743, when the celebrated Du Hamel published an opinion, that bones grow by an extension in all directions: this he supported by the following experiment.

He applied a ring of silver wire round the bone of a living pigeon immediately over the periosteum. This was allowed to remain fixed upon the bone for a period not mentioned. When the parts were afterwards examined, the bone was found cut through, or nearly so (for it is not stated), only that the medullary canal of the bone equalled the diameter of the silver ring. From this experiment Du Hamel concludes, that the attempt of the fibres to extend themselves was resisted by the opposition of the silver wire, and became the cause of their being destroyed.

At the present time, when the knowledge of the absorption of solid parts is fully established, a doctrine first taught by Mr. Hunter, I must consider some apology as necessary for taking up the time of my audience with the refutation of an opinion formed more than half a century ago, and which has long been exploded in the English schools of anatomy: the only apology I can make is, that a Professor of Anatomy of high reputation in these kingdoms, has given his support to Du Hamel's theory.

At the time in which the theory was formed, the conclusion was ingenious, for at that period our knowledge of the animal œconomy was in its infancy; but now there is no difficulty in placing the result of the experiment in a very different light. The silver ring prevented any new matter from being deposited upon that part of the bone while it was taking place on the other portions of its surface; the growth of the part embraced by the ring was consequently completely checked, and the ring buried in the surrounding bone; but the enlargement of the canal was not interrupted by the silver ring; it therefore increased by the absorption of the inner surface till the whole of the bone included by the ring was removed.

Having made these objections to Du Hamel's experiment, I shall briefly state the experiments and observations which led Mr. Hunter to abandon the theory it was intended to support, and to take up that opinion which, I believe in England at least, is generally received, as the established doctrine respecting the growth of bone. Mr. Hunter began his experiments by feeding animals with madder, which has the property of tinging with a red colour that part only of the bone, which is added while the animal is confined to this particular food.

The madder is found to tinge the animal part of the growing bone, and not the earthy substance that is afterwards deposited.

He fed two pigs with madder for a fortnight, and at the end of that period one of them was killed: the bones upon examination externally had a red appearance. When sections were made of them, the exterior part was found to be principally coloured, and the interior much less tinged.

The other pig was allowed to live a fortnight longer, but had no madder in its food. It was then killed; and the exterior part of the bones was found of the natural colour; but the interior was red.

He made many other experiments of the same kind upon the increase of the thickness of the neck and head of the thigh bone. From these it appeared, that the addition of new matter was made to the upper surface, and a proportional quantity of the old removed from the lower, so as to keep the neck of the bone of the same form, and relatively in the same situation.

To ascertain whether the cylindrical bones are elongated by new matter being interposed in the insterstices of the old, he made the following experiment. He bored two holes in the tibia of a pig, one near the upper end, and the other near the lower; the space between the holes was exactly two inches. A small leaden shot was inserted into each hole. When the bone had been increased in its length by the growth of the animal, the pig was killed, and the space between the two shot was exactly two inches. This experiment was repeated several times on different pigs; but the space between the two shot was never increased during the growth of the bone.

Besides the experiments on the growth of bones, he made others to determine the process of their exfoliation. He cauterized portions of bone in the same way in several different animals, so as to be able to examine the bones in the different stages of this process; and found that the earthy part of the living bone in contact with the dead portion was first absorbed, afterwards the animal part, so as to form a groove between the two, which became deeper and deeper till the dead bone was entirely detached: the dead portion itself having undergone no change.

From these experiments he ascertained the changes which take place in bones during their growth, and the readiness with which the materials are absorbed; and was induced to lay it down as an established principle, that the absorbents are the agents, by means of which the bones during their growth are modelled and kept of the same shape.

A bone, according to Mr. Hunter's doctrine, grows by two processes going on at the same time, and assisting each other: the arteries bring the supplies for increase; the absorbents are employed in removing portions of the old bone, so as to give to the new the proper form. By these means it becomes larger, without having any change produced in its external shape.

Besides the common bones of an animal body, there are others peculiar to particular animals, which only last for a season. Of this kind are the bony projections or horns on the skull of the deer, peculiar to the male. As these are of quick growth, and only last for a season, the different stages of their formation can be readily traced; and when they are completed and the supply of blood is withdrawn, the process of exfoliation, by means of which they drop off, is a beautiful illustration of that operation.

In their growth, the first change which takes place is a very considerable enlargement of the arteries leading to that part of the skull; then the horn, as it is termed, begins to shoot. In the early stages it is a vascular cartilaginous structure, covered with a velvet-like cutaneous covering. The cartilage is gradually converted into bone; and when this process is completed, the covering becomes so thin, that it is readily rubbed off by friction in the use of the horns.

As soon as the horns become hard, the blood-vessels going to them gradually diminish in size till the horns are deprived of all support, after which they are exfoliated like any other dead bone. This is perhaps the most beautiful instance in nature, of a bone being formed for a temporary use, and cast off by absorption as soon as the purpose is answered for which it was intended: the use of the velvet-like covering is evident, as it corresponds to the periosteum of other bones, being the medium through which the nourishment is received; and as soon as that is separated, in both cases death takes place.

That this weapon of defence in the male of the deer kind should owe its growth, and its decay, to the state of the organs of generation, is a very extraordinary circumstance, and is such a deviation from the common course of nature, that it excites our wonder and astonishment.

When the testicles begin to enlarge in the beginning of May, the horns begin to bud; when they are at their full vigour, the horns are completely formed, and afterwards receive no future supplies; so that they are no longer any expence to the animal till they are thrown off. But if the testicles are removed before the horns begin to bud, they are never afterwards formed. If the testicles are removed after the horns have begun to grow, those horns are mewed, and replaced by others, which differ from the former in being smaller, and never arriving at perfection: they always continue soft, and covered with velvet; so that they retain their supply of blood, and therefore continue alive; which explains their never being thrown off, a process that can only take place in consequence of the part having previously been deprived of vitality.

In comparing the formation and growth of shell with that of bone, we find that in both the general principle is the same: the foundation first laid is animal matter. In many shells this is in the form of thin plates; in flat bones it is the same; in cylindrical bones it is in the form of fibres: the figure being thus marked out, the earth is deposited to give strength and hardness. There is, however, this great characteristic difference—in shells there is no evidence of any of the old materials being removed; there is only an increase of size from an addition of new substance; a species of architecture fitted to the powers of the animal employed in erecting the building. But in the growth of bone the process is infinitely more complex: The first part is making a temporary frame, the texture of which is afterwards changed in a variety of ways, according to the circumstances in which the bone is placed. In the young animal it is soft and spongy; in the full grown it is more compact: through life the work is constantly undergoing some alteration; the arteries are laying on new matter; the absorbents are removing a part of the old, not only while growing, to retain its form, but even afterwards when tending to decay; and it is an irregularity in these actions which makes the bones in many individuals much softer, of others much harder than common.

This is perhaps as complex and curious a process as any carried on in the animal œconomy, and very unlike that by which shell is formed. There is no wonder then that it was not discovered at a more early period; and no small credit is due to the person whose experiments and observations completely ascertained it.

In giving these Lectures, I shall ever esteem it the most pleasing and the most gratifying part of my task, fully to explain the discoveries which were made by the Founder of this Collection, during the progress of its formation; since by doing so, I shall make you acquainted with the real value of this great repository of anatomical facts; and shall hold up the Author of them not only as the object of your high estimation, but as a bright example, that *some* among you at least may be induced to follow up his pursuits.

LECTURE V.

Of the Skeleton.

As some animals are entirely composed of soft parts; and others, of which the number is much greater, have more solid substances introduced into their frame, we are led to enquire into the cause of this striking difference.

In the operations of nature we find that there is every where a rigid œconomy; the materials employed are such as are required, and always the most simple, by which the purposes to which they are appropriated can be performed.

The means of defence are proportioned to the necessity, whether of the whole, or only of particular parts of the animal. In this view of the structures of animals, forming the different gradations in nature, we are led at every step to look up to their Creator with wonder and admiration, and in the contemplation of his works to learn what constitutes perfection.

The lower orders of animals have no bony skeleton, since it was not necessary for their progressive motion; and there are no peculiar parts in their form so delicate in structure, and at the same time essential to the well being of the whole, as to require such a support or defence. Many, it is true, from the softness of their texture, and the dangers to which they are exposed from the situations in which they are placed, would soon be deprived of existence, were they not supplied with an habitation into which they can withdraw, and there remain in security. This habitation, however, is intirely distinct, and makes no part of the animal itself.

The bony skeleton appears only to be given to animals possessed of a regularly formed brain; and therefore one of its essential uses is to defend that organ from injury, a purpose for which shell appears to be unfit, since in all those that I have examined there is no provision in the mode of its growth for the enlargement of the original cavity. This leads me to infer that the formation of bone, as it is a more complex operation than that of shell, may exceed the limited powers of these inferior animals to perform.

As the discoveries made in animal chemistry, render it probable that the secretions depend upon the nerves, so the modelling process, by which a bone retains its shape during the increase of its size, may require some action of the nerves, which can only be effected where that system is connected with a brain whose structure and dimensions are enlarged to a certain degree.

The most simple bony skeleton that is met with, is where the brain and spinal marrow only are inclosed in a bony case, composed of a number of bones closely connected with one another, but readily admitting of motion,

The skeletons of some fishes, the common eel for example, are of this kind. The skull incloses the brain; it also forms a defence for the organs of sense, in which the tongue may be included; and the vertebræ that compose the spine, form a canal of bone in which the spinal marrow is contained. These are the principal, although not absolutely all the bones of these fishes; and we shall find that it is by their means the progressive motion of the animal is performed.

In tracing the various additions that are made to this simple skeleton in different animals, to answer a variety of purposes connected with their modes of life, the situations in which they are placed, and the manner of catching their food, we shall meet with some beautiful illustrations of the regularity which is observed in the gradation of animated beings.

The most simple addition to this skeleton is the processes of the vertebræ being elongated in different degrees in the various kinds of flat-fishes; and having other bones connected to their extremities belonging to the fins, as in the turbot. In such fishes, these processes have nearly an uniform thickness; but in a species of chœtodon from the coast of Sumatra, they have large knobs on them; and there are other bones of a similar kind, but unconnected with the spine, at the extremities of which there are knobs also.

The skull in many animals not only serves as a covering and defence for the brain and organs of sense, but has projections of different kinds, as in the chœtodon above-mentioned, and in the fish from the South Seas called the light-horseman: of the same kind may be considered the sword in the sword-fish; and in the more complex animals the horns of the stag, and the core of the horns in black cattle, all which are bony processes from the skull.

Of the two species of esox, met with in the East Indian seas, described and delineated by the late Dr. Russell, in one, the esox brasiliensis of Linnæus, the lower jaw projects beyond the upper one-sixth of the length of the fish; in the other species, not described by Linnæus, nearly one-fourth as a weapon of defence, very sharp at the end.

The spine is also extended in many animals beyond what is necessary to defend the spinal marrow, and then forms the tail, which answers a variety of purposes.

As the first and essential use of the skeleton is to defend the brain and its appendages, the second is to assist in respiration, and different bones are added for that purpose, rendering the skeleton still more complex.

In fishes which breathe the air contained in water, there are strong cartilages on which the gills are supported and kept apart from each other. In animals that breathe the air of the atmosphere, there are ribs; these in the snake tribe are only connected with the spine; the other extremeties are loose, and are employed, as we shall find, in the progressive motion of the animal; but in birds and quadrupeds there is in addition to these, the breast-bone.

Although the ribs are in most animals employed entirely for the office of respiration, yet in the flying lizard the lower ribs on each side are extended to a considerable length, and support the expanded membrane which, in that animal, serves the purpose of wings. In the cobra-de-capello snake, some of the ribs are so shaped as to support the hood from which the snake takes its name.*

The extremities form the next addition. In many sea-animals there are only two, called the pectoral fins, as in the whale tribe, corresponding to the anterior extremities of quadrupeds. In others there are four, as in the seal and turtle, that come occasionally on shore, and in all land animals, as well as the inhabitants of the air, whose skeleton is formed of bone.

The bones of the trunk and four extremities form the essential part of the skeleton, for in the most perfect animals

* Tab. II. III. IV.

no new parts can be said to be added. In the different classes of animals they bear a much greater degree of resemblance than one would reasonably expect, from the uses to which they are applied, and the coverings in which they are enveloped; and there is no evident reason for this resemblance, unless it be intended to show that all the animals in this world come from the same hand, and belong to the same general scheme of creation. In what other way can we explain the fins of the whale, having nearly the same number of bones, and a similar form to those of the human hand, although the two parts in the living animals are so exceedingly unlike? or the still more remarkable circumstance which may be observed in the turtle, where there is even the resemblance of a thumb?

Of this analogy in the number and appearance of the bones of animals many instances may be mentioned.

None is more remarkable than the circumstance of the neck of the camelopardalis, of the seal, and of man, having exactly the same number of vertebræ, although that part in these different animals differs so much in its length.

Animals that walk, appear to have no general likeness in the form of their bodies to those that creep, and still less to those that fly; yet in all of them, however differently the bones are fashioned to adapt them to these various uses, the skeleton consists of a skull and four extremities which have a correspondence in their bones; so that although the parts are fitted for uses not at all similar, they are all links of the same chain. The bones of the fin of the seal, which is formed for swimming, and those of the bat, which are made for flying, resemble the human hand, which has so different an office.

The pectoral fin of the shark is a near approach to that of the whale, and there is something analogous to a scapula and clavicle; and the holders, by means of which the male shark grasps the female in the act of copulation, is composed of bones, which correspond in number and form with those of the thigh, leg, and foot, and have been absolutely mistaken for legs in the skeleton, so great is their resemblance to them, and yet when seen in the living fish no two parts can be more unlike.

Besides the bones, which may be said to be common to quadrupeds generally, there are particular bones only met with in certain tribes whose habits of life make them necessary.

One of the most remarkable of these is the clavicle, which is peculiar to those animals that use their anterior extremities as hands. They are therefore met with in very few, as the squirrel, the monkey, and man. They keep the scapulæ at a distance from the sternum. A bone answering a similar purpose is found in birds that fly, but is wanting in those that walk, as in the cassowary and ostrich.

Many animals have bones peculiar to them to assist in catching their prey, to assist in the act of copulation, or as a weapon of offence. There is a bone in the tongues of many fishes, birds, and some quadrupeds, as in the shark, woodpecker, and camelion. These animals use their tongues for the purpose of catching their prey.

In the dog, bear, hippopotamus, there is a bone in the penis. In the la-paca this has a peculiar structure; it does not extend beyond the glans, and has two hook-like processes which point backwards.

In the oppossum tribe there are two bones connected to the pelvis as a support to the pouch, or false belly.*

* Vide Tab. V.

There is a bone on the back of some species of chœtodon with a sharp point, which the fish has a power of raising up and keeping it in that state as a defence, allowing it when not wanted to fall into a groove, where it lies concealed.

There is in some animals a bony case, in which the animal can nearly shut itself up, as in the turtle and land-tortoise. This is the nearest resemblance we have of a bony structure to the shells of fish.

Many of the bones in particular tribes of animals have a peculiarity belonging to them, adapting them to the circumstances connected with the modes of life, or the structure of such animals: of this kind is the cavity in the sternum of the crane, which receives the convolutions of the trachea of that bird.

The os humeri of the lion tribe, and many other animals, is perforated, to give a more direct course to the brachial artery, that it may not be compressed by the muscles in the act of seizing its prey.

The skull of the elephant which supports the enormous tusks, has a volume beyond what is met with in any other animal. This extent of surface admits of the insertion of the necessary number of muscles to raise the whole weight. The internal structure is, however, adapted to other purposes; principally employed as an appendage to the organ of hearing; but in part to that of smell. We are however at present only considering it as an uncommon structure of cranium, where, in place of the common spongy substance which forms the diploe, there is a curious bony net-work of four inches and a half in thickness between the two tables. That the principal object of this unusual size is for the support of the tusks, is in some measure proved by the skull in the young elephant being very small, and its increase in size keeping pace with that of the tusks.

It is a curious circumstance respecting the skulls of carnivorous animals, that they put on a very different appearance in the full-grown state, to what they did while the animal was growing. This change is independent of the increase of size, and is produced by the pressure of the temporal muscles while in action upon the bones, which is exceedingly great; the impression they make on the two sides of the skull makes its general form quite different from what it was in the young animal. This is remarkable in the seal and the bear; so much so, that when the bones were discovered in the caves of Bayreuth in Germany, the skulls of the young bears were so unlike those of the full-grown ones, that they were supposed to belong to a different animal.

Bones differ exceedingly in their texture, and are found upon all occasions to be adapted to the circumstances in which they are placed; the structure corresponding to the purposes for which they are employed.

At birth, the only bones that are hard are the ribs; these only at that age having occasion for that degree of strength; as the animal grows up, the other bones become hard. This, however, varies in degree not only according to the original law of their nature, but also in some measure according to the degree in which they are pressed upon. This corresponds with the increased strength of muscles from being frequently and actively employed; and it may be illustrated by what takes place in the union of broken bones; the new-formed bone does not acquire hardness till it has been used; and long and extensive use is necessary to make it as firm as the original bone.

It is upon this principle that the different bones of the same animal differ so much in their degree of compactness, a fact universally known to anatomists, and which will be found in proportion to the weight or exertion the bone is to support. The bones of the fore-foot of a race-horse and of a deer are very small, but unusually hard: this is so much the case in the fore-leg of the lion, that there was an idea of its being of a peculiar chemical composition: this, however, from Mr. Hatchett's examination, was found not to be the case, it only contains a greater proportion of phosphate of lime.

When the bones are increased in size for the purposes of sttrength, or to give attachment to muscles, the contrivances employed are of the most perfect kind; for, as it has been proved by Galileo, that in the increase of dimensions of solid bodies, the destroying power proceeds in a quadruplicate, while the preserving power rises only in a triplicate proportion, so we find all large bones are hollow, not only to avoid this disadvantage, but that by removing the centre of motion to the greatest possible distance from the centre of gravity, the greatest possible strength which can be derived from the same quantity of materials may be given; and the cavity in the middle of the bones is employed as a reservoir for different substances which are necessary for the animal, either as nourishment, or to adapt it to the medium in which it is to move.

Bones which have neither weight to support, nor great resistance to make, are weak, but to give them lightness they are hollow.

Where extent of surface is required for the attachment of muscles, and proportional strength, the sides are solid, and the internal cavity unusually large and filled with that kind of fat, which is called marrow, as in the thigh-bone of the bullock.

Independently of this variation in the structure of bones, fitting them for the office in which they are are employed, they are also adapted to the medium in which the animal is placed; for instance, the bones of all swimming animals are light: this property is acquired in very different ways; one is, by a small proportion of phosphate of lime being contained in the bones, as in those of the cartilaginous fishes. In the whale-tribe, where it becomes necessary that the bones should have strength as well as extent of surface, they are rendered light by the internal cavity of the bone being filled with oil. In one species, the spermaceti whale, there is a very large cavity in the upper part of the skull entirely filled with spermaceti, which renders the head of this enormous animal sufficiently buoyant to keep the blow-holes above the surface of the water.

These are certainly curious provisions of nature, making the bones so many reservoirs of supplies for the animal's support, at the same time that they are rendered lighter in those animals that live upon the land, and considerably more buoyant in those that swim in the water. The attention which has been paid by the Creator of all things, to adapt the structure of animals to the medium in which they are placed, is however still more strikingly conspicuous in the bones of birds, which have their internal cavities much larger than in other animals, and a communication is kept up between them and the lungs; so that they receive a supply of air, with which they are constantly filled; and this having a ready outlet by the wind-pipe, is allowed to become rarer, according to the distance to which the bird is removed from the surface of the earth.

The discovery of this mechanism, and one of the most extraordinary respecting the bones of animals, was made by Mr. Hunter, and proved in the most satisfactory manner by a variety of experiments; but the facts are sufficiently established to make it unnecessary for me now to dwell upon them.

In some animals the bones arrive at their full size in a short period compared with others ; and this does not appear at all connected with the length of the animal's life : the parrot and eagle live for a century, and yet do not acquire a great size ; but the alligator and whale must grow for almost the whole of that time, before they can arrive at the size that they sometimes attain.

The standard growth of animals of particular species is in general tolerably uniform ; indeed the exceptions when they occur are so rare, that they are considered as curiosities.

A horse was shewn in London on account of its uncommon size, and the man who owned it gained considerably by the exhibition ; which would not have been the case if similar instances had been common.

Instances of the bones growing to an unusual size, as well as of their falling short of the ordinary standard, more frequently occur, I believe, in the human species, than in other animals ; and these deviations occur in some countries more than in others. Giants are met with in Ireland, and dwarfs are common in Poland.

In the Collection there is a skeleton of an Irish giant, whose thigh-bone is the exact measure of the Polish dwarf Boruwlaski, who is still alive.

These deviations from the ordinary course of nature cannot, I believe, in any way be explained; their casual occurrence has led men of speculative minds to form singular conjectures respecting the original size of our species. These however do not receive any confirmation from the facts that are handed down to us.

The skeletons of the people called Guanches, from the Island of Teneriffe, are only five feet six inches in height. The mummies lately brought from Egypt do not exceed the size of ordinary men. One of the vertebræ of the back taken from the tomb of the uncle of Scipio Africanus, is exactly of the same size with that of a man of a very middling stature, and could not have belonged to one exceeding five feet seven inches in height.

There have been accounts of a race of men much above the ordinary stature still existing upon our globe; there are similar histories of a race of pigmies in the Island of Madagascar: both of them must be considered as fabulous, till better proofs than any which have been hitherto adduced can be brought forward. Nor have we better evidence of any such unusual dimensions having been common to mankind in any period of the world; although the casual instances which sometimes occur, make it evident that there is in our nature a power capable of producing such an effect.

LECTURE VI.

Of Joints.

THERE is nothing in the mechanicsal contrivances which are employed by man in different kinds of machinery, that can be compared to the mechanism of animal bodies, even in those parts that are most within the reach of imitation, which the articulations between the bones undoubtedly appear to be.

The various modes employed for uniting bones together according to the strength that is required, the quantity of motion that is to be produced, and the circumstances under which it is to take place, form as beautiful a series of structures as any that is met with in animal bodies; and the subject is rendered more interesting, as from its simplicity, and from its being wholly mechanical, it is within the reach of our knowledge, and is more readily comprehended than many others which will be taken notice of.

Joints are formed upon three different principles; the most simple is where an elastic substance connects the two bones, and by its thickness, and a mixture of oil in the interstices, is enabled to yield in any one direction to the force applied to it, the oil being squeezed out of that part; the substance, like a sponge, recovering its former state as soon as the force is removed.

The second is, where the two bones are kept apart from each other by means of a liquid, or a soft jelly, which serves as a centre, round which the motion take place.

The third, where the bones are covered with articulating cartilages, adapted to one another in form, and lubricated with a fluid which makes them move with more facility upon each other.

The first of these structures, which is the most simple that can be imagined, is rarely employed; it is however met with in the whale-bone whale. Between the condyles of the lower jaw and the basis of the skull is interposed a thick substance, made up of a net-work of ligamentous fibres, the interstices of which are filled with oil, so that the parts move readily on each other. The condyles have neither a smooth surface nor a cartilaginous covering, but are firmly attached to the intermediate substance, which in this animal is a substitute for the double joint met with in the quadruped, and is certainly a substitute of the most simple kind.

The second of these structures, where a fluid is interposed between the ends of the bones which are hollowed out to receive it, forming a ball-and-socket joint, is met with between the vertebræ of fishes in general. As this is a fact only lately ascertained, I shall mention the circumstances under which it was discovered.

A squalus maximus of Linnæus, the basking shark of Pennant, was thrown a-shore on the coast of Hastings in the winter of 1808, and a friend of mine upon the spot purchased it on my account. I requested the Conservator of this Museum to go down and examine its internal structure. The fish was 36 feet long, and the diameter of the larger vertebræ seven inches. As soon as Mr. Clift cut into the intervertebral substance with a view to separate the vertebræ, a liquid rushed out with so much velocity that it rose to the height of four feet. At the end of twelve days I had an opportunity of examing a portion of the spine, which was brought to town; and upon making a longitudinal section of two of the vertebræ and the intervertebral substance between them, a fluid was met with of the consistence of liquid jelly, with clots of different sizes floating in it; so that in ten days, although excluded from the external air, it had shewn a considerable disposition to coagulate. It was of an opal colour, semitransparent, and had a strong fishy smell and taste. Its chemical properties were examined by Mr. W. Brande, from which it appears to be of a peculiar nature; in its original properties it resembles mucus; but under certain circumstances is capable of being converted into modifications of gelatine and albumen.

The form of the cavity exposed in this section was nearly spherical, capable of containing about three pints, with a smooth internal surface. The lateral ligaments, by which the edges of the concave parts of the vertebræ are united externally, were very strong and elastic, but less and less so toward the inner edge: these ligaments were made up of layers, and when exposed to water in their divided state, it insinuated itself between them and made them swell, particularly the inner portion, which is the weakest; so that it projected into the cavity, putting on an appearance very different from what would be observed could the parts be inspected in the living animal. The preparation of this joint, without this explanation, would be quite unintelligible.*

This structure of an intervertebral joint has never before

* Tab. VI.

been made known to the public, and it is the only one met with in animal bodies which has not been imitated by the art of man ; and there are circumstances which render it very probable, that no ingenuity can make a joint artificially, that in all respects will resemble it. This opinion is founded upon the advantages that are given in the productions of nature to the elasticity of parts possessed of that property, by keeping them constantly in the degree of moisture, and in the exact temperature fitted for the fullest exertions of this peculiar property, which man, I am afraid, in his present imperfect state of knowledge, has neither the power to ascertain, nor the ability to produce; and which is so much diminished after death, that we have no opportunity of exactly determining it.

In this joint, the fluid which occupies the cavity keeps it constantly distended, and prevents the ends of the bones from approaching nearer to one another than the mean state of the elasticity of the lateral ligaments ; and being incompressible, forms a ball round which the bony cups move ; the parts that compose the ball having no cohesion, the centre of motion is always adapted to the changes which the joint undergoes without any friction being produced.

The elasticity of the ligaments, as it is the same on every side, keeps the joint steady without any lateral support, and preserves the whole length of the back-bone always in a straight line, when not acted on by the muscles ; and whenever any one, or greater number of joints, have been drawn to one side by the action of the muscles and by stretching the ligaments of the opposite side, as soon as the muscular power ceases to act, the elasticity restores the spine to a straight line again ; the use of antagonist muscles not being required for that purpose. This is one of the most beautiful instances we have in animal bodies of elasticity being employed as a substitute for muscular action; since it becomes not only a substitute for antagonist muscles to a certain extent, but also for the muscles commonly employed to steady joints, by passing over them, and bringing the ends of the bones into close contact while moving on one another.

Having made the discovery of this mechanism in a fish, where, from the size of the cavity and the quantity of the fluid, it was obvious, and in which the use of such a deviation from what is commonly met with in the intervertebral joints of land-animals, was evidently for the purpose of swimming, by admitting of the lateral vibratory motion peculiar to fishes being kept up with the least possible fatigue; it naturally suggested itself that this structure, as it is equally applicable to the motion of fishes in general, would be found in their intervertebral joints, although it had not been taken notice of. Upon examination this proved to be the case; and the reason of its not being before discovered, is the smallness of the quantity of the liquid in any one joint of such fishes as commonly come under our observation, and the readiness with which it coagulates immediately after death. There is, besides, another circumstance which tends to render this structure less liable to detection: when a longitudinal section of the back-bone of a fish is made, the elastic lateral ligaments, by their contraction, squeeze out the liquid in bringing the ends of the bones closer together, and the inner portion of the ligament is pressed inwards into the cavity, and when superficially examined, may be mistaken for a gelatinous substance naturally contained in it.

In the examination of a longitudinal section of a large skate recently killed, the intervertebral substance appeared to be a jelly, the central part nearly liquid, the lateral portions completely solid; but when another was examined while alive, the liquid was readily detected, and the lateral portion of the ligament, squeezed into the cavity, distinctly seen. This liquid is found in its chemical analysis to be similar to that of the shark. In all those fishes, therefore, in which the vertebræ have the cup-like form at their ends, the cavity, while the fish is alive, is filled with a liquid, and the structure of the intervertebral joints is exactly similar to that described in the squalus maximus.

The principle in all fishes is the same; but there are varieties in the structure of the back-bone in some, whose habits are peculiar to themselves. In the common eel the cavity between the vertebræ is not globular, but oval, the longitudinal diameter being one-third greater than the transverse one.

In the sturgeon the deviations are still greater. The backbone in its external appearance resembles that of other fishes, and there appear to be distinct vertebræ, with spinal and transverse processes, only very closely united to each other; but when a longitudinal section is made of the spine, what looked like solid vertebræ, is only a number of annular cartilaginous rings one quarter of an inch thick, their edges being nearly in contact, united together by an elastic ligamentous substance, so as to form a tube the whole length of the spine. Immediately within this is a firm compact elastic substance of the same thickness with the tube which surrounds it, containing a substance less dense in its texture, very soft and flexible, and in a slight degree elastic. In the centre there is a chain of cavities containing a liquid, each having the form of a lozenge. They appear to correspond in number with the cartilaginous rings, and communicate with each other by small apertures, so that the liquid passes readily along the whole chain. The habits of the sturgeon are not sufficiently known to enable us to explain the peculiar advantages which that fish derives from this structure; but we find the spine of the lamper eel and of the lampern to be exactly the same; we must therefore conclude that the sturgeon bears some resemblance to them in fixing the head to some particular spot, and its body being kept constantly moving in the water.

This structure, although common to fishes, is not met with in all animals that swim; it is confined to those in which the tail has a perpendicular direction. All the whale-tribe whose tails are horizontal, and whose motion through the water depends upon the tail, have an intervertebral substance of a very different kind, and exactly similar to what is commonly met with in quadrupeds.

In taking a general view of the different intervertebral joints met with in animals, of which there is considerable variety, we shall find that this of fishes is not only the most simple, but the principle on which it is formed is so obvious, that it enables us to trace the same principle in many of the others, in which it had been overlooked, and consequently the true mechanism had never been discovered. We were not even acquainted with it in the human body, which has been so constantly under our observation; so difficult is it to detect errors which are generally received, unless some particular circumstance gives a new turn to our observations.

It will appear from what has been stated, that in all intervertebral joints in which the bones do not move on each other by means of cartilaginous coverings adapted for that purpose, there must be inelastic centre pins to keep the vertebræ at the proper distance from each other, and that the motion to be produced must take place round these fixed central parts. In fishes, we find this office is performed by a liquid; and in the whale-tribe, the human body, and many quadrupeds, it is performed by a soft inelastic gelatinous substance. This is seen in the most distinct and satisfactory manner in a preparation from the whale, in which also the structure of the parts surrounding it are, from the size of the joint, rendered very conspicuous; I shall therefore describe this mechanism in the whale, and the same description will apply to the bullock, the monkey, man, and quadrupeds in general.

There are indeed exceptions, for in the hog and rabbit there is a central cavity filled with a liquid of a gelatinous nature; its extent is nearly half the diameter of the vertebræ, and it has a smooth internal surface. Such a mechanism was little to be expected in these animals; and whether it is to answer any essential purpose, or only to form an intermediate link in the gradation of animals, which is so uniformly adhered to in the productions of nature, cannot at present be determined.

In the whale the central portion is so soft, that it almost resembles condensed mucus; it is devoid of elasticity, admitting of extension without any recoil when the force is removed. This is surrounded by concentric layers of elastic ligament, the innermost very soft, but becoming stronger and denser towards the circumference, and the exterior part much firmer than any other.

These layers are connected together by a number of transverse fibres. The same structure is readily made out in the intervertebral substance of the human spine, but upon so much smaller a scale, that it requires that it should have been in the magnified view which is given of it in the whale, to enable us to discover it.

In the bullock it is very evident, and is distinctly seen by looking at the section of the spine in a longitudinal direction, made by the butcher in cutting up the animal; as in that state the elastic ligaments contract and push out the central pulpy substance, which projects beyond the cut surface of the section. This substance has been chemically examined by Mr. W. Brande, and it is found to consist principally of albumen; while elastic ligament has a considerable portion of gelatine in addition to its other ingredients, the gelatine being necessary to give it elasticity.

The knowledge of the structure of the human intervertebral substance thus acquired, is not only of importance as an anatomical fact, but gives us material assistance in the mode of treating curvatures of the spine when they have their origin in a weakness of these joints, which is the case in all the lateral curvatures so common in delicate young women who grow beyond their strength, or have been weakened by violent attacks of fever or other diseases. It shews us the disadvantages that arise from making too great an extension upon the ligaments of these weak joints, which will by this means be overstretched, and have their elasticity diminished; the central inelastic part will also be extended, leaving the vertebræ without support, and the joint will be rendered unsteady: too many instances of this effect, from the use of machines, have come under my observation; but I was unable, while ignorant of the true mechanism of the joint, to explain in what the practice was erroneous. Out of this knowledge the great benefit which is derived in such cases from carrying weights upon the head is readily explained. To support the weight while the patient is walking, all the muscles of the spine are kept in action to steady the different joints, and the elastic ligaments are kept in play by those modes of exercise; both parts are rendered strong, their weakness arising principally from want of use in persons of indolent habits. The bones themselves, and the inelastic centerpins, which become compact in proportion to the pressure they have to bear, are also restored to the natural standard.

The intervertebral joints in other animals have a very different structure. In the alligator, the vertebræ throughout the whole length of the spine have their surfaces covered with articulating cartilages fitted for motion; there is a capsular ligament surrounding the cavity which contains synovia, as in many other joints in the body. In the snake they have a different form; there is a regular ball-and-socket joint between every two vertebræ, like that of the head of the thigh-bone; so that in the back-bones of different animals there is a considerable variety in the mechanism made use of for the motion of the vertebræ on each other, fitting the animals for the sphere in which they are to move.

In considering the articulating cartilages of these joints which admit of much motion, we find that they have a structure of a particular kind, unlike any other in the body; it is compact, elastic, and its fibres are all placed at right angles to the surface of the bone, so as to have the full effects of its elasticity when they are pressed together, which prevents the jar that would otherwise be produced. Its external surface is polished, and is lubricated with synovia, to make the bones play more readily on one another. This is a provision of nature given to all joints with capsular ligaments, and is met with whatever is the particular form of the joint. The contrivances are so various as to strike us with astonishment and admiration; they seem in some instances to exceed the apparent necessity; such is the effect of infinite power.

As from an established law in mechanics a single joint cannot both have great strength, and admit of considerable extent of motion, we have in animal bodies some most beautiful instances of strength and motion combined, by the number of joints being great, and the motion in each of them exceedingly small. The back-bone, on which so much has been already said, is a very striking one; the arch of the human foot is another: it is necessarily strong, as it has the weight of the whole body to support, and often under very disadvantageous circumstances, and with much additional load: there is also required a considerable degree of play between its different parts to render the motion of the body easy, and to admit of the spring, by means of which all the movements of agility are produced, and the jar broken when the body comes to the ground with great velocity.

To answer these two purposes this arch is formed of a great number of bones, all of them united by joints with articular cartilages and synovia between them. The motion in each particular joint is very small; but the combined effect of the whole makes the quantity sufficient, without taking off from the required strength of the part.

A series of structures has been already given of some extent in the same joint in different animals, in describing those between the vertebræ; we shall now mention another series, where there is great variety, which is in the mode of articulation of the lower jaw; the strength being greater in some animals, and the motion more extensive in others, according to the nature of the food on which they live.

In the whale-bone-whale, which has no teeth, and where the mouth may be compared to a large net which is thrown open and closed again, we have mentioned that the joint of the lower jaw is of the most simple kind. In the sea-otter, as the animal feeds on shell-fish, great force is required to break the shells; and as no mastication is afterwards necessary, there is no need of lateral motion: to give the requisite strength, the condyles of the lower jaw are locked in a cavity in the basis of the skull; so that even after death, when all the soft parts are removed, they can with difficulty be disengaged. In this respect the joint resembles the hinge of many bivalve shells: its strength is prodigious; but then its motion is limited both in direction and extent; the animal cannot open its mouth very wide, nor give the jaw any lateral play.*

In carnivorous animals, as the lion tribe, that only divide their food, great strength is required; but it is also necessary that the mouth should admit of being opened to a great extent: the joint of the lower jaw is therefore less confined; it is formed upon the same principle with that of the sea-otter; but the bones have more play upon one another.

In graminivorous animals, and those which, like man, eat

* Tab. VII.

both kinds of food, and therefore employ mastication either constantly or occasionally; the jaw requires not only the motion by which the mouth is opened and shut, but a lateral motion for grinding: to perform this, the condyle must be occasionally moved out of its natural socket upon an eminence, in which situation it would be so unsteady as readily to admit of dislocation, were there not in all such animals a provision against this effect.

There is an elastic substance interposed between the skull and the condyles of the lower jaw, making a kind of double joint; and as the elastic substance moves along with the condyle, to which its concave surface is well adapted, it is carried with it to the eminence, and while there, provides for it a secure resting place. This mechanism is very distinct in man, and graminivorous animals in general; but is particularly conspicuous in the elephant, whose teeth have the broadest grinding surface of any of that tribe.

In the human knee there is another admirable contrivance to adapt the head of the tibia to the two very different surfaces of the condyles of the thigh-bone, which are applied to it in the different positions of the limb. Two semilunar elastic cartilages are interposed, which allow themselves to be stretched either in the one direction or the other, according to the form of the bone which is pressed against them. There are also two crucial ligaments in the middle space between the two condyles behind, connected to the tibia, to prevent the two bones in the straight position of the limb moving beyond the perpendicular line. The patella also is a loose bone which plays over the joint.

The knee-joint has the same structure in most animals in which the same variety of movements is required. In the wombat, however, the patella is wanting.

In some swimming birds, as the passage-duck, instead of a patella there is a process from the tibia of some length; so that the muscles applied to the end of it have a great mechanical advantage in moving the limb.

All these varieties are mentioned, although to many here present they must be well known; but I consider it as my duty to shew, upon every particular subject that comes before me, as far as I am able, the series of structures employed for the same purpose; and my illustrations will be better understood, where some parts of the series are already familiar to you.

Of the ball-and-socket joints, there is nothing in common mechanics, the workmanship of man, which can approach to the excellence of the human shoulder; but as the motions it can perform are extensive, so the mechanism is weak in proportion. In those animals which walk upon their fore-legs, the joint is much stronger, and the motion more limited; but a certain uniformity in the appearance of it is preserved. The joint of the thigh-bone with the pelvis, is also a ball-and-socket joint; but the socket is much deeper; there is also a strong ligament connecting the head of the thigh-bone to it. This ligament is common to most quadrupeds, even of the largest and most unwieldy kind, such as the hippopotamus, but is wanting in the elephant; this probably arises from the little strain to which the hind-legs of this animal are liable from its being an inhabitant of flat countries, compared with the other, which has to scramble upon the banks of rivers, the ground of which is slippery, making great exertion necessary to enable the animal to keep its footing.

In considering the joints of an animal body, those of the spine, those that are between the bones which form the arch of the foot, and some few others excepted, their principal support, and consequently their strength, seems to depend less upon their own ligaments than upon the action of the muscles whose tendons pass over them. As synovia is required to lubricate the surface of the articular cartilages, it is necessary that the capsular ligaments should form a cavity large enough to contain the necessary supply of that liquor, which will make the joint itself loose and unsteady, and the stronger ligaments which surround it partially, are only intended to confine the motion of the joint within its proper limits, not to give steadiness in the nicer movements: this is brought about by the action of the muscles which pass over the joint, pulling the ends of the bones together, and giving the joint a degree of rigidity it at no other time possesses.

This fact was strongly impressed upon my mind in the early part of my medical education, by seeing a deer, which leaped over the highest fences, and the joints of whose feet, when examined, were as rigid in every other direction, but that of their motion, as the bone itself; but when the tendo achillis, which passed over the joint, was divided, with a view to keep the animal from running away, the foot could readily be moved in any direction; the joint no longer having the smallest firmness.

This fact, which ought to be mentioned to all those who are learning the profession of surgery, explains the weakness of the ankles, as it is termed, in children of debilitated habits; or in young people whose general health has been impaired by disease, their muscles being rendered so deficient in power that they cannot give the ankle-joint, while supporting the weight of the body, the firmness which is required to keep the bones steadily opposed to each other: the consequence of this irregular bearing of the surfaces is, that the bones in their growth adapt themselves to it, producing a deformity of the limb. The truth of this observation is proved by the effects of the use of lead, which is attended by weakness of the joints, although the disease is confined to the muscles.

These observations explain the wonderful effect which is produced by early habits of exercising the body, in giving extent of motion, as well as an unusual strength to the different joints; two things which, so far as the mechanism of the joint only is concerned, are incompatible with each other; but by constant exercise both the powers of the muscles and the extent of their relaxation and contraction can be increased; and when these powers are acting upon joints in a growing state, the surfaces of the bones under such an influence will be adapted to a greater range of motion, as well as the ligaments belonging to them, than happens under the more usual circumstances of life.

The ancient Romans were sensible of the effects of such early habits of exercise upon the body; and at the present day the Beys of Egypt begin at an early age to have the joints of those youths who are to be trained to war, moved in every direction, and regularly kept in exercise; and it forms the principal branch of their education.

LECTURE VII.

On the Progressive Motion of Animals.

To consider the various modes by which animals are enabled, according to the peculiarities of their form, to move from place to place, is to embrace a subject of so much variety, and one in which the power and skill of the omnipotent Creator is so eminently and conspicuously displayed, that it must excite the highest degree of admiration.

Every animal, we shall find, is formed for the situation in which it is placed, and is provided with the means of progressive motion best adapted for these particular circumstances.

This is so true, that by examining the external form of any animal, we are enabled to determine whether it lives in the air; upon the earth; under the surface; or in the waters: we can even go still farther, and point out the climate, the soil, and situation for which it is destined.

In the attempt I am going to make, of giving a general view of a subject so complex, so extensive, and made up of such a variety of parts, it is difficult to arrange the materials, or to decide where we should begin. I shall, however, consider that kind of progressive motion as the most simple, in which the powers of the animal are least employed; and that the most complex, which is wholly performed by its own exertions.

This will lead me to begin with sailing upon the surface of the waters, and to conclude with the progressive motion of four-footed animals upon the surface of the earth.

Floating.

The most simple progressive motion that can be imagined is that belonging to those blubbers of different descriptions which, from their structure, are nearly of the same specific gravity with the sea they inhabit; and, from their expanded form, are enabled to float upon its surface, moving with the waves on which they are supported, and in this way passing from one place to another, and catching the food necessary for their support.

Next to this is the progressive motion which does not wholly depend upon the motion of the water, whether it arises from the winds or the tides, but where the animal itself is impelled by the wind, and has parts peculiar to it fitted for that purpose.

Sailing.

Some of the mollusca float upon the surface of the sea, and have their motion assisted by means of something resembling a sail.

The most beautiful contrivance of this kind is in the Portuguese man-of-war (holothuria physalis.) The lower part of the animal consists of innumerable tentacula hanging in the water; the upper part is an oval bag distended with air. I saw several of this species while at St. Lucia, in the West Indies, blown ashore upon the rocks. The bag had been dried by the sun, and was perfectly air-tight; but when it is examined in the moist state, there is found a small valvular aperture the size of a hog's bristle near the pointed end, and another of a smaller size near the opposite end, with a thickened edge, which looks like a dark spot transparent in the centre. There are preparations in the Collection made by Mr. Hunter, to shew both these openings. Dr. Telesius of St. Petersburgh, who had the opportunity of seeing these animals alive, has given very elegant engravings of them, and particularly describes the two orifices, of which no account had been before published. Some of the species he has delineated had a crest attached to the upper part of the bag, in a concave form, with transverse gelatinous bands, by the contraction of which it could be occasionally depressed, and afterwards raised by its own elasticity.

The paper-nautilus, argonautia-argo, is said to sail upon the surface of the sea; but as the animal to which this shell belongs, has, I believe, never been met with alive, all such accounts must be wholly fabulous.

The medusa velella is another of the gelatinous animals supposed to have the power of sailing; but never having seen the animal, I can say nothing respecting its means of doing so.

Many water-fowls, while in the water, employ their wings as sails, and are by that means carried forward with considerable velocity: the swan gives us the most beautiful illustration of this mode of progressive motion.

Rowing.

The mode of moving through the water employed by web-footed animals of every description, and also by quadrupeds and man, cannot be termed swimming, since it is a very different kind of progressive motion from that used by fishes: it is, more properly speaking, rowing, being exactly similar to the mode in which a boat is propelled through the water by means of oars.

The feet of many birds, and of some quadrupeds, are webbed, the better to fit them for being used as oars, and this mechanism of the foot makes them superior to any artificial oars whatever; because as soon as the expanded foot has pressed away the water from behind it, the toes collapse, and while it is drawn forward it presents a very small surface to the opposing water. These animals are not only adapted to live in water, by the form of their feet, but have their external covering so constructed as to prevent the water from penetrating it, whether that covering is hair or feathers: the coat of the beaver is perfectly dry the moment it comes out of the water, the feathers of a duck are equally so, which allows them to pass through the water with less resistance.

It is not necessary here to enumerate all the quadrupeds and different kinds of birds which live principally upon the water, I only purpose to point out the peculiarities in their form, by which they are fitted for that situation. There is, however, one animal of so extraordinary a nature, belonging to this tribe, that it is necessary to mention it. This is the ornithorinchus paradoxus: its fore-feet are well fitted for rowing, and its tail, like that of the beaver, for raising and depressing it in the water.

Some sea-fowls have their legs better formed for rowing, by means of a peculiar mechanism.

In the passage-duck there is a process of bone three inches long, projecting from the tibia, which is a substitute for the patella. This process is found in the great speckled diver, or loon of Pennant. Three strong muscles arise all along the ilium, and are inserted into it, which must give a great power to the forward motion of the leg.

This process also gives a greater surface for the origin of the extensors of the tarsus; for some of those muscles arise from its forepart, and wind round the tibia to get behind the tarsal joint. The tarsal bone is very thin, having its edges turned forwards and backwards: this may assist the bird in the fore-stroke, but must be an obstruction to the back-stroke.

The three toes are articulated almost in a straight line with the tarsus, and the second bones only stand a little forwards, so that the bird cannot possibly walk, and when it floats on the water its legs and toes are in a straight line along the belly.

These birds, we must conclude, either from the extent of sea they have to pass over, or the currents they have to row against, require greater powers than those that are not equally supplied with the means for that purpose.

Of this kind of progressive motion is that of all those animals that breathe air and move upon the surface of the water without penetrating into its depths, as the turtle. The frog, in its form, bears a very near approach to quadrupeds, but its hind legs are drawn out to an unusual length, compared to the size of the body, bringing it nearer to the swimmers; and the seal becomes a still closer link, for the body of the animal tapers off towards the lower extremities, which are placed so much behind, and are so close together, that they resemble a bifid tail; they not only act as oars, like those of the frog, but when closed together and depressed, or raised, can propel the animal forwards by that means.

In this way, there is an imperceptible gradation in the modes by which animals make their way through water, between rowing and swimming. But as in all the instances that have been adduced to illustrate rowing the motion is performed by regularly-formed hind extremities, and as the bones in the seal exactly resemble many of the others, it may not improperly be ranked with the rowers; although from the position of its hind legs, it is a near approach to the whale in some of its motions through the water. The beaver is a still nearer approach to the whale, in having a tail so formed as to enable it to raise and depress itself, although with a power infinitely short of what belongs to any of that tribe; it shews, however, the imperceptible shades by which the different inhabitants of the waters are made to form one connected chain of beings, each successive link being hardly distinguishable from that which is next to it.

Swimming.

This is a mode of progressive motion which enables the animals to approach the surface of the water, but necessarily keeps the greater part of the body below it, and gives a power of visiting the deepest recesses of the ocean.

It is differently performed by those animals that breathe air, and those that breathe through the medium of water; and as fishes, properly so called, are the best fitted to move in the waters, of which they are the natural and constant inhabitants, so we find them to be the most perfect in the art of swimming, towards which the others form so many different approaches, having the disadvantage of being obliged, at very short intervals, to reach the surface for the purpose of breathing.

All such animals have broader chests than belong to real fishes, and are more buoyant from the quantity of oil they contain, to insure their readily arriving at the surface when their natural powers are weakened.

In many of the more enormous whales the oil is placed in the head for the same purpose, as in all the spermaceti tribe. Their mode of moving through the water appears to be intended to allow of their more readily breathing atmospherical air, since the motion is alternately up and down, so as readily to bring the head to the surface.

The tail, which is horizontal, is the only part by which the animal is propelled: the flexibility of the lower part of the body, and the strength of its muscles, enables the animal to press the tail with very considerable force against the water, so as to impel itself with great velocity. The principal use of the pectoral fins in this tribe is to steady the body while in motion, and to assist in raising and depressing the head.

The tail is also its great weapon of defence with which it strikes its antagonists; in doing which it depresses the head, and raises the tail to a considerable height above the surface of the water, and then makes a stroke which is attended with a tremendous noise, and dashes the spray of the sea into the air in every direction, as I understand from those who have witnessed it.

The swimming of fishes, that breathe through the medium of water, differs from that of the whale tribe, in its being effected by lateral, instead of perpendicular strokes, and is more a continued motion; while the other is a succession of bounds. The structure, by which the spine of fishes is capable of keeping up this constant lateral motion of its body, has been already explained. The fins, however much they appear to do so, have no material effect in propelling the fish through the water; they only balance it; and when altogether deprived of their assistance, the centre of gravity being above the centre of motion, the fish turns upon its back. It is found, that when all the other fins are removed but the bifurcated one on the belly, the fish can still swim: this is therefore the most essential for that purpose.

A fish in swimming, after having bent the tail, extends the dorsal, anal, and caudal fins, so as to increase the surface, and steady its body in the water. Having extended the tail, it contracts the fins until the tail is again bent. The stroke of a fish's tail does not propel the fish straight forwards, but obliquely: to move forward, it must bend the tail first a little to the right side, and, after making this stroke, bend it to the left, so as to be propelled a little to that side; and thus the fish's motion is in a zigzag direction.

As fishes breathe through the medium of water, and are specifically heavier than the medium in which they live, they require some assistance to keep them from sinking to the bottom, while swimming: this purpose is answered by air-bladders, which the fish can at pleasure supply with air, so as to vary its specific gravity, as occasion requires. There are fishes, however, which have no air bladders, and therefore cannot rise far from the bottom of the waters in which they live; they are broad and flat in their form; their mode of swimming is different from that of common fishes; it consists in raising themselves by the motion of their lateral fins, and pressing perpendicularly against the water. This, however, would appear a kind of motion, which can neither be rapid nor long continued, and it is only occasionally employed; such fishes are consequently found to remain on sand-banks and in other situations which are adapted to them, not changing their place like fishes which, from their form, are better fitted to swim.

In what has been stated, I have only attempted to give a general outline of the different parts furnished by nature to enable the inhabitants of the water to move in that medium, as well as those birds and quadrupeds which are destined to seek their prey in the ocean, or in fresh-water rivers. To go more particularly into the subject, would be deviating from the plan which I have laid down; there are, however, many considerations which force themselves upon the mind; none more so than the range which is taken by the cetaceous tribe and the larger fishes, and the velocity with which they go from one part of the globe to another. The greatest rapidity which can be given to a boat by oars does not exceed eight or nine miles in an hour; a ship cannot with safety go faster than 14 miles; but while moving at that rate, the porpoises will pass it with as much ease as if it was at anchor; and there can be little doubt that a whale is capable of swimming at the rate of 20 miles in an hour. As this animal is obliged to come to the surface of the water to breathe air, we have opportunities of forming a tolerably correct estimate of its rate of moving through the water. With respect to the larger fishes, as the squalus maximus, this is not the case; but from what we know of their form, there is no reason to believe that they are less rapid in their course when disposed to exert themselves. With what a magnificent idea does it fill the mind, that one of these enormous animals, were it not obliged to rest, would have the means of going from the Pole to the Equator by its own physical powers in thirty days, and of making the circuit of our globe in the same number of weeks. It is highly probable that the whale tribe cannot long continue so rapid a motion, and it is evident, from the structure of its spine, that the shark has a material advantage over them in this respect, and will not be liable to experience the effects of fatigue in a similar degree from the same apparent quantity of bodily exertion.

Flying.

This is a mode of progressive motion through a medium so much rarer than water, that much contrivance is necessary to enable animals to support themselves in it. There are two means combined for this purpose: one is, admitting the external air to pass into the different parts of the body, so as to diminish the specific gravity; and the other is, supplying the animal with wings and a tail to increase the surface, and by the actions they perform, produce progressive motion.

It has been already shewn that the bones of birds that fly, have their cavities filled with air from the lungs; there are also large cells in the cavity of the abdomen, which the bird has the power of distending with air, by communications with the lungs, resembling those of the bones.

The quills of the feathers which, while growing, are filled with a vascular pulp, as soon as they arrive at their full size are rendered light by this pulp being removed, and the atmospherical air being introduced into their cavity through a small orifice where the quill terminates and the feather begins.

In swimming, the lower extremities of whatever form, are the principal parts employed; but in flying, the upper extremities are the parts used; and those which correspond to the lower extremities in other animals, take no part in this mode of progressive motion, but are destined for one of another kind, and the tail is added to direct their movements.

Many of the inhabitants of the sea, and rivers, are entirely confined to that medium, and therefore have only one kind of progressive motion, which is swimming. Those animals which, although they reside in the ocean, require being occasionally on land, make use of the same parts to move in the water and upon the surface of the earth, which being adapted for two such distinct purposes, are consequently not perfectly fitted for either; and such animals neither swim so well as fishes, nor walk so well as quadrupeds: the air, however, is too rare a medium for any animal to be supported always in it, since a constant exertion is necessary for that purpose. All animals that fly, require the means of resting upon some solid substance, and most of them have also a power of moving upon the surface of the earth.

The act of flying is performed in the following manner: the bird first launches itself into the air, either by dropping from a height, or leaping from the ground: it raises up at the same time the wings, the bones of which correspond very closely to those of the human arm; but instead of the hand, there is properly only one finger; it then spreads out the wings to their full extent, in a horizontal direction, and presses them down upon the air; and by a succession of these strokes, the bird rises up in the air with a velocity proportioned to the quickness with which they succeed each other. If the intervals between them are lengthened, the bird remains on the same level, and when made still greater, it descends. This vertical movement can only be performed by birds whose wings are horizontal, as is probably the case with the lark and quail.

In general the wings are placed oblique: this is principally owing to the length of their feathers, the fixed point of which is at the root. When birds fly horizontally, their motion is not in a straight line, but obliquely upwards, and they allow the body to come down to a lower level before a second stroke is made by the wings, so that they move in a succession of curves. To ascend obliquely, the wings must repeat their strokes upon the air in quick succession; and in descending obliquely, these actions are proportionally slower.

In birds of prey the form of the wings is very oblique, so that they cannot rise in the air perpendicularly unless they fly against the wind; they have, however, a greater power of horizontal motion than other birds, because the extreme parts of the wings are long, and the ends of the feathers lap over each other, which opposes an uniform resistance to the air; while in other birds the air passes through between the feathers, which lessens the power of keeping the wing oblique. To enable themselves to turn to the right or left, they move one wing more rapidly than the other. This is attended with difficulty when the flight is rapid, they therefore make a large sweep before they can turn round.

The tail in its expanded state supports the hind part of the body; when it is depressed while the bird is flying with great velocity, it retards the motion; and by raising the hinder part of the body, it depresses the head. When the tail is turned up it produces a contrary effect, and raises the head. Some birds employ the tail to direct their course, by turning it to one side or the other in the same manner as a helm is used in steering a ship. The flight of some birds is prodigiously swift, and may be rated at considerably more than a mile in a minute, since a horse has possessed that speed; it however appears less extraordinary, that so light a form should have such a velocity in so rare a medium as the air, as that the enormous bulk of the whale should move through the water with one-fourth part of it.

Flying is not confined to those inhabitants of the air which have wings composed of feathers ; there are many of them whose bodies are so light as not to require wings made of such strong materials, and which have them composed of thin membranes of the slightest texture. This is the case in all the flying insects ; such wings may be in some measure considered as additional parts superadded to the insect, there being nothing corresponding to them in those insects which do not fly.

Birds and flying insects include all the animals that have regularly-formed wings, and whose usual mode of progressive motion is flying, which they perform in the most perfect manner.

There are, however, some particular species of the fish, and the lizard, which although they are not endowed with regularly-formed wings, yet have a substitute for them, by means of which they support themselves in the air, and fly, for short distances, tolerably well. What is still more extraordinary, there is an animal, the bat, belonging to the class mammalia, which in its internal structure bears a resemblance to the quadruped, that is supplied with a kind of wing peculiar to itself, which may be considered as an intermediate link in the gradation between the wings of birds, and those of the different animals above-mentioned.

The bat's wings are formed of membranes spread upon the bones which correspond to those of the arm, fore-arm, and hand in man; and of the fore-leg in the quadruped. So far they resemble those of birds; they differ, however, in the materials of which the wings are composed; and in the bones bearing a closer resemblance to those of the human hand. They have, what is peculiar to themselves, a hook-like process attached to the bone of the wing by which they lay hold, and support themselves upon the cornices of buildings, and so far employ their wings as hands. These wings, when extended, are of great length.

In the larger species, each wing is not less than two feet in length; and in the smaller ones the proportions to the size of the bat do not appear to be materially different.

As the bat itself is not rendered buoyant by any of the means employed in the internal structure of birds, and its wings are membranes of some strength, great extent of surface is required; they are not, however, fitted for long flights, and must be considered as a very remarkable deviation from the bird on the one part, and from the quadruped on the other. The only quadruped which is regularly formed that has the power of flying, is a species of squirrel.

The substitute for wings in the flying squirrel is of the most simple kind; it is nothing more than a broad fold of the common integuments of the animal, spread out on each side of the body, and attached to the fore and hind legs, reaching as far as the feet; so that the animal by stretching out its feet, spreads this fold and keeps it in that extended state; in which it may be better compared to a parachute than to a wing. It is an apparatus for flying very inferior to that of the bat.

The flying lizard has its substitute for wings quite unconnected with the anterior extremities of the animal, for on each side of the body there is a double membrane expanded, and kept in that state by bony ribs, like those belonging to the chest, connected in the same manner with the spine, differing only in their direction, being turned backwards and included in this membrane, while the others are bent forwards and go to the sternum, so that for this purpose there are no new structures superadded, but only a greater number of ribs than would otherwise have been required.

From this structure of wing the animal can only move in one direction, so that the act of flying is but an imperfect operation.

The flying fish has no new parts superadded to enable it to fly; the contrivance employed for that purpose is nothing more than lengthening the pectoral fins to a sufficient extent to support the animal's weight; in this respect corresponding with the wings of birds, since the pectoral fin is analogous to the anterior extremity in the quadruped and bird.

There is a common notion, that these fins only answer the purpose of wings while they are wet, and that as soon as they become dry the fish drops into the water, so that the extent of its flight, under the immediate influence of a tropical sun, is thus explained to be very short; there is, however, a more satisfactory reason for their not remaining long out of their natural element; for as they cannot breathe in the air, so soon as their gills become dry, they must require fresh moisture to carry on the functions of life; the gills, however, will retain their moisture much longer than the thin membrane composing the fin, which must be almost instantaneously dried. This occasional mode of progressive motion is, I believe, principally employed to enable them to escape from the fishes that are in pursuit of them.

There is nothing that looks more like the sport of nature than the flying-fish and flying-squirrel being endowed with the power of supporting themselves in the air, even for a short time; it is the more extraordinary, as there are other fishes whose habits of life are nearly the same; and other squirrels that live on the same food as those which fly: so that there is no general principle requiring such a power being given to them; it looks like an indulgence granted to them to show the power of their Maker, and the readiness with which animals can be removed from their natural situation and adapted to others.

Creeping.

The most simple mode of loco-motion upon the surface of the earth is in those animals which move upon their belly, or the under surface of their body fitted for that purpose. In some animals of this kind there are no bones, and the muscles are attached to ligaments, on which they act.

That animals should be able to move by their muscles alone, and even have the power of passing through bodies of considerable solidity, as the common earth, appears at first extraordinary; but is well illustrated by the actions of the human tongue, which is wholly muscular, and produces its own motions, and can stiffen itself so as to press against any body with considerable force. The progressive motion of the earth-worm is of this kind.

An earth-worm begins its progressive motion by protruding the head, or elongating it, while the rest of the body is fixed upon the earth; the head is then made the fixed point, and the part next it, which had been elongated, is now contracted; to do which, an equal portion beyond must be elongated and then contracted, and so on in succession till the whole is brought forwards to the head, after this the head sets out anew. A worm can reverse this motion.

This is also the kind of progressive motion used by many caterpillars, and the motion of the snail is similar to it; but as the muscles of that animal employed for this purpose are short, and only belong to the under surface, an undulation is produced like a succession of waves, which makes the motion of the body of the animal so regular and uniform, that it appears as if it were carried along without any action in itself. This motion can only be seen when the snail is moving on a transparent substance, as glass.

There are other caterpillars in which the progressive motion is a little different; they stretch out the head, and then bring forward the tail under the body: in this action the body is raised from the ground and bent almost double; as soon as the tail arrives at the head, it is made the fixed point from which the head moves forward.

Many worms and caterpillars have holders, which they fix in the ground so as to push themselves off from it, and therefore are not improperly named feet.

In the different species of nereis, a sea-worm, round the edge of that surface adapted for progressive motion, there are one hundred pair of little tufts of strong bristles; between these are tentacula, to prevent the animal from running against any thing by which it might be injured; upon the under surface of the body are transverse ligamentous lines to which the muscles are attached; these tufts move forward in pairs in regular progression, answering the same purpose as the holders in the caterpillar, but also keeping the belly from the ground, and as they are employed in moving under water, very little support is necessary for that purpose.

The centipede (scolopendra morsitans) has more regularly formed feet, of which there are twenty-one pair.

In creeping, which is the most simple kind of progressive motion that an animal can perform by its own exertions, the body is first elongated, and in that state the head is made the fixed point, after which the body is contracted so as to be brought forward to the head. This mode of progressive motion is rendered more complex by a variety of modes being employed to make the motion more easy, so as to adapt the parts to rough surfaces, and to increase the power as well as the velocity.

In the caterpillar there are not only short levers to push it on, but the ends of many of them are so formed as to attach themselves to the surface over which the animal moves, to prevent its slipping.

Before I close this subject, I will explain a mode of progressive motion which has not before been taken notice of; it is peculiar to the snake, and must be considered as a species of creeping, although the parts by which it is performed are the ribs, which in these animals are made subservient both to the purposes of breathing and loco-motion.

An observation of Sir Joseph Banks, during the exhibition of a coluber of unusual size first led to this discovery. While it was moving briskly along the carpet, he said he thought he saw the ribs come forward in succession, like the feet of a caterpillar. This remark led me to examine the animal's motion with more accuracy, and on putting the hand under its belly, while the snake was in the act of passing over the palm, the ends of the ribs were distinctly felt pressing upon the surface in regular succession, so as to leave no doubt of the ribs forming so many pairs of levers, by which the animal moves its body from place to place.

The mechanism by which the ribs are enabled to answer this purpose, and which is not met with in the ribs of other animals, establishes the fact.

The ribs are not articulated in snakes between the vertebræ, but each vertebra has a rib attached to it by two slightly concave surfaces, that move upon a convex protuberance on the side of the vertebra, by which means the extent of motion is unusually great, and the lower end of each vertebra having a globular form fitted to a concavity in the upper end of the vertebra below it, they move readily on one another in all directions.

The following is the description of the muscles which act on the ribs for the purposes of progressive motion.

The muscles, which bring the ribs forward, consist of five sets, one from the transverse process of each vertebra to the rib immediately behind it, which rib is attached to the next vertebra. The next set goes from the rib a little way from the spine just beyond where the former terminates, it passes over two ribs, sending a slip to each, and is inserted into the third: there is a slip also connecting it with the next muscle in succession. Under this is the third set, which arises from the posterior side of each rib, passes over two ribs, sending a lateral slip to the next muscle, and is inserted into the third rib behind it.

The fourth set passes from one rib over the next, and is inserted into the second rib.

The fifth set goes from rib to rib.

On the inside of the chest there is a strong set of muscles attached to the anterior surface of each vertebra, and passing obliquely forwards over four ribs to be inserted into the fifth, nearly at the middle part between the two extremities.

From this part of each rib a strong flat muscle comes forward on each side before the viscera, forming the abdominal muscles, and uniting in a beautiful middle tendon, so that the lower half of each rib, which is beyond the origin of this muscle, and which is only laterally connected to it by loose cellular membrane, is external to the belly of the animal, and is used for the purpose of progressive motion; while that half of each rib next the spine, as far as the lungs extend, is employed in respiration.

At the termination of each rib is a small cartilage in shape corresponding to the rib, only tapering to the point. Those of the opposite ribs have no connection, and when the ribs are drawn outwards by the muscles, they are separated to some distance, and rest through their whole length on the inner surface of the abdominal scuta, to which they are connected by a set of short muscles: they have also a connection with the cartilages of the neighbouring ribs by a set of short straight muscles.

These observations apply to snakes in general: but the muscles have been particularly examined in a boa constrictor, three feet nine inches long, preserved in the Hunterian

Museum. In all snakes, the ribs are continued to the anus, but the lungs seldom occupy more than one-half of the extent of the cavity covered by the ribs. Consequently these lower ribs can only be employed for the purpose of progressive motion, and therefore correspond in that respect with the ribs in the draco volans superadded to form the wings.

The parts of which a description has been attempted, will be better understood by an inspection of Tab. VIII. and IX. than by any explanation that words can convey.

In Tab. X. the joints between the vertebræ and ribs are represented of the natural size from the skeleton of a large boa, sent from the East Indies by the late Sir William Jones, and deposited in the Hunterian Museum. On the under surface of the vertebra is a protuberance for the attachment of muscles peculiar to this genus; it varies in size in the different species, and explains the power attributed to the boa constrictor.

When the snake begins to put itself in motion, the ribs of the opposite sides are drawn apart from each other, and the small cartilages at the ends of them are bent upon the upper surfaces of the abdominal scuta, on which the ends of the ribs rest; and as the ribs move in pairs, the scutum under each pair is carried along with it. This scutum, by its posterior edge, lays hold of the ground, and becomes a fixed point from whence to set out anew. This motion is beautifully seen when a snake is climbing over an angle to get upon a flat surface.

When the animal is moving, it alters its shape from a circular or oval form, to something approaching to a triangle, of which the surface on the ground forms the base.

The coluber and boa having large abdominal scuta, which may be considered as hoofs or shoes, are the best fitted for this kind of progressive motion; there is, however, a similar structure of ribs and muscles in the anguis and amphisbæna.

In the anguis the ribs are proportionally weaker, and as these have nothing that corresponds with the scuta, it is probable that this mode of progressive motion is less necessary to them.

The rings of the amphisbæna are a near approach to the large scuta.

Having thus given a general account of the progressive motion of those animals that inhabit the sea, ascend into the air, and creep upon the surface of the earth, I shall conclude the present Lecture.

LECTURE VIII.

Progressive Motion on Two Legs.

Birds and man are, properly speaking, the only animals that move entirely upon two legs: there are others, as monkeys, the jerboa, and kangaroo, which occasionally do so, but in many of their movements all the four are employed; and in some of them the tail is also used as an additional one.

All animals that fly require to have feet, even although they are not intended to walk, since they cannot be always on the wing; and when they are not, must have some substance to rest upon with security, were it only during sleep.

The bat has feet for this purpose; but they are disadvantageously placed, and throw the centre of gravity between the wings; so that the animal cannot walk upright. The feet are only fitted to rest upon, and with the assistance of the wings enable the animal to hop along the ground.

The speckled diver has its feet so formed as to be unable to walk, as has been shewn.

Those birds, as the martin, that have long wings and short legs, cannot rise upon the wing from an horizontal plane; they are therefore intended by nature to make little use of their legs in progressive motion.

All birds that catch their prey with their talons, have them made sharp for that purpose, and were they to be used in walking they would be rendered blunt, and unfit for tearing the prey; and we find that the eagle does not walk; but when moving along the ground, partly supports the body by the motion of the wings.

Many birds that fly, can also walk very well; others again are entirely formed for walking, as the ostrich and cassowary; their wings being so very short as to be incapable of supporting the bird in the air. They however assist in balancing the body in walking or running.

All birds walk on their toes, the bones commonly considered to belong to the leg corresponding with the tarsus of the human foot.

As birds have their centre of gravity not directly over their legs, but more forward, it requires several peculiarities in their form to enable them to balance themselves on their toes; one of these is the great flexion of the leg upon the thigh, which brings the toes more under the centre of gravity; another is the length of the toes, which have four internodes instead of three, as in man and in quadrupeds.

As the standing posture to a bird is the state of greatest rest, corresponding to the horizontal posture in quadrupeds, there are particular provisions made by nature that it may be maintained with little or no exertion. Of this kind is the following contrivance, first explained by Borelli: the tendons of the flexors of the claws pass over the joint of the heel, and there are joined by a muscle whose origin is at the pubis, and which passes over the joint of the knee. When the bird is perched on a branch, the weight of the body bends those joints, and this puts the tendons on the stretch; so that the claws are drawn in, and lay hold of the branch without any muscular action being employed.

In the stork there is a process from the metatarsal bone, which passes up on the anterior part of the tibia and prevents the flexion of the leg. It would totally obstruct the motion of the joint, if there were not a socket in the upper part of the pully of the tibia to receive it, when the leg is in a bent position. The lower edge of the socket being prominent, presents an obstruction to the admission of the process that requires a voluntary exertion of the bird to overcome.

Birds, from the length of their toes, are enabled to stand steadily on one leg, which many are in the habit of doing. Those birds that rest on the banks of rivers stand on one leg, and hold a stone or other heavy body in the claws of the other to give them weight. Some birds while they stand on one leg, use the other as a hand; in these the head is generally too heavy to be readily brought to the ground, as the parroquets.

The flexibility of the bird's neck allows it to be brought back upon the body, and the head placed under the wing, so as to bring the centre of gravity more over the feet, and therefore enable the bird to stand more steadily.

The penguin and other birds, whose legs are very much behind the centre of gravity, are obliged to hold themselves very erect when they walk.

Some birds move the two legs at once, so that their motion is more a hop or bound: this is, I believe, confined to birds with short legs. The crow and raven are the largest that use this motion. In them, putting one leg before the other, would make their walk very slow.

In birds the body is light, requiring less support; and the wings give them a buoyancy, and balance them while moving with velocity: from these causes, the bird's foot admits of being more simple than either the quadrupeds or the human; it consists of only one bone, to which the bones of the toes are connected; nor has this any projection at its upper end posteriorly, to give the muscles an advantage in throwing the body forward, not even in the ostrich or cassowary. There is such a projection in the common cock laterally; but that is probably for the purposes of fighting.

The human is probably the only animal without wings that moves upon two legs; for although some apes can walk erect, there is reason to believe that they never adopt that mode when pursued, or making use of all their powers. The tendon of the flexor muscles of the toes passing over the os calcis in the monkey, is a proof that walking on the sole is not the most easy to them; walking on two legs therefore is in them only occasional.

Man also differs from other animals, in standing and walking upon the heel and toes; this became necessary to enable him to steady himself on the ground, which his form requires, and which is not necessary in other animals; nor are any of them, except the ape, capable of walking with the os calcis on the ground. A dog can stand on his hind feet, and so can the kanguroo, and indeed the kanguroo does so naturally, and can move along in that posture; but then it is by putting its fore-feet to the ground and drawing his hind ones forwards.

This circumstance of man standing and walking on the whole extent of his feet in some measure makes up for his having only two. He does not stand on the whole surface, but upon a tripod which supports a bony arch, all the parts of which move on one another. The first act of his progressive motion is raising the heel, which throws the body forwards on the toes, and before the toes are moved from the ground, the other foot is brought before them, so as to support the body. This gives a spring to the motion, and takes off the jarr which the body would otherwise receive.

The joints have no firmness in themselves, as has been already explained; if, therefore, a man faints, or is killed while in the erect posture, those of the extremities bend, and he falls to the ground. To support the body the extensor muscles are called into action, and by means of their exertions, he sustains himself in the standing posture; and therefore the buttocks, the muscles on the fore-part of the thigh, and those of the calf of the leg, are stronger and larger in proportion than in other animals.

The unusual breadth of the human pelvis throws the bones of the thigh further off from each other, and therefore the feet to so great a distance, as to give the body more steadiness in the standing posture: the thigh-bone is also nearly in a line with the trunk, which makes the erect posture more easy, the support being directly under the centre of gravity.

In going down stairs, or down hill, the leg in front is always lower than the hind-leg, and the body has a constant tendency to fall forwards. In order to prevent this from happening, the glutæi muscles are called into action to counteract the effect of gravity; hence arises the uneasiness which is felt in these muscles on such occasions.

When a man walks up-stairs or up-hill, he has to raise his body against its own weight by means of the extensors of the leg, which are in front, and those of the foot, which are behind; hence he feels uneasiness in the knees and calves of the legs.

When a man walks with long strides, the feet being at a great distance from each other, the body is lower than natural; the same muscles are called into action in order to raise it, as in walking up-stairs; and the same uneasiness is felt.

When a man walks upon a narrow space he balances himself with his arms, in the same manner as a rope-dancer balances himself with a pole.

In the act of running the heel is not at every step brought to the ground, but it is occasionally; in moving with great velocity the body is supported entirely on the toes, and the arms move to steady and assist its motions, as the wings of the cassowary and ostrich.

Those animals that have four legs have the bones of the feet differently constructed from man, the toes only come to the ground, and the os calcis is considerably raised; as there are four points of support, it is not necessary the feet should be so broad, nor would their being so admit of the animal moving with so much velocity. There is still a great general resemblance kept up in the bones of the feet of different animals, beyond what could be expected from the external appearance.

In the human foot and that of a lion there are nearly all the same bones, only the lion has four toes on the hind foot instead of five; and the fore-foot of the lion has the same bones and the same number of claws as the human fingers. The hippopotamus, whose foot externally is so different from that of either the lion or man, has nearly the same bones; it has only one toe less than man; but on the hind-foot the same number as the lion. In this animal the hind and fore-feet are nearly alike, and have the same number of toes.

Progressive motion on two legs is readily followed by the eye. It consists in an alternate motion of the legs in one direction; one leg is thrown before the centre of gravity, while the other supports the body; then raising the heel of the leg that was stationary, brings it upon the toe, and this throws the body upon the leg before it, but rather more forward; so that the body would fall, if the leg behind were not soon brought forward. When the motion is slow and uniform, it is called walking.

When, before the first foot is set down, the other is raised with a spring or jerk, the first foot is thrown further forward than it would otherwise be; and this is running; in which the heel is not put to the ground as in walking, but either the whole sole of the foot or only the toes. This is a much more uneasy motion than walking, from the jerk that is given, and from the body coming to the ground with its whole weight.

The progressive motion with four legs is more complex, and is performed in several different ways. Of these the most common are the walk, trot, and gallop.

Walking.

In this mode of progressive motion, only one leg may be said to move at a time. If a horse begins to move from a standing posture by raising his near fore-leg, just before that is set down he raises his off hind-leg; before that comes to the ground he raises the off fore-leg, and does not set that down till the near hind-leg is raised. Although this may be said to be the motion of four legs in succession, yet it is so quick, that there are two legs for an instant of time, off the ground; and by the fore feet being raised before the others are set down, the hind ones come more forward than they could otherwise do, and the step is lengthened. A continued walk consists of a repetition of these movements.

Trotting.

In the trot there are always two legs moving exactly together; that is, the fore and hind-leg of the opposite sides; but before the two legs first in motion are set down, the others are raised; so that there is an instant of time in which all four are in the air. The legs are also raised with a spring or jerk, which throws the body more forwards than it could be brought by the simple motion of the feet. This jerk is produced by some of the joints of the leg being bent while the feet are on the ground, and then extended quickly before the feet are moved, which conveys to the whole body a degree of velocity that continues after the feet have been raised. This jerk is mostly in the hind-feet, where the toes project so much forwards under the body of the animal: when the hind feet have their joints brought into a straight line by a jerk, it raises the body higher than their own length would do.

The animal in this movement raises his whole weight with a jerk, and comes to the ground with considerable velocity, which renders it an uneasy motion.

The Pace (Amble.)

This is a motion which some horses have instead of a trot, and resembles it in the circumstance of two feet moving together;

but they are those of the same side, and the body of the animal is always supported; the four feet never being all off the ground at the same time; and although two feet move with a jerk, the effect is confined to the legs; the body being supported by the others, does not feel the jerk, and the feet come to the ground without the weight of the body, which prevents the jar, and makes it an easy motion.

This mode of progressive motion is only occasional to the horse, but is always used by the camel and the lion.

In walking, the camel and giraffe move the legs in succession, first a fore-leg, then a hind of the same side, and when going with greater speed, move them together.

Canter.

Cantering is an union of walking with trotting; one fore-leg and its opposite hind-leg move alternately, as in a walk, and the other two move together as in a trot. The near fore-leg moves first, then the off hind-leg, and the off fore-leg and the near hind-leg move together, which gives three sounds, viz. fore, hind, both; the last the greatest sound.

The transition from the trot to the canter is very easy, and is effected simply by altering the times of movement of one fore and one hind-leg of opposite sides; and it is generally the off fore-leg and the near hind-leg that take on the different movements when the horse changes from the one to the other.

The Gallop.

The gallop may be supposed only to be the canter with greater speed, but there is a difference; the motion of the two fore feet is not together, but in quick succession, and the motion of the hind feet nearly together, and the spring in them very great, when the animal is at full speed.

When the two fore feet come to the ground, one after the other, and the hind feet come together, there are three sounds. When the two fore feet come to the ground together, and the hind feet come to the ground one after the other, there are also three sounds. In the forced gallop the two fore feet fall together and the two hind feet fall together, and then there are two sounds.

From the walk to the trot and from the trot to the gallop, there is an increase in speed generally in arithmetical progression. A horse that can walk five miles in an hour, can trot ten, and gallop twenty; but as the fatigue is proportionally increased, the distance he can go will be diminished in the same proportion. This observation, although it applies to a race-horse, will not to a cart-horse; this last is unable to double his speed by the gallop, for which he is ill adapted.

The Bound.

The bound is where all the feet move off the ground at once, and come back to it in the same manner. This must necessarily be done with a jerk.

This motion is more commonly employed by the deer than other animals, particularly in sport, and when they have neither courage to attack, nor are sufficiently alarmed to run away. Sheep use this motion, and principally in play; but not so much as the deer.

The Leap.

Running, trotting, cantering, and galloping, when strictly considered, are only a succession of leaps; as the leap depends upon the relative situation of the centre of gravity to the limbs, man and birds can alone leap vertically; quadrupeds forward. Spiders can leap from side to side as well as forwards.

A small animal leaps to a greater distance in proportion than a larger one; the powers being nearly proportional to the bulk, they impart to the body the same degree of velocity and the resistance is diminished. This explains the great distance which some small insects, as fleas, appear to leap.

Snakes leap by coiling themselves up and extending the body all at once. Fishes by bending their bodies and suddenly straightening them: the salmon, when it makes a great leap, first bends itself into a circle.

Maggots also bend into a circle before they leap. Lobsters leap by bending their tails.

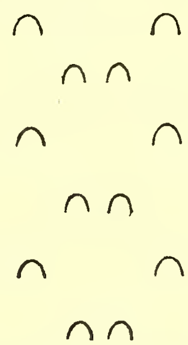
Oysters and scallops leap in a manner which has not been noticed, by suddenly closing the shell and forcing out the water; fishermen tell me they have seen them in this way leap to a considerable distance.

Progressive Motion of Animals with short fore Legs and long hind Ones.

The hare and rabbit move the two fore legs together, and the hind legs in the same manner. The fore legs appear to be little more than supporters, while these animals move their bodies horizontally, and the spring for their progressive motion is wholly in the hind legs.

The first motion is raising the fore legs and fore part of the body off from the ground, they then make a spring with their hind legs, which throws the body upwards and forwards so as to pitch on the fore feet, and as the body is still moving, it overhangs the fore feet, and the hind legs come forward before them, one on each side, and support the centre of gravity, which the fore feet do not. The hind feet then make another spring and the same thing again takes place.

The marks in snow shew this:



The kanguroo when walking slowly, moves in the same way; but in its speed it jumps on two legs, and is balanced by its tail. The leaps it takes are prodigious, the animal almost appearing to fly. When it stands it uses the tail as a third foot. The jerboa moves in the same way.

There are many sea and land insects that have a number of legs, which they move in pairs in quick succession. Of this kind is the land and sea crab. The progressive motion of the echinus upon its spines may be said to be peculiar to that tribe, The spines resemble a number of levers applied to the ground one after the other, each of which has a ball-and-socket joint connecting it to the body of the echinus.

In quadrupeds, it is to be observed that the hind legs are longer than the fore, especially in those that have considerable progressive motion: perhaps the camelopardalis is the only exception to this rule; were it made in this respect like a hare, and its powers were in the same proportion, the velocity of the motion would have been prodigious. The hind legs being much longer than the fore fits the animal for quick progressive motion. The hare is a very striking instance of it.

The best proof of it, however, is met with in comparing the varieties of the same species, the horse for instance; we always find that the swiftest have the hind legs too long to be in proportion as to beauty.

The grey-hound illustrates this proposition, for although his hind legs are not much longer than the fore, yet in the motion of the hind part, the centre of motion is in the loins: the pelvis is drawn under him along with the legs, and it springs back with them, which enlarges the stroke or circle of motion of the legs.

In animals with short legs, that have at times considerable progressive motion we find their loins very long, and when they run fast they raise their backs into an arch, increasing the sweep of the legs in both directions, as may be seen in the ferret, but more especially in the pole-cat, or martin. The squirrel is also an instance of this.

Animals that have slow progressive motion have their fore and hind legs of equal length: as terriers, badgers, otters, &c. and they have but very little spring in their back so as to increase the sweep of the hind legs; therefore they are formed by nature in every respect to have but slow progressive motion.

Climbing.

This is a kind of progressive motion which many quadrupeds are capable of performing; but some are more particularly fitted for it, and these have clavicles to give a greater space between the fore legs. The fore feet are formed like hands, and the thumb is large and prominent, something analogous to a great toe upon the foot. Of this kind are all the monkey tribe, the squirrels, and the lemurs.

Where there are talons they are directed backwards. In the bradypus, the elastic ligaments draw down the talons, and the muscles raise them. This arises from their being used to lay hold as their more constant employment,

To assist in climbing, the tail is made use of to prevent them from falling, or to lay hold and allow the animal to swing from one branch to another: as in the simia and lemur. Among reptiles, the cameleon has the same structure of tail.

Birds of the woodpecker kind support themselves against the tree by the tail, which is strong for that purpose.

The tree-frog has its feet totally different from other frogs, there being a flat surface on the toes for laying hold.

Burrowing.

This mode of progressive motion appears to be so opposite to climbing, that it was not to be expected that the same animal should in its natural habits be fitted for both; and yet we find in nature this to be the case.

Among the extraordinary animals from New South Wales, the wombat is met with, which is formed for burrowing, and another species of the same genus, the koala, which exactly resembles it in its internal structure, is a climber, and lives on the tops of the highest trees; but in the night descends to the ground, and burrows in search of roots. These animals are the most perfectly adapted for burrowing of any we know; since their hind legs are formed in a different manner from those of any other species of quadruped, having a close resemblance to the human fore-arm, and this structure evidently for the purpose of burrowing. As this is a new fact in comparative anatomy, I shall mention this structure more in detail.

There is no patella, but the tendon of the extensor muscles of the leg, where that bone is usually situated, is much thickened.

The fibula is proportionally larger than in most animals. At the upper extremity it is broad, and has two distinct articulating surfaces: the anterior of which is articulated to the tibia, and the posterior to a small bone of a pyramidal shape, which is connected to the tendon of the external head of the gastro-cnemius muscle, like a sesamoid bone. The lower extremity of the fibula is large, and forms about half of the articulating surface for receiving the tarsus at the ankle. An interarticular cartilage is here interposed between the tibia and the fibula, and another between the fibula and the tarsus.

The fibula has a slight degree of motion on the tibia on its upper end, and a half rotatory motion on it at its lower end. Between the two bones is a strong muscle which passes from one to the other throughout their whole length; the fibres have their origin from the inner edge of the fibula and pass obliquely inward and downward to be inserted into the opposite surface of the tibia. When this muscle contracts, it pulls the fibula forwards, and produces a degree of rotation on the tibia which turns the toes inwards. The anterior surface of the muscle is covered by a thin fascia, or interosseous ligament; and there is another fascia less complete on its posterior surface. The muscle of the leg corresponding to the biceps flexor of the human body is inserted into the posterior part of the fibula, and is an antagonist to the muscle just described. Its action brings the toes back to a straight line, but does not turn them outwards.

The use of this mechanism appears to be for throwing back the earth while the animal is burrowing. There is nothing at all similar to it in the hind legs of other burrowing animals, it may therefore be adapted to particular soils.

The mole, which is one of the most perfect burrowers in this country, has the soles of its feet smooth and flat, to throw back the earth; but there is no motion of this kind between the bones of the leg.

In so extensive a subject as this, it is necessary that I should confine myself to a general view of the different kinds of progressive motion; each of which, when all the animals that make use of it are considered, might form a separate Lecture.

There is another purpose for which the feet and legs are particularly fitted in many animals, this is offence and defence; but all such structures belong to the peculiarities of animals, and are to be considered weapons, and therefore are connected with another part of the Collection.

As animals have a variety of motions, for which they are so admirably fitted in their nature, it is evident that the structure of the feet must vary, and very different portions of their surface be applied to the ground; we find accordingly, that the horse treads entirely upon one toe, which lengthens the leg, and the smallness of the surface applied to the ground enables it to be more active; while the dog, the bear, and the monkey, can walk upon the whole sole: but in running, raise the heel and rest upon the toes.

The feet, however, are not only formed with a view to the progressive motion of animals, but to adapt them to the soil on which they are naturally intended to tread, or over which they are to climb; the camel for the desert has the sole soft and broad; the hippopotamus for the beds of rivers has it broad, but with toes to keep its hold: the goat for the craggy rocks, has its hoof hard to defend the toes; and the hoof double and pointed to keep it from slipping.

Out of these varieties of structures we have a regular series of the number of toes, varying from one to five.

The horse and ass have only one on both fore and hind feet. The deer, cow, camelopardalis, camel, ostrich, two: the hog, pecari, tapir, three on the hind feet, but four on the fore-feet. The cassowary also has three.

The hippopotamus has four toes both on the fore and hind feet. The kanguroo has five before and four behind. The lion and dog have the same. The bear has five, both on the fore and hind feet. Lizards have the same.

I have now completed my account of the preparations which compose the first part of the Collection, in which are included all that belongs to the moving powers of animals.

It is hardly possible, in considering a subject like this, to confine the descriptions to the facts which it is my province to detail. I am imperceptibly and involuntarily drawn aside from them by wonder and admiration; and tempted to make digressions upon the beauty, the fitness, and the perfection of the different parts. It is not, however, for me in this place to indulge in such speculations; I am only to lay before you the facts; the pleasing task of contemplating them will employ your leisure hours, and such contemplations will lead you to humble yourselves before the Creator, by whom all these, and yourselves, were made.

LECTURE IX.

On the Stomach.

THE second series of preparations contained in this Collection, consists of those organs into which the food is received, and by which the nutritious part of it is extracted and converted into a fluid called chyle, for the nourishment of the animal.

In all animals the principal organ of digestion is the stomach: it forms one of the most essential parts of their œconomy, and is wanting in vegetables; its presence therefore becomes a mark, which enables us to distinguish these two great divisions of animated nature from each other.

The consideration of the mode in which vegetables are supplied with nourishment is connected with another series of preparations in the Collection; for, as they have no digestive organ with which we are at present acquainted, there are no preparations belonging to plants in the series I am about to describe.

In explaining the structure of the stomach, I shall not venture to begin with that organ in animals of the lowest class, and from thence to proceed gradually to those of the highest, which had I a perfect knowledge of the subject I should feel it my duty to do; I shall prefer, in the present imperfect state of our knowledge respecting digestion, to begin with the stomachs of the highest class; and in those, with which I am better acquainted, explain the facts connected with their functions which I have been able to collect; and having done so, proceed to the stomachs of the lower classes in regular order.

The most simple structure of the stomach in the quadruped, is that formed for the digestion of animal substances swallowed before absolute death has taken place in them. Of this description is that of the lion, tyger, and lynx, and other ravenous animals that devour their prey.

The stomachs of animals have, in general, been considered by physiologists with a view to their external form; and even that form has been commonly distorted by distending them, for the purpose of obtaining it more easily. This is the mode that was adopted by the great man who formed this Collection: and there are many preparations in a dried state, in which the external shape of the stomach thus distended is satisfactorily shewn. Some are round, others oblong, others again have a more oval form; but unfortunately in acquiring this superficial information, all opportunity of knowing their real shape, while performing their functions, and of examining the internal membrane, is lost.

Having in the first instance made myself master of these facts, I have been led to prosecute the subject, and endeavour to advance our knowledge respecting the process of digestion. The mode of doing this which suggested itself, was to invert the stomachs of different animals, and in that state gently distend them immediately after apparent death had taken place, and before their muscular action is entirely destroyed. In this way I hoped to come at their real shape in the living body, as well as to see the appearance of the internal membrane, and learn the exact situation of the glands employed in the different processes carried on within the cavity.

I was led to this by a train of investigations which are recorded in the Philosophical Transactions, step by step as they were made ; but here I shall take advantage of the knowledge thus acquired, and give the whole a more regular form. I feel it at the same time necessary to give this introduction, that I might not appear to assume to myself having made an advancement in this branch of comparative anatomy from any superior talent of my own ; but by following the track in which I was instructed to walk; and by the same patient and laborious examinations, collecting facts on which observations might be made ; and when the number was sufficiently great, drawing such conclusions from the whole as the data appeared to warrant.

The truly carnivorous stomach, as well as the human, which in its structure is closely allied to it, I found capable of dividing its cavity into two distinct portions, by a transverse contraction of its coats ; in which state the cardiac portion is, in length, two-thirds of the whole, but in capacity much greater; and in several instances where the opportunity was afforded me of examining the parts immediately after death, I found the stomach in this form both in the human body and other animals.

This will be found to correspond with the permanent form of the stomach of many other animals.

This appearance is not frequently met with, the fibres of the stomach being readily relaxed very soon after death by the motion of the liquid commonly retained in its cavity, and the air which is let loose; so that such contraction is only to be expected, where opportunities occur of a very early inspection of the stomach after death.

Upon inverting the stomach of the lynx and examining its internal membrane, the surface was found covered with a gelatinous secretion, which adhered closely to the membrane over which it was spread. There were also immediately beyond the termination of the œsophagus, on the small arch of the stomach, a set of glands which are very distinct. They are seen in the human stomach, but are less obvious. As glands corresponding to them, only a great deal larger, are met with in the stomachs of birds, there is every reason to believe that they secrete the gastric juice.

Near the small extremity there are also orifices of glands very distinctly seen scattered over the surface, and a zone of them at the pylorus. These last are not seen in the human stomach.*

In prosecuting this investigation, I found many reasons to doubt that the liquids conveyed into the stomach all pass out at the pylorus; and on putting it to the test of experiment, by tying up the duodenum in a dog, and injecting liquids by the mouth into the stomach, I found that they were readily carried off without passing out at the pylorus. I found also, in the necessary examinations, that the dog's stomach, while digestion is going on, is divided by a muscular contraction into two portions; that next the cardia the largest, and usually containing a quantity of liquid, in which there was some solid food; but the other, which extended to the pylorus, being filled entirely with half-digested food of an uniform consistence. I shall, therefore, in my future description, call that part which constitutes the first cavity the cardiac portion, and that which constitutes the second, the pyloric portion.

* Vide Tab. XI. XII.

From these experiments the following facts are ascertained: that while the process of digestion is going on in the cavity of the stomach, it is divided by means of a muscular contraction of its coats into two portions; that the first receives the solids and fluids taken in by the mouth. The food is there mixed up with the secretion of the gastric glands and mucus, becomes coagulated, and by that means separated from the liquids contained in the cavity: these superfluous liquids are carried off without passing into the pyloric portion, which only receives the solid food, with the necessary proportion of liquid, and in that portion of the stomach the change into chyle takes place.

This enables us to explain, what otherwise appeared incomprehensible, how the process of digestion can go on in the stomachs of men, who immediately after having eaten a hearty meal, drink several quarts of different liquors: these liquids, however, we now find are carried off without being applied to that part of the food in the pyloric portion on which digestion is performed. The experiments from which these conclusions are drawn will be detailed at length in a future Lecture, when the other parts of the investigation to which they lead, have been rendered more complete: it may be sufficient upon the present occasion to state, that they were repeated several times, so as to leave no doubt of the correctness of the facts which have been mentioned.

This circumstance of the stomach being required to form itself into two cavities during the process of digestion, accounts for its being so much bent upon itself, as by that means an angle is formed at the part where the temporary contraction takes place. It also accounts for men occasionally ruminating, which, without such a contraction, they could not do. That some men ruminate, the accounts of authors are sufficiently explicit to put beyond all doubt; particularly the instances collected by Peyer from Fabricius ab Aquapendente and others, as well as from his cotemporaries, in all six or seven in number. Of these, two were examined after death. In one of them the œsophagus was unusually muscular, but nothing particular was met with in the stomach; in the other, nothing is said of the œsophagus, but the internal surface of the stomach was very rough.

The fact, however, does not rest on these authorities, since a case of this kind has come within my own observation.

The man to whom I allude was nineteen years of age when I saw him, blind, and an ideot from his birth. He is very ravenous, and they are obliged to restrict him in the quantity of his food, since if he eats too much it disorders his bowels. Fluid food does not remain on his stomach, but comes up again. He swallows his dinner, which consists of a pound and a half of meat and vegetables, in two minutes, and in about a quarter of an hour he begins to chew the cud. I was once present on this occasion. The morsel is brought up from the stomach with apparently a very slight effort, and the muscles of the throat are seen in action when it comes into the mouth; he chews it three or four times and swallows it; there is then a pause, and another morsel is brought up. This process is continued for half an hour, and he appears to be more quiet at that time than any other. Whether the regurgitation of the food is voluntary or involuntary cannot be ascertained, the man being too deficient in understanding to give any information on the subject.

This contraction of the stomach also explains the circumstance of its contents not being completely discharged by the first effect of an emetic, which only empties the cardiac portion; the contraction preventing the pyloric portion from being emptied till the violence of the straining ceases, at which time relaxation takes place.

It may also enable us to account for many symptoms that occur in the diseases of this organ, particularly the violent cramps to which it is liable; as from the situation of the pain they probably arise from preternatural contractions of these muscular fibres. On the other hand, the indigestion met with in debilitated stomachs, may proceed from this part having lost its proper degree of action, and therefore the food is mixed with too great a proportion of liquid to be acted on by the different secretions.

That the glands at the cardia secrete the gastric juice is, in some measure, proved by the curious fact of a portion of the stomach, where the person dies soon after having eaten a hearty meal, being frequently found in a dissolved state; and the part so acted upon is just at the great end immediately below the glands, the part to which this secretion is most readily applied.

The stomachs of animals wholly carnivorous bear a general resemblance to each other; and it is a circumstance deserving of remark, that the human stomach which readily digests many parts of vegetables, and that of the monkey and squirrel, which are wholly employed in acting upon vegetable substances, do not materially differ in their internal structure from those of the carnivorous animals. It would appear that the preparation the vegetables go through in the mode of cooking them, and in mastication, enables our stomach to act upon them; but there are vegetables which no cookery hitherto discovered can enable us to digest: of this kind are all the grasses.

The fruits on which the monkeys and squirrels feed are those which we are able to digest, without any culinary preparation, and therefore require no peculiar organization in their stomachs for that purpose.

To trace the stomach from this more simple state through all the complications which are met with in nature, is attended with so many difficulties, that it is hardly possible to take any course which is not liable to many objections; for as the structure of the stomach is fitted for the kind of food the animal is intended to live upon, without regard to other circumstances, every attempt to class the stomachs separately from the animals must break through all other arrangements; and if this is done, the whole will be thrown into confusion.

Where there is such a mass of materials, it is necessary to attend to perspicuity, and although there are stomachs belonging to birds and fishes, as well as to animals of the inferior orders that resemble those of the carnivorous quadruped, I dare not grasp at so enlarged a view of the subject, as to bring them all under one head, for fear of losing myself in attempting to describe so complex and extensive a series, of which my knowledge is not sufficiently correct to enable me to render it complete.

It will be safer first to trace the varieties in quadrupeds, up to the most complex of the ruminating tribe; and afterwards to take a similar course with respect to birds; then the same with reptiles and fishes; since in each of these divisions, however much the animals may differ among themselves, their mode of life and kind of food bear a general resemblance.

The human stomach has the glands at the cardia less distinct, the division between the cardiac and pyloric portions less decided, and the coats of the pyloric portion thinner in proportion to those of the cardia, than in the lynx; so that it would appear that the ravenous animals that live on flesh have the secretory organs of digestion more obvious than the human species.

As the great object of comparative anatomy is to make us better acquainted with the structure of the human body, so in this instance we find that there are several appearances in the human stomach only to be discovered by having seen them in those of other animals.

The next variety which I shall notice is in the beaver. The stomach of the beaver is divided by a muscular contraction into two portions: the cardiac, which is of an oval form, may be called the descending portion; the pyloric, which is much smaller and bent upwards, may be called the ascending portion: the contraction between them is sufficiently strong to bear the force necessary to distend the stomach without yielding to it. The cuticular lining of the œsophagus terminates at the orifice of the stomach. Just within that orifice, upon the upper or small curvature, is a large oval glandular structure, subdivided into three prominent ridges placed in the direction of the stomach and projecting into its cavity, one in the middle line, and one on each side of it. In the middle ridge there are nine large openings through the internal membrane capable of contracting so as to shut up the orifices, or of dilating so as to expose three inner orifices leading to the gland; each of these is continued into five or six processes, whose length is proportioned to the thickness of the glandular mass, extending nearly to its external surface. In each of the lateral ridges there are seven orifices. The internal membrane of the descending portion of the stomach into which these excretory ducts open, is uniformly smooth in every other part of it; but the lining of the smaller ascending portion has a villous appearance, subdivided by slight fissures: this, however, is only to be seen when minutely examined.

The part next the pylorus has a strong muscular covering of some thickness.*

The wombat, one of the opossum tribe from New South Wales, has the same peculiarities in its stomach as the beaver, which it in no other respect resembles; it lives in trees, and digs up roots.† This fact does away entirely the vulgar error of the beaver living on fishes, for which its stomach is not at all adapted, though positively asserted by some German writers, that they even declare they have opened their stomachs and taken the fishes out whole.

Of the same kind, with some shades of variation, is the stomach of the dormouse.‡

It is divided into two portions by a muscular contraction, which is very distinct when examined immediately after death. At the orifice of the stomach there is a peculiarity, shewn to me several years ago by Mr. Macartney, which I had never seen till that time.

This peculiarity is a glandular substance immediately with-

* Tab. XIII. † Tab. XIV. ‡ Tab. XIII.

in the termination of the œsophagus, the orifices of which open on the internal membrane. Mr. Macartney left me a drawing of the external appearance of the gland when the stomach was in a distended state. He said nothing about the structure of the gland, and as it was a subject which did not then engage my attention, I did not enquire into it. In the course of the present investigation it occurred to my recollection, and in comparing this gland, in the recent subject, with that of the beaver, I found it to correspond very minutely in its internal structure, and it becomes a fact of no small importance in forming a series of glandular structures belonging to the stomach. In making use of it, I have great pleasure in acknowledging the source from whence my first knowledge of it was derived.

This glandular structure viewed externally is like a mulberry, being made up of a number of small projections: the orifices admit of distension with air, and when expanded each orifice exposes three small openings; these again lead to several processes, as has been described and delineated in the glandular structure of the beaver.

The first portion of the stomach forms about two-thirds of the whole, while the second is only the remaining third; internally the membrane has no peculiar appearance, and is uniformly the same in both portions. The cuticular lining of the œsophagus terminates immediately above the glandular structure which has just been described, so that if the stomach is considered to begin there, it is in all respects very similar to that of the beaver.

In the stomachs which have been described, the gastric glands that are hardly perceptible in the human stomach, and of small size in the lynx, are of considerable magnitude, but are exactly in the same situation.

In the hare and rabbit the division between the cardiac and pyloric portions is more distinct than in any which have been described.

The stomach of the hare, when forcibly distended, appears to be one nearly uniform cavity; but when examined immediately after death, before the parts have been disturbed, is found to have a partial contraction, dividing it into two; the cardiac portion is two-thirds, and the pyloric portion is one-third of the whole cavity.

The muscular coat of the cardiac portion is weak, but at the division between it and the pyloric, the fibres become much stronger: they are regularly circular, and continue so half way to the pylorus; there they form a thick projecting band, and afterwards become spiral towards the pylorus. There are two layers of these spiral fibres in opposite directions crossing each other, which gives them great power in their contraction, and very considerably increases its effect.

The internal membrane of the cardiac portion forms one uniform surface. Where the pyloric portion begins, the membrane is thicker in its substance, and the surface more villous; further on, where it is surrounded by the projecting band, there are small distinct orifices, largest, and in greatest number on the lower curvature, but met with all round; these appear to be the excretory ducts of the glands which secrete the gastric juice. From this part to the pylorus, the surface is smoother, and has a more delicate texture.*

The rabbit's stomach corresponds in every respect with that

* Tab. XV.

of the hare, only that the parts are on a smaller scale, and less conspicuous. The orifices of the ducts above described, were not detected in the rabbit till they had been seen in the hare; but then were readily distinguished.*

These animals are allied to the ruminants in their mode of digestion, like them retain the food in the cardiac portion of the stomach, that it may undergo a change before it is submitted to the action of the gastric juice; and when so hard as to render it necessary, return it into the mouth to be masticated a second time.

The cardiac portion of the stomach is never completely emptied, and they occasionally ruminate. In proof of both these facts, a rabbit which had been seven days without food, died, and the cardiac portion of the stomach was found to contain more than half of its usual quantity of contents: they were rather softer than common, and a number amounting to fifty or sixty of distinctly formed pellets of the size of shot were collected together in the cardiac extremity immediately below the œsophagus. These could not have been formed at the time of eating, since in seven days the action of the stomach would have destroyed their shape. They must therefore have acquired it by the animal chewing the cud.

In the horse and ass there is not only an occasional division between the two portions of the stomach, but the first portion is lined with cuticle.

The stomach of the horse, as it is most commonly met with after death, appears to be an oval bag, the internal surface of which, next the great end, is covered with a cuticle continued from the œsophagus, and extending further towards the

* Tab. XV.

pylorus on the small curvature than on the great one. The œsophagus enters obliquely; which prevents regurgitation from readily taking place. At the great curvature immediately beyond the termination of the cuticle, which forms a prominent ridge, there is a glandular structure of some extent; this is insensibly lost in the more membranous portion, which extends to the pylorus, and appears to be a villous surface subdivided into small portions of unequal size, giving it a tesselated appearance.

When the horse's stomach is procured in an empty state, or nearly so, immediately after death, and is inverted and gradually distended, it is found to consist of two very distinct portions, there being a muscular contraction between the cuticular portion and the other.

The stomach of the ass resembles that of the horse in all respects, and being of a more delicate structure, its minuter parts are more easily distinguished. A number of orifices of glands immediately beyond the cuticular portion on the upper curvature are distinctly seen, which I was unable to distinguish in the horse; but there can be no doubt of their existence in that animal, although I was not so fortunate as to observe them.*

In the rat and water-rat the division between the cardiac and pyloric portions is more distinct than in the horse, and more permanent.

In the common rat, when examined recently after death, there is a contraction dividing the stomach into two parts; but when it is distended, this disappears, and the whole becomes one cavity; so that in this animal the division is only muscular.

* Tab. XVI.

The first cavity is about three-fourths of the whole. It is lined with a cuticle which terminates in a line like a thread, formed by a doubling of the cuticular edge, but not projecting or serrated. This line surrounds the stomach, but projects furthest on the lower part or great curvature, where it terminates in a point: there are also two lateral cuticular processes.

The stomach of the mouse is similar to that of the common rat in its general characters.

The stomach of the water-rat is made up of two cavities, with a narrow communication between them. The cavity into which the œsophagus opens is nearly two-thirds, and the other rather more than one-third of whole. The stomach terminates at the pylorus by a very contracted orifice.

The first cavity has a cuticular lining continued from the œsophagus over the whole of its internal surface, terminating in a prominent serrated edge at the contracted part, except that on each side an oval portion of cuticle extends into the second cavity; this is seen through the other coats of the stomach. There are no apparent orifices in this cuticular lining leading to glands. The œsophagus opens into it obliquely, so that regurgitation can hardly take place.

The second cavity is lined with a membrane, which at the lower part or great curvature is thicker than at any other; the surface is convoluted, and appears to secrete a thick viscid mucus; beyond this there is an irregular zone of orifices, which I consider to belong to the ducts of the gastric glands. From this part to the pylorus the membrane is more smooth, and made up of small villi.*

* Tab. XIII.

The horse and the ass, although animals in all other respects different, correspond so very closely in the structure of their stomachs with the rat and mouse, that their stomachs must be considered of the same kind.

In these the food is rendered easy of solution by remaining in the cuticular reservoirs, it is then acted on by the gastric liquor, and in the pyloric portion converted into chyle.

The stomachs which I have still to consider, are more complex in their structure, and in that respect more nearly allied to the ruminating stomach.

LECTURE X.

On the Stomach.

In the preceding Lecture, the internal appearance of the more simple stomachs has been described: those stomachs which I am about to notice, have appendages or smaller cavities not met with in the others, and form an intermediate link between them and the truly ruminating stomach; in which the cavities for preparing the food are found to be of an enormous size.

In ruminating animals there is also a striking peculiarity in the food being brought back into the mouth, and not afterwards returned into the same cavity, but conveyed into another, and thence into the cavity in which digestion is completed.

The next variety of stomach to that of the horse, is that of the common hog and pecari.

The Hog,

The general form of the stomach in the hog is nearly that of the beaver; it is divided by a muscular contraction into two portions. The cardiac cavity is large and oval, its direction obliquely downwards; the pyloric cavity is small and conical, its direction upwards. There is a process continued from the cardiac extremity, turned back upon the upper part of the stomach, which terminates in a blunted end.

The cuticular lining of the œsophagus extends along the small curvature of the stomach in both directions; in one it terminates at the base of the process above-mentioned; in the other it stops where the pyloric portion begins; and there the gastric glands are placed in a row on each side. This process is sometimes found contracted and quite empty; so that it does not appear to form a part of the receptacle for food.

The internal membrane of the cardiac portion of the stomach as far as the opening of the œsophagus is an uniform surface; but immediately beyond, on the lower side or great curvature, there is a thick glandular substance of an oval form, bounded laterally by two prominent ridges, one on each side, with a similar ridge in the middle line of the stomach; there are also three smaller ridges, passing transversely from the middle one to the lateral ones. A small part of this glandular structure is situated in the pyloric portion. The pyloric portion has a smooth villous appearance. Just within the pylorus there is a round glandular projection, apparently for the purpose of occasionally shutting up the orifice.*

The stomach of the pecari differs from that of the common hog, in there being two processes at the cardiac extremity, and these having a more lateral direction; so that the stomach appears to be composed of three bags; one general and two lateral cavities; that which projects anteriorly is nearly double the size of the other. The cuticular lining of the œsophagus extends further on the sides of the general cavity of the stomach than in the hog.

The stomach of the hippopotamus I have not examined; but according to Daubenton's account of it, there is a close

* Tab. XVII.

resemblance to that of the pecari; for he describes a large pouch on each side of the cardiac portion. Its internal appearance has not been examined with sufficient accuracy to enable me to explain its structure.

The Elephant.

The elephant has another kind of peculiarity in the internal structure of its stomach. The stomach is longer and narrower than that of most other animals; the whole length is three feet three inches, and its diameter in the middle line, which is the widest part, is one foot two inches. The cuticular lining of the œsophagus terminates at the orifice of the stomach. The internal membrane of the stomach differs in appearance in different parts. At the cardia, which is very narrow and pointed at its extremity, the lining is thick and glandular for eight inches in extent, and is thrown into transverse folds, of which five are broad and nine narrow; that nearest the orifice of the œsophagus is the broadest, and appears to act occasionally as a valve; so that the part beyond may be considered as an appendage similar to the processes in the hog and pecari; the membrane of the cardiac portion is uniformly smooth; that of the pyloric is thicker and more vascular.*

The Kanguroo.

The kanguroo in its peculiarities follows the elephant. The stomach of the kanguroo differs in many particulars from that of any other known animal, and bears a greater resemblance to the human cœcum and colon than to any stomach. The œsophagus enters the stomach very near its left extremity,

* Tab. XVIII.

which, unlike the corresponding part in other animals, is very small and bifid. From the entrance of the œsophagus the cavity extends towards the right side of the body, then passes upwards, makes a turn upon itself, crosses over to the left side before the œsophagus, and again crosses the abdomen towards the right, making a complete circle round the portion into which the œsophagus enters, and terminates by a contracted orifice at the pylorus.

Its cavity gradually enlarges from the left extremity through its whole course, till it approaches the pylorus; it then contracts, and dilates again into a rounded cavity with two lateral processes: beyond this is the pylorus, the orifice of which is extremely small. On the anterior and posterior side of the stomach there is a longitudinal band, similar to those of the human colon, beginning faintly at the left termination and extending as far as the enlargement near the pylorus: these bands being shorter than the coats of the stomach, the latter are consequently puckered, forming sacculi, as in the human colon.

When the cavity of the stomach is laid open, the cuticular lining of the œsophagus is found to be continued over the portion immediately below it, and extends to the termination of the smallest process at the left extremity, and nearly to the same distance in the opposite direction; the cuticular covering is very thin, and extremely smooth.

The lining of the larger process at the left extremity is thick and glandular, and in the living body probably receives no part of the food; but is to be considered as a glandular appendage.

On the right of the œsophagus the cuticle does not end by a transverse line, but terminates first upon the middle of the great curvature, where a villous surface begins by a point, and gradually encreases in breadth till it extends all round the cavity: its origin therefore is in the form of an acute angle. The villous surface is continued over the remaining cavity as far as the longitudinal bands extend: and that half of it next the pylorus has three rows of clusters of glands: one row is situated along the great curvature, and consists of fifteen in number; the other two rows are close to the two longitudinal bands, and consist only of nine. Besides these there are two large clusters of an oblong form, situated transversely, where the longitudinal bands terminate. The internal surface of the rounded cavity next the pylorus has a different structure, putting on a tesselated appearance, formed by a corrugated state of the membrane. Immediately beyond the pylorus is a ring of a glandular structure surrounding the inner surface of the duodenum.*

The stomach of the kanguroo in the peculiarities of its structure, forms an intermediate link between the stomachs of animals which occasionally ruminate; those which have a cuticular reservoir; and those with processes or pouches at their cardiac extremity, the internal membrane of which is more or less glandular. The kanguroo is found to ruminate when fed on hard food. This was observed by Sir Joseph Banks, who has several of these animals in his possession, and frequently amused himself in observing their habits. It is not, however, their constant practice, since those kept in Exeter Change have not been detected in that act. This occasional rumination connects the kanguroo with the ruminant. The stomach having a portion of its surface covered

* Tab. XIX.

by cuticle, renders it similar to those with cuticular reservoirs; and the small process from the cardia, gives it the third distinctive character; indeed it is so small, that it would appear as if it were placed there for no other purpose.

The kanguroo's stomach is occasionally divided into a greater number of portions than any other, since every part of it, like a portion of intestine, can be contracted separately; and when its length, and the thinness of its coats are considered, this action becomes necessary to propel the food from one extremity to the other.

Such a structure of stomach makes regurgitation of its contents into the mouth very easily performed. The food in this stomach goes through several preparatory processes; it is macerated in the cuticular portion; it has the secretion from the pouch at the cardia mixed with it; and is occasionally ruminated. Thus prepared, it is acted on by the secretion of the gastric glands, which probably are those met with in clusters in the course of the longitudinal bands, and afterwards converted by the secretions near the pylorus into chyle.

The Vampyre Bat

The vampyre bat bears so near a resemblance in its stomach to that of the kanguroo, that it must be considered of that kind, however much the two animals differ from one another: there is only the kanguroo-rat between them, which has a valvular structure at the orifice of the cardia, and its cardiac portion is longer, and the pyloric shorter than in the vampyre bat. I have not dissected the kanguroo-rat myself, but Cuvier has given a drawing of it.

The vampyre bat, from which the stomach now described was taken, was nine inches long; the extent of its wings thirty-six inches.

The œsophagus swells out before it enters the general cavity, and that dilatation, from its internal structure, appears to belong to the stomach, as there is no contraction or distinct orifice beyond it. To the left of the œsophagus there are two dilatations with a contraction between them; the furthest of these has a smooth surface, and the coats are very thin; in the other there are several deep longitudinal rugæ, some of which are continued into similar rugæ or bands in the dilated portion of the œsophagus. This portion of the stomach has more the appearance of an appendix than of belonging to the general canal. There are six rugæ or bands in the œsophageal portion, four of which are continued towards the pylorus, giving a direction to the food in that course. After the stomach has extended the same length on the left of the œsophagus as on the right, it is turned back upon itself, as far as the entrance of the œsophagus, then makes another turn, and ends in the pylorus by a very small valvular opening, which scarcely gives a passage to air when in a contracted state. No part of the stomach is lined with a cuticle, and a quarter of an inch from the pylorus there is an appearance of glandular structure; this is probably less conspicuous, in consequence of the animal having been kept long in spirits.*

This animal feeds on the flowers of the eugenia, the stamina of which were found filling up several portions of the stomach, the filiments and antheræ being in a perfect state.

The vernacular name of a pentandrian plant at Chili, with small petals, is chichinicuma, which means the food of bats.

* Tab. XX.

These facts prove that the vampyre bat lives on the sweetest of vegetables; and all the stories related with so much confidence, of its living on blood and coming in the night to destroy people while asleep, are entirely fabulous; their only foundation being, that other bats are carnivorous, and it was therefore presumed this species was so likewise, which, contrary to every thing which could be expected from analogy, is not the case.

As it is probably the most remarkable instance of two animals whose external form is so nearly the same, having stomachs so totally unlike, I shall describe here the stomach of the common bat, in other respects out of its place.

The long-eared Bat.

The common bat, from which the stomach now described was taken, was two inches and a quarter long, and the tail included in the web about two inches. The wings extended nine inches. The œsophagus is extremely small, and lined with a cuticle whch terminates at the orifice of the stomach. The general cavity is distinctly divided into a cardiac and a pyloric portion: close to the pylorus, and surrounding it, there is an appearance of small glands.*

In the spectre bat there is a swell in the œsophagus, as in the vampyre bat; so that in the different species of bats, the stomachs vary very much from one another.

The stomachs of ruminating animals may be divided into two kinds: the first or most simple is met with in the bullock, sheep, and deer; and all those that have horns. The other,

* Tab. XX.

which is more complex, is confined to the camel, dromedary, and lama, which are without horns.

The most satisfactory mode of explaining the difference between them, will be first to describe the stomach of the bullock, and then that of the camel; and afterwards to point out the peculiarities by which the camel is enabled to go a longer time without drink, and thereby is fitted to live in those sandy desarts, of which it is the natural inhabitant.

In my description I shall consider the animal to be suspended by the head, as that is the position in which the different cavities of the stomach can be most accurately examined without disturbing their contents.

When the first cavity of the bullock's stomach is laid open by a longitudinal incision on the left side of the œsophagus, and the solid contents are removed, which in general are very dry, the cavity appears to be made up of two large compartments, separated from each other by two transverse bands of considerable thickness; and the second cavity forms a pouch or lesser compartment on the anterior part of it, rather to the right of the œsophagus, so that the first and second cavities are both included in one, forming separate compartments lined with a cuticle.

The œsophagus appears to open into the first cavity; but on each side of its termination there is a muscular ridge projecting from the orifice of this cavity, so as to form a channel leading into the second. These muscular bands however do not terminate there, but are continued on to the orifice of the third cavity, in which they are lost.

When these parts are examined, it is evident that the food can readily pass from the œsophagus either into the first cavity, or into the second; which last is peculiarly fitted by its situation, and the muscular power of its coats, both to throw up its contents into the mouth, and to receive a supply from the first cavity at the will of the animal.*

It was ascertained, by examining the stomachs of several bullocks immediately after they were knocked down, that the second cavity contained the same kind of food as the first, only more moist; it would appear that it is from this cavity that the food is regurgitated along the canal continued from the œsophagus. There is indeed no other mode by which this can be effected, since it is hardly possible for the animal to separate small portions from the surface of the mass of dry food in the first cavity and force it up into the mouth.

It was also found that when the bullock had been four da y without water before it was killed, which is by no means uncommon, the food in the second cavity was very moist, while that in the first was very dry; and when the animal was killed twenty-four hours after drinking water, upon making an opening into the second cavity, before the other parts were disturbed, nearly a quart of water ran out of it, little mixed with solid food. The man of the slaughter-house also mentioned, upon being asked where the water was met with, that it was always found in the honey-combed bag. The water must be received into this cavity while the animal is drinking, for it could not afterwards be conveyed there from the first, as it would naturally drain through the food, and remain at the bottom of its cavity.

Tab. XXI. XXII.

The second cavity, by receiving the water, is enabled to have its contents always in a proper state of moisture to admit of being readily thrown up into the mouth for rumination, which appears to be the true office of this cavity, and not to receive the food after that process has been gone through, as is very generally believed, for in that case the cud would be mixed, and lost in the general contents of this cavity, instead of being forwarded to the true digesting stomach.

When the food is swallowed the second time, the orifice of the third cavity is brought forwards by the muscular bands which terminate in it, so as to oppose the end of the œsophagus and receive the morsel without the smallest risk of its dropping into the second.

The third cavity in the bullock has the form of a crescent containing twenty-four septa, seven inches broad; about twenty-three, four inches broad; and about forty-eight of one inch and a quarter at their broadest part. They are ranged in the following order: one broad one with one of the narrowest next it, then a narrow one with one of the narrowest next it; then a broad one, and so on. The septa are very thin membranes covered with a cuticle, and have their origin in the orifice leading from the œsophagus, so that whatever passes into the cavity must fall between these septa, and describe three-fourths of a circle before it can arrive at the orifice leading to the fourth cavity, which is so near the other, that the distance between them does not exceed three inches; and therefore the direct line from the termination of the œsophagus to the orifice of the fourth cavi y is only of that length. While the young calf is fed on milk, that liquor, which does not require to be ruminated, is conveyed directly from the œsophagus to the fourth cavity not passing into the first or second nor between the plicæ of the third, which at that time adhere together, and afterwards the solid food is directed into the spaces between them by the plicæ being separated from each other.

The food found in the third cavity is of the consistence of thick paste: and is met with in the form of flattened pellets distributed between the different septa.

When this cavity is opened, it emits an odour of a very unpleasant kind, arising from the process which the food undergoes in it.

The third cavity opens into the fourth by a projecting valvular orifice, and the cuticular lining terminates exactly on the edge of this valve, covering only that half of it which belongs to the third.

The fourth cavity is about two feet nine inches long: its internal membrane has eighteen plicæ, beginning at its orifice (nine on each side) four inches broad. They are continued down for about twenty-two inches, increasing to a great degree its internal surface: beyond these the internal membrane is thrown into rugæ which follow a very serpentine direction, and close to the pylorus there is a glandular projection, one end of which is opposed to the orifice, and closes it up when in a collapsed state.

Opportunities of examining the stomach of the camel rarely occur in this country. One of these, however, was met with thirty years ago, and the late Mr. Hunter availed himself of it, and made several preparations to illustrate different parts of its structure, which are now in the Collection. As the stomach was blown up and preserved in a dried state, many peculiarities were left unexamined, particularly those respecting the power which the animal has of carrying a provision of water as a supply when traversing the desarts.

I was led by many circumstances to be very desirous of investigating this subject, and in the year 1805, a favourable opportunity presented itself.

The Board of Curators of this College, formed of seven Members of the Court of Assistants, who have, from their first appointment, embraced every opportunity of augmenting the Hunterian Collection, in December, 1805, hearing that a camel in a dying state was to be sold, purchased it with a view of illustrating the anatomy of that animal. They appointed Mr. Long (their Chairman), Mr. Cline, Teacher of Anatomy, with Sir William Blizard and myself, the two Professors of Anatomy and Surgery to the College, a Committee for that purpose.

As Professor of Comparative Anatomy, I was directed to examine the peculiarities of the stomach, and to make a report on that subject.

The camel, the subject of the following observations, was a female, brought from Arabia, twenty-eight years old, and said to have been twenty years in England, and twelve years in the possession of the person from whom the Board of Curators purchased it. Its height was seven feet from the ground to the tip of the anterior hump.

In December, 1805, it came under the care of the Committee. At that time it was so weak, as hardly to be able to stand. It got up with difficulty, and almost immediately kneeled down again.

By being kept warm, and well fed, it recovered so as to be able to walk, but was exceedingly infirm on its feet: and moved with a very slow pace.

It drank regularly every second day six gallons of water, and occasionally seven and a half; but refused to drink in the intervening period. It took the water by large mouthfuls, and slowly, till it had done. The quantity of food it daily consumed, was one peck of oats, one of chaff, and one-third of a truss of hay.

In the beginning of February, 1806, it began to shed its coat. Towards the end of March the wind became extremely cold, and the animal suffered so much from it, that it lost its strength, refused its food, and drank only a small quantity of water at a time.

In this state it was thought advisable to put an end to so miserable an existence, and it suggested itself to the Committee, that if this was done soon after the animal had drank a quantity of water, the real state of the stomach might be assertained.

On the second day of April, by giving the animal hay mixed with a little salt, it was induced to drink in the course of two hours, three gallons of water; not having taken any the three preceding days, or shewn the least disposition to do so.

Three hours after this, its head was fixed to a beam to prevent the body from falling to the ground after it was dead, and in this situation it was pithed by Mr. Cline, junior, assisted by Mr. Brodie and Mr. Clift.

This operation was performed with a narrow double edged poniard passed in between the skull and first vertebra of the neck; in this way the medulla oblongata was divided, and the animal instantaneously deprived of sensibility.

In the common mode of pithing cattle, the medulla spinalis only is cut through, and the head remains alive, which renders it the most cruel mode of killing animals that could be devised.

The animal was kept suspended that the viscera might remain in their natural state, and in two hours the cavities of the chest and abdomen were laid open, in the presence of all the Members of the Committee, and Mr. Chandler, a member of the Board of Curators.

The first stomach was the only part of the contents of the abdomen which appeared in view. The smooth portion of the paunch was on the left side, and on the right towards the chest was a cellular structure, in which it was evident to the feeling that there was air; but no part of the solid food with which the general cavity was distended. On the lower posterior part towards the pelvis there was another portion made up of cells, larger and more extensive than that which was anterior. On pressing on this part, a fluctuation of its contents could be distinctly perceived. A trochar with the canula was plunged into the most prominent of the cells, and on withdrawing it, there passed through the canula twelve ounces of water of a yellow colour, but unmixed with any solid matter.

This fact having been ascertained, the first cavity was laid open on the left side at a distance from the cellular structure, and the solid contents were all removed.

While this was doing, some water flowed out of the cells, and some out of the second cavity; but the greater part was retained.

That in the second cavity was found nearly pure: while the other was muddy, and of a yellow colour, tinged by the solid contents of the first cavity.

On examining the cellular structure, no part of the solid food had entered it, nor was there any in the second cavity: those cavities having their orifices so constructed as to prevent the solid food from entering even when empty.

On measuring the capacities of these different reservoirs in the dead body, they were as follows:

The anterior cells of the first cavity were capable of containing one quart of water when poured into them. The posterior cells three quarts. One of the largest cells held two ounces and a half: and the cells of the second cavity four quarts. This, however, must be considered as much short of what those cavities can contain in the living animal, since there are large muscles covering the bottom of the cellular structure, to force out the water, which must have been contracted immediately after death, and by that means had diminished the cavities.

By this examination it was proved, in the most satisfactory manner, that the camel, when it drinks, conducts the water in a pure state into the second cavity; that part of it is retained there, and the rest runs over into the cellular structure of the first, acquiring a yellow colour in its course.

This confirms the account given by M. Buffon, in his examination of the camel's stomach, as well as that of travellers, who state that when a camel dies in the desart, they open the stomach and take out the water which is contained in it, to quench their thirst.

That the second cavity in the camel contained water had been generally asserted, but by what means the water was kept separated from the food had never been explained, nor had any other part been discovered by which the common offices of a second cavity could be performed. On these grounds Mr. Hunter did not give credit to the assertion, but considered the second cavity of the camel to correspond in its use with that of other ruminants, as appears from his observations on this subject, stated by Dr. Russel in his History of Aleppo.

The difference of opinion on this subject led me to examine accurately the structure of the stomach of the camel, and of those ruminants which have horns, so as to determine, if possible, the peculiar offices belonging to their different cavities.

The camel's stomach anteriorly forms one large bag, but when laid open this is found to be divided into two compartments on its posterior part by a strong ridge, which passes down from the right side of the orifice of the œsophagus in a longitudinal direction. This ridge forms one side of a groove that leads to the orifice of the second cavity, and is continued on beyond that part, becoming one boundary to the cellular structure met with in that situation. From this ridge, eight strong muscular bands go off at right angles, and afterwards form curved lines till they are insensibly lost in the coats of the stomach. These are at equal distances from each other, and, being intersected in a regular way by transverse muscular septa form the cells.

This cellular structure is in the left compartment of the first cavity, and there is another of a more superficial kind on the right, placed in exactly the opposite direction, made up of twenty-one rows of smaller cells, but entirely unconnected with the great ridge.

On the left side of the termination of the œsophagus, a broad muscular band has its origin, from the coats of the first cavity, and passes down in the form of a fold parallel to the great ridge, till it enters the orifice of the second, where it takes another direction. It is continued along the upper edge of that cavity, and terminates within the orifice of a small bag, which may be termed the third cavity.

This band on one side, and the great ridge on the other, form a canal which leads from the œsophagus down to the cellular structure in the lower part of the first cavity.

The orifice of the second cavity, when this muscle is not in action, is nearly shut; it is at right angles to the side of the first. The second cavity forms a pendulous bag, in which there are twelve rows of cells, formed by as many strong muscular bands, passing in a tranverse direction, and intersected by weaker muscular bands, so as to form the orifices of the cells. Above these cells, between them and the muscle which passes along the upper part of this cavity, is a smooth surface extending from the orifice of this cavity to the termination in the third.

From this account it is evident, that the second cavity neither receives the solid food in the first instance, as in the bullock, nor does the food afterwards pass into the cavity or cellular structure.

The food first passes into the first compartment of the first cavity, and that portion of it which lies in the recess, immediately below the entrance of the œsophagus, under which the cells are situated, is kept moist, and is readily returned into the mouth along the groove formed for that purpose, by the action of the strong muscle which surrounds this part of the stomach; so that the cellular portion of the first cavity in the camel, performs the same office as the second in the ruminants with horns.

While the camel is drinking, the action of the muscular band opens the orifice of the second cavity at the same time that it directs the water into it; and when the cells of that cavity are full, the rest runs off into the cellular structure of the first cavity immediately below, and afterwards into the general cavity. It would appear that camels, when accustomed to go journeys in which they are kept for an unusual number of days without water, acquire the power of dilating the cells, so as to make them contain a more than ordinary quantity as a supply for their journey; at least such is the account given by those who have been in Egypt.

When the cud has been chewed, it has to pass along the upper part of the second cavity before it can reach the third. How this is effected without its falling into the cellular portion, could not, from any inspection of dried specimens, be ascertained; but when the recent stomach is accurately examined, the mode in which this is managed becomes very obvious.

At the time that the cud is to pass from the mouth, the muscular band contracts with so much force, that it not only opens the orifice of the second cavity, but acting on the mouth of the third, brings it forwards into the second, by which means the muscular ridges that separate the rows of cells are brought close together, so as to exclude these cavities from the canal through which the cud passes.

It is this beautiful and very curious mechanism which forms the peculiar character of the stomach of the camel, dromedary, and lama, fitting them to live in the sandy deserts where the supplies of water are so very precarious.

The first and second cavities of the camel, as well as those of the bullock, are lined with a cuticle.

The third cavity in the camel is so small, that were it not for the distinctness of its orifices it might be overlooked. It is nearly spherical, four inches in diameter, is not like the third of the bullock, lined with a cuticle, nor has it any septa projecting into it. The cuticle, continued from the second cavity, terminates immediately within the orifice of the third, the surface of which has a faint appearance of honey-combed structure; but this is so slight as to requre a close inspection to ascertain it.

This cavity can answer no other purpose in the œconomy of the animal, than that of retarding the progress of the food, and making it pass by small portions into the fourth cavity; so that the process, whatever it is, which the food undergoes in the third cavity of other ruminants, would appear to be wanting in the camel, and consequently not required.

The fourth cavity lies to the right of the first, and has for a great part of its length the appearance of an intestine; it then contracts partially, and the lower portion has a near resemblance in its shape to the human stomach. Its whole length is four feet four inches; when laid open, the internal membrane of the upper portion is thrown into longitudinal narrow folds, which are continued for about three feet of its length; these terminate in a welted appearance; the rugæ are large as in the bullock, but not so prominent, nor so serpentine in their course, and for the last nine inches the membrane has a villous appearance, as in the human stomach. Close to the pylorus there is a glandular substance of a conical form, which projects into the cavity; the blunt end of it resting upon the orifice of the pylorus. This is similar to what is met with in the bullock, but still more conspicuous.*

The fourth cavity of the camel corresponds with that of the bullock in all the general characters, and resembles it in most particulars. It exceeds it in length; but the plicæ are so much smaller, that the extent of the internal surface must be very nearly the same in both. It differs from it in having a contraction in a transverse direction, immediately below the termination of the plicated part, which has led both Daubenton and Cuvier to consider these two portions as separate cavities. I should have been induced to adopt this opinion, were it not for the circumstance of the internal structure of both portions being the same as that of the bullock, which must be admitted to be only one cavity; and as the uses of these corresponding structures must be similar, the analogy between the two is better kept up by considering it in both animals as one cavity, only remarking the contraction in that of the camel as a peculiarity belonging to ruminants without horns.

From the comparative view which has been taken of the stomach of the bullock and camel, it appears, that in the bullock there are three cavities formed for the preparation of the food, and one for its digestion. In the camel, there is one cavity fitted to answer the purposes of two of the bullock; a second, employed as a reservoir for water, having nothing to do with the preparation of the food; a third, so small and simple in its

* Tab. XXIII. XXIV. XXV.

structure, that it is not easy to ascertain its particular office. It cannot be compared to any of the preparatory cavities of the bullock, as all of them have a cuticular lining, which this has not; we must therefore consider it as a cavity peculiar to ruminants without horns, and that the fourth is the cavity in which the process of digestion is carried on.

In the stomachs of ruminating animals, the processes which the food undergoesbefore it is converted into chyle are more complex than in any others. It is cropped from the ground by the fore-teeth, then passes into the paunch, where it is mixed with the food in that cavity; and it is deserving of remark, that a certain portion is always retained there; for although a bullock is frequently kept without food seven days before it is killed, the paunch is always found more than half full; and as the motion in that cavity is known to be rotatory, by the hair-balls found there being all spherical or oval, with the hairs laid in the same direction, the contents must be intimately mixed together. The food is also acted upon by the secretions belonging to the first and second cavities; for although they are lined with a cuticle, they have secretions peculiar to them. In the second cavity these appear to be conveyed through the papillæ, which in the deer are conical; and when examined in a lens, whose focus is half an inch, they are found to have three distinct orifices, and that part of each papilla next the point is semi-transparent. These secretions are ascertained, by Dr. Stevens's experiments, to have a solvent power in a slight degree, since vegetable substances contained in tubes were dissolved in the paunch of a sheep.*

* Dissertatio Physiologica inauguralis de Alimentorum concoctione. Auctore Edwardo Stevens, Edinb. 1777.

The food thus mixed is returned into the mouth, where it is masticated by the grinding teeth; it is then conveyed into the third cavity, in which a gas is emitted. This was examined by Sir Humphry Davy and Mr. William Brande, and was found to be inflammable, and not to contain carbonic acid, which establishes a difference between this process and fermentation; the food is then received into the upper portion of the fourth cavity.

The changes which are produced on the food in the three first cavities, are only such as are preparatory to digestion; and it is in the fourth alone that that process is carried on. In the plicated portion, the food is acted on by the secretion of the gastric glands; and in that portion of the fourth cavity of the deer's stomach, small orifices are seen in the internal membrane leading to the cavities, which I consider to be the openings of these glands, since they bear some resemblance to them in other stomachs.

In the lower portion the formation of chyle is completed.

LECTURE XI.

On the Teeth of Quadrupeds.

The teeth are employed to prepare the food before it is received into the stomach; and as they vary in their form to adapt them to the different substances on which the animal is destined to live, I have considered them as appendages to the stomach, and shall describe their structure and form in each class of animals immediately after the organs of digestion.

The teeth of the animals whose stomachs have been described differ very much among themselves; but by dividing them according to their structure into three kinds, the subject will be rendered more simple, and will be better understood.

The first of these divisions comprehends all teeth, the crowns and bodies of which are incased in enamel.

The second comprehends all such teeth as have the enamel and the substance of the tooth jointly employed to form the surface by which mastication is performed.

The third includes teeth more complex in their structure, being made up of three substances, all which make a part of the grinding surface.

The first kind of teeth belongs to carnivorous animals in general, to man, and many animals whose food is partly animal and partly vegetable; and to others that live on fruits, seeds, &c. as the monkey tribe.

The rudiments of such teeth consist of vascular pulps, formed in cells surrounded by bone, placed between the two bony plates of both the upper and lower jaw. These pulps increase in size till they have acquired the dimensions and exact form of the body of the future tooth. The surface is surrounded by a capsule, which does not adhere to it nor extend beyond the neck. The tooth begins to form upon the upper surface of the most prominent points of the pulp; and when the whole of that surface has undergone this change, and the crown of the tooth, as it is termed, is completed, a continuance of the deposition of this solid matter in layers composes the body of the tooth, and afterwards the fangs, the central part of each being the last which becomes solid. The hardening matter deposited on the pulp is found by Mr. Hatchett's chemical analysis to be principally phosphate of lime, with a very small proportion of carbonate of lime. This composition of animal pulp, phosphate and carbonate of lime, as it is harder than bone, and differs from it in the mode of growth as well as in its structure, constitutes a distinct substance, which I propose to call ivory, although that term has not before been generally applied to it, but confined to the tusks of the elephant, which are not coated with enamel; but in all other respects it is the same substance, as will be more fully explained.

As soon as the crown of the tooth is formed, there is a deposit made upon its surface of phosphate of lime, with a small portion of gelatine, but unmixed with albumen: this crystallizes and becomes the enamel. It is a deposit made from the smaller arteries of the capsule, which are fitted to throw out such a secretion; only that part of the tooth covered with the capsule is supplied with enamel; the neck and fangs, which are not intended by nature to protrude beyond the gums, having no such covering.

The tooth, when once formed, has no power of growth within itself, not having any supply of blood-vessels or nerves; but while the tooth is growing, the pulp is capable of inflammation; and in that state the fangs become enlarged, and put on a preternatural appearance. It has been asserted, that blood-vessels and nerves can be traced into the substance of the tooth; this is, however, evidently untrue, since portions of the elephant's tusks are not uncommonly cut off while the animal is alive; and there has been no appearance whatever upon the cut surface of vessels of any description having been divided.

The pulps of the teeth, like other parts of the body, are occasionally met with distorted and misplaced, rendering the future teeth irregular, and sometimes so situated, as to answer no useful purpose. A curious instance of this kind is in the Collection; two pulps have come in contact, their positions with respect to each other being reversed; so that when cursorily examined, there appears to be only one tooth with a crown above, and one below; but a small portion of the fang of the lower tooth remaining, shews that they were originally two separate teeth.

There is also a tooth appearing in the nostril instead of the mouth.

There are many instances of teeth found in unusual situations. The most extraordinary are, where tolerably formed teeth covered with enamel are found mixed with hair in diseased ovaria. These, till lately, have been considered to belong to imperfectly-formed fœtuses, the other parts of which had been absorbed; but a similar formation has been found in a tumor on the loins of a gelding; which makes it evident that teeth are formed in different situations in consequence of disease.

This circumstance enables us to explain the formation of tumours of ivory, of which I have known two instances, in the neighbourhood of the orbit in the human skull.

The structure and appearance of the pulp on which a tooth is formed, is particularly well seen in the preparations in the Collection; one of these is of the dens cuspidatus of the lion, while in a growing state.

As it is necessary that the young animal should have teeth before the jaws arrive at their full size, the first teeth are of a size adapted to the state of the jaws, and are afterwards shed to make room for the full sized teeth; the rudiments of the front teeth begin to form four or five months before birth; the sacs, in which the permanent teeth are formed, appear about the eighth month: they are not deeper seated in the jaw than the others, but situated behind them; that is, towards the inside of the mouth: they are contained in the same sockets with the temporary teeth, and intimately connected with their membranes.

As the sacs of the permanent teeth increase, the sockets of the temporary teeth enlarge, and the alveolar processes rise up, so that the two different sets become contained in separate cavities, with a hole between them by which the membranes of both are connected. In proportion as the fangs of the temporary teeth form, their bodies are pushed up, and the alveolar processes grow so that they arise along with them, leaving the permanent teeth below, and the connecting membrane elongated, so as to appear like nervous twigs passing up to the temporary teeth.

As the fangs of the permanent teeth increase, the temporary teeth have theirs absorbed, and the others rise into their sockets, and partly into those in the neighbourhood. This union of the sacs of the temporary and permanent teeth has been explained in a very satisfactory manner by Dr. Blake, in his inaugural thesis at Edinburgh, since republished in English.

The times at which the teeth first appear, and the times of their shedding, admit of considerable latitude; nothing can shew more satisfactorily the temporary teeth in their place, and the permanent ones within the jaw, than a preparation in the Collection made from a child about five years old.

This preparation was made under particularly favourable circumstances. The jaws contain the greatest number of teeth which can possibly be met with, all the temporary teeth are in their places, amounting to twenty-four; all those that are to replace them, which are twenty, and the four permanent grinders.

It is only the teeth of the fore and lateral parts of the jaws which are shed, as those are the only parts of the jaws formed in early infancy; the posterior part is later in forming and is of an increased size, admitting of teeth of the full size, and therefore permanent.

In the human species the number of the temporary teeth is twenty-four: of the permanent, thirty-two. The whole set of teeth consists of three different kinds: the incisores in the front of the jaws; the cuspidati, which are next to them, and project in different degrees beyond the other teeth; and the molares, which occupy the lateral and posterior parts of the jaw.

In all animals that have the teeth encased with enamel, the teeth in the upper and lower jaw correspond; but the number of the incisores is not always the same in both. In some, the incisores of the upper jaw are more numerous than in the lower; thus in the opossum from America, they are ten in the upper, and eight in the lower jaw; while in the mole, on the contrary, there are six in the upper and eight in the lower jaw.

The number of molares differs in different genera of animals. As Linnæus has made the teeth the distinguishing mark between the genera of animals, their number and appearance are better known to all students in natural history than any other parts of animals; it is therefore unnecessary to go more minutely into that part of the subject on the present occasion.

It is only intended to point out the most marked differences that are met with in the teeth of different animals. The incisores vary very little among themselves, as they are to answer a very similar purpose, even where the kind of food admits of considerable variety; but the molares have very different forms, adapting them to the substances on which the animal lives. In the lion, and all the truly carnivorous animals, the crown consists of a cutting edge of an irregular form: in man, monkeys, and bears, the crown is flat, with a number of points on the margin: while in the sea otter the crown has the form of knobs, fitting it for breaking shells, &c.*

* Tab. XXVI.

The joint between the two jaws is much more firm and limited in its motion than in other quadrupeds.

The cuspidati are evidently intended for a different use from the other teeth; they are calculated for seizing the animal's prey, and for fighting; and in the lion, tiger, and all that tribe, are formidable weapons.

In men and monkeys they are less fitted for such purposes than in any other animal; they become, however, a defence to the weaker incisores, and perform the offices for which strength is required. In some of the monkey tribe they project so far beyond the neighbouring teeth, as to be an approach to those of quadrupeds in general.

In the hog, their direction is more outwards from the mouth, forming the first approach to the tusk.

In the babyroussa, the cuspidati are changed for tusks both in the upper and lower jaw, in no respect having the structure, shape, or use of cuspidati; they have no enamel, and so much are they curved upon themselves, that they cannot be used as teeth. They appear to be the intermediate link between the tusks of the hog-tribe and those of the elephant; the other gradations of which, belong to animals with teeth of a more compound structure.

The teeth which have been described, not undergoing a great deal of friction, and being coated upon those surfaces which are applied to the food with enamel, have their bodies completely formed at the time of their appearing through the gum, so that they are calculated by nature to last during the the animal's life; in many, the number of molares is very small, and as the animal increases in years no new ones are added. This is the case in the lion-tribe, where a small tooth appears close to the last molaris to increase the surface in the upper jaw, but not in the lower.

In such animals as live on flesh, and whose teeth from their form are little liable to be worn, this structure is sufficient even where the life is of long duration. How far in the lion-tribe there is ever a new set formed, late in life, cannot readily be known; but that there is such a provision in nature should the animal be in vigour at the period in which the present teeth are worn out, is evident, as there is a sufficient number of instances in our own species to establish the fact; and when it occurs, it is a proof that the frame of the individual is composed of more durable materials than that of mankind in general. On the other hand, we sometimes find that the teeth fall out without any assignable cause, between fifty and sixty years of age; the alveoli being absorbed; the time of their duration appearing to have expired: in all such instances the animal machine must be considered as not fitted for long continuance, from which so useful a part has been removed.

The frequent instances which occur in the human species of teeth being imperfect in their structure, are to be considered as an imperfection communicated to the offspring in consequences of our artificial modes of life. Many of the diseases to which the human teeth are liable, arise from the vapours which issue from the stomach acting upon their substance.

In the lion-tribe, and many other animals, the molares do not increase in number or size. This is, however, found to be the case in the sus Æthiopicus, as will be explained in the next Lecture, and therefore I was desirous of seeing whether it was so in a less degree in any of the other species of sus, or animals nearly allied to them. I did not meet with it in the tapir or the babyroussa, nor could I see any approach to it in the common hog. This made me desirous of examining the grinding teeth of the wild boar in the different stages of their growth, and, if possible, after the animal had arrived at an advanced age.

My wishes respecting the wild boar were mentioned to Sir Joseph Banks, who very obligingly sent me two skulls he had received from Germany; and Mr. George Best was so good as to send over to Hanover for the head of one of the largest boars that could be procured: his request was immediately complied with, and the animal to which the head belonged was considered, by the hunters, as under seven years of age.

From an examination of these different specimens I have been able to make out, very satisfactorily, the mode of dentition of the wild-boar during the first seven years, and to ascertain that there is a succession of grinding teeth beyond that period.

In this species of sus, the temporary grinders consist of sixteen; four on each side both of the upper and under jaw. These sixteen teeth are shed in the usual manner, and their places supplied by larger teeth rising up from the substance of the jaw, immediately under the old ones.

Before these first teeth are shed, one of the grinders in the posterior part of each side of both the upper and under jaw is formed.

In explaining the subsequent changes which take place, I shall confine myself to the lower jaw, as the preparations which I have made are taken from the teeth in that jaw.

Of the five teeth on each side of the lower jaw, one is separated from the rest, and is close to the tusk; which admits of a space for the curve of the upper tusk to rest upon, so that there are, properly speaking, only four grinders forming a regular row.

As the jaw increases in length, a small cell is formed in its substance behind the last grinder in which the rudiments of a new tooth appear: this increases along with the cavity in which it is contained, and the new tooth is, in every respect, larger than the preceding one. By the time it is completely formed, and ready to cut the gum, the jaw has extended itself so that there is room for it to come into its place as the posterior grinder.

While this tooth is concealed in the jaw, another cell is formed immediately beyond it, and there is a small round hole of communication between the two cells, similar to what has been explained to exist between the cells of the temporary and permanent teeth in the infant.

The last mentioned cell is at first very small, but gradually increases to a prodigious size; and the tooth formed in it is nearly double the size of the preceding large grinder. Its masticating surface has a row of four projections on each side, and the tooth has eight fangs; so that it very much resembles two large grinding teeth incorporated into one: the posterior fangs are not completely formed at seven years of age.

This large tooth, although it is formed in the posterior part of the jaw, is brought sufficiently forward, by the growth of the jaw bone to cut the gum, and range in the line with the other teeth, making the connected row of grinders six in number. From its very great size, it not only fills the jaw completely, but all the bodies of the other five teeth are pushed by it out of their perpendicular direction, leaning a little forwards.

As soon as the sixth grinder has cut the gum, a new cell begins to appear immediately beyond it, to receive the rudiments of another tooth.

This last cell at seven years of age is very small, and the specimens in my possession do not enable me to prosecute the enquiry; but there is every reason to believe the tooth formed in it equals, or exceeds the large one that has been described.*

In the human species the mode of dentition is upon the same principle as in the wild boar; only the last-formed grinding teeth in each jaw, called dentes sapientiæ, do not in size exceed the others, but are rather smaller, and very often have not sufficient room in the jaw to come into their regular place, although they do not usually make their appearance till between twenty and thirty years of age. This arises from the jaw not increasing in length in proportion with the body.

In the Negro, the dentes sapientiæ have sufficient room to come into their place ; and are, in general, full as large as the other grinders, the growth of the posterior part of the jaw being evidently greater than in the European.

If the age of man were at any time much greater than at present, it is natural to suppose the growth of the posterior part of the jaw was continued for a longer time, and the space for the dentes sapientiæ was more extensive.

Under such circumstances these teeth would probably be large, in proportion to the space which was to receive them ;

* Tab. XXVII.

and if, instead of threescore and ten, as at present, a thousand years were the period of a man's life, we should be led to conclude from the preceding observations, that there was a succession of dentes sapientiæ, as a necessary provision for enabling him to masticate his food at that very advanced age.

Upon the subject of this conjecture a very curious circumstance has been mentioned to me by Sir Joseph Banks. In Otaheite, the natives have a tradition, that Adam, or the first man, was remarkable for the length of his jaws. His name, in their language, is Taa roa tahi etoomoo, which signifies, the one (the stock) from which all others sprung, with the long jaws; so that these islanders have a tradition of the original race of men, having had their jaws much longer than the present.

Although the grinder of the boar differs in appearance, as in extent of surface, from those of all the recent animals that have their teeth incased in enamel, yet upon comparing it with the large fossil teeth found on the banks of the river Ohio in North America, belonging to the animal incognitum, they are so much alike both in their external appearance and internal structure, that it is evident they are teeth of the same kind, only of very different sizes.

This animal has lately got the name of mammoth, from being believed to be the same as the animal whose fossil remains are found in Siberia, known by that name: but it is now ascertained that the mammoth is a species of elephant; and therefore the same name being applied to both, must involve every account in considerable error; which makes it necessary to go back to the name animal incognitum, as more appropriate to the American bones.

This resemblance led me to examine the mode of dentition of this unknown animal, as far as could be done from the specimens preserved in this country, to see if any resemblance could be traced between it and that of the wild-boar.

From the different specimens of these fossil teeth deposited in the British Museum, the Collection of the late Dr. William Hunter, and the Hunterian Museum, together with one in my own possession, presented to me by Sir Joseph Banks, the following facts have been ascertained.

The first grinders are small when compared with those which are afterwards formed, being scarcely more than half their size; they have three transverse projecting ridges completely encrusted with enamel, as well as every other part of the masticating surface.

Two of these grinders, and probably more, are present on each side of the jaw at the same time. As the animal increases in size and the jaw extends itself, a larger kind of grinder is formed in the posterior part of the jaw, exactly similar to what happens in the elephant; and, as this large tooth, which has five projecting transverse ridges on the masticating surface, becomes completely formed, it comes forward, and occupies the principal seat in the jaw, as the others drop out.

When the smaller grinders are examined, the greater number of them have their fangs all bent in one direction, in consequence of the bodies of the teeth having been pushed forward by the large posterior tooth coming into their place.

This process is well illustrated by two specimens, which shew the teeth in the two stages of growth, and which are represented in the engravings.* The first is from the lower jaw, in which the two small grinders are in their sockets; and the cavity for the formation of the large grinder has, upon its sides, the impression of the different parts of the body of the tooth.

The other is from a lower jaw in the British Museum, in which the large grinder is completely formed, and occupies the principal part of the jaw; at the anterior part of which, are the remains of the sockets from which the smaller grinders had fallen out.

The animal incognitum with respect to its teeth, and the mode of their succession, forms an intermediate step between the wild-boar and the elephant; and now that it is ascertained to have tusks, the characteristic difference between it and the elephant is, the grinding teeth being encased with enamel.

The account of its tusks was first sent to me by Dr. Physic, an eminent physician in Philadelphia, in March 1802, accompanied with a drawing and the following description.

" As the upper part of the skull when found, was much broken, the whole of the head above the red line is imaginary, and made of wax. The tusks are also artificial; but copied exactly from a natural one which was found in the head. They pass out from the anterior part of the upper jaw, and at their origin are about six inches distant from each other. They diverge gradually, until at their extremities they are eight feet nine inches apart: their direction is, in a slight degree, spiral; but this could not be represented in the sketch.

" The socket in the upper jaw for the insertion of the tusk is eight inches deep.

* Tab. XXVIII. XXIX. XXX.

" The teeth are eight in number, two of which are situated on each side of each jaw. The grinding surfaces of the teeth in the lower jaw are worn nearly flat; and the foremost teeth on the lower jaw are worn so as to terminate in an acute angle anteriorly. The roots of the foremost teeth in the upper jaw are turned backwards, to make room for the tusks.

" The anterior termination of the lower jaw is particular; each side projects three or four inches beyond the symphysis, and their ends are ragged and uneven. They unite below, leaving a space above their union so large, that a man's head could be introduced into the mouth when the jaws are closed. The distance between the two anterior teeth in each jaw is about ten inches."

From the structure of its teeth, the founder of this Collection was disposed to consider it as a carnivorous animal. This, however, now that its affinity to the elephant is made out, is by no means probable; and the molares are well calculated to bruise and masticate the hardest kinds of vegetable substances. In proof of their being adapted to vegetable food, they bear a very close resemblance in their grinding surface to those of the kanguroo, only differing in their size.

This mode of dentition appears to be confined to those animals of great longevity, whose food has so much resistance, as to require the teeth being of a size too large to admit of the new tooth and the old being contained in the same portion of the jaw at the same time.

That the elephant lives to a great age is sufficiently ascertained; and the size of the bones of the animal incognitum is almost sufficient evidence of its being a long-lived animal.

The wild boar of Germany, from living in a savage state, cannot have its natural life appreciated with any accuracy; but if we may credit the accounts recorded, of the size to which it grows, it may be presumed that many years are necessary for that purpose.

The following statements upon this subject, have been communicated to me by Mr. Best, from Hanover.

In 1581, a boar was killed at Koningsberg, in Prussia, of six hundred pounds weight.

In 1507, one was killed in the dukedom of Wirtemberg, seven feet three inches long, by five feet three inches high. The length of the head was twenty-three inches.

From these accounts of the enormous size of the wild boar in the sixteenth century, it cannot be doubted that the animal, where its haunts are not disturbed by hunters, lives to a great age; if that were not the case, the mode by which its teeth are renewed would be entirely unnecessary.

A boar of this description, matured in its native forests, when it arrived at the age of sixty or one hundred years, possessed of the strength and sagacity to be acquired in that time, must have been an animal more formidable than any which are at present to be met with; and when it made occasional excursions into the nearest cultivated lands, it must have excited the greatest degree of terror and alarm among the inhabitants.

Before the use of fire-arms, it is not at all improbable, that such an animal should drive before it the peasantry of a whole district; and that the boldest warriors should be solicited to come from the neighbouring cities, to put a stop to its ravages.

The histories of this kind which are to be met with in the works of the ancient poets and historians, are therefore not to be considered as wholly fabulous, but the recital of events which really happened, although probably, in many instances, much exaggerated and embellished.

Ovid's description of the wild boar killed by Meleager, which he asserts to be larger than the Sicilian bulls, with tusks equal in size to those of the elephant, was probably taken from some Greek account, which, being founded on tradition, may be supposed, from the preceding observations, to have been in its origin a true history.

It is deserving of remark, in proof of the Roman poets having considered the wild-boar as an animal that lived to a great age and grew to an enormous size; that, while Ovid gives the particulars of his bulk, Virgil thinks it sufficient when he means to describe the animal in all its power, to say it had lived many years, without at all particularizing its size.

The second kind of teeth, or those in which the enamel does not enclose the ivory, but the two substances are mixed together in different ways, includes a very small proportion of animals when compared with the whole number. They are met with in the rhinoceros and hippopotamus, and some of the tribe of animals which have been called by Mr. Hunter scalpris dentata; the incisores of which are in the form of a chisel, and only two in number, both in the upper and lower jaw.

All these chisel-teeth may be said to belong to the present class, since there is enamel on the external curve and none on the internal; so that as the teeth are worn down by use, the same degree of sharpness on the cutting edge is always preserved, which is an admirable provision of nature to keep them constantly fit for use during their whole growth, which is of longer continuance and to a greater extent than in any other teeth: in this respect they resemble the tusk.

In some of this tribe the molares are completely incased, as in the common rat; but in others, as the beaver, the enamel pervades the body of the tooth at the same time that it surrounds the external surface.

The waving lines of the enamel are beautifully seen in specimens where the tooth has been partly worn: in all the molares of this construction in the scalpris dentata tribe, there is not, as in the incased teeth, a body and a set of fangs; but the body is of the same form through the whole length of the tooth, and is not set perpendicularly in the jaw, but forms a curve, the convex side of which is towards the mouth. This gives the tooth firmness in its socket, and it rises in the jaw, as it is worn, exactly similar to the chisel-tooth; so that it always appears of nearly the same length, the growth making up for the loss by being worn.

The teeth of the hippopotamus bring it in one respect near the scalpris dentata, having tusks of the same structure, and wearing in the same way, always retaining a chisel form; and in this animal there is a peculiarity,—the two teeth corresponding to incisores in the upper jaw, have an outer crust of enamel; while the corresponding ones in the lower, consist wholly of ivory.

The molares of the hippopotamus have a very unusual surface before they are begun to be worn. It consists of two cones with the points uppermost, and split, for a little way, in a perpendicular direction. These cones are placed close to each other, and there is a plate of enamel passing down to a certain depth into each cone at its subdivision.

One of the cones is larger than the other, and the plate of enamel goes to a greater depth in the smaller than in the large cone. The enamel also surrounds every part of the tooth, so that when the tooth is a little worn, the grinding surface has every where a mixture of ivory and enamel, and the external surface has a number of irregular indentations.* These teeth consist of a body and regular fangs, like those encased with enamel, and the body of the tooth is completely formed when it first appears to its proper height above the gum.

They are sufficiently strong in their texture to last the animal during its life, so that they are not succeeded by others at a later period of life of a larger size, as in the wild boar, and animal incognitum.

The rhinoceros has no tusks or chisel-teeth, but two short and flat incisores in the upper jaw; and two teeth projecting horizontally in the lower; all of these are completely coated with enamel, in their form they resemble those of the kanguroo.

The molares are unlike those of any other animal with which I am acquainted; their external surface has a very strong coat of enamel, and the body of the tooth does not present a solid crown as in other teeth, but forms only two sides of a triangle with a hollow space in the middle, into which there are irregular projections every where covered with enamel, so as to form a number of ridges of enamel on the grinding surface, when it becomes a little worn.*

These different forms of teeth are evidently given, to adapt them to particular kinds of food on which the animals in a wild state are intended to feed; the variety in form, however,

* Tab. XXXI. † Tab. XXXII.

appears to exceed the absolute necessity, since we find that many animals whose food is nearly the same have a difference in the form of their teeth; but we are unable to form a correct judgment upon this subject, not having any accurate knowledge of the modes of life of any animals in a state of nature before the arts of cultivation were employed.

LECTURE XII.

Of the Complex Teeth.

Having explained the structure of those teeth in which the ivory is encased in enamel, and those in which the two are mixed, I now come to the third kind, composed of three different substances; two of these are the enamel and ivory already noticed; the third, I have been induced to consider as similar to common bone.

Teeth of this structure belong to a very large range of animals: the elephant, horse, sus æthiopicus, many of the scalpris dentata tribe, and all the ruminating tribes are furnished with teeth of this description.

As there is great difference of opinion among physiologists respecting the nature of this third substance, and the mode of its formation, it is necessary that I should explain the grounds upon which my own has been formed, and state the observations of other anatomists with which they agree, as well as those from which they differ.

Mr. Tenon, who has distinguished himself by his masterly investigation of the dentition of the horse, explained so early as the year 1770 the structure of this third substance, and stated that it resembled common bone.

Dr. Blake, in an inaugural Thesis, published at Edinburgh in 1798, took up the opinion that it was a secretion of a peculiar kind, and formed a substance of so dense a texture, as to deserve the term crusta petrosa.

In 1799, from the accidental examination of the section of an elephant's grinder, which had been polished, and which in that state shewed the different densities of the component parts of the tooth, by the degree of polish which each of them bears, I was led to a conclusion diametrically opposite to that of Dr. Blake, that this substance is of a softer texture than the other component parts of the tooth; and upon examining the ligamentous structure met with in the young elephant, upon which this third portion of the tooth in the elephant is formed,* a new idea came into my mind respecting it, which I conceived would explain the general principle upon which these three parts of a tooth so different from each other are formed, and which since I have been able to realize; that the enamel having no animal basis on which it is deposited, consists of little more than crystals of phosphate of lime, mixed with a small portion of gelatine, as has been proved by my friend, Mr. Hatchett's experiments: that the substance of the tooth which I call ivory, is a deposit of phosphate, and a small proportion of carbonate of lime on an animal basis, in the form of a pulp, which leads to the conclusion that all the hard parts of an animal body having similar pulps for their base, bear a resemblance to each other, and are to be classed under the general term ivory; whether in the form of a grinding tooth, a tusk, or the rounded form of a tumour, which is sometimes, though rarely, met with in the frontal sinus of the human skull; two instances of which have come under my observation; and one of the same kind from the skull of the ox is in the Collection;

* Tab. XXXIII. XXXIV. XXXV.

that all hard parts which have a common membrane or cartilage for their base, resemble common bone, and belong to the same species of structure.

This view of the subject was laid before the Royal Society, and published in the Philosophical Transactions. At that time I was unacquainted with Mr. Tenon's observations, with which mine so entirely agree.

Dr. Blake's Thesis I had seen, but certainly in no respect received any information from it on this subject, since what I advanced was in direct opposition to what is there stated; and I was led to believe, that the mistake which, in my opinion, he had gone into, arose from his not having had the opportunity of examining the elephant's grinder under the same circumstances with myself. Dr. Blake, however, has thought proper to make a violent attack upon me for having robbed him of the credit of a discovery.

In offering a new view of any subject to the public, I have ever thought it right to state the facts which led to it, and the opinion itself, without adverting to those of others, which ever leads to controversy, and is unnecessary with respect to the direct observations that are brought forwards.

Upon this occasion I followed this rule, and shall continue to do so in every thing respecting myself; in the hope that, by stating the mode by which I have been led to such conclusions, I shall prove satisfactorily the real source from which they have been derived.

Knowing, as I have done, from a very early period of my life, the irritability of mind, which belongs to those who are candidates for making discoveries, I can make every allowance for the violence of Dr. Blake's attack: I have, however, to regret that he had not been led in his Thesis to tread more lightly upon the ashes of the great Man who formed this Collection; and to pay that respect to his integrity, as well as his anatomical knowledge, of which they were certainly deserving in the most eminent degree.

Since that time M. Cuvier, who has paid great attention to this subject, has published his opinion on this third substance, and considers it not analogous to bone, but a peculiar secretion. From the high respect I hold for every thing that has been done by that great luminary in comparative anatomy, I have reconsidered the subject with no view to controversy, but an ardent desire to discover truth, and shall state the following reasons for not assenting to his opinion, wishing him to consider it as an amicable contest; since in the imperfect state of our knowledge on these matters, we must all too frequently fall into error, and be satisfied if in some few instances we can establish a truth not previously known; nor is it altogether unworthy of praise to have made the attempt, even when we fail of success.

I am led to consider this to be an ossification, not a secretion, in consequence of there being no instance of a secretion of hard materials in an animal body, except the enamel; and there it takes on the form of crystals, and when decomposed, the animal part is devoid of form. In ivory and in bone there is always a soft substance from which the shape is derived, to which the harder materials are added. I therefore thought it would throw some light upon this disputed point, to have the earthy part removed from ivory and from this third substance, and then to compare the animal part which remained with the pulp, before there is any addition of earthy matter.

Mr. William Brande has been kind enough to make this analysis; and we shall find that the objects of anatomy can be very essentially promoted by the aid of chemistry, in the examination of the harder structures of the body, which cannot be examined by the knife.

In examining the enamel of the elephant's grinding teeth, he found that when the phosphate of lime is extracted in the most gradual manner, so as to disturb in the smallest possible degree, the animal base in which it is contained; that nothing remains but so small a portion of gelatine, as to require the nicest chemical tests to ascertain its presence.

In separating the gelatine from the albumen in the pulps of the grinders of the common hog before the ivory is formed, in boiling water, the proportion of gelatine to albumen is nearly ten per cent.

In making a comparative analysis of the ivory contained in the grinding tooth of the hog in its perfect state, by extracting the phosphate of lime, and carbonate of lime and gelatine, by very dilute muriatic acid, the proportion of gelatine to albumen is nearly ten per cent.

In the grinder of the elephant, the proportion of gelatine to albumen is considerably less than ten per cent.

In the ivory of the elephant's tusk, the proportion of gelatine to albumen is fifteen per cent., or nearly so.

In the third substance in the elephant's grinder, when the carbonate of lime, phosphate of lime, and gelatine are extracted, the albumen is in a very compact form, and the proportion between the gelatine and the albumen is under five per cent.

In common bone, the proportion of gelatine to albumen is seven per cent.

From these analyses it appears that in the enamel, which is admitted to be a secretion, there is no albumen, and the fluid gelatine is probably the best medium in which the phosphate of lime can crystallize.

The ivory of the elephant's tusk contains a proportion of gelatine to albumen of fifteen per cent.; the ivory of the grinding teeth of ten per cent.; common bone, seven per cent.; the third substance in the elephant's grinder, under five per cent. So that in its materials, chemically considered, it bears the closest resemblance to common bone, and is the most distant in its texture from the enamel, which is the only substance that can in any way be proved to be a secretion.

I have since had an opportunity of examining the elephant's grinder in an early stage of its growth, where the parts have been dried; the ligamentous structure on which the third substance is formed is divisible into layers, shewing that it is made up of separate membranes, and between these, small ossifications in different places are readily detected. This fact, which is illustrated by a preparation in the Collection, puts an end to all controversy, and establishes the opinion, that the mode of formation is the same as in common bone. These ossifications towards the fangs are very numerous, and put on the appearance of dots, which might have induced M. Cuvier to believe they were secreted.

As the elephant is the largest animal with tusks and compound teeth, I shall describe the progress of dentition in that animal, Mr. Corse having furnished me with the most correct information upon the subject.

The first or milk-tusks of an elephant never grow to a large size, but are shed between the first and second year, when not two inches in length. The tusks, which are shed, have a considerable part of the fang absorbed before this happens, as may be seen by comparing one that has been shed, with another lodged in the socket of a young elephant before it had cut the gum. The time at which the tusks cut the gum varies considerably: a young one has been known to get his tusks when about five months old; whereas, the tusks of another did not cut the gum till he was seven months old. Those tusks which are deciduous are perfect, and without any hollow in the root, in a fœtus which is come to its full time: at this period the socket of the permanent tusk begins to be formed behind the deciduous tusk.

A young elephant shed one of his milk-tusks when near thirteen months old, and the other when above fourteen months old: they were merely two black-coloured stumps when shed; but, two months afterwards the permanent ones cut the gum, and in two months more were an inch long, but black and ragged at the ends. When they became longer and projected beyond the lip, they soon were worn smooth by the motion and friction of the trunk.

Another young elephant did not shed his milk-tusks till he was sixteen months old; which proves that there is considerable variety in the time at which this happens.

The permanent tusks of the female are very small in comparison with those of the male, and do not take their rise so deep in the jaw; but they use them as weapons of defence, by putting their head above another elephant, and pressing their tusks down into the animal.

These tusks are never shed, and sometimes grow to a very large size in the male. The largest known in Bengal did not exceed seventy-two pounds avoirdupois; at Teperah, they seldom exceed fifty pounds: but both these weights are very inferior to that of the tusks brought from other places to the India House, where some are near one hundred and fifty pounds each. From what part of Asia they came is not ascertained, but probably they were imported from Pegu.

The grinders are composed of a number of perpendicular laminæ, each covered with a strong enamel, and joined to one another by osseous matter. This, being much softer than the enamel, wears away faster by the mastication of the food; and in a few months after some of these laminæ cut the gum, the enamel remains considerably higher; so that the surface of each grinder soon acquires a ribbed appearance, as if it had been originally formed with ridges. This, however, is not the case, as may be seen by examining a grinder just cutting the gum.

These laminæ when first formed have no firm attachment to each other, but always appear separate and distinct when contained in their bony sockets within the jaw, after their membranes and soft parts have been destroyed.

Before any part of a grinder cuts the gum, there is a bony crust formed above the enamel, which gives a smoothness to the grinding surface; but, after the grinders cut the gum, and the convex surface has been worn down a little by the trituration of the food, each lamina appears to have been formed on several points, which are covered by a strong enamel. There are from four to eight of these points joined together by the common bony matter, which fills up the space between the enamelled portions.

When the grinder, however, is farther advanced in the mouth, its foremost laminæ are gradually worn down by the mastication of the food; and these enamelled points or denticuli disappear one after another, till the enamel at last runs quite across the tooth, surrounding the central part on which it was formed, and taking the irregular indented plaited shape of the laminæ.

The number of laminæ of which a grinder is composed, varies from four to twenty-three, according as the elephant advances in years; so that a grinder in full grown elephants is more than sufficient to fill one side of the mouth: in proportion, however, as the foremost laminæ are worn away, the succeeding laminæ come forward to supply their places.

The denticuli, of which each lamina is composed, are much larger and fewer in number in old than in young elephants; in consequence of this, the same number of laminæ generally fills the jaw of a young or of an old elephant; and from three till fifty years of age, there are from ten to twelve laminæ in use on each side of either jaw, for the mastication of the food.

When several of the anterior laminæ of which a grinder is composed have been completely formed, and each covered with its proper enamel, they become firmly united (beginning at the fore part) by the bony matter, which gradually forms in the interstices between them.

When the bodies of several of the anterior laminæ have been connected together, the inferior edge of each becomes united in the same manner to the one next it, till the whole are thus gradually joined, and form the complete grinder.

As soon as the anterior parts of the grinder are thus firmly united, the fangs are next added: these, at first, appear in the form of a thin curtain or lamella of ivory, extending backwards, along some of the anterior laminæ, at their lower edges.

A fang, common to the three anterior laminæ, first begins to be formed. These join and become longer, assuming a conical shape, hollow in the centre; the hollow is gradually filled up by successive layers of ivory as the fang lengthens, till at last it becomes solid. This, however, does not happen till the three laminæ, to which the fang is attached, are nearly worn away. When its formation is almost completed another process begins to take place, which is, the absorption of the fang.

By the time that the anterior laminæ of the grinders are completely worn down, both the fangs and the alveolar processes begin to be absorbed. Their places are gradually supplied by the next laminæ of the grinder, and their fangs coming forward in a constant succession. When the last lamina of a grinder has advanced sufficiently in the jaw to supply the place of its predecessor, the anterior lamina of the next succeeding grinder comes forward to supply its place.

From the peculiar manner in which the grinders are supplied from behind, but never from beneath the preceding grinder, it must appear evident that an elephant may, at one period, have only a single grinder in each side of either jaw, and at another there may be one, and part of a second.

In the third year, the jaws of the elephant are filled with as many laminæ on each side as they can hold.

While the grinders advance forward in the mouth, in regular succession, the alveolus of each advances along with them; and as the anterior fangs are absorbed, the same process is going on in the alveoli.

In the partition between each alveolus there is a communication, which in young elephants is larger than in those farther advanced in years: this canal between the different alveoli is similar to that described in the teeth encased with enamel.

The time requisite for the complete formation of a grinder, varies from two to six or eight years; and, when an elephant has attained its full size, a considerable number of the anterior laminæ must be worn away, and the fangs absorbed before the posterior ones can be sufficiently advanced to cut the gum.

Where the three anterior laminæ are worn down to the fangs, there are still ten of the posterior ones that cannot come into use, till the same number of their predecessors are worn away in regular succession.

Before this can happen several years must elapse, and in that period the posterior laminæ will have been completed.

In the lower jaw the same circumstances take place; the laminæ of the grinders rise by the addition of their fangs, and cut the gum as they advance forward in the jaw. The grinding surface has rather a concave form to adapt itself to that of the grinder in the upper jaw.

The number of laminæ does not always correspond with those of the grinder in the upper jaw, but like them consists of from four to about twenty-three.

In both jaws the alveoli are firmly attached anteriorly and laterally to the bony plates of which the jaw is composed; but at the posterior part these alveoli are separate from the jaw, and have only a membranous attachment. The alveoli become thicker and stronger, as the elephant advances in years.

In the lower jaw, the portion of the alveolus which is attached to the inner plate is thick and spongy; and through the under part of this spongy substance, there is a foramen for transmitting the blood-vessels and nerves of the teeth. By this means there is a supply of blood to the membranes on which the third substance is formed, after the crown of the tooth has begun to be worn, which M. Cuvier did not advert to.

As the grinders of the upper and under jaws wear away, the fangs are lengthened and become more solid, by the addition of new matter till the cavity is intirely filled up. This lengthening of the fangs is necessary, to give that portion of the grinder, in use, sufficient firmness in the jaw, as well as to keep the surface at a proper level above the gum.

When the anterior teeth are worn down, their sockets begin to be absorbed to make room for their successors which are coming forwards.

The shape of a grinder of the lower jaw is very different from that of one of the upper: in the latter, the grinder advances from behind straight forwards, and the back part has a very convex shape; whereas, the lower grinder advances rather in a bent, or curved direction, adapting itself to the shape of the jaw.

In a young elephant soon after birth, the milk grinders with their fangs are completely formed, and even the succeeding or second grinder has the fangs partly added to some of the anterior laminæ, which are soon to cut the gum; but the posterior layers are then without fangs.

Farther back in the jaw, the third grinder, which is composed of about thirteen laminæ, has no appearance of fangs, nor have the different laminæ any connection with each other, except by the common membranes. When these are destroyed, the laminæ or rudiments of a succeeding grinder can be easily separated from each other.

At this period the enamel of the third grinder has not been formed, but only the substance of the laminæ, which it afterwards covers, adapting themselves to the irregularities of the surface.

The first set of grinders or milk teeth begin to cut the gum eight or ten days after birth, and the grinders of the upper jaw appear before those of the lower. Though this happens at first, yet in a few months the grinders in the lower jaw come forward faster than those in the upper, as may be observed in the heads of several elephants.

In about six weeks the first set of grinders can be easily felt, consisting of four teeth, viz. one on each side of either jaw; and, as young elephants begin to eat grass or some soft succulent food before they are three months old, we may conclude that the first set of grinders have then completely cut the gum, and that dentition is not attended with any symptoms of pain or irritation in the system.

The milk grinders are not shed as the tusks are, but are gradually worn away during the time the second set are coming forward; and as soon as the body of the grinder is nearly worn away, the fangs begin to be absorbed.

It is difficult to ascertain the exact time when the second set of grinders make their appearance, as an elephant will not open his mouth in such a manner as to permit any one to examine his teeth accurately; but when the elephant is about two years old the second tooth is completely in use.

At this period the third begins to cut the gum; from the end of the second to the beginning of the sixth year, the third comes gradually forward as the jaw lengthens, not only to fill up this additional space, but also to supply the place of the second, which is, during the same period, gradually worn away, and the fangs absorbed.

From the beginning of the sixth to the end of the ninth year, the fourth grinder comes forward to supply the gradual waste of the third.

After this period several others are produced. In what time these succeeding grinders come forward, compared with their predecessors, has not been ascertained, but there are grounds to conclude that every succeeding grinder takes a year more than its predecessor to be completed; consequently, that the fifth, sixth, seventh, and eighth grinders will take from five to eight years, before the posterior lamina has cut the gum.

The milk grinders consist each of four laminæ or plates; the second grinders of eight or nine laminæ; the third of twelve or thirteen; the fourth of fifteen; and so on to the seventh or eighth, when each grinder consists of twenty-two or twenty-three.

The teeth of the Siberian mammoth, which is decidedly an elephant, have the plates thinner than in the Asiatic: this is also the case with the fossil elephants' teeth found in this country.

The teeth of the African elephant differ in the arrangement of the enamel, which in the centre of each plate takes the form of a lozenge.*

In the sus Æthiopicus, the grinding teeth in the young head are distinct from each other, and four in number on each side of the jaw.

That which is most anterior is the smallest, and has a grinding surface only equal in extent to that of one of the processes contained in the large tooth of the full-grown animal: the second has a grinding surface equal to that of two such processes; the third is still larger, its surface being equal to that of three processes.

These three teeth in their general appearance resemble those of the common hog; they have also the same kind of fangs; their only peculiarity is, the enamel being intermixed with the substance of the tooth, but without any bony matter surrounding it.

The fourth or last tooth is very different from the others, and resembles that of the elephant in a growing state. It is composed of seven processes united together; these are in different stages of growth, fitting them to come forward in succession, similar to those of the elephant. The two first have their grinding surface worn smooth: the points of the two next have recently cut the gum; and the other three are still concealed in the jaw, not being completely formed; of the last of these, the first rudiments only are to be seen.

This large tooth (which may be considered to be a second set of teeth), as the concealed processes enlarge, advances forwards, pushing the other teeth before it: the most anterior of these, as soon as its body is worn away, has its fangs

* Tab. XXXVI. XXXVII.

removed by absorption, and drops out; the same thing takes place with the second and third; and, in this way, room is made for the large tooth to supply the place of all the others.*

The mode in which they succeed each other is illustrated by the engraving of a side view of the jaw, in which the fangs of the different teeth are exposed; and the body of the third tooth gradually moved forward, as the last increased in size, is distinctly seen.

In the full-grown sus Æthiopicus there is only one molaris filling the whole jaw; but there does not appear any preparation for a succession.

The tusks of the sus Æthiopicus resemble those of the elephant; while those in the lower jaw, have enamel like those of the boar.

The use of the tusks of the elephant, the sus Æthiopicus, and common boar, appears evidently to be that of defence, and very tremendous weapons they must be: but those of the babyroussa are so formed that they can not be used for that purpose; and such is their situation and their shape, that it is difficult, on the first view, to conjecture in what way they are employed.

There is a ridiculous notion that the animal uses them as hooks, by which it suspends itself to the branches of trees: this is too absurd to gain the least credit.

Upon reflecting on this subject, and bearing in mind that the elephant, when enraged, raises his head and presses down his tusks upon his antagonist, it leads to the belief, that one of the uses of the tusks in all these animals, is to clear a

* Tab. XXXVIII. XXXIX.

passage through the thick woods which they inhabit, and to defend the face and eyes from injury.

In the elephant, boar, and sus Æthiopicus, this is a secondary use; but in the babyroussa, which is a less warlike animal, it is the only one; and my friend Mr. Marsden informs me, that in Sumatra, this animal inhabits the thickest and most uncleared thickets.

The elephant and sus Æthiopicus are not the only animals with teeth of a complex structure, which have this uncommon increase of size at a later period of life: they are met with in the cabyai, which Linnæus has made a species of cavia among the glires; but which certainly should be made a new genus. In this animal the third substance cements the plates composed of ivory and enamel together, as in the elephant; and when the size of the animal is considered, the compound tooth is equally large in proportion to it.

The teeth of the horse, cow, and sheep, are of the same structure,* but differ from those already mentioned, in not being brought forward in succession: in the horse, the teeth which succeed what are called the milk-teeth, are destined to last through the animal's life, and are provided with a mode of growth accordingly. The body of the tooth is in length equal to the depth of the jaw, before it cuts the gum; and as the upper surface wears away, the fangs begin to form, and the tooth consequently rises, in the same manner as the candles in the modern carriage-lamps rise up as they burn, so as always to be at the same level; the tooth is therefore never at its full length. When the body is formed the fangs are wanting; and when a part is worn away, the fangs begin to form;

* Tab. XXXI.

but this is not all: that the whole tooth may be brought above the gum, the fangs that were in the lower part of the jaw are forced up, so as at last to be near the upper part.

In the incisores there is in the middle a portion of the third substance, and round it a plate of enamel, on the outside of which is the ivory; and this is surrounded by a second plate of enamel, and the whole is encased by the third substance; so that in a transverse section, there is an external and internal circle of enamel; but the inner enamel only extends a certain way in the tooth, between one-third and one-half; so that, according to Mr. Tenon, the tooth at ten years of age is worn down to its termination.

In a skull in the Collection, in consequence of the teeth in the lower jaw on one side not opposing those of the upper jaw, the teeth have grown to their full length without being at all worn away; so that they are much longer than those on the opposite side of the mouth; but the portion remaining in the jaw is the same, which was proved by a tooth being drawn to ascertain that fact.

In comparing the teeth of those animals that ruminate, with those of the horse and ass, which live on nearly the same kind of food, the following peculiarities are met with.

The ruminants with horns have molares in both jaws, and incisores only in the lower jaw.

The ruminants without horns have, in addition to these, what may be called fighting teeth, or a substitute for horns: these are tusks in both jaws; intermediate teeth between the molares and tusks; and in the upper jaw two small teeth anterior to the tusks, none of which can be of any use in eating.

The camelopardalis forms an intermediate link in these respects; it has short horns, and no tusks.

The molares in both these genera of ruminants are open in the structure of their crown, which is not horizontal, but oblique, the outer edge in the upper jaw, and the inner in the lower jaw being the most prominent, so as to adapt them to each other.

The lower jaw has less width than the upper, so that the lower molares fall considerably within the upper. When the animal eats, it can only masticate with one side of the mouth at a time, by bringing the lower jaw to that side, so as to make the teeth of both jaws oppose each other; the teeth of that side are applied to the food three or four times, and then those of the opposite side.

This mode of mastication appears to be peculiar to the ruminants, and certainly is very different from the mastication of the horse, whose molares are very compact in the texture of their crowns, and are opposed directly to each other in horizontal planes.

It appears that in the ruminant, the front teeth in the lower jaw are sufficient to nip-off the blade of grass, without having any opposing teeth in the upper; and that in this state the food is conveyed into the stomach, from whence, after remaining a certain time, and being mixed with what has been macerated before, it is brought up again into the mouth; and this peculiar oblique mastication is the best fitted to prepare it, when reduced to this soft state, for the future processes connected with digestion.

As the teeth encased in enamel are fitted, as has been shewn, to the duration of the animal's life, so also are these compound teeth; and from the difference in the durability of the teeth alone, the period of the animal's natural life may be determined.

The teeth of the deer and sheep are worn down in a much less time than fifteen years; those of horned cattle in twenty years; those of the horse in forty or fifty years; while those of the elephant last a century: and if the animal was to grow to double its present size, there is a provision for the continuance of the teeth; but as soon as the growth of the jaw is stopped, the succession of the teeth is arrested also; which fixes the duration of the animal's life.

Man can exist after his teeth are worn out, since his food can be prepared by art, so as not to require mastication; but all animals in a natural state must die as soon as they are unable to prepare their food; and in this respect the ruminants labour under the greatest disadvantage; for as soon as the fore teeth, which are only in the lower jaw, are gone, they are unable to crop the grass from the ground, and therefore are deprived of subsistence.

Having gone through this Series of the stomachs of quadrupeds, and explained the kind of teeth peculiar to the animals to which these different stomachs belong, it is not necessary for me to dwell upon the correspondence, which is so evident between the stomachs and the teeth, adapting them to the particular kinds of food on which it was intended that the animals should live; nor minutely to explain to this audience, the variety of substances the same stomach can digest, which is a provision in nature for the support of life in whatever situation the animal may be occasionally placed.

In the stomach, we see to what perfection the powers of nature bring the principle of enabling an animal to draw the greatest quantity of nutriment from any particular kind of food in the shortest time; in the teeth, we see the extent to which the general principle is carried, of feeding animals under the most unfavourable circumstances which admit of animals being supported.

In illustration of these two principles I shall give the ruminating stomach, which is capable of drawing sufficient nourishment from common grass, the most indigestible substance upon which animals feed; not only for support, but to produce fat. The horse, and other animals not furnished with the same means of preparing grass for digestion, can live upon it, but do not receive an equal degree of nutriment: it is therefore fair to conclude, that grass is the natural food of the ruminating animal, for the digestion of which its stomach is peculiarly adapted, and in which that process is performed in the most efficient and œconomical manner; and that no animal whose stomach has not the same peculiarities, can be intended to live entirely upon grass.

This is one of the nicest distinctions between the different kinds of food that animals are intended to feed upon, and could only be discovered by a knowledge of Comparative Anatomy; since the bullock and the horse, to the common observer, must appear equally fitted by nature to graze.

On the other hand, when we find the bullock, under circumstances in which it is cut off from its natural food, living upon fish, we see as wide a range of diet as can be possibly imagined; and there is no doubt that in Shetland, and many parts of Holland, the horned cattle live entirely upon fish during a part of the winter season.

I shall here conclude this Lecture, which is the last of the present Course. At some future time I hope to be able to renew them, and shew the structure of the stomachs of cetaceous animals, birds, lizards, fishes, and those animals which hold a still lower place in the order of created beings.

SECOND COURSE OF LECTURES,

DELIVERED IN THE

THEATRE OF THE ROYAL COLLEGE OF SURGEONS,

IN THE SPRING, 1813.

LECTURE I.

On the passing of Fluids from the cardiac Portion of the Stomach into the Circulation of the Blood.

In resuming these Lectures on the Preparations illustrative of Comparative Anatomy contained in this Museum, I feel more forcibly at every step of my progress, my own inadequacy to the undertaking, and the great indulgence which I must necessarily require from my Audience: I wish it, however, to be understood, that this does not arise from any exertions having been wanting, or pains having been spared; but from my being engaged in a profession, the necessary acquirements in which are attended with so much difficulty, and the duties of which deprive me of that portion of leisure which should be given to the pursuits of Comparative Anatomy, by the person who fills this office: for in this situation, nothing is to be taken for granted, or given upon the authority of others. These ought not to be Lectures of compilation; they should consist of an exposition of facts, of which the knowledge has been derived from actual observation, and the application of them to the improvement of our knowledge in the animal economy.

This, at least, is the plan which I have laid down for myself; I shall explain to you the preparations that are contained in the Collection, and lay before you the results of Mr.

Hunter's labours, and sometimes of my own, upon the subjects connected with them. Had that great man lived to complete his collection, and to leave behind him a descriptive catalogue of the preparations, the task would have been less difficult; but the imperfect state in which he left the records of his knowledge, places me under great disadvantages, and makes it necessary, in very many instances, that I should examine the parts in the recent subject, before I am able to make use of the materials contained in the Museum.

The various structures employed for the progressive motion of animals have been explained in a former Course, in which I also demonstrated many of the varieties in the digestive organs of that part of the class mammalia, which live upon the surface of the earth, and which are commonly called quadrupeds.

I then mentioned, that a portion of the liquids received by the mouth were employed in the process of digestion, and that the rest were conveyed by secret channels from the cardiac portion of the stomach into the circulation of the blood. I shall now lay before you additional proofs, that such fluids do not pass into the thoracic duct, which at that time I had not sufficiently established: in doing so, allow me to trespass upon your time, by tracing this investigation through its whole course, and stating the first opinions which I entertained, and which, although in themselves erroneous, led me to a further inquiry.

Here I may be allowed to remark, that the first step towards improvement in physiology, is generally attained by obtaining a new view of the subject under investigation, which serves to disengage the mind from the commonly received opinions respecting it, giving rise to a new train of reasoning, out of which the discovery is ultimately produced; so that, even where the first view has been in itself incorrect, and is afterwards abandoned, it must still be admitted to have been the first link of the chain that led to the discovery.

Theories, in the hands of men who only consider them as heads of inquiry, and examine into them experimentally with industry and judgment, lead to the advancement of science; but when they are taken up by those who apply to them no other test than the suggestions of their own imaginations, they must be productive of error and deception, and unfit the persons who adopt them for the acquirement of real knowledge.

These observations are thrown out, in vindication of myself, whom, it will be found, a false theory had misled: they are also intended for the instruction of the younger part of my audience, who may not have had opportunities of being initiated in philosophical inquiries.

During my investigation of the functions of the stomach, it was found, that while digestion is going on, there is a separation between the cardiac and pyloric portions, either by means of a permanent or muscular contraction. This fact placed the process of digestion in a new light; and led me to consider, in what way the quantities of different liquors, which are so often taken into the stomach, can be prevented from being mixed with the half digested food, and interfering with the formation of chyle.

Pursuing this inquiry, I found that the fluids are principally contained in the cardiac portion, and that the food which has reached the pyloric portion is usually of one uniform consistence, so that the fluids, beyond what are necessary for digestion, would appear to be carried out of the stomach, without ever reaching so far as the pylorus.

The lymphatic vessels of the stomach are numerous, but they are equally, or more so, in the other viscera. Many circumstances appeared to render it probable, that the spleen is the route by which liquids are conveyed. The more I considered the subject, the more reasons in favour of this opinion crowded on my mind, and made me set about devising various methods by which its truth or falsehood might be established.

The first point to be decided was, whether the liquids, received into the stomach, do escape in any considerable quantity, when prevented from passing out at the pylorus.

This was ascertained by the following experiment, made October 31, 1807, with the assistance of Mr. Brodie, Mr. W. Brande, and Mr. Clift.

The pylorus of a small dog was secured by a ligature, and a few minutes afterwards five ounces by measure of an infusion of indigo in water, of the temperature of the atmosphere, were injected by the mouth into the stomach.

At the end of half an hour the dog became sick, and brought up by vomiting two ounces of a nearly colourless fluid. The dog was immediately killed, and the different parts were examined. The pylorus was found completely secured by the ligature, so that nothing could pass in that direction. The pyloric portion of the stomach was found empty, and contracted; the cardiac portion contained about two ounces of solid contents enveloped in a gelatinous substance, and one ounce of water with little or no colour; the indigo being completely separated from it, and spread over the surface of the internal membrane.

Of the five ounces of water thrown into the stomach two were brought up by vomiting, and one only remained; two ounces had therefore escaped in the course of half an hour. As the stomach contained two ounces of solid food at the time the experiment was made, it is reasonable to suppose that there was also some liquid in it, and in this case, the whole quantity that escaped must have exceeded two ounces. On examining the external covering of the stomach and along the course of the vasa brevia, where the absorbents usually pass, none were discovered, so that these vessels were not at that time carrying any liquid.

The spleen was unusually large, and its external surface very irregular: when cut into, the cells were very turgid and distinct. This circumstance led me to believe that the fluid from the stomach passed through the spleen.

This theory I put to the test of experiment.

Nov. 8th, 1807. Seven ounces of a strong decoction of madder were injected into the stomach of a dog, immediately after the pylorus had been secured. At this time the dog voided some urine which was limpid and colourless. In forty-two minutes, two ounces of a yellowish fluid were brought up by vomiting; in eighteen minutes more, the dog vomited again; what came up proved to consist of three ounces and a half of solid matter, and three ounces of liquid. In fifteen minutes afterwards, five ounces of the decoction were injected, which remained quietly on the stomach for two hours and a quarter, at the end of which period the dog was killed.

In the act of dying he made water, in the quantity of two ounces, of a dark muddy colour. This was saved and afterwards compared with the remaining liquid in the stomach, which it exactly resembled. On examining the connections between the stomach and spleen, none of the absorbent vessels were apparent more than in the former experiment. The pyloric portion of the stomach contained about two ounces of half-digested food, but no liquid. The cardiac portion contained four ounces of liquid and half an ounce of solid food, so that the act of vomiting, which appeared, at the time, a sufficient exertion to have completely emptied the stomach, had brought up no part of the contents of the pyloric portion, and had not even completely emptied the cardiac portion. In this experiment, without making allowance for any liquid in the stomach, prior to the decoction of madder being injected, one fourth part of the quantity thrown in had escaped.

Although there was every reason to believe that the colouring matter of the madder had been conveyed into the urinary bladder, yet so muddy and indistinct was the colour that it was by no means completely ascertained; I therefore resolved, in my future experiments, to make use of some colouring substance, the presence of which could be detected in a very diluted state, by means of a chemical test; and I requested Mr. W. Brande, of whose assistance I had before availed myself, to point out the substances best fitted for this purpose. He immediately suggested that rhubarb was a substance which he had made use of, as a test to ascertain the presence of alkali, and therefore had no doubt that the caustic alkali would prove a test of rhubarb. This substance has also another advantage; it is well known to pass very readily by the kidneys without being decomposed.

The following are the results of experiments made with rhubarb to ascertain the best modes of detecting it in the urine and blood, and the time which it takes to pass from the stomach to the urinary bladder.

Five drops of tincture of rhubarb, added to three ounces of water, are found to strike an orange tint when the test is added, which does not take place when the rhubarb is more diluted.

Six drops of tincture of rhubarb, added to three ounces of serum, are readily detected by the eye, but the colour is not heightened by applying the test; the alkali contained in the serum being sufficient to strike as bright a tint, as that quantity of rhubarb can receive from the addition of alkali.

When tincture of rhubarb is mixed with blood just taken from the arm, its colouring matter is afterwards found both in the serum and in the coagulum.

When blood is drawn from the arm of a person who has taken rhubarb in sufficient quantity to affect the urine, the serum is found to have a slight tinge from it, equal to that, which one drop of tincture of rhubarb gives to half an ounce of serum when added to it.

Half an ounce of tincture of rhubarb, diluted in an ounce and half of water, taken in the interval between meals, did not pass off by urine in less than an hour; and even then, was not in sufficient quantity to be discovered, till the test was applied.

The same quantity was taken immediately before a breakfast, consisting of tea; and in seventeen minutes half an ounce of urine was voided, which, when tested, had a light tinge; in thirty minutes another half ounce was made, in which the tinge was stronger; and in forty-one minutes a third half ounce was made, in which it was very deep. In an hour and ten minutes seven ounces were voided, in which the tinge of rhubarb was very weak; and in two hours twelve ounces were voided, in which it was hardly perceptible.

In six hours and a half, the rhubarb acted on the bowels and gave a decided tinge to the fæces; the urine made at the same time had a much stronger tinge than what was voided at one hour and ten minutes.

In this experiment the rhubarb appeared to have escaped from the cardiac portion of the stomach, and in two hours ceased to pass through that channel; but was afterwards carried into the system from the intestines, and again appeared in the urine.

This experiment was repeated on another person; the rhubarb was detected in the urine in twenty minutes; in two hours the tinge became very faint; in five hours it was scarcely perceptible; in seven hours the rhubarb acted on the bowels; and the urine made after that period, became again as highly tinged as at first.

It was suggested by a chemical friend, that the prussiate of potash might be a better substance than rhubarb, for the present experiments, since the solution of a quarter of a grain in two ounces of water becomes of a blue colour on the addition of the acidulous muriate of iron.

To determine this point, one quarter of a grain was dissolved in two ounces of serum, but no blue colour was produced by the addition of the test, nor did this effect take place till the quantity of prussiate was increased to a grain; so that minute quantities of the prussiate of potash, or at least of the prussic acid, may exist in the blood, without being detected by adding solution of iron. When we consider that so large a proportion as a grain to every two ounces of blood is necessary to enable us to detect the prussiate of potash, and that the prussiate goes off by the secretions as fast as it is received into the blood, it will be seen that it must be difficult in a living animal to throw into the circulation the necessary quantity for this purpose. Any further experiments with the prussiate of potash were therefore abandoned.

The effects of rhubarb on the urine and the different parts of the blood having been thus ascertained, a third experiment was made, in which that substance was employed.

On November 17th, 1807, at thirty-five minutes past eleven o'clock, five drachms of a mixture of tincture of rhubarb and water, in the proportion of a drachm to an ounce, were injected into the stomach of a dog, whose pylorus had been secured. At twenty minutes past one, two ounces of fluid were brought up by vomiting: ten minutes afterwards another ounce of the mixture was injected, as were nine drachms more at half past four o'clock. The two last portions were retained, and at eight o'clock in the evening the dog was killed.

On examining the parts after death, the pylorus was found to be completely secured; the stomach contained about two ounces of fluid; none of the absorbent vessels passing from its great curvature were in a distended state, so as to be rendered visible. The spleen was turgid as in the former experiment, and the urinary bladder full of urine.

This urine, tested by the alkali, received a deeper tinge of rhubarb than the human urine, after rhubarb had been taken three hours by the mouth, and in other respects resembled it.

When the spleen was cut into, the cells were found particularly large and distinct. A portion of it was then macerated in two drachms of water for ten minutes, in a glass phial. All the parts were exposed to the water, by its being divided in all directions. The water thus impregnated was strained, and tested by the alkali, and immediately the reddish brown colour was produced in the centre, and no where else, but in less than a minute it began to diffuse itself, and extended over the whole.

A similar portion of the liver was treated in the same way, and the alkali was added to the strained liquor, which was very bloody, and no change could be perceived.

In this experiment the rhubarb was detected in the juices of the spleen, as well as in the urine; and as there was not the same evidence of it in the liver, it was concluded that it had not arrived there.

This experiment was repeated with similar results, affording evidence of fluids getting readily into the circulation when the pylorus is rendered impervious; at that time the spleen is unusually large, and its cells turgid, which is not the case at other times; and an infusion of the spleen is distinctly tinged with rhubarb, which an infusion of the liver is not.

There was, however, no positive, although there was presumptive evidence, of fluids passing from the stomach to the spleen; and under this impression I laid the matter before the Royal Society. I felt, however, that further investigation was necessary; and lost no opportunity of devising new experiments to elucidate this subject. The circumstance of Mr. Brodie, the assistant of my philosophical, as well as professional labours, having tied the thoracic duct in some experiments, since laid before the Royal Society, suggested to me the idea, that if experiments were made after the thoracic duct was tied, there could be no difficulty in ascertaining whether there was any other channel between the stomach and the circulation of the blood.

With this view I instituted the following experiment, which was made on the 29th of September, 1810.

A ligature was passed round the thoracic duct of a rabbit, just before it enters at the junction between the left jugular and subclavian veins: an ounce of strong infusion of rhubarb was then injected into the stomach.

In three quarters of an hour some urine was voided, in which rhubarb was distinctly detected by the addition of potash. An hour and a quarter after the injection of the rhubarb the animal was killed: a drachm and half of urine was found in the bladder, highly tinged with rhubarb, and the usual alteration of colour took place on the addition of potash.

The coats of the thoracic duct had given way opposite the middle dorsal vertebra, and nearly an ounce of chyle was found effused into the cavity of the thorax, besides a considerable quantity in the cellular membrane of the posterior mediastinum.

Above the ruptured part the thoracic duct was entire, much distended with chyle; and on tracing it upwards, the termination of the duct in the vein was found to be completely secured by the ligature. The lacteal and lymphatic vessels had given way in several parts of the abdomen, and chyle and lymph were extravasated underneath the peritonæum.

The experiment was repeated upon a dog. After the thoracic duct had been secured, two ounces of strong infusion of rhubarb were injected into the stomach, and in an hour the dog was killed. The urine in the bladder, on the addition of potash, became deeply tinged with rhubarb; the bile in the gall bladder by a similar test, was found to contain rhubarb. The lacteal vessels in several parts of the mesentery had burst, and chyle was extravasated into the cellular membrane; the thoracic duct had given way in the lower part of the posterior mediastinum, and chyle was extravasated. Above the ruptured part the thoracic duct was much distended with chyle; it was readily traced to the ligature, by which it was completely secured.

These experiments appeared to establish the fact, that the thoracic duct was not the channel through which the infusion of rhubarb was conveyed to the circulation of the blood; and it now became easy to ascertain, whether it passed through the spleen, by extirpating that organ, and repeating the last experiment.

The thoracic duct near its termination, was secured in a dog, whose spleen had been removed four days before, and three ounces of infusion of rhubarb were injected into the stomach; in an hour and a half the dog was killed, and the urine was found strongly impregnated with rhubarb; and on examination, the thoracic duct was found to be completely secured by the ligature. Several of the lacteals had burst, but the duct itself had not given way; it was greatly distended with chyle and lymph.

By this experiment it was completely ascertained, that the spleen is not the channel through which the infusion of rhubarb is conveyed into the circulation of the blood, as I had been led to believe; and therefore the rhubarb detected in the spleen in my former experiments, must have been deposited there in the same manner as in the urine, and in the bile.

The detection of this error made me more anxious to avoid being misled respecting the thoracic duct; and, therefore, although there was little probability that the infusion of rhubarb could have passed into the lymphatic vessels which open into the blood vessels of the right side of the neck, I thought it right, before I proceeded further, to repeat the experiment, securing the termination of the thoracic duct on the left side, and the lymphatic trunk of the right side where it empties itself into the angle between the right jugular and subclavian vein.

The thoracic duct of a dog was tied, as in the former experiment; in doing it the duct was wounded, and about a dram of chyle flowed out; the lymphatic trunk of the right side was then secured. After this, three ounces of infusion of rhubarb were injected into the stomach, and in an hour the dog was killed. The urine and the bile in the gall-bladder were found distinctly impregnated with rhubarb. On opening the thorax, some absorbent vessels, distended with lymph, were seen on the right side of the spine, entering an absorbent gland on the second dorsal vertebra, and the vasa efferentia from the gland were seen uniting with other absorbent vessels, and extending towards the right shoulder, where they formed a common trunk with the absorbents from the neck and axilla: this trunk was found included in the ligature. The thoracic duct was moderately distended with a mixture of chyle and lymph. In tracing it upwards an opening was seen in it, immediately below the ligature, through which the contents readily passed out, when pressure was made on the duct: above this opening, the duct was completely secured by the ligature.

Nearly a dram of the fluid contained in the thoracic duct was collected, and tested by potash, but there did not appear to be any impregnation of rhubarb.

The last experiment was repeated on another dog. The animal was killed an hour after the thoracic duct and lymphatic trunk had been secured, and the infusion of rhubarb had been injected into the stomach.

In tying the right lymphatic trunk, a lymphatic vessel from the thorax going to join it was wounded, from which chyle flowed out in considerable quantity during the whole time of the experiment; a short time before the dog was killed some of it was collected, but on testing it with potash no rhubarb was detected in it.

The urine was found impregnated with rhubarb, as was also the bile from the gall bladder; but both in a less degree than in the last experiment. The lacteal vessels and mesenteric glands were much distended with chyle; and on cutting into the glands, chyle flowed out in considerable quantity. Some of this was collected and tested with potash, but shewed no evidence of rhubarb being contained in it. The thoracic duct was much distended; it was traced to the ligature, and was found to be completely secured.

Lymphatic vessels from the right side of the posterior mediastinum were seen extending towards the ligature that had been tied on that side; they were nearly empty; and the trunk formed by the junction of these with the lymphatic vessels from the right axilla, and from the right side of the neck, was seen distinctly included in the ligature.

While Mr. Brodie was tracing the thoracic duct, Mr. W. Brande was making an infusion of the spleen, and shewed me a section of it, in which the cells were larger and more distinct than I had ever seen them in a dog. There was a slight tinge of rhubarb in the infusion from the spleen. A similar infusion was made of the liver; but the quantity of blood contained in it being much greater than in the spleen, the appearance was not sufficiently distinct to decide whether it contained rhubarb or not.

These experiments appear completely to establish the fact, that the rhubarb did not pass through the thoracic duct, and therefore must have got into the circulation of the blood by some other channel. They likewise completely overturn the opinion, which I had adopted, of the spleen being the medium by which the rhubarb had been conveyed, and shew that the spleen answers some other purposes in the animal economy.

The rhubarb found in the spleen does not arrive there before it enters the circulation; it is therefore most probably afterwards deposited in the cells in the form of a secretion.

That the fluid contained in the cells of the spleen is secreted there, is rendered highly probable, since it is most abundant while the digestive organs are employed, and scarcely at all met with when the animal has been some time without food.

The great objection to this opinion is, there being no excretory duct but the lymphatic vessels of the spleen; these, however, are both larger and more numerous than in any other organ: they are found in the ass to form one common trunk, which opens into a large gland on the side of the thoracic duct just above the receptalum chyli; and when the quicksilver is made to pass through the branches of this gland, there is a trunk equally large on the opposite side, which makes an angle, and then terminates in the thoracic duct. This fact I ascertained at the Veterinary College, assisted by the Deputy Professor Mr. Sewell, and Mr. Clift.

These lymphatic vessels are equally large as the excretory ducts of any other glands, and therefore sufficient to carry off the secretion formed in the cells of the spleen; and where a secretion is to be carried into the thoracic duct, it would be a deviation from the general plan of the animal economy, were any but lymphatic vessels employed for that purpose.

The facts which have been brought forward do not form a sufficient body of evidence to render the investigation complete, since the road by which fluids are conveyed into the circulation, and the particular blood-vessels which receive them, have not been made out: that link is still wanting, and this remains to be cleared up by the labours of some future physiologist, and will form a very important discovery.

The opinion, that fluids do pass out of the cardiac portion of the stomach, and are conveyed into the circulation of the blood, receives such support from the facts which have been adduced, that it cannot be controverted; and the knowledge of this being the case, explains many circumstances that take place during the process of digestion, which I endeavoured to point out in a former Lecture. As these are of considerable importance, it became necessary fully to establish the facts on which my opinions respecting them were founded; and as I had been led into an error with respect to the functions of the spleen, and that error stands upon record in the Philosophical Transactions, I felt myself particularly called upon on this occasion to expose the mistake which I had committed; explain the manner in which I had been led into it, and detail the experiments by which it had been detected; and in so doing, offer some vindication, that I had not rashly adopted an erroneous opinion, nor when I had adopted it, pertinaciously adhered to it.

As the road between the stomach and the circulation is not ascertained, it may be an advantage to collect all the collateral evidence we can upon the subject, as the best mode I can devise to lead to the discovery.

That fluids absorbed from the stomach do not pass by the thoracic duct, is not to be explained upon the idea of this route being a circuitous one, for the rapidity with which liquids pass along the lymphatic vessels and the thoracic duct is so great, that even in that way they would very soon arrive at the circulating blood; but it is probable that such a torrent, as it would occasionally be, might too much dilute or otherwise disturb the mixture of the chyle, and either decompose it, or render it unfit for becoming the nutriment of the body. The same objection will in some respect apply to the fluid being received into any branch of the arterial system, whose office is to keep up the growth and repairs of the body. Were it poured into the vena-cava, or any of its branches, the blood returned to the heart and to be acted upon by the lungs would be, by such dilution, making an unnecessary increase of quantity of blood to receive the influence of the atmospheric air. No objection of this kind applies to its being carried into the splenic vein, since the blood is carried into the liver and employed there before it is received into the general circulation. It is indeed not improbable that such liquids may form a necessary component part of the bile, and allow of that secretion being carried on at a less expence to the circulating blood than it otherwise could be.

The blood in the splenic vein has always been considered as more limpid than in the aorta and vena-cava, and the following experiments tend to show that the rhubarb contained in the liquids that were carried out of the stomach was much more distinctly detected in that vein than in the vena-cava.

The ass is made use of to teach the veterinary pupils the anatomy of that tribe of animals, and I applied to the Professor for permission to make my experiments in the Theatre of the Veterinary College on this animal.

This was granted me in the most obliging manner; the subjects were also supplied by the College; and Mr. Sewell, the Assistant Professor, gave me his personal aid with a degree of zeal and ability I have rarely met with, and have much pleasure in acknowledging.

An ass, which had been kept twenty-four hours without hay, to prevent the liquor that was to be poured into its stomach from being soaked up and retained there, had a drench given it in the evening, consisting of half a pint of the spirituous tincture of rhubarb diluted in half a pint of water.

On the following morning this was repeated at eight o'clock, and again at twelve. At two o'clock the animal was pithed, so as to destroy its sensibility, and before the circulation was intirely stopped, six ounces of blood were taken from the splenic vein into a graduated glass measure, and a similar quantity was taken from the left auricle of the heart into a vessel of the same kind; these were allowed to coagulate and separate their serum.

The spleen was large and turgid; upon making sections of it, the cells were found to be very numerous; and towards the great end and near the edge they were particularly distinct to the naked eye. The cut surface had a strong smell of rhubarb, and when it was applied to white paper wetted with the alkaline test, an orange tinge was produced. This was strongly contrasted by a stain made in the same manner with a section of the liver, which had no such tinge.

Infusions were made of the spleen and liver under similar circumstances; these were strained off into separate glasses, and tested by the alkali. The urine was tested in the same way. The serum from the different portions of blood was also poured off into separate glass vessels, to which the test was added. In nineteen hours after the blood had been taken from the veins they were all compared together. The urine had so deep a tinge, that it nearly resembled the pure tincture of rhubarb in appearance; the others had a tinge, although in very different degrees; the quantity of rhubarb they contained was estimated by adding tincture of rhubarb to alkaline water, so as to produce corresponding tints.

The infusion of spleen had a tint equal to that of sixty drops of tincture of rhubarb in two ounces of alkaline water: the serum of the splenic vein to fifteen drops; the serum from the left auricle of the heart to three drops in the same quantity. The infusion of the liver gave no orange tinge; but had it not been obscured by the red particles of the blood, it must have been equal to that of the serum from the auricle.

The last experiment was repeated upon another ass with similar results, but less strongly marked; the cause of this difference was explained by the abdominal viscera being in an inflamed state.

The urine was less impregnated with rhubarb; the infusion of the spleen had a lighter tinge, and the serum of the splenic vein had it in a still less degree; but evidently exceeding that of the serum from the vena cava inferior, opened just below the diaphragm, which was substituted for the left auricle of the heart, with a view to vary the experiment.

The same experiment was made on a third ass with similar results.

Having been informed by Mr. Sewell that spirituous liquors given in large quantities to horses produce inflammation of the brain, and sometimes death; and this information having been in some measure confirmed by an ass in a sickly state, that had taken half a pint of the spirituous tincture of rhubarb in the evening, dying in the night, I thought it right to make a comparative experiment with the infusion of rhubarb, to determine whether the result would be the same as with the tincture.

An ass had a pint of infusion of rhubarb given to it in the evening; the same dose was repeated at six o'clock the next morning, and again at nine o'clock, and at twelve. At two o'clock the animal was pithed, and two ounces of blood were taken from the splenic vein, two from the vein of the colon, and two from the inferior cava, in the lower part of the loins.

The spleen was found turgid, and large: when the cut surface was rubbed on white paper, the orange tint was very evident without any test being applied to it; particularly so, when compared with a similar stain made by a section of the liver, in which there was no such tinge.

In the stomach and duodenum the rhubarb was found in large quantities; but none was met with in the cœcum.

The urine was impregnated with rhubarb, the orange tint upon the application of the alkali being very distinct.

At the end of twenty hours, the serum of the blood and the urine corresponded exactly with that of the tincture in the former experiments, but was in a less degree of intensity.

From these experiments it is evident, that the rhubarb passes from the circulation into the fluid contained in the cells of the spleen, and the urine; and in those made upon the dog, into the bile in the gall-bladder. The ass having no gall-bladder, the effects on the bile could not be observed in these experiments: it appears also, that the rhubarb is detected in the serum of the blood, but decidedly giving a brighter tint to the serum in the splenic vein than in any other. The rhubarb not being detected in the liver, arose from its being concealed by the red globules.

In the course of these experiments an attempt was made to ascertain whether the blood in the splenic vein has a greater proportion of serum than in the other veins of the body, and the general results were in favour of such an opinion; but it will appear from what follows, that the quantity of serum separated in twenty-four hours, is by no means a just criterion of the proportion which the blood contains.

Three ounces of blood from the arm of a healthy person were received into a graduated glass vessel, previously cooled to the temperature of 32°; three more into a second glass of the temperature of 50°; and three more into a third at 70°. The three glasses were brought into a room, the temperature of which varied from 40° to 50°. At the end of nineteen hours, the serum was found in the following quantities.

In the glass at	32°	9 drachms.
	50°	11
	70°	10

The blood did not flow so freely into the glass at the highest temperature, as in the other two.

This experiment was repeated, and the serum examined at the end of forty-three hours.

In the glass at	32°	12 drachms.
	50°	12
	70°	13

It was repeated, and the serum examined at the end of sixty-seven hours.

In the glass at	32°	11 drachms.
	50°	$11\frac{1}{2}$
	70	$11\frac{1}{2}$

It was repeated, and the serum measured at the end of ninety hours.

In the glass at	32°	$11\frac{1}{2}$ drachms.
	50°	13
	70°	$10\frac{1}{2}$

The blood did not flow so readily into the glass at the highest temperature, as into the other two.

From these experiments, it appears that the serum separates in larger quantity, when the blood is received into a vessel at the temperature of 70 degrees, than at 50°, or 32°; this, however, is prevented from taking place, by the blood not flowing readily from the vein.

If the conclusions drawn from these experiments are to be depended upon, they go a great way to prove that the fluids are received into some of the branches of the splenic vein;

and certainly none is more conveniently situated for that purpose in all animals; and if this is the case, there is no wonder that the channel has not been discovered, since the vasa brevia surround the cardiac extremity of the stomach; and any communication between them and that cavity must be with great difficulty detected, if that ever can happen.

If the fluids take this course, it will account for many circumstances in the formation of the bile, as well as in the diseases of the liver.

The power which the stomach possesses, of throwing off fluids from its cardiac extremity, is not indiscriminately employed simply as a waste-pipe, to regulate the quantity which is to be mixed with the food while the process of digestion is going on, but seems to depend upon the nature of the fluids themselves; water, essential oils, and the colouring matter of many vegetables, we find are readily carried off; but alcohol would appear not to be so readily received through these channels; at least in many experiments made upon the human urine, voided by persons who had been making large potations of wine, none was detected. This may be explained upon the principle of alcohol being an improper ingredient in the circulation, and hurtful to the animal œconomy; also from its being a salutary ingredient in the food, promoting digestion; when taken in small quantities, which in many stomachs is the case. In some particular kinds of food, as fish of various descriptions, the presence of alcohol is necessary to enable the stomach to retain them.

When the quantity of alcohol is too great, it gives a false appetite or craving, increasing the powers of digestion to an unnatural degree; but if the quantity exceeds certain limits, digestion stops altogether, and the food, after lying in the stomach for ten or twelve hours, is rejected without having undergone any change.

These facts, which only require being mentioned, prove that the alcohol is carried along with the food into the pyloric portion of the stomach.

Alkalies pass off readily from the cardiac extremity; so much so indeed, that their efficacy in medicine, under certain circumstances, is much diminished.

Acids, on the contrary, appear to pass less readily in that direction. Neutral salts are found to go very freely both ways, and according to circumstances which are too slight to be detected, even in the same stomach, go almost wholly by the one or the other.

The consideration of these circumstances may, in time, enable us to improve upon the practice of medicine, by pointing out to us the best mode of making combinations and decompositions in the cardiac portion of the stomach, a subject we are at present little acquainted with: at least the attempts which I have made are favourable to such an opinion.

The soda-water, which has been in general use not only in the metropolis, but almost throughout England, with a view to prevent the formation of gravel, is found to be incapable of producing that effect, since uric acid is equally abundant in the urine of those who drink it, even while it is passing off by the kidneys, as at other times: this arises from the fixed air saturating the alkali, and rendering it incapable of preventing the formation of uric acid; while on the other hand, the alkalies uncombined with fixed air, are found to produce that effect: so that in this instance, the most generally received practice proves to be fallacious.

The soda, when given alone, passes off so readily by the kidneys, that to render it an efficacious medicine against gravel, it should be mixed with every thing we eat or drink. To arrive at such a medicine, we must have recourse to substances of similar efficacy that remain a longer time in the stomach. Magnesia being insoluble in water, is not carried off from the cardiac portion of the stomach; and as it is only acted on by acids, will unite with those that are met with either in the cardiac or pyloric portions, and furnish the means of preventing the formation of uric acid, and of destroying it when formed, more effectually than any other medicine now in use. This is not only true in theory, but as far as our experience has gone, has proved to be so in practice.

With these observations, which are brought forward to prove the utility of our researches, and to call your attention to them not only as a branch of philosophy, but of a science in which the dearest interests of mankind are concerned, since it tends to relieve and remove, as well as prevent, many of the maladies to which human nature is liable, I shall finish this subject.

LECTURE II.

On the Stomachs and Teeth of the Whale Tribe.

On the Stomachs.

After having described the structure of the stomach and of the teeth in the various animals of the class mammalia, that live upon the surface of the earth, I shall now proceed to the different tribes of the same class, that inhabit the ocean.

This series is composed of few genera of animals; but the peculiarities in the structure of their stomachs are such, as entitle them to be considered separately from the others. It consists of the seal, morse, manati, and the different species of whale. Their stomachs vary very much from one another; so that the range is nearly as extensive as that met with in quadrupeds: the principle, however, upon which they are formed, is not exactly the same as in the latter.

In the whales, the more complex structure is given to the stomach to prevent the escape of the food before the process of digestion is completed, and not to adapt it to the degree of preparation the substances may require, before they are fitted to undergo that process.

In this tribe the stomach is made up of several distinct cavities, communicating by small orifices with one another; so that the food must be reduced to a jelly before it can enter the second cavity; and thence it passes slowly through the others till it arrives at the last, in which the process of digestion is completed.

The contemplation of the stomach in the whale, and a comparison between it and that of the ruminant, first led me to attempt an investigation of the process of digestion ; a subject which had always before appeared to me to be involved in too much difficulty to hold out any encouragement for such an undertaking.

If, therefore, my labours in this department of Comparative Anatomy have in the smallest degree elucidated this important enquiry, it has arisen entirely from my having seen in a recent state the stomach of this tribe of animals.

Upon this, and upon every other proper occasion in these Lectures, I am desirous of stating the advantages of Comparative Anatomy : indeed I feel it to be one of the duties of the Professor who fills this Chair, to set the study in the most favourable light ; a duty which I have every disposition to perform.

I am anxious to invite and encourage such of the younger part of my audience as are born with independent minds, and are blest with habits of application, who are led on by ambition, and do not mean to confine our profession within the limits of a trade, but pursue it as a science ; to cultivate the study of Comparative Anatomy, a pursuit which has hitherto been so much neglected, that even the small advances which I have made in it, have raised me to this Chair.

I have been led aside from my subject to make these observations by an enthusiasm which, I trust, is laudable ; since without it, my exertions would have been less vigorous, and I should have proved even less equal than I now am, to the duties of my office.

THE seal and the morse bear so close a resemblance in their general appearance and habits, that they must be considered nearly allied to each other, and their stomachs to have the same structure.

The œsophagus is large, but becomes wider towards the stomach, the cardiac portion of which appears to be a continuation of it, having the same direction, only dilated a little on the lower curvature. The pyloric portion bends upon the cardiac at an acute angle, making the division between the two portions very distinct. The pyloric portion is about half the length of the cardiac, and much less in diameter. The internal membrane of the stomach is plicated, the folds having a longitudinal direction; but at the angle which the stomach makes between the cardiac and pyloric portions, the plicæ are wanting.

This structure of stomach is evidently adapted for digesting animal food, and there can be no doubt that the seal lives upon fish; and if we may judge from the form of the teeth of the morse, and the degree in which they are generally worn, this animal must be accustomed to feed on the species of sea-worms contained in the harder kinds of shells.

It is even in these days a vulgar error, that the seal comes ashore to graze; and this error has been confirmed, from its having been gravely mentioned as a fact in Anson's Voyage.

In the account of that Voyage, the sea-lions (the great seals), are said to divide their time equally between the land and the sea; continuing at sea all the summer, and coming on shore at the setting in of winter, where they reside during the whole season; and that they feed on the grass and verdure which grows near the banks of the fresh water streams." *

The same thing is believed of the walrus. This has probably had its origin in the following circumstance, which was communicated to me by Sir Joseph Banks. The walrus, like the seal, goes ashore to sleep; and instead of choosing flat ground for that purpose, takes advantage of its long tusks in pulling his body up upon the cliffs; and as those animals herd together, the first that gets upon the rock is pushed on by the one behind to take its place; and so on in succession, till the foremost is goaded to the top of the cliff, and even still further, so that there is a line of them down to the sea. The men who are employed in killing them go to the sea-shore, and attack the hindmost, so as to drive the whole string as far as possible from the water; and having done so, they begin destroying them; upon which the animals come tumbling down the cliffs, and crush every thing that impedes their course.

This is the mode of procuring their tusks in the Madeline Isles, in the Gulph of St. Lawrence, to which they resort in great numbers at particular seasons of the year. Mr. Londt mentions, that on the sea coast near the Ferroe Islands, two walrusses were seen hanging fast to a rock by their tusks.

The nearest approach to the walrus, is an animal found in the Indian Seas, with short tusks just appearing through the gums. It has no hind feet, and the tail is flat, like a beaver.

There is another species of this animal met with in the great rivers on the Spanish Main, opposite to Jamaica, which has

* Anson's Voyage, 4to. edition, p. 123.

no appearance of tusks: it is called by the Negroes, manati; a name which I shall give to both species.

The stomach of the manati has a small process from the cardiac portion, like that in the hog; the pyloric portion is bent upon the cardiac, and there are two lateral cavities. These last, as well as the process near the cardia, communicate by small orifices with the general cavity.

This bears a very near resemblance to the stomach of the hippopotamus; and the teeth, which are all molares, resemble those of the hippopotamus also. The different species of manati appear, therefore, to be intermediate links between the hippopotamus and walrus.

The stomachs of the manati and hippopotamus bear a close resemblance to each other in structure, and are in many respects similar to that of the pecari, which is a variation from the hog's, to which the tapir is also allied; and these circumstances throw no small light upon the preparatory processes required for the digestion of the different kinds of vegetable food. The grass of the field we know is the food of ruminating animals, and from the description which has been given of their digestive organs, it is evident that much previous preparation is necessary to fit it for digestion. The grass and weeds at the bottom and on the banks of rivers is the food of the manati and hippopotamus, and the apparatus formed for preparing these substances forms an approach to the stomachs in ruminants.

In the hog tribe the resemblance is less, those animals having a more indiscriminate diet; the structure of their stomachs shews clearly that common grass is by no means their natural food. The stomachs, then, of the manati and hippopotamus, which at first sight appear so extraordinary and incomprehensible, are in fact the links which unite the ruminants to those animals which feed on roots and various vegetable substances ; and form a key, without which, the different gradations cannot be satisfactorily explained.

The stomachs of the whale tribe are all formed upon one general principle, and are very complex in their structure: the substances on which they feed vary very much in consistence : they are, however, all animal ; indeed vegetable diet is not within the reach of the inhabitants of the Great Ocean, and their digestive organs are not fitted for such food. The larger whales, whose bulk is so enormous, contrary to what could be expected, live upon animals of a very small size ; the different medusæ, cuttle-fish, and shrimps appear to constitute the principal food of the whalebone-whale, and of many others. A large whalebone-whale when killed, had nothing in its stomach but shrimps half an inch long, semitransparent and of a pale red colour. These could only have been met with at the bottom of the ocean.

The porpoise, and the other smaller species, live on fish of a more solid texture, and devour their own kind; and the similarity of their stomachs to those of the large whales, shews that they are also capable of digesting fish of every description, as well as the flesh of quadrupeds, since there is no material difference in texture or taste between a steak taken from a whale, and from a bullock, except a certain degree of rankness of flavour.

It has been already shewn, that the processes necessary for digesting animal food, of whatever description, require less variety of structure in the stomach, than might at first be imagined; all that is wanted is the proper secretions, which are thrown out by organs, many of them too minute for the eye of the physiologist to investigate, and not to be examined by the hand of the anatomist. What principally comes within the reach of our observation, is the grosser mechanism for bruising, agitating, and mixing the different substances together. Although this is the case in quadrupeds, we shall find, that in birds, the glands employed in the digestion of animal substances are more conspicuous, and admit of an anatomical examination.

The mechanical means employed in the whale's stomach, are, however, not wholly of this description; for although there is certainly a muscular action employed in the first cavity of considerable power, and even in the others the coats are strong, yet the principal peculiarity, as I have already noticed, is the mechanism to retain the contents in the different cavities till the requisite processes have been gone through; the looseness of their texture being commonly such as to make this precaution necessary, and which in the food of quadrupeds in general is not required. In the first cavity, when the food has been swallowed whole, were it not retained there, the bones would be allowed to pass on to the others, without having undergone any change, and the most mischievous effects would be produced. The communication between this first reservoir and the second cavity is so small, that no part of the food can pass till it is reduced to a kind of pulp.

I shall first describe the stomach of the porpoise, and then mention the varieties met with in the other kinds of whale.*

In the bottle-nose porpoise the œsophagus is very wide, has a number of longitudinal folds, and is lined with a strong white

* Tab. XL. XLI.

cuticle which is continued over the internal surface of the first cavity.

The first cavity lies in the direction of the œsophagus, which is continued into it, there being no contraction to mark its origin. It is of an oval form, and bears a resemblance in shape to a Florence flask. The animal, which I examined, was about eleven feet long. The first cavity of the stomach is fifteen inches in length and nine in diameter; the internal surface has a very corrugated appearance, and its cuticular covering is thick and strong. The coats are firm, and its depending part is surrounded by a strong muscular covering.

The orifice which leads to the second cavity is at right angles to it, and is situated a little way below the termination of the œsophagus. It is surrounded by several semi-circular doublings of the internal membrane; the broadest of these is on the lower part; these are thick, and appear to be glandular.

There is a canal between the first and second cavity three inches long, which opens into the second by an orifice with a projecting margin, and the cuticular covering of the first cavity terminates immediately beyond this orifice, which is two inches and a half in diameter.

This second cavity is nearly spherical, about seven inches in diameter. Its internal surface has a honey-combed appearance, formed by soft ridges of a glandular structure, leaving interstices of some depth between them. This structure gives the coats a considerable degree of thickness.

The opening into the third cavity is almost close to that which enters the second, and is only five-eighths of an inch in diameter.

The third cavity is nearly spherical, and is two inches in diameter. Its internal surface is smooth, and there are every where small orifices of ducts of glands opening into it. The aperture, which communicates between this and the fourth, is three-eighths of an inch in diameter.

The fourth cavity is nearly cylindrical, like an intestine, but rather widest at its furthest extremity. It is fourteen inches and an half long; its greatest diameter is three inches. The internal membrane is smooth, and for three inches towards its origin, and four inches towards its termination, has numerous orifices through which secretions are poured into it. The pylorus, which is the boundary of this cavity, is a round orifice a quarter of an inch in diameter.

Immediately beyond the pylorus there is a dilatation of the gut, which must be considered as duodenum, since the common duct of the liver and pancreas open into it, the longitudinal valvulæ conniventes have their origin in it, and there is no transverse constriction any where beyond it, to mark the beginning of an intestine. Such an enlargement of the duodenum is very common in other animals, and has been described in the account of the camel. The coats of this portion of the duodenum are thicker than those of the fourth cavity. The engraving will give a better idea of these different parts than can be conveyed by any verbal description.

The number of cavities constituting the stomach are not the same in all animals of the whale tribe. In the common porpoise, grampus, and piked whale, the number is the same as in the bottle-nose porpoise; but in the bottle-nose whale of Dale there are two more cavities. This variation is however by no means material, since the general structure of the stomach is the same.

In all of the whale tribe there is one cavity lined with a cuticle, as in the bullock and camel. In all of them there is a second cavity made up of a very glandular structure. In the porpoise, grampus, and large bottle-nose whale, this structure resembles that which is above described. In the piked whale the rugæ are longitudinal and deep, but in some places united by cross bands; and as the piked whale has whalebone teeth, it is probable, from the analogy of the teeth, that the great whalebone whale resembles it in the structure of its stomach.

The third cavity in all of them is very small, and bears a resemblance to the third cavity in the camel's stomach; its use, therefore, is probably the same.

The fourth cavity in all of them has a smooth internal surface, with the orifices of glands opening into it. In the bottle-nose whale of Dale, the two additional cavities have the same internal structure, and therefore must have the same general use, with a greater extension of surface; and the subdivisions will make the food pass more slowly into the intestine.

The first cavity of the stomach of the whale is not only a reservoir, but the food undergoes a considerable change in it. The flesh of its prey is entirely separated from the bones, which proves that the secretion from the glandular part has a solvent power. This was found to be the case in the bottle-nose porpoise and large bottle-nose whale. In both of them several handfuls of bones were found in the first cavity, without the smallest remains of the fish to which they belonged. In others the earth had been absorbed, so that only the soft parts remained; and indeed it is only those that can be conveyed into the second and third cavities, the orifices being too small to admit the bones to pass. The bones must therefore be reduced to a jelly in the first cavity; and although the process by which this is effected is slower than that which separates the flesh, which is the reason of bones being found in such quantity, the means are probably the same.

The second cavity was supposed by Mr. Hunter to be the digesting stomach, in which the food becomes chyle; and the use of the third and fourth cavities he looked upon as not exactly ascertained.*

Upon what ground Mr. Hunter was led to draw this conclusion cannot now be ascertained; and such is my respect for his opinion, that nothing but the following observations, supported by facts, could have led me to form a different one. In considering this subject, it struck me that the second cavity could not be that in which chyle is formed, since that process having been completed, any other cavities would be superfluous. The last cavity in all stomachs, is that in which the process must be brought to perfection; and therefore the most essential change which the food undergoes, or that by which it is formed into chyle, should be performed in that cavity.

Surveying the different cavities in the whale's and ruminants' stomachs with this impression on my mind, and comparing them with the stomachs of carnivorous animals, it appeared that the first point which required to be ascertained was, which of the cavities in these more complex stomachs bears the greatest resemblance to the simple one. The fourth

* Vide Observations on the Structure and Œconomy of Whales, by John Hunter. Phil. Trans. Vol. LXXXVII. p. 411.

of the whale is certainly more like the human stomach than the second or third; I therefore concluded that the fourth, both from analogy and situation, is that in which the process is completed: and that in this animal, from the peculiarities of its œconomy and the nature of the food, not only a cuticular cavity is necessary, but also two glandular, in which the food it may undergo changes preparatory to its being converted into chyle.

The fish-bones swallowed by the whale tribe being retained in the cuticular bag till they are reduced to jelly, explains the circumstance of cows, and other ruminating animals, being able occasionally to live on fish; a fact which has been mentioned in a former Lecture.

On the Teeth of the Whale Tribe.

THE teeth of the seal resemble those of carnivorous quadrupeds, so that the incisores and cuspidati are not to be distinguished from them. The molares are flat, with a cutting edge like those of the lion-tribe, but upon a much smaller scale; and those of the under jaw have their points passing between their antagonists in the upper; so that when the mouth is shut, the whole space is occupied. They are all encased with enamel.

The teeth of the walrus are all anterior to the roots of the tusks, and therefore correspond with the incisores of other animals. They are eight in number, and conical in their form; they are wholly composed of ivory without any covering of enamel, as well as the tusks: they are generally much worn, and the upper surface is rendered more or less concave. They appear particularly well adapted for breaking shells; and the tusks, from their direction, are fitted to dislodge the shell-fish from the sand or mud, so as to enable the animal to get them into its mouth. They also serve as holders in climbing the rocks, as has been mentioned.

The manati of the East Indies is very different from the walrus. The grinders are six in number, on each side of each jaw; they are a good deal similar to those of the hog, increasing in size posteriorly, and the hindmost has three projections: they are covered with enamel. In some species there are no tusks; but there is no doubt that others have them, although such species have not come under my observation.

The manati of the West Indies has no appearance of tusks or incisores: the molares resemble those of the tapir. They do not increase in size in the posterior part of the jaw, as in the hog; the last being of the same form as that which is before it.

In the whale tribe there is great variety in the number of the teeth. The porpoise and grampus have them in both jaws: in the spermaceti-whale they are only in the lower jaw; and in the large bottle-nose-whale, described by Dale, in his Antiquities of Harwich, there are only two small teeth in the anterior part of the lower jaw.

In those whales which have teeth in both jaws, the number in each varies considerably. The small bottle-nose whale had forty-six in the upper, and fifty in the lower jaw; and in the jaws of others there are only five or six in each.

The nar-whale differs from all the rest of the tribe, in having no teeth either in the upper or lower jaw; only two tusks in the front of the mouth.

These tusks in the male are commonly only met with on the left side, so that there appears to be only one; and a very intelligent captain in the Greenland fishery, who has gone thirty-five voyages, never saw a nar-whale with two tusks but once, and then from the mast-head. The left appeared to be two-thirds longer than the right, and was above five feet out of the water; the point of the right appearing just above the surface; so that the small one must have been about three feet.

Nar-whales with two tusks are, therefore, rarely met with; but I shall shew a specimen of the male nar-whale, in which the left tusk is seven feet nine inches, the milk-tusk on the right side, which had not yet appeared, nine inches long, the point being six inches from the front of the skull; and in which, therefore, it is evident, that in process of time two permanent tusks would have been in use, only of very different lengths. The milk-tusks in the nar-whale are to be distinguished from the permanent tusks, by being solid throughout their whole length; whereas the others have a cavity of considerable extent. In the elephant, the milk-tusk is full grown when about two inches long. In the nar-whale it appears not to be full grown till about nine inches long in the male, and eight in the female. The tusk in the nar-whale differs from that in the elephant, by never becoming solid, except at its point and at its base. Through the rest of its length there is a middle cavity of considerable size, very similar to that of a bamboo. By this means it is much lighter, and the formation of it is less expensive to the animal œconomy.

In the female the tusks appear so much later than in the male, that they are generally believed to have no tusks at all; and yet there is a very well authenticated record of the skull of a female nar-whale having been brought to Hamburgh in the year 1684, by Dick Peterson, with two tusks; the left, seven feet five inches, the right, seven feet long. This is referred to by many writers on the subject; and is, I believe, the only instance upon record. This fact, so contrary to common observation, has involved the subject in much obscurity; but the female skull in the Collection enables me to clear up the difficulty; to support the veracity of Peterson; and to vindicate the observation made by the Greenland voyager.

This female skull which I have compared with that of the male, above described, in which the sutures are not nearly so much closed, is four feet long; and the milk-tusk will prove, that the female, although older, had not yet shewn any external appearance of tusks whatever, although it had two milk-tusks embedded in the bone, both of the length of eight inches; therefore equally ready to come forward, and which would be necessarily followed by permanent tusks of equal length, as Peterson found them; but female nar-whales of that age, it would seem, are rarely met with.

The nar-whale ought no longer to retain the present Linnæan name, *monodon monoceros*, since in all of them there are two tusks; in the male, the one precedes the other, and is early in its appearance; in the female, two come together, but at a more advanced age; and in both, the permanent tusks are preceded by milk-tusks.

The lower jaw has a smooth surface, and evidently has no place for teeth to spring from at any age.*

The teeth in the whale tribe are not divisible into different classes, as in quadrupeds; nor are they, like those of land

* Tab. XLII.

animals, fixed to any depth, in bony sockets, but are all pointed, and are commonly a good deal alike. Each tooth is a double cone; one point being fastened in the gum, the other projecting. They are, however, not all exactly of this shape.

In some species of porpoise the fang is flattened, and thin at its extremity. In the spermaceti-whale, the body of the tooth is a little curved towards the back part of the mouth. This is also the case in some others.

The teeth are composed of ivory, without any covering of enamel. The upper teeth are commonly worn down upon the inside, the lower on the outside; this arises from the upper jaw being in general the largest.

The situation of the teeth when first formed, and their progress afterwards, as far as I have been able to observe, is very different from those of the quadruped. In the quadruped, the teeth are formed in the jaw, surrounded by the alveoli, or sockets, and rise up as they increase in length; the alveoli afterwards rise with the teeth, inclosing the whole fang: but in this tribe the teeth appear to form in the gum, upon the edge of the jaw, and the alveoli rise to enclose them, increasing the deph of the jaw, and making the teeth appear to sink deeper and deeper into it.

This formation is readily discovered in jaws not full-grown; for as the jaw lengthens, new teeth are formed, similar to what happens in other animals; and in tracing the sockets backwards, they are seen becoming shallower and shallower, and at last there is only a slight depression.

It would appear that whales do not shed their teeth, nor have they new teeth formed similar to the old. It would appear that the jaw, as it increases posteriorly, decays at the symphysis; and thus while the growth is going on, there is a constant succession of new teeth, by which means the new-formed teeth are proportioned to the jaw, as in the elephant.

The depth of the alveoli seems to prove this, being shallow at the back part of the jaw, and becoming deeper towards the middle, where they are the deepest, the teeth there having come to their full size. From this forwards, they are again becoming shallower, the teeth being smaller, the sockets wasting, and at the symphysis there are hardly any sockets at all: hence, it appears, that the exact number of teeth in any species is uncertain.

Some genera of this tribe have another mode of catching their food, and retaining it till swallowed, by means of the substance called whalebone. Of this there are two kinds known; one very large, probably from the largest whale yet discovered, the great balæna mysticetus; the other from a smaller species, the piked-whale.

The whalebone, which is placed on the inside of the mouth, and attached to the upper jaw, is one of the most singular circumstances belonging to this species, as they have most other parts in common with quadrupeds. It is a substance, I believe, peculiar to the whale, partaking of the nature both of horn and hair.

Whalebone consists of thin plates of some breadth, and in some, of very considerable length; their breadth and length, in some degree, corresponding to one another, and the longest are commonly the broadest, but not always.

These plates are very different in size in different parts of the same mouth, more especially in the large whalebone-whale, whose upper jaw makes an arch, the semidiameter of which is about one fourth of the length of the jaw.

The skull in the Museum is nineteen feet long, the semidiameter not quite five feet: if this proportion be preserved, those whales which have whalebone fifteen feet long must be of an immense size. In a whale sixty feet long, the head is one third the bulk of the whale.

These plates are placed in several rows, encompassing the outer skirts of the upper jaw, similar to teeth in other animals. They stand parallel to each other, having one edge towards the circumference of the mouth, the other towards the centre, or cavity.

They are placed near together in the piked-whale, not being a quarter of an inch asunder, where at the greatest distance, yet differing in this respect in different parts of the same mouth; but in the great whale, the distances are more considerable.

The outer row is composed of the longest plates; and these are in proportion to the different distances between the two jaws, some being fourteen or fifteen feet long, and twelve or fifteen inches broad, but towards the anterior and posterior part of the mouth they are very short: they rise for half a foot or more, nearly of equal breadths, and afterwards shelve off from their inner side until they come near to a point at the outer. The exterior of the inner rows are the longest, corresponding to the termination of the declivity of the outer, and become shorter and shorter till they hardly rise above the gum.

The inner rows are closer than the outer, and rise almost perpendicularly from the gum, being longitudinally straight, and have less of the declivity than the outer. The plates of the outer row laterally are not quite flat, but make a serpentine line, more especially in the piked-whale, the outer edge is thicker than the inner. All round the line made by their outer edge is placed a substance, resembling a small white bead, which is formed along with the whalebone, and wears down with it. The smaller plates are nearly of an equal thickness upon both edges. In all of them is inclosed a kind of hair, which extends beyond the edge of each plate.

The two sides of the mouth composed of these rows meet nearly in a point at the tip of the jaw, and spread or recede laterally from each other as they pass back; and at their posterior ends, in the piked-whale, they make a turn inwards, and come very near each other just before the opening of the œsophagus.

In the piked-whale there were above three hundred plates in the outer rows on each side of the mouth. Each layer terminates in an oblique surface, which obliquity inclines to the roof of the mouth, answering to the gradual diminution of their length; so that the whole surface composed of these terminations forms one plane, rising gradually from the roof of the mouth; from this obliquity of the edge of the outer row we may, in some measure, judge of the extent of the whole base, but not exactly, as it makes a curve, which increases the base.

The whole surface resembles the skin of an animal covered with strong hair, under which the tongue lies. This hair is of a light brown colour in the piked-whale, and is darker in the large whale.

In the piked-whale when the mouth is shut, the projecting whalebone remains intirely on the inside of the lower jaw, the two jaws meeting every where along their surface; but in the large whale the horizontal plane made by the lower jaw being straight as in the piked-whale, and the upper jaw being an arch, it cannot be hid by the lower; and a broad lower lip covers the whole of the outer edges of the exterior rows.

The whalebone is continually wearing down, and is renewed in the same proportion. When the animal is growing, it is renewed faster.

Whalebone is composed of two parts, one of which is a kind of hair, the other corresponding very nearly to the human nails; and these substances are formed under the same circumstances as hair and nails in other situations.

The jaw bone is covered with a dense structure like the cutis; from the surface of this, at regular distances arise vascular pulps, upon which a single row of hairs is formed, and on the intermediate spaces, a soft white substance of the consistence of curd is spread, which terminates in two upright plates of whalebone in contact with the two rows of hair, by which the space is bounded; the white soft substance corresponding with the soft roots of the nails of the human finger, only that each edge gives origin to a plate of whalebone. There is a succession of the layers of the white substance, and a consequent succession of plates till the whalebone acquires the proper thickness, and then the white substance rises no higher; terminating in a line with the outer edge of the jaw, putting on the appearance of a white bead.

In this way the plates are formed on each side of every row of hair; and as the growth of the hair always precedes that of the inclosing plates, it forms a close covering, and retains the smallest substances taken into the mouth, allowing the water to drain off between the plates of the whalebone.*

Upon examining the chemical properties of the plates and hair, they are found to be exactly the same, even when the analysis is conducted with the greatest accuracy, which was done in the present instance by Mr. Brande. They consist of albumen with such slight traces of gelatine as hardly to be perceptible, and phosphate of lime, in the proportion of three and an half per cent. This substance therefore differs from the human hair, which contains from ten to fifteen per cent. of gelatine ; and from the filamentous substance by which the muscles attach themselves to rocks, which contains six per cent. of gelatine.

I had the chemical analysis of the plates and hair made, with a view to determine whether the two different structures on which they are formed, answer any other purpose than giving them the proper shape required; and from their containing the same materials in exactly the same proportions, it is evident they do not.

* The whalebone only grows on the two sides of the upper part of the mouth, leaving a central space very narrow anteriorly, but wider backwards, which is smooth and of a beautifully shining white colour.

LECTURE III.

On the Digestive Organs of Birds.

Having in former Lectures explained the structure of the stomach in the different animals belonging to the class mammalia of Linnæus, among which we find stomachs fitted to digest almost every imaginable kind of food, the subject might appear to be exhausted; this is, however, by no means the case, for we shall find that the animals belonging to other classes, which live upon the same kinds of food as those in the class mammalia, have not the same structure of stomach: so that it is necessary to examine the means employed for digesting food in all the classes of the animal kingdom, before a thorough knowledge of the subject can be obtained, and the use of every part connected with these organs completely made out.

It is only by such extensive views of the organs of animal bodies, that an adequate notion can be formed of them, or just ideas acquired of the animal œconomy.

There is no organ whose functions are more important than those of the stomach, since digestion is carried on in it, a process by means of which dead animal and vegetable matter are rendered fit for the nourishment of the bodies of living animals.

The consideration of this subject will be drawn out to considerable length in these Lectures; and I regret exceedingly, that it is not in my power to explain it still more fully; to establish a greater number of facts, and embody them in a more complete and comprehensive arrangement.

I have, however, the satisfaction of having begun this investigation, by making a more extensive comparison between the stomachs of different animals than has hitherto been made; and the subject appears to me the more important, since the improvement of the practice of medicine must greatly depend on an intimate knowledge of the structure and functions of the stomach.

Let me proceed in this most useful enquiry, and endeavour with the means that are in my power, however inadequate they may be, to lay before you a description of the stomachs of the other classes of animals.

The second class consists wholly of birds, whose food is various in the same extent as that of quadrupeds; since the eagle and all the hawk tribe devour the flesh of living animals equally with the lion and other beasts of prey; nor are there wanting birds that live upon dead animals; upon all the different kinds of fish; upon insects; and upon every species of vegetable substance, even grasses, which I have already stated to be more difficult of digestion than most other vegetable productions.

In birds, the stomach is much smaller in proportion to their size, than it generally is in quadrupeds; this arises from the bodies of birds containing a less quantity of animal matter, the better to fit them for progressive motion, and therefore requiring a less degree of nourishment.

Although there is a great difference between the structure of the stomachs of birds and quadrupeds, nature has formed intermediate links, by means of which they run imperceptibly into one another. These links are the ornithorhynchi; they are not, properly speaking, of the class mammalia, although they are quadrupeds, since they have no breasts for the nourishment of the young; nor can they be classed with birds: but one species partakes more of the quadruped, the other is a nearer approach to the bird.

The ornithorhynchus hystrix belongs to the tribe of ant-eaters, and its stomach is an approach to those of that tribe; and the stomach of the ornithorhynchus paradoxus, is the connecting link between that of the hystrix and the stomach of the bird; it has, at the same time, peculiarities not met with either in quadrupeds or birds.

For these reasons, I have reserved the description of the stomachs of the ornithorhynchi to this place.

The stomach of the hystrix is, in shape, not unlike the human; in the instance which I examined, it was four inches long, and three broad. The internal cavity contained sand, and had a cuticular lining; at the pylorus there is a glandular structure, and a number of pointed horny papillæ, appearing to be excretory ducts. These glands, as no others could be discovered, must be considered to be the gastric glands, although their situation is at the end of the stomach instead of the beginning. This deviation from what is commonly met with in other animals, is less striking in so extaordin ary a production of nature, in which every part has some peculiarity. *

The stomach of the paradoxus has a different form; it is a

* Tab. XLIII.

pouch or lateral dilatation, the œsophagus and duodenum forming a continued canal, which is only partially interrupted where it passes over the orifice; in other respects it is exactly like the stomach of the hystrix.

The stomach of the bird is exactly similar in its form and relative situation as to the œsophagus and duodenum to that of the ornithorhynchus paradoxus, but differs from it in being covered by a digastric muscle, in which it is completely inclosed; the two bellies of the muscle being united together by means of two flat tendons, one on each side.

This structure of muscle forms the characteristic distinction between the muscular coats of the stomachs of quadrupeds, and birds, and is intended by nature to answer every purpose of the muscular coats in quadrupeds, so far as their action is necessary for the purpose of assisting the process of digestion.

It also affords the means of mastication, for which there is no provision in the mouths of birds.

The ornithorhynchus paradoxus having teeth, there is no digastric muscle surrounding the stomach.

The form of the stomach in birds is such as gives the digastric muscle every mechanical advantage in its action.

In those birds in which the digastric muscle is very strong, the stomachs have acquired the name of gizzard, which is derived from the Punic word *Giger.* It is used by Apicius, who wrote upon cookery in the time of Nero, and signifies a small bird brought from Africa, whose stomach was reckoned a delicacy among the Romans.

As the name is now generally received, I shall apply it to all stomachs which have a digastric muscle, and in this way distinguish the stomachs of birds from those of quadrupeds.

There is also another reason, for we shall find, however weak the digastric muscle may be while the bird is living on flesh, that it is rendered stronger when it lives upon grain; and therefore, unless the name be made general, the same organ might be called stomach in one state, and gizzard in another.

To illustrate this in birds of prey, the digastric muscle has the bellies which compose it so weak, that nothing but an accurate examination can determine the existence of such a muscle; the strength being proportioned to the force required. But if a bird of this kind, from want of animal food, is obliged to live on grain, the bellies of this muscle become so large, that they would not be recognized as belonging to the stomach of a bird of prey.

This admirable provision of nature is illustrated by a preparation of the stomach of a sea-gull, which had been kept by Mr. Hunter for a year, living, contrary to its nature, upon grain; the strength acquired by the muscle is very great, when compared with what it was in its natural state while living upon fish, as may be seen by examining the preparation opposed to it.

In birds, the organs of digestion are not, as in quadrupeds, confined wholly to the cavity of the stomach; they include not only that cavity, but the crop in those birds that have one, and in others the lower portion of the œsophagus, which commonly answers the purpose of a crop; also a portion of the duodenum, since all these parts are concerned in the preparation of the food, or perfecting the process of digestion. It will therefore shorten my future descriptions, to make a general division of the different parts of these organs into four: viz. the crop, the cardiac cavity, the gizzard, and the pyloric cavity; in which last is included a portion of the duodenum.

In my account of the organs of digestion in birds, I shall first mention those that are intended by nature for the digestion of animal food, although capable of digesting vegetable substances; and then those that are more particularly fitted for digesting vegetable substances, although capable of making animal matter go through the same process.

In birds of prey, which stand at the head of the first division, the gastric glands have the same relative situation to the gizzard, as they have to the stomach in quadrupeds of the same description; they are much more conspicuous, and are formed upon a larger scale: so that I am enabled to explain many circumstances respecting them, which I could not do in quadrupeds.

They are placed immediately behind the inner membrane of the cavity into which their secretion is conveyed, forming a belt quite round it. The glands are placed at right angles to the membrane, through which there are openings for the excretory ducts; they appear like so many cylinders in contact with one another: each cylinder has a small tube in its centre, open at one end and close at the other, which is bent a little upwards, so as to make a depending orifice. The coats are thick in proportion to the tube, and the internal surface of the tube is villous.

In the golden eagle, the œsophagus is dilated near its termination; and there is a regularly-formed single crop of large dimensions rather on the right side, resting in the hollow of the bone which corresponds to the clavicles in quadrupeds.

Below this, is the cavity into which the ducts of the gastric glands open. These glands form a broad belt, each separate gland being very distinct; at the lower end of the belt there is a second contraction, separating this cavity from that of the gizzard, which is immediately below, of an oval form, swelling out near the pylorus, and about half the size of the crop. It is surrounded by a digastric muscle of weak power, has a soft internal membrane, and on the right side below the middle the duodenum has its origin. At that part there is no enlargement from which the intestine begins.

At the pylorus is a valve, formed by three projections covered with cuticle, two above and a third below, which fits in between them. In the sea eagle the structure of these parts is exactly the same, which might not have been expected, as that bird feeds frequently on fishes.

In the hawk and kite the digestive organs differ from those of the eagle in there being no crop, only a simple dilatation in the lower part of the œsophagus, the gizzard not being dilated near the pylorus, and there being an enlargement at the origin of the duodenum, and the gastric glands being separated by slight interstices into four divisions.

The representation of these parts in the hawk will make them better understood than any verbal description.*

In one species of hawk there was found a globular cavity in the lower part of the œsophagus, formed by two simple contractions in that canal, and a dilatation of the intermediate space. This cavity was full of food; and there is reason to believe that in all the hawks there is a power of forming this part into a crop.

* Tab. XLIV.

In the owl the œsophagus is larger than in the eagle, the gizzard has the same shape, the digastric muscle is weak.

In the vulture there is a crop in the anterior part of the œsophagus, the gizzard has a rounded form, the digastric muscle is stronger than in the owl, and the tendon is circular, and nearly half an inch in diameter.

All those birds that live upon animal food, and have soft membranous linings to their gizzard, readily *cast*, as it is termed, the contents of the gizzard; and although they frequently swallow the bones, hair, and feathers of their prey, always regurgitate them.

The old books on hawking recommend, when it is wished to make a young hawk *cast*, to give it three oats stuck in a piece of flesh, which make it immediately throw every thing off from the stomach, so readily are these parts irritated.

Although animal substance is decidedly the natural food of the eagle and all that tribe, and the gastric glands belonging to the digestive organs of such birds are formed more peculiarly for digesting such food, the provision of Nature for the preservation of animal life under all circumstances is so great, that even the eagle is capable of being nourished by vegetable matter. Mr. Hunter ascertained this by gradually mixing fat with the flesh with which an eagle was fed, and then bread with the fat, till at last the bird ate bread by itself and seemed to thrive very well; but was not perfectly satisfied with this food, for it took the first opportunity of breaking its chain, and flew away.

There are many birds whose food is the flesh of dead animals, grubs, and all kinds of insects, that correspond in the structure of their digestive organs with those of birds of prey, only having the inner membrane of their gizzard defended by a cuticular covering, of different thickness and hardness, according to the kind of insects on which they feed.

The gastric glands are shorter and thinner, and form an uniform belt, not being divided into distinct portions, as in the hawk.

The common crow of this country, which feeds upon carrion and all kinds of grubs, is of this description respecting the gastric glands.

The cavity of the gizzard is of an oval form; there is a thick corrugated cuticular lining, and the digastric muscle nearly of the same strength as in birds of prey.

The crow lives principally upon carrion: it is sagacious in the extreme in discovering a dead carcase, and has discernment enough to know when an animal is likely to die. When one of these crows is seen waiting alone in an unusual place, it is known that a sheep or other animal is sick, and near the crow, being separated from the flock. As the animal becomes worse the crow approaches nearer, and when it seems unable to move from the place where it lies, the crow begins to peck out its eyes. Sheep are often found in this state, although still alive.

The crow feeds, however, occasionally on grain; I have found grain in its gizzard: but it is not the kind of food of which it is most fond. The crow is by many accused of destroying the grass, by pulling it up by the roots. This is an error arising out of the following very curious circumstance. In searching for grubs which are concealed in the earth, and supported by eating the roots of the grass, the crow pulls at the blade of grass with its bill, and when the grass comes up, the bird knows that there are, under it, insects which have destroyed its roots, and in this way detects them; but if the blade of grass is firm, it goes to another part of the ground.

In a field where grubs are very abundant, the crows scatter the grass every where, so as to give the appearance of having rooted it up; while they have only exposed the depredations of the insects, by which the roots had been destroyed.

As the rook lives occasionally upon grain, it was natural to suppose there would be some characteristic distinction between the digestive organs of that bird, and those of the crow, whose food is chiefly animal; but upon the most accurate examination no difference whatever can be detected, except the cuticular lining being thinner. This leads me to conclude that although the rook does eat vegetable substances, the principle upon which the gizzard is formed is such as to fit it more particularly for the digestion of insects. The gizzard of the raven is like that of the crow.

There are many other birds under similar circumstances; they eat and digest vegetable food very readily, but when the choice is given them prefer that of the animal kind; and from the weakness of the digastric muscle, the gizzard is evidently not to be classed with those of the truly granivorous birds.

The bustard is of this kind; its gizzard is not unlike that of the raven. It has a thick cuticular lining, and a weak digastric muscle, but the gastric glands are uncommonly large; so as to have attracted the attention of M. Perrault, who has given an account of their structure, saying that they are conical tubes terminating in a point at one end, and open at the other, and are larger than in any other bird, except the ostrich, whose solvent glands he appears not to have examined. As

I have not had an opportunity of examining these glands in the bustard, I must rest this account of the structure of the glands upon M. Perrault's authority, as stated in the work on Comparative Anatomy, published under the patronage of Louis the XIVth in 1676.

Understanding that the bustard, in India, is a favourite bird for the table, and that all bustards are there considered to be granivorous birds, I was unable to reconcile this circumstance with the structure of its digestive organs; but this difficulty is solved by the following account of the mode of feeding of this bird, which is taken from Mr. Hunter's notes upon this subject, who kept a cock-bustard a whole summer in his garden. It died in November, apparently from the cold of the winter.

He killed mice and sparrows with his bill by pinching their heads, and then swallowed them whole, even when of considerable size. It was easy to observe a large mouse going down his throat making a moving tumour till it came to the turn of the neck: it then moved backwards; and although out of sight, yet its progress was traced by the feathers between the shoulders separating, and closing again as soon as it passed into the gizzard. It was fond of worms, and while the gardener was digging, stood by him and looked out for them. It ate the buds of flowers, and particularly of roses; also the substance of cucumbers, but not the outside. From these observations the bustard is evidently fitted more particularly to live on animal food.

The male bustard in some particular species which I have examined, has a long bag which hangs down on the anterior part of the œsophagus as low as the middle of the neck, communicating with the mouth by an opening under the tongue, which appears to have a sphincter muscle. This bag was not met with in the young bustard, and is unknown to several very intelligent naturalists in Bengal, where the bustard is common, and of several different species.

The ardea argala of Linnæus, commonly called the adjutant, a very ravenous bird, and also an inhabitant of Bengal, has a similar bag, which is common to the male and female. I have had an opportunity of examining it in the living bird; and there is no doubt of its containing nothing but air, which the bird has a power of expelling, and filling the bag again at pleasure. This makes an alliance between the bustard and adjutant, both having so uncommon a peculiarity; and their mode of life is less unlike than is in general imagined; indeed as little so, as that of the rook and crow.

In the argala, the bag does not communicate with the mouth, but with the large air-cells on the back of the neck. In this bird the œsophagus is very large; the gastric glands are not placed round the cardiac cavity, but form two circular figures, about one inch and a half in diameter on the fore and back part of it.* The gizzard is nearly of the same strength, and has a cuticular lining similar to that of the crow; the orifice at the pylorus is very small.* In all the birds whose digestive organs have been described, the gastric glands have the same situation respecting the gizzard, and the same structure.

In some birds of prey they are arranged in four distinct sets; in others, they form one uniform belt.

I shall now describe the digestive organs of another set of

* Tab. XLV.

birds, that live principally on fish, and in which the gastric glands have a different situation, extending considerably into the cavity of the gizzard.

The pelican is one of the principal birds of this kind. The gastric glands are very numerous, and are placed all round the cavity of the gizzard, extending nearly as low as where the duodenum has its origin: their structure is the same as in birds of prey. In this bird, there is a distinct globular cavity between the gizzard and the duodenum. This is seen in a preparation in the Collection.

The pelecanus bassanus, or soland-goose, has the gastric glands exactly similar to those of the common pelican, and they are distinctly seen in the engraving. The gastric glands form four distinct portions, as in the hawk, but the interstices are not so distinct; the digastric muscle is weak, the form of the cavity is an oval, and the duodenum goes off on the right side, about its middle.*

In both these birds the internal surface of the gizzard is soft and villous, as in birds of prey; and this is the case in all the other birds which I am about to mention, except those in which the contrary will be stated.

In the heron, the gastric glands are in the same situation as in the soland-goose. They do not form a complete belt, nor are they divided into distinct portions; they are more thinly spread, and more numerous on the anterior and posterior surfaces than on the sides. They are much smaller, not having a cylindrical, but a pyramidal form; the orifice is at the small end, which is the most depending. The other parts of the digestive organs resemble those of the soland-goose.

* Tab. XLVI.

There is, however, no globular cavity at the origin of the duodenum.

In the small penguin, the gastric glands have the same situation and form as in the heron, are less numerous, and for a small space on the two sides are entirely wanting. The digastric muscle and the coats of the stomach are so thin and transparent, that when held before the light, the gastric glands are very distinctly seen, like so many studs, all at some distance from one another.

In the cormorant, the gastric glands are situated within the cavity of the gizzard, but do not extend all round; they form two circular portions, one on the anterior, the other on the posterior surface, extending about one-half the length of the cavity; or in other words, from its cardiac orifice to the orifice of the duodenum, which begins by a globular cavity, as in the pelican. The gastric glands are in close contact with one another, forming a compact mass. The gizzard, in other respects, resembles that of the pelican.*

In examining the digestive organs of a cormorant suspected of being poisoned, it was found that the bird had died in consequence of a newt having been put into its mouth with the hind feet foremost, by the person who fed it; the newt spreading its legs, could neither be forced down into the gizzard, nor thrown up by the mouth: the irritated œsophagus became inflamed, and the inflammation extended along the inner membrane of the gizzard, the contents of which were enveloped in a thick mucus: the inner membrane generally was very vascular: but the two circular portions where the gastric glands are situated, were coated over with a thick, and almost

* Tab. XLVII.

solid mucus, which could not be completely removed, so firmly did it adhere. This appearance was so very extraordinary, and the orifices of the gastric glands were so completely choaked with the mucus, that it was difficult to believe the mucus had not been secreted by the gastric glands, and poured out by their excretory ducts. This, however, was ascertained not to be the case, by cutting off the orifices and the membrane through which they open, and finding the ducts themselves entirely empty.

This opportunity accidentally afforded to me shews, that the inner membrane of the gizzard has a power of secreting such mucus; and as a similar mucus is met with in the stomachs of most quadrupeds, when examined recently after death, it may be concluded, that in all such instances there is a portion of the inner membrane, forming the secreting surface from which the mucus is derived, and that is afterwards coagulated, by being mixed with the secretion of the gastric glands. That such power of coagulation belongs to this secretion, and that it is the first stage of the process of digestion, will be more fully explained in a future Lecture.

These circumstances explain a disease to which that bird is liable, and is not uncommon to other birds; this is, having ascarides in the gizzard; and these, as is shewn in a preparation in the Collection, are confined to those particular spots. The worms irritate the membrane, and then feed upon the secretion produced by such irritation.

This is analogous to the disease in sheep called the rot; the flukes in the biliary ducts, which constitute that disease, irritate those ducts, and feed upon the bile which is secreted in increased quantity, in consequence of the disturbed state in which the ducts are constantly kept.

In some of the birds that feed principally on fishes, the gizzard has not the same form as in those which have been mentioned; for instance, the East Indian bittern has a gizzard of the shape of a pear. The Portuguese bittern has one of the shape of the human cœcum; the spoonbill of a circular form, flattened on the sides.

In all these birds which have the gastric glands contained within the gizzard, and spread over a large portion of its surface, the food is swallowed whole, and is either fish, frogs, lizards, or other reptiles of that kind; so that it is probable in such birds, the gastric liquor is required to be applied very generally to the surface of the prey that is swallowed for the purpose of accelerating the process of digestion. This observation is confirmed by Mr. Bullock, who spent some days on the Bass rocks to watch the habits of the Soland-geese, and saw them go and fish for herrings; and often watched a particular bird catch a herring and swallow it, then return to its young, and regurgitate the herring into the mouth of the young; and in that short time the skin of the herring was entirely destroyed.

In some birds that live upon fish and sea-insects, the gizzard has a cuticular lining; and the gastric glands are placed in the same situation respecting it, as in birds of prey. Of this kind is the flamingo; the cuticular lining is thick and hard, the digastric muscle strong. In its cavity were found broken bivalves and stones.

The sea-gull has a similar gizzard,* as is shewn in the

* Tab. XLVIII.

preparation. The gastric glands are divided into different portions. The sea-parrot or diver has its gizzard lined with a transparent horny coat.

This apparatus in the gizzards of such birds, is evidently to enable them to feed upon shell-fish and crustaceous insects, without the hazard of injury to the gizzard. There are birds that live upon land-insects, some of which are soft, others having cuticular coverings, whose digestive organs are composed of the two substances last described. The woodpecker, I shall give as an instance of this. The œsophagus terminates in a large rounded cavity projecting on the left side, four times the size of the œsophagus. On the posterior surface of this cavity there is a triangular space in which the gastric glands are situated; at the upper part, extending over the whole cavity; and below, coming to a point; the surrounding surface being covered with a thin cuticle. Below this, there is a regularly-formed gizzard, with a strong digastric muscle and firm cuticular lining, at the upper part of which the duodenum goes off. The soft insects have the gastric liquor applied to them in the first cavity; those with hard coverings, in the gizzard. There is a dilatation at the opening of the duodenum, as in other birds. The parts are shewn in the engraving. The first cavity in the instance which I examined, was full of ants.*

There is still one more variety in the structure of the digestive organs of birds, that live principally upon animal food, which has come under my observation; and with an account of which I shall conclude the present Lecture.

This bird is the alca alle of Linnæus, the little auk. The termination of the œsophagus is only known by the ending of

* Tab. XLVIII.

the cuticular lining, and the beginning of the gastric glands; for the cardiac cavity is one continued tube, extending considerably lower down in the cavity of the abdomen, and gradually enlarging at the lower part: it then turns up to the right side, about half way to the origin of the cavity, and is there connected to a small gizzard, the digastric muscle of which is strong, and a small portion of the internal surface on each side has a hard cuticular covering.

The gastric glands at the upper part are placed in four distinct longitudinal rows, becoming more and more numerous towards the lower part of the cavity, and extend to the bottom, where it turns up.

The extent of the cavity in which the gastric glands are placed, exceeds any thing met with in the other birds that live upon fish; and the turn which the cavity takes almost directly upwards, and the gizzard being at the highest part instead of the lowest, are peculiarities, as far as I am acquainted, not met with in any other birds of prey.*

This mechanism, which will be better understood by examining the engraving, makes the obstacles to the food in its passage to the intestines unusually great; and enables the bird to digest both fishes and sea-worms with crustaceous shells. It appears to be given for the purpose of œconomising the food in two different ways; one, retaining it longer in the cardiac cavity; the other, supplying that cavity with a greater quantity of gastric liquor than in other birds.

This opinion is further confirmed by the habits of life of this particular species of bird, which spends a portion of the year in the frozen regions of Nova Zembla, where the supplies of nourishment must be both scanty and precarious.

* Tab. XLVIII.

LECTURE IV.

On the Digestive Organs of Birds.

Having in the preceding Lecture explained the digestive organs in birds that feed principally on animal substances, I shall now pursue the same subject in birds that live chiefly on vegetable food.

I have already stated that birds of prey, even the eagle itself, are capable of digesting vegetables; and there are hardly any of those birds which we are about to mention, that do not occasionally eat worms and other small animals. We must not, however, conclude from this, that the digestive organs of the eagle are equally fitted for the digestion of all kinds of food.

The structure of the gastric glands of the eagle, we may safely infer, is the best possible for producing a secretion that can act on animal matter; but we must go to the turkey or the ostrich to determine what is the structure best fitted to secrete a liquor fit for digesting vegetable substances; and if we find, (which is the case,) that in these birds the glands are very different from those in the eagle, we cannot hesitate in concluding that there are at least shades of difference between the secretions; making them more peculiarly fitted for the particular effects which they are intended by nature to produce.

In birds whose food is of a vegetable nature, the digestive organs have in general several characteristic differences from those organs in birds that live on animal food.

The gastric glands have commonly a different structure. There is in general a regular formed crop, which may be considered analogous to the first cavity of the stomach in ruminating quadrupeds, in which the vegetable substances undergo a preparation, fitting them for being more readily acted on by the gastric liquor, and where there is no crop, the lower part of the œsophagus is dilated so as to form a reservoir; but in such birds we must suppose that the same degree of preparation cannot be required, as where there is a regular crop.

In most birds with this formation of the digestive organs, the opening from the gizzard into the duodenum has no valve or other mechanism to prevent a portion of the contents of the cavity of the gizzard, when it is full, from escaping into the intestine without being digested, in this way occasioning considerable waste of the food; this however will always be in the greatest degree when the bird has the most liberal supply.

Out of this waste such beneficial effects are produced in disseminating plants over a great extent of country, that it is impossible not to consider it as one of the modes adopted by Nature for that purpose.

The following information upon this subject, which is derived from Sir Joseph Banks, is extremely curious and satisfactory. The seeds which pass through the gizzards of birds without having been acted on by the organs of digestion, are not only fit for vegetation, but have the period of their vegetating much accelerated. The haws or berries of white thorn require being buried in the earth for a year before they are fit to be sown; but if turkeys are fed with them in the autumn, and the dung is sown, the plants begin to vegetate in the following spring. So ready are the seeds that have passed through the intestines of a bird to grow, that it is sufficient for them to be enveloped in the dung of the bird without being covered with earth.

At a country house of Sir Joseph Banks's, when the family are from home, the blackbirds are in the habit of perching on the iron rails of a stone staircase leading up to the house, and a currant-tree, a wayfaring-tree, and a yew-tree, grew up from the place where they dropt their dung, and were evidently disseminated by them. The various plants found in our hedges, as the dog-rose, the briars, the bramble, the common and water-elder, and a great variety of other plants have the same origin, particularly cherry-trees.

As the gizzards of birds which live on vegetable food have their internal lining composed of a cuticular structure of different degrees of hardness, the coats are less sensible than in birds of prey; the consequence of which is, that the bird never refuses food even when it is dying, and when none of the functions of digestion are going on. This readiness to peck, gives the bye-standers hopes of recovery, and they go on feeding the bird till it drops down dead; and when examined after death the gizzard is generally quite full. The strong gizzard of the granivorous bird, and the stones contained in it, are substitutes for grinding teeth, and for the strong muscles employed in moving the jaws. As the food is first macerated in the crop, and is then by little and little carried down into the gizzard, there to be triturated, the process of digestion in such birds bears a closer resemblance to that in ruminating animals which chew the cud, than in other quadrupeds.

The structure and motion of the gizzards do not belong to the present subject, any more than the beaks, which correspond to the fore teeth of land animals; we shall therefore take up the consideration of the beaks and the gizzards as a separate subject after the digestive organs.

In describing the digestive organs of the different kinds of birds, I shall begin with those that have the gastric glands nearest in structure to the glands of birds of prey, and so on, as they become more and more complex. I am not prepared to explain what the circumstances are which give one structure of gastric gland an advantage over another; whether it is in forming a gastric liquor of more intensity in the one case, and with a weaker power but more abundant in quantity in the other; although many arguments might be brought in favour of such opinion, were we to speculate on the subject; but this is by no means my intention; it is enough upon the present occasion to state the facts, and such circumstances as I am acquainted with, in any way connected with them.

The pigeon has its gastric glands of a very simple structure. They appear to be small oval bags with large orifices; the coats of the cavity are thinner than in the sea-gull, and the opening is larger, so that the quantity of gastric liquor secreted by each gland in the pigeon is probably the largest. In this bird the crop is double, and so large, that a great quantity of food can be constantly retained there, undergoing a previous preparation before it is triturated in the gizzard, or exposed to the action of the gastric liquor.

The space between the double crop and the gizzard is so long as almost to deserve the name of inferior œsophagus. From the lower part of the crop there are eight double rows of glands passing down in a longitudinal direction, and lost in the surface of the lower œsophagus, distinctly seen in the preparation.

The bellies of the digastric muscle are very thick, the horny lining is strong, and corrugated longitudinally.

In the blue crowned pigeon from the East Indies, there are only two rows of these glands in the œsophagus, and the gizzard has its internal lining furrowed in a longitudinal direction, and more slightly in a transverse one. This lining is thickest at the ends, where covered by the bellies of the muscle.

The natural food of pigeons is pulse of different kinds. It is peculiarly grateful to them, as they can readily throw it up from their crop while feeding their young, and give it them. But it is natural to believe that maceration for a longer or a shorter time, in the crop, may make many different kinds of vegetable substances equally fitted for digestion.

The swan has the gastric glands of a large size; externally they appear to be cylindrical, or nearly so; their length is about equal to three diameters; internally, the tube has the appearance of an irregular broken surface, more caranculated than villous. They lie in contact with one another, nearly in the same manner as in birds of prey.

In this bird there is no crop, but the lower portion of the œsophagus is very large, serving as a reservoir. The cardiac cavity, into which the ducts of the gastric glands open, is more capacious than the œsophagus above: the inner membrane is generally coated with a thick mucus, which appears to be secreted from the surface on which it lies, and the pyloric cavity at the duodenum is large, and distinct from that intestine.

In the goose, the gastric glands are rather more complex than in the swan. Each gland is not a cylinder, but has two or three lateral projections, and the internal tube to which these belong is thus rendered much more capacious; in other respects the digestive organs correspond in structure with those of the swan. The food of the swan is the weeds and grasses which grow on the sides of rivers, and that of the goose is the common grass of the fields; so that the goose is the only true grazing bird met with in this country.

It has been already mentioned, that grass appears more difficult of digestion than any other vegetable substance used for food; and that no preparation hitherto employed has rendered the human stomach capable of converting it into nourishment.

This circumstance makes it a matter of some importance to be acquainted with the structure of the gastric glands employed for its digestion in birds, since they are formed upon too small a scale in ruminating animals to admit of anatomical investigation.

The birds whose gastric glands are next in order of complexity of structure, are the common fowl, the pheasant, and partridge; the structure of their digestive organs corresponding very much with one another.

In the common fowl there is a crop, but only on the right side; the gastric glands have the usual situation, and the ordinary appearance when not particularly examined, but when carefully dissected, each gland is found to consist of a tube, on the sides of which there are three or four small short processes, or sacculi: the internal surface has a pulpy appearance, and the coats are thin.

The food of the common fowl is partly animal and partly vegetable; but different kinds of grain are probably the food which they would choose in preference, were they capable of procuring it.

In the turkey, the orifices which open into the cardiac cavity are fewer in number, and have a greater space between them than in the fowl; the gastric glands themselves have a similar structure, only that the processes are longer and more numerous, being in general six in number: they are not, however, the same exactly in every gland. The cardiac cavity is less capacious than in the swan, the gizzard is very strong, the pyloric cavity is not separate from the duodenum, and is hardly to be distinguished without a minute inspection. Immediately beyond the gizzard, the internal membrane has a number of small villi very closely compacted together, and that part corresponds to the pyloric cavity in other birds.*

This bird, in a wild state, must have a considerable variety of food, consisting chiefly of grain and seeds. It swallows walnuts with great avidity, and readily breaks the shells to pieces in the gizzard.

In the parrot-tribe, which feed principally on seeds and fruits, there is a different formation of the digestive organs. There is a crop on the right side, as in the fowl, but the cardiac portion is unusually large, and the gastric glands are spread over a considerable portion of its surface, but are wanting at the lower part; and immediately below, there is a

* Tab. XLIX.

regularly-formed gizzard of a very diminutive size. In this respect the parrot accords very nearly in its digestive organs to the wood-pecker, among those birds that live upon animal food, having a cavity in which the soft substances may be acted upon by the gastric liquor, and also a gizzard, in which any harder substances may be broken down, and by that means rendered fit to be acted upon by the secretion of the gastric glands. The parts are shewn in the engraving.*

I have, hitherto, only considered the digestive organs of birds that fly; and have noticed all the varieties in their structure that have come to my knowledge. There is a tribe of birds which, from the weight of their bodies, have no power of raising themselves from the ground; and their whole progressive motion consists in walking and running.

There are four different species of birds of this description; two of the cassowary, and two of the ostrich. They differ from each other with respect to their digestive organs; so as to form a regular series of structures connected with digestion: I shall, therefore, describe these organs in each species separately.

In the true cassowary, a native of Java in the East Indies, there is a crop; the œsophagus is unusually large: it dilates into the cardiac cavity, which is a direct continuation of it, and is every where studded over with small gastric glands of a simple structure: these are placed on each side in oblique rows, which terminate in a middle row, extending the whole length of the cavity. The termination is marked on the lower part by the commencement of the cuticular lining, which covers the whole internal surface, being very thin for a little way, as

* Tab. L.

well as upon all the anterior part, becoming thicker and thicker posteriorly, where the cavity of the gizzard is situated.

There is an oblique valvular constriction, formed by muscular fibres, between the cardiac cavity and that of the gizzard; there is also a canal leading directly from the cardiac cavity into the duodenum, the gizzard forming a pouch projecting from the posterior side; so that the food does not necessarily go into the gizzard, but may either do so, or pass on into the duodenum, and this most probably at the will of the bird. The cuticular lining extends a little way below the cavity of the gizzard, and terminates upon the edge of a broad valve, which may be considered as its boundary, separating it from a large oval cavity about four inches long, where the duodenum has its origin, and valvulæ conniventes are met wiih in a transverse direction. This cavity may be considered as an appendage to the stomach.*

In the cassowary from New South Wales, the digestive organs have the same general character as in that from Java, but differ in this particular, that the gastric glands are larger in size, although similar in structure. They are placed in regular transverse rows; the gizzard is thicker, has a stronger cuticular lining, and is rather more in the direct line of receiving the food from the cardiac cavity. The cavity between the transverse valve and the duodenum, in which the valvulæ conniventes are met with, is much smaller in size.†

In the American ostrich, the gastric glands are fewer in number, when compared with its size, than in other birds. They only occupy a small space of a circular form, on the posterior side of the cardiac cavity: the smallness of their number is,

* Tab. LI. † Tab. LII.

however, compensated, by the complexity of their structure. To each gland there is one common orifice; and when the cavity to which it leads is laid open, three smaller orifices are exposed, each of which communicates with five or six processes, not unlike the fingers of a glove. This structure is similar to that of the gastric glands in the beaver among quadrupeds.

The cardiac cavity, into which the gastric glands open, is dilated to a large size, as in the cassowary; and there is a similar oblique muscular valve, by which it is separated from the cavity of the gizzard. The digastric muscle is stronger in its power, and the tendons between the two bellies of the muscle are beautifully distinct. The appearance which they put on is represented in the engraving.*

In the African ostrich the gastric glands are similar in their structure to those of the American, only the processes belonging to each gland are much more numerous; they are, in general, twenty or thereabouts. The cardiac cavity into which they open is not only very large, but is continued down in the abdomen below the liver to a considerable length, and then is bent up to the right side, and is there connected with a gizzard, the digastric muscle of which is as strong as in granivorous birds in general. This gizzard is situated so high up, as to be nearly upon a level with the termination of the œsophagus. The cardiac cavity is every where lined with a thin cuticle, except where the ducts of the gastric glands open. Their orifices occupy an oval space on the left side, extending from the top to the bottom of the cavity, and about four inches broad. The size of the gizzard is small, when compared with that of the bird. The grinding surfaces do

* Tab. LIII. LIV.

not admit of being separated to any great distance from one another. On one side there are two grooves, and two corresponding ridges on the other. Beyond the cavity of the gizzard is an oval aperture with six ridges, covered with cuticle, which oppose the passage of the contents of the cavity till they are reduced to a small size. All these parts are exhibited in the engraving.*

In the cassowaries, and American ostrich, the stones and other hard bodies which those birds swallow must, from their weight, force their way into the gizzard, which has a large cavity adapted to receive them; but in the African ostrich, all such substances must remain in the cardiac cazity, both from its being the most depending part, and from the cavity of the gizzard being too small to admit of their entering it.

The cardiac cavity in the instance which I examined contained stones of various sizes, pieces of iron and halfpence; but between the grinding surfaces of the gizzard, there were only broken glass beads of different colours and hard gravel mixed with food.

All the varieties in the structure of the digestive organs in birds that fly, which have been described in a former, as well as in the present Lectures, whether the birds live on animal or vegetable substances, appear to be adapted to the kind of food and the mode of life; so that from every thing that has been said upon that subject, we should be led to conclude, that these were the principal, if not the only causes of such peculiarities of structure.

In this singular tribe of walking birds, it will be found that one of the varieties which is met with, and which is common

* Tab. LV. LVI.

to them all, appears adapted to their peculiar mode of progressive motion; and the others, of which there are several, are almost entirely independent of the nature of the food or mode of life, which is nearly, if not exactly the same in the whole tribe.

No facts which I have met with in Comparative Anatomy, throw so much light on the real uses of the different parts of the digestive organs, as the series of structures met with in this tribe. We shall find, in the review which I mean to take of them, all the varieties of structure of glands, and nearly all the varieties of structure of gizzard, met with in the whole class of birds; and these entirely for adapting the bird to the supply of provisions which its native soil affords; so that it appears that every one of these structures of glands produces a secretion fitted for the digestion of all the different kinds of food, and that any complexity which is met with in such structures, is only for the purpose of œconomising the food, by preventing so large a portion of it escaping without having gone through this process.

The cassowary of Java, as it lives in the most luxuriant country in the world, has digestive organs adapted to such abundance. The gastric glands are very small, and simple in structure; the gizzard is only for occasional use, and is weak in its muscles. The motion of the animal's body, when walking or running, shakes the stones in the gizzard with so much violence, as to triturate the food without much assistance from the action of the muscles. The oblique valve between the cardiac cavity and gizzard retains the food, and allows the liquor of the gastric glands to mix with it before it enters the gizzard, and probably a great part of it never enters that cavity at all.

The passage from the digestive organs is so free, that the stones swallowed for the use of the gizzard readily pass into the intestines, which is not the case in the others ; and these intestines, we shall find, when we come to that part of the subject, are wider and shorter than in any other bird.

The fact of the stones passing along the intestines I learnt from Sir Joseph Banks, who, while he was visiting the menagerie at the Cape of Good Hope, was much astonished to see a cassowary which was feeding very voraciously on fruits which Sir Joseph gave it, void by the anus a large quantity of stones, some of them of considerable size.

The cassowary of New South Wales, as it lives in a country naturally fertile, but less luxuriant than Java, has its digestive organs formed on the same principle as the other species ; but the gastric glands are larger, the gizzard better situated for common use, and rather stronger in its coats, and the passage from the stomach into the intestine is less open.

The South American ostrich, the native of a less productive soil, has gastric glands of an unusually complex structure, a capacious gizzard, the muscles of which are by no means weak, and the orifice leading from the gizzard very narrow, so that nothing can pass out of it that has not been reduced to a small size.

The African ostrich, an inhabitant of the Desert, where there are very few plants, has means of œconomising its food much beyond the others. The gastric glands are not only more complex, but more numerous ; their secretion is applied to the food in the cardiac cavity, in which it is retained by its gravity ; is triturated by the extraneous hard bodies that are swallowed, and is then forced up into the gizzard to undergo a second trituration.

Nothing in nature can be more beautiful, nothing can shew more conspicuously the dispensing hand of an all-wise Creator, than the means with which these different birds are provided, to enable them to subsist in the best possible manner in the situations upon the globe for which they were destined. The cassowary of Java may devour the stores so lavishly provided for it, without injury to its health, since its means of retaining and digesting its food are so small. The African ostrich, whose provision is so scanty, has large means of œconomising it, that circumstanced as it is, it can procure a subsistence. In this respect it very closely resembles the little auk, among birds that live on animal food, whose digestive organs have been already explained.

In attempts to investigate the process of digestion in quadrupeds, the difficulties which occur are almost insurmountable: the gastric glands are scarcely perceptible, and occupy a small portion of the stomach; every other part of the inner membrane is throwing out secretions of a different kind, and these are all mixed together with the food in the general cavity. Under these circumstances the properties of the secretion of the gastric glands can never be ascertained, since it cannot be procured in a pure state.

It is generally allowed that the first process which the food undergoes in the stomachs of animals of whatever description, is being converted into a jelly; but whether this is produced by the gastric liquor as the previous change to dissolution; or whether it takes place before that liquor is applied, in consequence of the action of other secretions, has not been ascertained.

Mr. Hunter made many experiments upon the coagulating power of the secretions of the stomach, which establish the fact of its existing in the stomachs of animals of very different classes.

The lining of the fourth cavity of the stomach of the calf, is in common use in a dried state, for the purpose of the coagulation of milk; and it is sufficiently proved, that every part of this membrane possesses the same property.

Mr. Hunter found, by experiment, that the mucus contained in the fourth cavity of a slink calf, made into a solution with a small quantity of water, had the power of coagulating milk; but the mucus found in the three first cavities under similar circumstances had no such power.

This mucus, even after it had been kept several days, and was beginning to become putrid, retained the power of producing coagulation.

The duodenum and jejunum, with their contents, had this power: but the coagulation was very slow, and therefore may have been independent of the intestines employed for that purpose.

He found that the inner membrane of the fourth cavity in the calf, when old enough to be killed for veal, had the power of readily coagulating milk.

Portions of the cuticular part, of the massy glandular part, and of the portion near the pylorus of the boar's stomach, being prepared as rennet, it was found that no part had the effect of producing coagulation but that near the pylorus.

After reading the result of this experiment, I referred to the plate I have given of the boar's stomach, and found the gastric glands very conspicuous on the upper part of the cavity near the pylorus.

The crop of a cock and the gizzard were salted and dried, and afterwards steeped in water, the solution was put into milk. The portion of crop coagulated it in two hours, the portion of the gizzard in half an hour.

The contents of a shark's stomach and duodenum coagulated milk immediately. Pieces of the stomach were washed clean and steeped sixteen hours in water, the solution in the water coagulated milk immediately. Pieces of the duodenum produced the same effect. When the milk was heated to 96°, the coagulation took place in half an hour; when the milk was cold, in an hour and a quarter.

The stomach of a salmon made into rennet, coagulated milk in four or five hours.

The stomach of the thornback treated in the same way had a similar effect.

These experiments of Mr. Hunter go far enough to prove the coagulating power of the secretions of the stomachs of quadrupeds after the animals have left off sucking; and of the same power belonging to the stomachs of birds and fishes; but instead of leading to the particular secretions that produce this effect, rather tend to make it a general property of the whole internal membrane.

To carry on this enquiry, my friends Mr. Hatchett and Mr. Brande, fellow labourers in animal chemistry, at my request make the following experiments. Mr. Hatchett took the lining of the cardiac cavity and glands which open into it, of a chicken, and put it into a glass; the hard internal membrane of the gizzard into another; milk was added to these, and was converted into a curd. That in the glass with the cuticular lining was the strongest.

Mr. Brande tried the comparative powers of the glandular portion of the cardiac cavity of the fowl and hawk, and found that of the hawk rather the most powerful.

Taking the results of all the experiments which have been related, it appears that the exact source of the liquor by which the milk is coagulated, has not been determined; but as the same effect is produced by the cuticular lining of the gizzard, and by the mucus in the stomach, it is evident that every part imbued by it, becomes possessed of the same power.

To determine accurately whether the coagulating power is inherent in the gastric glands themselves, I selected those of the turkey, which from their size are better fitted for such an experiment than those of any other bird except the ostrich; a young turkey was kept a day without food, and was then killed, the gastric glands were carefully dissected separately from the lining of the cardiac cavity, cutting off the duct of each before it pierces the membrane, so that no part but the glands themselves were removed. Forty grains by weight of these glands were infused into two ounces of new milk. Similar experiments were made with rennet, with the lining of the cardiac cavity of the turkey, and with the inner membrane of the fourth cavity of the calf's stomach.

The experiment commenced at ten o'clock in the morning. At half past ten the milk with the rennet became thick; at twelve, curd was formed; at two, whey separated; at four, the formation of curds and whey appeared complete.

At half past eleven the milk containing the glands became thick; at one, curd was formed; at three, whey separated; and at six, the formation of curds and whey was complete.

The milk containing the fresh stomach of the calf underwent the same changes in the same periods as that containing the glands.

The milk containing the cardiac membrane of the turkey became thick at four; at eight curd was formed; the separation into curds and whey was not complete till the next morning.

A portion of the same milk used in the experiments in twenty-four hours underwent no change, except that the cream had separated.

The rennet in a dried state had at least four times the quantity of membrane employed in the experiment with the recent calf's stomach, which accounts for its more readily producing coagulation.

From these experiments it is clear that the power of coagulation is in the secretion of the gastric glands, and is communicated to the other parts by their being more or less impregnated with it, and that coagulation is the first change which the food undergoes in the process of digestion.

LECTURE V.

On the Bills and Gizzards of Birds.

As appendages to the stomachs of quadrupeds, the parts by which the food is broken down, and prepared for being received into the stomach, have been already considered. These were the cutting and grinding teeth.

In birds there are no such parts, but a similar purpose is answered by the bills and gizzards; the first performing the office of cutting teeth, the second of the grinders.

The parts themselves are certainly very unlike. The teeth are composed of ivory; the bills, and the linings of the gizzards, of cuticle or horn. So widely do they differ, that it was not easy to imagine how a link could have been contrived that should connect the one with the other; yet this is found to be the case in this as well as in all the other series of structures in animal bodies. To keep up this chain of gradation between the bird and quadruped with respect to their teeth, a genus of animals differing from all others appears to have been formed; this is the ornithorhynchi.

The hystrix has a mouth and a tongue resembling that of the ant-eaters, but differs from them in having near the root of the tongue, upon a space which is broader than the rest, about twenty small teeth composed of an horny substance, projecting about one-tenth of an inch, and blunt at the ends.

On that part of the palate immediately opposite these teeth, there are seven transverse rows of very slender teeth composed of horn also with their points directed backwards, each row looking somewhat like a small-toothed comb laid flat upon the palate.*

In the duck, on the sides of the tongue and on the palate, there are horny papillæ which have a slight resemblance to those which I have just described, and in the flamingo there is a row of short horny teeth on each side of the tongue.

In the ornithorynchus paradoxus there is a mouth regularly formed like that of the quadruped; but projecting beyond it is a bill so like that of a duck, that it might be almost taken for it, but still more like that of the spoonbill, the middle part being composed of bone, and the whole having a very strong cuticular covering.

In the upper mandible of the bill the lip extends for half an inch every where beyond the bony part, and is thick and fleshy; the upper surface is smooth, and where it joins the head there is a circular flap which lies loose upon the hair; the under surface of this portion is also smooth, but has two hard ridges of a horny nature situated longitudinally on each side of the middle line of the bill.

The lower mandible of the bill is much smaller than the upper, and when opposed to it the upper lip extends beyond it for the whole of its breadth. The edges of the lower mandible, have deep lateral transverse serræ in the fleshy part, and immediately within them are grooves placed longitudinally and lined with a horny cuticle to receive the ridges in the upper.

* Tab. LVII.

In the posterior part of the mouth, both in the upper and lower jaw, are placed grinding teeth with broad flattened crowns, four in number, one on each side of each jaw. They are composed of a horny substance, only imbedded in the gum, to which they are connected by an irregular surface in the place of fangs. When cut through, the substance appears fibrous like that of nail; the direction of the fibres being perpendicular to the crown, similar to that of the horny crust of the gizzard. The teeth in the young animal are smaller, and two on each side, so that the first teeth are probably shed, and two small ones replaced by one large one.

Between the cheek and jaw, there is on each side of the mouth a pouch lined with cuticle, as in many other animals. Besides the grinding teeth, there are two small pointed horny teeth upon a prominent part of the root of the tongue, the points directed forward, as if intended to be a guard to the fauces.*

In birds of prey, the beak, as it is termed in them, corresponds not only to the incisor teeth of carnivorous animals, but also to the cuspidati or fangs; since with their beak they tear their prey to pieces. The eagle first plucks away some of the feathers of the bird it is going to devour, so as to lay the skin bare before opening into the body. If the prey is a hare or rabbit, it makes an opening in the side, and gets at once into the entrails.

The beak of the eagle and hawk tribe is very strong and very much curved, terminating in a sharp point which overlaps considerably the lower jaw.

The beaks of all the birds that prey on land animals have

* Tab. LVIII, LIX, LX.

nearly the same form, and the varieties are too few to require being noticed. The butcher-bird, which lives upon other birds, is said to have habits peculiar to itself, such as hanging up the bird upon a stake and then flaying it like a butcher: this is however only an idle story. The beak is longer and less bent than in the hawk, and has a small process on each side near the point, which is also met with in some hawks. It is probable that these processes gave rise to the fable, and in consequence of it, to the name.

In birds that catch fishes by diving, the bill is often of considerable length, the better to secure the prey, and to enable the bird to change the position of the fish in its bill for the purpose of swallowing it. The pelican has in this respect an advantage over all the others, having a sac which answers the purpose of a net, into which the food is received; and I have been informed by Sir Joseph Banks (who amused himself in observing it) of the dexterity with which the bird tossed about the fish in the bag, till it lay in the proper position to be swallowed.

We cannot account for the fabulous histories that are given of this bird; one, that the bag is to carry a supply of water in the desarts: the other, that the point of its bill is made sharp, to wound its breast for the purpose of feeding its young with its blood. They are intirely without foundation; and their not having been completely exploded is a melancholy proof of the small progress that has been made in this branch of natural history.

The bill of the spoonbill is of that form which is nearest allied to the pelican's; after which may be noticed the bill of the soland-goose, which is well fitted for catching fishes.

The bill of the adjutant is also of this description; although the bird feeds upon carrion whenever such food is within its reach, it is curious to see the dexterity with which it manages this long bill, and tosses about in it the smallest substances, even a piece of paper.

The varieties of structure in the bills of birds that dive, is very great; and although many are formed upon the same principle as that of the soland-goose, the bill being pointed and having considerable length, many of them, as the albatross, have a hook at the end of the upper mandible to secure their prey when once it is caught.

In some rare instances, birds of this description have regularly formed teeth, as in the mergus serrator.

There are many birds that live upon the inhabitants of the ocean whose bills do not come within this description. Of this kind are all those birds with short flattened strong beaks, as the alca turda, one of the divers. The bill in this bird does not become broad till the second year, and does not acquire the furrows on the sides till the third. The beak is not unlike that of the parrot, but flattened at the sides, and the bird is thence called the sea-parrot. As the bird has a horny gizzard, there is no doubt of its occasionally living upon sea insects with crustaceous coverings, or mollusca inclosed in shells, like the sea-gull. The little auk has a short thick beak, by which it is fitted to feed upon every different kind of food that comes within its reach, either on shore or at sea.

The procellaria pelagica has a beak of no great length, but slender, and hooked at the point. These birds in general sleep in the day, and go out in search of food at night, more particularly in stormy weather. They do not dive, but pick from the surface of the waves whatever is thrown up; indeed all the procellariæ feed upon dead fishes, and whales when they can procure such food.

The black skimmer has a beak peculiar to itself, the lower mandible being much longer than the upper, and extremely narrow; it feeds upon the surface of the waves, the lower jaw cutting the water like a ploughshare.

Birds that live upon land-insects which are concealed in trees, or in the earth, have bills provided for procuring their natural food. Such is the bill of the woodpeckers, with which that genus of birds is enabled to bore holes in the bark of trees where its instincts acquaint it there are insects concealed; but when an ant-hill is within reach, it supplies itself with food in a more summary manner, and at a much easier rate.

In birds that feed upon vegetable substances, the bills are equally adapted for the purposes for which they are by nature intended. The different kinds of toucan, of which the species are very numerous, offer to us a structure of bill evidently fitted for feeding upon the softest fruits, and some of these are of considerable size, as plantains, bananas, gourds, water-melons, granadillas, and fruits of this description. The beaks are long, large and pointed, but so delicate and light that the birds can employ no great force with them.

The beaks of the buceros or hornbill are of another kind; in them there is the appearance of a helmet of the same light delicate structure, so that it might almost become a question whether it is to be considered as an ornament, or is to answer any useful purpose. I have no doubt of its being a defence for the eyes of this bird against the prickly leaves or branches by which the fruits are surrounded, on which they are destined to feed.

And such are the varieties met with in nature, that in no two species have these helmets the same form, or the bills themselves the same appearance, as if it were intended to shew the different ways in which the same purpose can be answered; and afford a lesson to reasoning man when he studies nature, how much instruction he may receive from the examination of the most simple contrivances with which the birds of the air are provided, to enable them to reap the fruits on which they feed with the least harm to themselves. The abagumba or buceros abyssinicus has a crest of a more imperfect kind; this bird, I learn from Mr. Salt, is met with in the ploughed fields, and probably feeds on the large bulbous roots which are abundant in that country.

There are birds with helmets composed of a solid cuticular substance covering a dense bony structure, but the habits of such birds we are not acquainted with. Specimens of such helmets are in the collection, but no one I have met with has ever seen the bird. Sir Joseph Banks has a faint recollection of having seen it figured on Chinese paper.

In quadrupeds the upper jaw is a part of the skull, and immoveable; this is not the case with the bony part of the beaks and bills of birds: the projecting bone which forms the beak or bill does not, as in the quadruped, form any part of the skull itself; and we find that even in the eagle there is a slight degree of motion in the upper mandible; there is no absolute joint, but a part at the root of the beak is thin and elastic, so as to admit of some motion, and the parts are so formed, that in the act of opening the beak, the upper mandible is moved upwards. This is the case in most birds, as in the crow, adjutant, soland-goose, swan, and common goose.

In the parrot tribe the joint between the upper mandible and the skull is the most remarkable: I have therefore thought this the most proper to select, as furnishing an example of the general mechanism.

The beak of the parrot is very strong and much curved; the natural food of this bird is seeds and nuts of different kinds, and the upper mandible in the act of opening the mouth is forced upwards, and is then pulled down with considerable force. In this way two advantages are gained; the one, that the bill opens to a greater extent; the other, that it lays hold with a greater degree of firmness than it would do, if only one mandible moved and the other were kept fast. The mechanism by which this is effected is very beautiful. In all birds which have this motion of the upper mandible, there is a chain of elastic bones connecting it to the skull, which do not exist in the quadruped; and the lower mandible is not articulated to the skull itself, but to the last of these bones which projects from the basis of the skull, on which it moves with more or less freedom. When the lower mandible is pulled down, this bone is thrown forward and pushes up the moveable upper mandible, by means of two slender bones on each side which are interposed between them, one connected to the palate bone, the other to the side of the mandible, corresponding in situation to the zygoma in the quadruped. All these bones are connected by joints, so that in the whole a great deal of motion is produced, although that of each joint is very small.

The bone with which the lower mandible is articulated, and on which the motion of the upper mandible depends, is in form not unlike a very short thigh bone of a quadruped, attached to the skull by the head and great trochanter, and connected to the beak by the condyles: one of them being attached to the zygomatic process, the other to that connected with the palate-bone. There is a long process on the anterior part of the body of this bone for the attachment of the muscle which is to bring it forwards; so that its motion does not depend entirely on the lower mandible moving upon it, although probably begun by it.

This bone varies in its shape in different birds, according to the degree of motion of the upper mandible. In the bustard, and those birds in which the motion is very small, the end connected with the skull has a broad surface of articulation; and the process for the attachment of the muscle to move it forwards, is bent down so as to give insertion to the muscle at a small distance from the head of the bone.

In the soland-goose, where the motion is more extensive, the articulation with the skull is by a smaller surface, and the process to which the muscle is attached, is nearly in the middle of the cylindrical part of the bone.

In the parrot, where the motion is very great, the head of the bone which moves in a socket on the basis of the skull is very narrow from side to side, which gives it great latitude in the motion backwards and forwards, and the process for muscular attachment is close to the condyles, so as to give the muscular action of the fibres every mechanical advantage.*

The degree of motion in the large maccaw is very great; and when the mandible is moved upwards, there are strong muscles employed to bring it down; so that this action is performed with great force. To give every possible mechanical

* Tab. LXI.

advantage, there are two very long flat bones projecting from the under surface of the moveable part of the mandible, corresponding in situation with the pterygoide processes in the human skull, to which these muscles are attached; but in this case they are separate bones, connected by a joint.

To complete this curious contrivance, there is a smooth ridge with a fine edge, on which these parts move with the least possible friction; while at the same time they are prevented from going out of the middle line, and kept in their course by a kind of groove, like a rail-way.

There is in nature an established principle of uniformity, even when the uses to which corresponding parts are applied are very different. The curious bone that we have just described, is somewhat analogous to the moveable cartilage interposed in the quadruped between the skull and condyle of the lower jaw. In them it gives a latitude of motion to the lower jaw; this bone in the bird does the same to the upper jaw.

In the swan and goose, there is not only a distinct hinge at the root of the upper mandible, but there is a species of horny teeth at the edge of the bill. There is the same in the duck; but in the eider duck, which feeds upon the razor fish, the beak has no such distinct teeth; nor is it so broad, being intermediate in its form between that of the common duck and of many sea fowls.

The strong short bills of birds that feed on grain, are fitted not only to pick up the seed, but to take off the husk before it is taken into the mouth. This is done with great quickness and dexterity. The grouse, which feeds upon the buds of the heaths, has a similar form of bill.

The cross-bill furnishes an instance of a curious contrivance which is given to those birds, whose natural food is the stones of fruits: I understand this bird splits cherry-stones with the utmost ease, and in the shortest possible time. It is commonly said, that there is a regularly-formed joint in the upper mandible of this bird; but this is not the case.

Much of my information respecting the habits and food of different birds I have acquired from Mr. Bullock, whose knowledge upon these subjects, I may assert, upon the authority of Sir Joseph Banks, is greater than that of any other person with whom I am acquainted.

Mastication in birds is performed by the stones received into the cavity of the gizzard, acted upon by the digastric muscle which surrounds that cavity. This has been denied by some physiologists, who venture to assert that the stones are swallowed by birds from stupidity. I shall make no answer to such an assertion, believing that no one here present will adopt it.

The strength of the digastric muscle, and also the thickness of the cuticular lining of the cavity of the gizzard, varies according to the substances on which the bird is intended to live; and in the same bird will even vary, according to the nature of the food on which it has been accustomed to be fed.

From these observations, it is evident that the powers of the gizzard, which have attracted the notice of some physiologists, have little or nothing to do with the process of digestion; and no more light can be thrown upon that process by such investigation, than can be derived from a correct knowledge of the powers of the grinding teeth of the elephant.

In describing the teeth in quadrupeds, the grinders of ruminating animals were shewn to have a different form of surface from those of other animals. In examining the different gizzards, I find that those belonging to birds that feed upon grain generally, have a cavity, the sides of which are not formed to correspond with each other, and the contents undergo a rotatory motion ; this also is the case in the gizzards of birds of prey, as well as of those that feed on vegetables.

In the cuckoo's stomach a ball of hair is often found curiously rolled up. It is of various sizes, from that of a pea to a nutmeg, and is evidently brought into that form by the motion of the gizzard, which is principally employed in digesting animal food. The ball is composed of the hair of caterpillars, on which the cuckoo feeds.

In the gizzard of the alca alle, or little auk, and of the African ostrich, with respect to the form of the internal surface, as well as in grazing birds, there is a different motion arising out of a different form of gizzard.

This difference will be best explained by describing the structure of the gizzard in the turkey and swan. In the turkey, when the external surface of the gizzard is first attentively examined, viewing that side which is anterior in the living bird, and on which the two bellies of the muscle and middle tendon are most distinct, there being no other part to obstruct the view, the belly of the muscle on the left side is seen to be larger than on the right, as may be observed in the annexed engravings.* This appears on reflection to be of great advantage in producing the necessary motion; for if the two muscles were of equal strength, they must keep up

* Tab. LXII.· LXIII.

a greater degree of exertion than is necessary; while in the present case, the principal effect is produced by that of the left side, and a smaller force is used by that of the right to bring the parts back again.

The muscle when dissected is found to be composed of fasciculi of fibres, connected together by a loose cellular membrane, appearing like so many separate muscles lying parallel to each other. They all arise from the anterior strong flat tendon, and are inserted into the posterior; as they are very numerous, and require a large surface of insertion, part of them, on a superficial examination, appear to be lost on the internal membrane of the gizzard.

The two bellies of the muscle by their alternate action produce two effects; the one, a constant friction on the contents of the cavity; the other, a pressure on them. This last arises from the swelling of the muscle inwards, which readily explains all the instances which have been given by Spallanzani and others, of the force of the gizzard upon substances introduced into it, which force is found by their experiments, always to act in an oblique direction.

The internal cavity when opened in this distended state is found to be of an oval form, the long diameter being in the line of the body: its capacity nearly equal to the size of the pullet's egg; and there are, laterally, ridges in the horny coat in the long direction of the oval.

When the horny coat is examined in its internal structure, the fibres of which it is formed are not found in a direction perpendicular to the ligamentous substance behind it; but in the upper portion of the cavity they have a direction obliquely downwards, and in the lower portion obliquely upwards.

From this form of cavity, it is evident that no part of the sides are ever intended to be brought in contact; and that the food is triturated by being mixed with hard bodies, and acted on by the powerful muscles which form the gizzard.

In the goose, the gizzard differs very much in its external form from that of the turkey; being oval in its transverse direction, and having the lateral edges very thin; this arises from the fasciculi of fibres of the muscle being more numerous than in the turkey. The disproportion between the left belly of the muscle and the right, is still greater than in the turkey; and when the cavity is opened, the internal surfaces are found to be flat, divided into two equal portions; that on the right side convex above, forming a projection into the cavity, and concave below, forming a hollow. On the left side there is a corresponding surface, only that the cavity is above, answering to the convex part opposite: and there is a convexity below, fitted to the opposite concavity.

The horny covering of these surfaces is very strong, much more so than in the turkey; and when the structure is examined, the direction of its fibres is found to be oblique, on the right side from above downwards, and on the left side from below upwards.

In the swan, the gizzard is altogether larger than in the goose, and more flattened at the external edge, the muscular fibres being shorter; on its internal cavity the appearances are nearly the same; but there is a less strongly marked ridge and concavity; and the surface of the oval portion in which these are met with, is smaller in size. The substance of that part of the gizzard appears to be less dense, but the cuticular covering is thicker, and its fibrous texture more conspicuous. The direction of the fibres is exactly the same as in the goose.

From this construction, it is evident that these two corresponding surfaces are intended to move on one another with little more than the food between them; the hard substances interposed being only of a small size, so as not to interfere with their regular correspondence with each other.

In these gizzards there is not that rotatory motion mentioned in the turkey; but a regular sliding motion, begun by the strong muscle forcing one of the horny surfaces over the other; and the parts are brought back by the action of the weaker to their former state.

This motion bears so great a resemblance to that of the grinding teeth of ruminating animals, in which the teeth of the under jaw slide upwards within those of the upper, pressing the food between them, and fitting it by this peculiar kind of trituration for being digested; that it is fair to conclude it is for the same purpose, more especially as we only find it to take place in those birds that graze.

The gizzard of the goose is evidently fitted for a harsher kind of grass than that of the swan; and we find that the goose prefers the common grass of the fields; while the swan is partial to the soft weed found in ponds and rivers, and only grazes occasionally.

The bill of the goose breaks off the grass short from the ground, nearly in the same manner as the fore teeth of ruminants. In like manner, as ruminants have only teeth in the under jaw, so has the goose small-pointed cuticular teeth in the lower portion of the bill; which, when the bill is closed, fit into grooves in the upper one; so that the grass inclosed in the space between the teeth and grooves is nipped off.

These facts shew how the goose and swan are fitted to live upon a species of food not adapted for birds in general; and it appears that in this class of animals, a peculiar conformation of the gizzard is required, as well as of the teeth in quadrupeds, when they are intended by nature to feed intirely upon grass.

The flamingo lives upon the margin of the sea, and feeds upon sea-weed and shell-fish, both having been found in its gizzard. It is constantly met with watching the ebbing of the tide, and picking up what it can catch in the shallow water. Its bill resembles that of the swan, in having cuticular teeth on the edge of the lower mandible; and probably it commonly uses its bill in the same manner as the swan, and goose, but from the length of its neck and the form of its bill it is unable, without some contrivance, to pick up small grain from the ground: this is done by the goose and swan by lowering the head and laying the lower mandible almost flat on the ground, then moving it forward by jerks, so that the grain, with the help of the tongue, is shovelled into the mouth; but the flamingo takes a very different mode; he bends his head backwards so that it reaches the ground rather under him than before him, and thus the upper mandible becomes the lower; and he probably pushes it along the ground in the same manner as the goose does the lower, and in this way picks up sand and small shells.

LECTURE VI.

On the Stomachs and Teeth of cold-blooded Animals, that breathe atmospherical Air.

The animals whose stomachs I am about to describe in the present Lecture, have been called amphibious, from their being capable of remaining a longer time without the air applied to their lungs being renewed than either quadrupeds or birds, therefore having the power of living under water, and only occasionally coming to the surface to breathe.

They differ in many respects from the two classes of animals whose stomachs have been already considered, and form a well marked intermediate link between them and fishes; they ought not however to retain the name amphibious, since there is a class of animals capable of breathing the air of the atmosphere with one set of organs, and the air contained in water with another, therefore entitled to be called amphibious in the fullest acceptation of the word; and forming a regular link in the gradation between the class now under consideration, and fishes.

The animals which compose the present class differ very much from one another in their external appearance; they are crocodiles, lizards, camelions, turtles, frogs, toads, and snakes.

In examining the stomachs, the arrangement that best accords with the plan that has been hitherto followed, is to describe, first the stomachs of the different animals that live principally on animal food, and afterwards those that are fitted more particularly for the digestion of vegetable substances.

The animals which I am about to consider, are under very different circumstances respecting digestion, from those of which I have treated, for they have no power of generating heat within themselves, always remaining of the temperature of the atmosphere, which is in many climates too cold at certain seasons to admit of the functions of digestion being carried on. The tropical are therefore the only regions in which the stomachs of those animals can uninterruptedly perform their fnnctions, and even there they will be carried on with less activity than in warm-blooded animals, whose power of generating heat and keeping it up to a standard of nearly 100° is independent of all external circumstances; so that the stomach is preserved always at one uniform temperature, or nearly so.

Digestion must be performed to a disadvantage in the whole of this class of animals, although placed under the most favourable circumstances of climate, since even when the animal is basking in the rays of the sun, the heat of its stomach will be below that which, from the principle established in birds and quadrupeds, is best fitted for that process. Under all other circumstances digestion must be less and less perfectly performed, and when the heat of the season is diminished below a certain point, stopt altogether. To prevent the destruction of the animal when that takes place, all the other functions are made to cease, and it remains in a torpid state.

The stomachs of the different orders of this class are variously formed, but all their varieties are intermediate between those of birds and fishes; I shall therefore endeavour to trace the regular series from the one to the other as well as I am able, by describing first those stomachs which form the nearest approach to the bird, and afterwards those allied to the fish.

The stomach of the crocodile bears a considerable resemblance to those of birds of prey. It is tolerably large for the size of the animal; its situation is nearly the same as in quadrupeds in general; it is surrounded by a digastric muscle, as in birds, the middle tendons of which are each about the size of a shilling, and the bellies of the muscle resemble in size those of the gizzard of an eagle. The orifice of the pylorus is at a short distance from that at the cardia, and is extremely small; and beyond it there is a dilatation, forming a small cavity before the duodenum begins. The general cavity is more globular than in birds of prey, and there are no conspicuous gastric glands, as in them; this however may be accounted for, from the process of digestion not being required to be so rapid, and therefore the gastric liquor is secreted in the most sparing and œconomical manner.

While I was resident in the island of Jamaica, I saw a number of alligators in a fresh water lake situated between the mountainous part of the country and the sea. It was a place to which sportsmen used to resort for the purpose of shooting pigeons, that came there in great numbers to drink: the alligators lay with their noses just on the surface of the water, and when the pigeons were drinking, used to spring upon them and eat them.

One of my companions shot a small alligator, which I sent to England to Mr. Hunter, in spirits. He found in its stomach pigeons' bones, some stones the size of nutmegs, and also the seeds of some vegetables, which had probably been contained in the pigeons' crops. The earthy part of the bones was entirely gone, so that digestion had begun.

In proof of birds being their favourite food, I shall mention the following circumstances. Mr. Hunter kept an alligator alive for a year, and we found that when fishes were offered, it refused to eat them, but readily devoured sparrows whole. He did not, like the eagle and owl, throw up the feathers, but they passed through the intestines, and had their texture in part destroyed. It only ate at intervals, for after a hearty meal even sparrows were refused for several days; after which it again began to eat.

Keeping the relationship to the bird in view, the stomach of the eft is next in order, having a dilatation in the œsophagus just before it terminates in the stomach, lined with a cuticle resembling a crop. The stomach itself is a straight tube, a direct continuation of the œsophagus; the pyloric portion is turned up to the right side, and is only one fourth of the length of the cardiac portion. The eft resembles the crocodile in living in water and feeding upon animal food, but in the form of its stomach is nearer to the lizard.

The flying lizard has exactly the same structure of stomach as the eft. In the one which I examined the contents were gnat-flies or mosquitoes. Nothing can be more unlike than the external appearance of the eft and this species of lizard, but the similarity in their food accounts for their digestive organs having the same structure.

Lizards in general live upon insects, and there is little variety in the form of their stomachs. The stomach of the lizard is a continued canal from the œsophagus, without any contraction to mark its origin, or any enlargement of the cardiac portion; looking more like an intestine than a stomach. It bends upon itself on the anterior part, instead of laterally, as in other animals; and a little way before it terminates in the pylorus it contracts considerably, and continues of that form: this narrow part may be called the pyloric portion. There are longitudinal rugæ running along the whole length of the internal surface of the stomach. The coats of the stomach are of the same thickness through its whole length, so that in the narrow part they are thicker in proportion to the cavity.

The stomachs of the camelion, the salamander, the flat-toed lizards, both those that are smooth and those that are warted or tuberculated, have the same conformation.

All snakes I believe live principally, if not wholly, on animal food; and their stomachs, as far as I have had opportunity of examining them, are formed upon the same principle. In their shape they are adapted to the form of the animal, and are so much alike in the different species, that I shall not think it necessary to do more than describe one, as an example of the whole order.*

The stomach of the snake is a continuation of the œsophagus, and only distinguished from it by the termination of the cuticular lining; the coats become thicker where the stomach begins, and continue to encrease in thickness through the extent of the cardiac portion, which terminates in a rounded extremity. There is an aperture of a small size, compared to the width of the

* Tab. LXIV.

cavity leading to the pyloric portion, which continues of the same dimensions as the aperture, forming a canal about half as long as the cardiac portion. There is a valve at the pylorus; and beyond it the duct of the liver opens into the duodenum. Immediately within the orifice of the cardiac portion are situated the gastric glands, surrounding the canal, as in birds. The internal membrane of the pyloric portion has longitudinal folds, which terminate where the intestine begins.

This structure approaches nearly to that of the stomach of the birds with membranous gizzards, only the pyloric portion is more like that of many fish, making this stomach in those respects the intermediate link between the two.

The gastric glands in the snake are more conspicuous than in any other animals of this class. The snake swallows animals of a larger size, compared with its own bulk, than any other animal whatever: and as such a mass cannot be at all acted upon by the weak coats of such a stomach, into which it is received with all its cuticular coverings of hair or feathers, a larger proportion of gastric liquor must be required than in the crocodile or turtle, however slowly the process of digestion is to go on.

Frogs, toads, and many of the turtles live upon animal food; and therefore the description of their stomachs becomes necessary, before we proceed to the stomachs of those lizards and turtles that live upon vegetable food. The frogs, toads, and camelions, have nearly the same form of stomach.* It is situated in the left side; swells out at the termination of the œsophagus, not uniformly, but most on the left side, lies in the direction of the body; and where it terminates in the

* Tab. LXIV.

pylorus, bends a little to the right, and is very small at that part; there is a thickening of the coats at the pylorus. The pyloric portion is very small, and hardly to be distinguished from the cardiac.

The small tortoise, and the concentric-scaled tortoise, which has an hawk's bill, and feeds on worms, have the stomach lying more across the body. The tadpole of the bull-frog has its stomach lying in the direction of the body; it is a straight canal, not to be distinguished in size from the duodenum; so that we cannot determine where the intestine begins.

The logger-head turtles feed on fish; and their flesh is not eatable, so rank is its taste.

The hawk's-bill turtle, from which the tortoise-shell is procured, is also a bad article of food, from its feeding on animal substances. The Mediterranean turtles when eaten often, prove so purgative that they are unfit for the table; and there is every reason to believe that all these, as well as the lizards that live upon animal food, have the same form of stomach.

Having described the stomachs of all the different orders of this class of animals that live upon animal food, it is now necessary to take notice of those that feed on vegetables. Of these, the number is very small, since it is confined to the lizard tribe and the turtles. It is, however, very instructive to shew the peculiarities which are adopted by nature in the stomachs of animals, whose external form is the same, according to the food, whether it is animal or vegetable.

There are only two kinds of lizard that I know of, which feed on vegetables. These are the scincus and the iguana.

In them the stomach is not, as in the others, a direct continuation of the œsophagus: there is a dilatation at the beginning of the cardiac cavity, beyond which the canal continues of the same size like a large gut. Near the pylorus it bends upon itself, and becomes very narrow just at this part for about an inch in length, and the coats are six times thicker here than elsewhere. This thickening terminates at the beginning of the narrow part, which may be called the pyloric portion, and which is one-sixth the length of the cardiac. The structure of stomach is the same in the iguana from the West Indies, and the broad-tailed iguana from the East Indies; and there is no material difference between them and that of the scincus.

In the stomach of the scincus which I examined, were found hard berries filled with seeds, some whole, others broken to pieces; a species of food which its round and blunt teeth are fitted to masticate.

In the stomach of the iguana there were the leaves of plants, and nothing else; in one specimen the stomach was quite full of them; they were perfect in their form in the stomach, and in the intestines the fibrous parts, or the skeletons of the leaves only were met with, the softer substance having been digested. The thick muscular part of the stomach must be considered as forming an approach towards a gizzard for bruising the macerated parts, and assisting the process of digestion,

In the West Indies the iguana is sold in the market, and is esteemed a delicacy on the table; while none of the other lizards are considered as proper to be eaten, even by the Negroes. Sir Joseph Banks shot a large lizard in Batavia six feet long, which was the terror of the neighbourhood, as it devoured the poultry. He had it dressed for the table, as a matter of curiosity, but the flesh was so rank that nobody could eat it.

There is only one species of turtle which I know of, that lives upon vegetable food; and it is this species only which is brought to table. The reefers, who catch this turtle, agree in its food being a sea-weed called zostira maritima; and there is no reason for doubting their account, particularly when we find its flesh is so pleasant to the taste, and that of the others, whose food is not vegetable, not fit to be eaten. It also corresponds with what has been stated respecting lizards.

The stomach of this kind of turtle has its cardiac orifice distinctly marked by the termination of a number of pointed projecting processes, with which the internal membrane of the œsophagus is covered. The cardiac portion swells out, so as to be much wider than the œsophagus; it is of an oval form, has a rugous internal surface, but no distinct glands are to be observed: it communicates with the pyloric portion by a small orifice. The pyloric portion viewed externally, appears nearly as large as the cardiac, and is about half its length. It is bent upwards, and retained in that position by the mesogaster. When opened, the internal cavity is found very to be narrow, but the muscular coats are extremely thick, more than four times that of the cardiac; their principal part is made up of circular fibres: there is also a layer of longitudinal fibres, but it is very thin. This peculiarity of the pyloric portion being furnished with such strong muscles, is evidenly that it may answer the purpose of a gizzard, and triturate the sea-weed after it has been macerated and prepared in the cardiac portion; a use which we should not have been led to ascribe to it, had we not been previously acquainted with the means employed in the stomachs of other animals, that do not masticate their food, to render it fit for being digested.

From the specimens in the Collection, the force that can be exerted by the muscles of the pyloric portion, is hardly to be considered less than that employed by the swan's gizzard, when the extent of this cavity is compared with that in the swan, which it exceeds, at least in the proportion of three to one.*

The stomach of the large land tortoise from South Carolina, lies nearly horizontally across the belly; the internal membrane is slightly rugous; the coats of the pyloric portion are much thicker and more muscular than those of the cardiac, they terminate abrubtly in the duodenum, the coats of which are very thin.

The tortoise from the Seyschalla isles, which is of a most enormous size, with a concavity of considerable depth under the belly shell, is also a grazing animal. One of them was sent alive to Lord Egremont, and lived in the park of Petworth from the 12th of August till the 1st of December, when it was found dead from the cold. It fed heartily on the grass in the park, and ate all kinds of vegetables. In warm weather it swam in the pond for eight or ten minutes at a time, in doing which it was raised out of the water by the hollow under the shell being filled with air: it weighed in August, one hundred and seventy-eight pounds: it left off eating the 1st of November; on the 12th it weighed two hundred and seven pounds.

When it came out to feed, it ate nearly as much grass as a

* Tab. LXIV.

Lincolnshire sheep. Its stomach was not examined. The small tortoise from Germany being about six inches long, and having the shell less curved than that from South America, has its stomach lying across the body; the pylorus situated on the right side. There is a glandular structure near the pylorus, with a number of orifices opening into the cavity.

The land tortoise from South America has its stomach of the same form; the coats of the pyloric portion are very thick; and there is an oblong glandular part, with orifices opening on its inner surface, near the pylorus.

The teeth in all the animals belonging to this class are not for the purpose of mastication, nor even adapted to tearing the prey to pieces; they are simply for catching it, and preventing its escape till it is swallowed; the slow digestion which is carried on in the stomach, making any previous preparation of the food unnecessary.

In the crocodile, and the lizards, the teeth are commonly pointed, but not always so; as for example, in the scincus. They have the same composition as the teeth of quadrupeds, being made up of ivory and enamel; at least this is the case in the crocodile. They differ entirely in their mode of succession, the tooth forming a hollow cone, and that which succeeds it, rising into the cavity; and when the old tooth drops out, the other is in its place fit for use.

Although there are several kinds of crocodiles which differ in the shape of the mouth, the teeth are all of the same kind. They are very sharp at the points. Those in the upper jaw stand on the outside of those of the under, which fits them for holding fast any thing inclosed between them ; but I should doubt their being able to cut off any part of an animal, however confidently this may be asserted.

The number of teeth is not always the same in different crocodiles of the same species. In the alligator they vary from nineteen to twenty-two in the lower jaw ; in the upper, from nineteen to twenty.

In the crocodile, properly so called, there are fifteen teeth in each side of the lower jaw, and nineteen on each side in the upper. The foremost teeth in the lower jaw at a certain age, pierce the upper jaw. The fourth on each side, which are longer than the others, pass into grooves in the upper.

Another species has from twenty-five to twenty-seven on each side of the lower jaw, and from twenty-seven to twenty-eight on each side of the upper jaw ; the first and fourth of the lower jaw are received into grooves in the upper.

In crocodiles, the number of teeth may be the same in the young and the old. The young tooth is not inclosed in a cavity in the maxillary bone, but arises from the bottom of the alveolus of the tooth which it is to replace. As the young tooth increases in size, it presses against the base of the one above ; it enters its conical cavity, and acquires the same conical form, and when the old one is shed, comes into its place.

The succession of teeth in crocodiles appears to take place several times, so that they are sharp and perfect at all ages.

The mode of opening the mouth is very different from that of quadrupeds ; for instead of the lower jaw moving upon the head, the head moves upon the lower jaw. The mechanism by which this is effected is as follows : the centre of motion of the lower jaw is placed a little further back than the centre of motion of the head upon the vertebra of the neck; so that there is one centre of motion to the jaw, and the first vertebra of the neck, upon the second vertebra. All the muscles employed to open the mouth have their origin from the head, at a great distance from the centre of motion. The muscles which raise the jaw and depress the head, have very extensive origins from the head as far forwards as the middle space between the anterior and posterior nares, making laterally part of the roof of the mouth and bottom of the orbit. This origin is continued backwards along the basis of the skull under the ear, as far as the foramen occipitale. From this extensive origin the muscles pass backwards and downwards to be inserted into the upper edge and inner side of the lower jaw, principally before the centre of motion, but partly behind it. The use of these muscles is to raise the head upon the lower jaw, which is extended further back than the centre of motion; so that the muscles inserted behind that centre pass over a ridge of bone as over a pully, when the mouth is open, and are put on the stretch; whence even these are enabled to assist in this action, although at first sight their contraction would appear to produce an opposite effect.

There is a bony process on each side, passing down from the skull, just before the insertion of these muscles; and these on their exterior surface are covered with articulating cartilages, and move on the inside of the jaw, which is covered by a soft ligament. These bony processes prevent lateral motion; and therefore there is no moveable cartilage in the joint between the upper and lower jaw.

The toad appears to have no teeth of any kind in either jaw, only the hard gum forming a regular edge. The frog has small teeth in the upper jaw, the points of which turn backwards, so as to become holders. There are none in the lower jaw. The rana paradoxa has the teeth like those of the common frog.

The turtles and tortoises have beaks in many respects like those of birds, having a horny covering of the same kind.

The teeth of the snake tribe, like those of the lizards, are not fitted for mastication, but are employed only as holders; for which they are admirably adapted, being all inclined with their points backwards towards the throat.

The arrangement of the teeth in the snakes without the poison glands, is different from that of those which have them. There is a double row in the upper jaw, and a single row in the under; the two upper rows may be distinguished, by calling the one marginal, and the other palatine. The palatine rows are fixed in that portion of the bone which constitutes the principal part of the upper jaw, the marginal row is fixed in an exterior portion, weaker than the other.

In poisonous snakes, the apparatus for raising and depressing the fang, occupies the place of the marginal row; and in those snakes there is only the palatine row, and the poison fangs on the outside of them in the upper jaw, and one row of common teeth in the lower jaw, as in other snakes.

The poison-fangs must be considered as weapons of defence, having nothing to do with catching prey, or retaining it when caught; for, I believe poisonous snakes never eat the animals they kill by poison, they simply wound them and leave them; but as these fangs are decidedly teeth, I shall give a general description of them.

The poison fang is fixed in a strong bony socket, which is articulated to the upper jaw; and the jaw itself is made up of two parts articulated together, giving it an appearance as if it had been fractured, and united again; between the socket and the margin of the mouth laterally there is a slender bone connected to the socket and jaw, which corresponds with that portion of the jaw in which the marginal row of teeth is inserted in innocuous snakes.

When the extreme point of the jaw is moved outwards in the act of opening the mouth, the upper jaw from the joint in its anterior part, readily bends, and the bone which connects the jaw to the socket being pressed forwards, it pushes the socket up and erects the fang.

As the fangs are very liable to accidents, there are subsidiary teeth ready to supply their place. Of these there are commonly two or three half grown; they are only connected by soft parts, and are successively moved forward into the socket to replace the fang when removed. There is an opening leading into the cavity of the tooth by which the poison is received, and another orifice near the point through which it is inserted into the wound, the moment it is made by the tooth. The fangs are inclosed in a fold of membrane resembling a hood, which covers them in the recumbent posture all but the points; when erected, they become denuded.*

In snakes, the lower jaw is not articulated with the upper, in the same way as in other animals, but by means of two bones connected to the occiput. The extreme points of the posterior part of the upper jaw lie exactly between and within the condyles of the lower, and are loosely connected to them by ligaments.

* Tab. LXV.

By this mechanism, when the snake opens its mouth, the condyles of the lower jaw moving on the occiput by these intermediate bones, are thrown outwards, and carry the extreme points of the upper jaw along with them, which dilates the fauces to a very great degree.

The mode in which a snake swallows its prey is also peculiar to this tribe. It is hardly credible that it should swallow animals so much larger than its own natural thickness, as some which are found in its stomach. Having had an opportunity of seeing snakes swallow rabbits, I shall describe the mode of doing it, as an illustration of the manner in which they devour their prey.

The snake first fixes its eye upon the animal it intends to seize, the effect of which is to intimidate to such a degree as to deprive the animal of all efforts to escape. Whether quadruped or bird, it remains trembling in the same posture, looking at the snake, who gradually and slowly approaches, and when near enough, coils itself up and makes a dart at its victim, seizing it by the nose and mouth; so that the animal appears to die by suffocation. When once it has got hold, it remains quiet for some minutes, at the end of which period the animal appears to be motionless; the snake then coils itself twice or three times round the body, pressing it into a smaller form, and then very slowly gets the whole head into its mouth, the teeth allowing it to pass readily in that direction, and of taking a fresh hold as it is moved on. The length of time before the whole animal is swallowed is considerable; a rabbit required full half an hour.

This is a very extraordinary mode of feeding, almost surpassing belief; and travellers who have witnessed such sights, are so astonished as to be unable to set any bounds to their accounts of them, and nothing can exceed the extravagant stories that are told; but in general, for want of a correct knowledge of those matters, some error is commonly committed, which leads to the fallacy of the account being detected; of this, the following is a striking example.

It is boldly asserted by many persons who have been in India, that they have either seen or have no doubt of the truth of its having happened, that a snake swallows a buffalo except the horns, which remain sticking out of the snake's mouth; this however cannot be true, since snakes invariably seize by the head, and were they not to do so, they would be unable to pass the limbs of the animal along the œsophagus and stomach without injury to the internal membranes.

LECTURE VII.

On the Stomachs of the truly Amphibious Animals, and Fishes.

The truly amphibious animals form a link in the gradation between those cold-blooded animals that breathe by means of lungs, and fishes which breathe by means of gills, since they are themselves cold-blooded, and are possessed of both organs of respiration.

It has long been a question whether the animals of this kind are really full-grown, or only the tadpoles of a species of frog which has never been seen in the perfect state. This point is however now determined in the most satisfactory manner in favour of their being a distinct class of animals, since M. Cuvier has had an opportunity of examining the skeleton, and finds the bones to be completely formed, which is the most decisive proof that can be produced, of the animal to which they belong having arrived at its perfect state.

Of this class only two distinct kinds have been ascertained; these are very readily distinguished from one another, as one species has two short legs, situated immediately below or behind the gills; and the other has, besides these, two other legs between the termination of the body of the animal, and the origin of the tail. They are called syrens, and are in many respects, intermediate between lizards and fishes. They resemble lizards in their legs and feet, and in having lungs. They resemble fishes in the structure of the heart and in having gills. One species lives upon vegetable food, which is rarely the case with lizards, and never I believe with fishes in a natural state. The other upon animal food, and in this respect resembles the generality of lizards and all the fishes.

The syren with four legs lives upon animal food, and its digestive organs have a very simple form. The œsophagus is a narrow canal about an inch long, the coats are strong, and on its inner surface are longitudinal rugæ, increasing in number near its termination at the stomach. The cavity of the stomach is considerably wider than that of the œsophagus, and is two inches long; it is continued into the duodenum by an infundibular contraction, below which, the gut forms a straight canal, having no convolutions. The inner membrane of the stomach is thrown into longitudinal rugæ, and these are so numerous at the pylorus as to close the orifice.

Dr. Schreiber, who has given an account of the dissection of this syren, found the head and bones of a small fish in the stomach; and he mentions that Baron Zois, who procured them from a small lake in Carniola in Germany, called Sitheker Sea, and kept them alive, observed that they lived chiefly if not intirely on animal food.

Mr. Hunter received a speciment of the same species from Carolina, and his description of the stomach agrees with that given by Dr. Schreiber. He mentions that the internal membrane is soft and villous.

The syren with two legs, has, I believe, only been met with in South Carolina. The specimens in the Hunterian Collection, of both kinds, were brought from thence.

The stomach of the syren with two legs differs from that which has been described, in having the muscular coat towards the pylorus considerably thicker than that of the cardiac portion, and the termination of its cavity at the origin of the duodenum distinctly marked by the coats becoming very thin, and a sudden enlargement taking place.

The stomach contained grass, and a good deal of that kind of moss which grows upon stones under water, and some pebbles: some stones were also found in the intestine.

These two species, like those of the lizard, have a marked character in the construction of the stomach, by which the kind of food the animal feeds upon may be readily ascertained; a greater muscular action upon the food being necessary for completing the process of digestion even of the softest vegetable substances, than those of an animal nature.

After having described the different formations of stomach, as far as they are yet known in this extraordinary class of animals, I shall take notice of their teeth, as I have done in speaking of the other classes.

The syren that lives on animal food has small sharp teeth, as is common in lizards.

The syren which feeds on vegetable substances, has a horny beak like the turtle, the lower portion is more extensive than the upper, the two cutting edges oppose one another; behind the horny bill in each jaw are two teeth. These are all of the same kind, serrated on both sides; and they may be considered as holders.

On the Stomachs of Fishes.

In all the classes of animals that have been hitherto considered, some of the genera have stomachs peculiarly fitted for the digestion of vegetable food: this however does not appear to be the case in any genus belonging to the present class, for although many fishes eat bread and other vegetable matter, none appear to have digestive organs more than others adapted to this kind of food.

In the unfathomable depths of the sea, and even in rivers, vegetable food can rarely be procured, so that there appears to be an obvious reason why fishes should not have organs formed peculiarly for digesting such food.

Vegetable substances are also less proper for the food of fishes than of land animals, since when not completely digested, air is frequently let loose in the bowels, which would, by lessening the specific gravity of the fish, bring it to the surface and turn its belly upwards, and by that means render it incapable of swimming.

Sir Joseph Banks, at one of his country-houses, has a pond in which there are gold and silver fishes. These are fed while the family is in the country, with bread, and thrive very much. They appear to be very partial to this food, but Sir Joseph has occasionally found one of them dead, upon the surface of the water, its belly uppermost, and exceedingly distended; and upon examination the bowels have been found in a state of dissolution.

When these fishes eat bread they do not swallow the morsel immediately, but keep it in their mouth some time, and even are known to throw out that which is in the mouth, to take another which appears preferable.

Carp eat peas voraciously and may be fattened upon them, but the waste they make in passing them through the bowels without the whole being digested, makes it too extravagant a plan to be adopted, and shews that the digestion is slow.

The digestion of fishes as well as of all other cold-blooded animals must be slow, but it is difficult to obtain accurate information upon this subject: the following fact, which I learnt from Sir Joseph Banks, is a sufficient proof that this is the case. A perch which was very tame, and fond of young perch, would eat out of the hand, and devour thirteen of them at once, but would not eat again for ten or fourteen days. I have frequently seen fishes with their stomachs quite full, and with only that part of the food contained in the lower portion of the stomach digested. Fishes therefore in their mode of digestion very closely resemble snakes and lizards: they gorge the stomach even to the throat, and remain without food till that is digested. A trout has been caught with the hind legs of a toad sticking out at the sides of the mouth, the stomach being so full that the toad could not get lower down in the gullet.

Fishes not only feed on one another, even upon their own species, but they also devour the various kinds of worms and insects, both belonging to the sea and the land, when they come within their reach. Besides these, there must be other means by which they can be nourished, since they are often placed in circumstances which exclude them from the possibility of receiving these kinds of food, and yet they not only subsist, but increase in bulk.

What this nourishment is, and in what manner it is received, whether by the mouth or through the pores of the skin, are points which have not been ascertained; and physiologists appear to differ in opinion respecting them.

I shall not so completely confine myself to the simple explanation of the facts which have been ascertained in comparative anatomy, as to lose sight of the principal object of these Lectures, which is, to employ those facts for the improvement of the study of the animal œconomy, by drawing from them such conclusions as tend to elucidate those branches of physiology which are still involved in obscurity.

As whatever may be applied to the surface of the body can also gain admission into the digestive organs, I am inclined to believe that no substances are converted into nourishment until they have undergone the process of digestion, or some secondary change in the intestines.

It is strongly in favour of such a general principle, that when the chicken it hatched, the yolk of the egg, which is given to it as a supply of nourishment, till it can either receive food from the parent birds, or procure it for itself, does not remain in the beginning of the intestine into which it is received, but passes up into the gizzard, and then into the crop, from whence it descends and undergoes the necessary changes.

As the yolk of egg, which is a substance formed by nature for the nourishment of young birds, and therefore the best fitted for that purpose, undergoes the digestive process, is it not reasonable to conclude that all other substances must do the same? It is well established, that life can be supported for a time by the absorption of the different parts of the animal, without their passing again through the stomach; but we have no direct proof of the same effect being produced by the absorption of other substances from the surface of the body.

Water, under many circumstances, as has been already explained, passes directly from the stomach into the circulation of the blood; and there is little reason to doubt, that it is absorbed occasionally from the surface of the body. In either way it may preserve the blood in a state to carry on the functions of life longer than it could otherwise do, by enabling the body to use more extensively that, of which it is already in possession, without imparting any absolute nourishment; since the nutritious part of water, probably requires undergoing the process of digestion, as much as the yolk of the egg. It appears therefore more probable, that water does not nourish the body, unless it is received into the stomach, and mixed with the mucus secreted in that viscus, and is digested along with it.

It has been believed that distilling water, would take from it its nutritious quality. To ascertain this, Sir Joseph Banks requested Mr. Hatchett to use every chemical means of making water unfit for nourishing plants; but after these were employed, plants still grew in it better than in any common water. In distilled water they grow, though not so fast as in rain-water, and only half as fast as in pond-water.

This explains the fact, which has created so much surprise, of gold fishes living for years in distilled water; distillation not destroying the nourishment it contains. Toads have been known to live for several years in moist air, without any other nourishment, so little support is required for these cold-blooded animals when much bodily exertion is not used.

Shoals of herrings and other fishes are known to traverse a large extent of the ocean without any of them appearing to want nourishment; and yet the only food which they can possibly receive, is contained in the water through which they swim.

This fact, and a very extraordinary one it is, in no way militates against the observations I have made; for the nourishment, whatever it is, can be more readily received into the body by the stomach, than through the medium of cutaneous absorption; and when we consider the nutritious quality of water, the myriads of phosphorescent, and other animals of that class that are found in the sea; these mixed with the mucus which passes off from the surfaces of surrounding fishes may, by the process of digestion, form a considerable supply of nourishment. These fishes are never found with any thing in their stomachs: but that part of a shoal of herrings which passes on the side of England next the narrow seas, appears to have less opportunity of procuring food than the other which passes through the open ocean; for the last, when caught, are found more oily than the former; and the herrings caught on the coast of Wales and Ireland, are richer food than those caught at Yarmouth, having expended less of their oil in their support.

In describing the stomachs of fishes, I shall begin with that of the flying fish from the West Indies, which has the most simple form that I have met with, and is in that respect, different from any that has hitherto come under our notice; for the stomach comprehends the whole of the digestive organs. There is one simple canal extending from the mouth to the anus, gradually diminishing in size to the lower extremity.

In one specimen, the contents of this cavity examined upon the field of the microscope, consisted of parts of small medusæ, young shrimps or animalculæ resembling them. The œsophagus is internally corrugated, and terminates in a transverse ridge; the stomach has a villous surface, becoming less so towards the anus.

In the flounder, the stomach is a direct continuation of the œsophagus; is cylindrical, short, and a little contracted at the pylorus, where there are two cœca or pancreatic processes. In the internal membrane of the stomach there are narrow plicæ.

In the sole, the stomach is distinguished from the œsophagus by the canal becoming more dilated: it is divided into a cardiac and pyloric portion, by being bent upon itself; its internal surface is plicated; and there is a transverse ridge at the pylorus, close to which is the opening of the ducts of the liver and gall-bladder.

In the turbot, the stomach is a direct continuation of the œsophagus, but is not straight in its course, forming a curve before it bends up. The pyloric portion is very short, and terminates where two pancreatic cœca are situated. The internal membrane of the œsophagus appears to be continued into the stomach; and there, is slightly rugous longitudinally. The aperture at the pylorus is very small.

In the lamprey eel, the stomach is short, of a cylindrical form, and gradually contracts to the size of a goose-quill, where it forms the pylorus. The œsophagus is strongly muscular, and fasciculated longitudinally. The internal membrane of the stomach has numerous slight longitudinal rugæ.

In the electrical eel, the stomach is a continuation of the œsophagus, but swells out into a rounded cavity, at the lower part flattened from side to side; it turns up to the right; the pyloric portion is short, and the pylorus about midway between the termination of the œsophagus and lowest part of the stomach; just beyond the pylorus are numerous pancreatic cœca. The inner surface of the stomach has a beautiful, delicate, honey-combed appearance, not unlike the surface of a fine sponge. The pyloric orifice is not very narrow.

The stomach of the scorpæna horrida resembles in its shape that of the electrical eel; the pyloric portion is very short, and there are only six pancreatic cœca.

In the gurnet, the bottom of the cardiac portion is more pointed.

In the haddock, the stomach swells out at the lower part of the cardiac portion and turns up to the right, is short, and completely surrounded by small pancreatic cœca. The internal surface is smooth; the muscular coats of the pyloric portion are thick and strong.

In the stomachs which have been described, they all, except the two first, are more or less bent upon themselves, and are divided into the cardiac and pyloric portions; in this respect resembling the stomachs of many quadrupeds; but in those which I am about to describe, the pyloric portion goes off from one side of the cardiac, as in birds with membranous gizzards.

In the pike, the stomach is a direct continuation of the œsophagus, swelling out at the lower part of the cardiac portion like a Florence flask. This extends almost as low as the anus. The pyloric portion is not to be distinguished from the duodenum, being very small, even smaller than that intestine; unless its boundary may be marked by the opening of the gall-duct. The lining of the stomach has a villous appearance.

In the cod, the cardiac portion of the stomach is a direct continuation of the œsophagus, and only to be distinguished by the termination of the cuticular lining. The œsophagus is short; the cardiac portion terminates in a rounded end, from the right side of which the pyloric portion goes off; the orifice between them is very small.

In the œsophagus are small cuticular papillæ; the internal membrane of the cardiac portion is thrown into serpentine folds in a longitudinal direction. On the edges of these, are the orifices of the glands; these are in greatest number towards the lower extremity. The pyloric portion is thick and muscular; its inner surface has the appearance of a fine net-work or honey-comb.* Just beyond the pylorus are numerous long pancreatic cœca.

In the whiting-polluck, the stomach resembles closely that of the cod. In the cavity of one examined by Mr. Howship, there were not only small fishes, but portions of crabs.

In the wolf-fish the cardiac cavity is short, and rounded at the bottom; the pyloric portion going off from the right side.

In the toad-fish, the stomach has the same form.

In the crop-fish, the cardiac cavity is of an enormous size, and the pyloric portion may be said to go off nearly as high as the cardiac orifice; but it is singularly situated, being quite on the posterior part. The pyloric portion forms a slight swelling at the beginning of the duodenum. The internal surface of the stomach is smooth.

In the lophius piscatorius, the stomach swells out on the left side; the opening from the œsophagus is very large: the pyloric portion goes off from the right side of the cardiac, and is unusually large and wide. It terminates by a narrow neck in one side of the duodenum, and has two pancreatic cœca.

In the following fishes, the stomach is a long slender pouch, with the openings of the œsophagus and duodenum at the upper end, or nearly so.

In the whiting, the cardiac cavity is continued from the œsophagus, terminating in a blunt point. The duodenum surrounded by small pancreatic cœca goes off from the pyloric portion, nearly on the same level with the entrance of the œsophagus. The inner membrane of the cardiac portion is rugous; the coats of the pyloric portion are much thicker, and the opening of the pylorus is very much contracted.

In the pilchard and herring, the cardiac portion of the stomach is a small tube closed at the bottom; the pyloric portion goes off from the right side.

In the common eel and zebra eel, the cardiac portion resembles in form the finger of a glove; the pyloric portion rises an inch above the cardiac orifice, bends to the right side, and forms a projecting valve. The inner membrane is corrugated and villous. In the conger eel the lower end of the cardiac cavity terminates in a point; and the pyloric portion communicates by a small orifice with the duodenum.

As all the fishes whose stomachs are about to be described, have more or less of a spiral valve in their intestine, I have brought their stomachs into the same series.

In the salmon, the cardiac portion of the stomach is a continuation of the œsophagus, and cylindrical; the pyloric portion bends up on the right. The coats of this part are little thicker than those of the cardiac portion, except near the pylorus. The pylorus terminates in a transverse projecting valve, immediately beyond which, the duodenum is large and its coats very thin. The whole stomach appears to have a cuticular lining. The pancreatic cœca extend along the duodenum.

In the common trout, the only difference between its stomach and that of the salmon is, that the coats of the pyloric portion are thicker in proportion to those of the cardiac; and uniformly so.

The stomach of the sturgeon has a peculiar course, as shewn in the engraving. The œsophagus internally has conical papillæ, large towards the mouth, smaller below. Where these terminate, the membrane of the stomach begins; it is smooth to the first turn, there it becomes plicated, and the coats stronger; so this must be considered the end of the cardiac portion, and the remaining part as the pyloric. At the pylorus there are thick rugæ, and for about two inches the muscular coats are very strong; the inner surface at this part has long villi. The pancreas is a large oval mass, situated immediately beyond the valve of the pylorus, which is very close and of some length. The pancreas is made up of ramifications of tubes, only covered with one general coat.

In the thornback, the stomach bends upon itself, the two portions having nearly equal lengths; but the pyloric much narrower, and the orifice at the pylorus very small; the inner membrane rugous in the cardiac, and slightly plicated longitudinally in the pyloric portion. There are pancreatic cœca.

In the maid, the structure of the stomach resembles that of the thornback, except that it has two large flat glands at the lower part of the œsophagus, where ducts open into it.

The Kingston skate differs from the maid, in having a short canal between the pylorus and duodenum.

In the torpedo, the pyloric portion is smaller, forming a narrow tube.

In the angel fish, the pyloric portion resembles that of the thornback.

In the squalus acanthias, there are projecting papillæ in the œsophagus; where these end the stomach begins, and there are plicæ of some breadth. These are gradually lost in a honey-combed structure, which is continued to the termination of the cardiac portion. The pyloric portion bends up, is short, its internal surface being nearly smooth; it becomes smaller towards the pylorus, which is a simple contraction; beyond this is a small canal, separated by a slight contraction from the duodenum.*

In the squalus canicula, the pyloric portion of the stomach is extremely narrow and long; so much so, that it has been disputed whether it really is a part belonging to the stomach.

In the blue shark, the stomach has the same structure. In one seven feet five inches long, the œsophagus was three inches long, lined with a cuticle; the cardiac portion was eighteen inches long, eight in diameter, the orifice between it and the pyloric portion one-eighth of an inch; the pyloric portion eighteen inches long, and one in diameter. The cardiac portion was rugous internally, and the orificecs of glands were very distinctly seen; the pyloric portion smooth.†

* Tab. LXVII † Tab. LXVIII.

In the hammer-headed shark, the stomach has the same structure.

In the squalus maximus, the general form of the stomach is the same; but there is an additional cavity of a small size interposed between the pyloric portion and the duodenum, which renders it more complex than in other fishes, so that it bears a resemblance to the stomach of the whale-tribe; and the principle upon which this addition is given, is probably the same as in the whale. The mode in which the biliary ducts terminate in many fishes to prevent a regurgitation of the bile, as well as all the other parts connected with the stomach, are so distinctly seen in the engravings, as to make further description unnecessary.*

Of the Teeth of Fishes.

In this class of animals there is a greater variety of circumstances respecting the teeth than in any other.

In some fishes they are entirely wanting, as in the sturgeon; and in those that have them they are met with in the margin of the mouth; upon the palate; on the tongue; in the fauces; and in the space between the two portions of the under jaw; and in some fishes, as the whiting and haddock, there are hook-like processes in the beginning of the œsophagus.

The teeth are not only met with in all these different situations, but are formed of various materials. In some they are semi-transparent and hard as chrystal, in others cartilaginous; in many, composed of ivory, without any coating of enamel; in others again this coating is given to them. In their mode

* Tab. LXIX.

of succession there is also a great variety. They are found to rise up in the jaw from below into the cavity of the teeth in use: to succeed one another in parallel rows, of which there are four or five in succession: to come forward along with the increase of the length of the jaw, the point of which is gradually worn away: also to rise up with the substance of the jaw, the surface of which is a congeries of teeth in different stages of growth.

I shall take notice of these different kinds of teeth, and mention their different modes of succession.

The sturgeon's mouth shews distinctly that there are no teeth in that fish.

In the chætodon nigricans the teeth are as hard as crystal, and nearly as transparent; but when examined by a powerful lens, a few opaque lines can be perceived. They are too small to be seen distinctly except in the field of the microscope; they are not all of the same length, being longest in the front of the mouth, and becoming gradually smaller towards the angle of the jaw. There are fourteen in each jaw, each tooth consists of a cylindrical body fixed in the jaw-bone; about this junction it spreads out into a flattened form, on the edge of which are twelve or thirteen denticuli. They are described in the Philosophical Transactions by my friend the late Mr. Andrè.

The most simple teeth for laying hold, are in the mouth of the chætodon from Sumatra, called ecan bonna by the Malays, forming a single row round the mouth. They are very delicate in their form, and cartilaginous in their structure.

In the lower jaw of the sword-fish, the teeth are short like the surface of a file, for laying hold, and are cartilaginous.

In the lophius piscatorius the pointed teeth are well calculated to be used as holders, and are cartilaginous in several irregular rows. Each tooth has an elastic ligament at its base, which allows it to bend readily towards the cavity of the mouth, so that its prey when once taken cannot recede.

In the salmon-trout the holders are cartilaginous, situated on the margin of the mouth, and upon the surface of the tongue.

In the cod there are teeth of the same kind placed laterally, and on the back part of the palate.

In the pike they are in several sets on the palate, and there is a bone for the purpose of giving origin to them.

In the wolf-fish there are holders, and a pavement composed of rounded teeth, both in the upper and lower jaw; the grinding teeth in the pavement are composed of ivory.

In the light-horseman from New South Wales, there is a similar pavement, but the teeth of which it is composed are encased with enamel.

In the flying-fish, at the root of the tongue there is a triangular pavement, composed of small teeth, the smallest placed anteriorly.

In the lamprey eel, the mouth which is quite circular, has a pavement composed of blunt teeth formed of ivory, completely encompassing it.

In the diodon hystrix, the palate is a solid bone, with a cutting edge in the front of the mouth.

In the parrot-fish the jaws are formed both for cutting and bruising; and have teeth every where inclosed in their substance.

In the baracouta, the teeth on each side of the mouth are formed like lancets, for cutting, and are covered with enamel.

In the globe-fish, the front of the jaws terminates in a cutting edge ; besides which there is a curious needle-formed tusk, projecting laterally on each side. Behind, in the space between the sides of the lower jaw, there is a bony pavement formed of two separate portions, unconnected with the jaw.

In the skate, the teeth are united together, forming a covering to the cartilage of which the jaws are formed. The teeth have the appearance of a tessellated pavement.

In the different genera of rays, the teeth are formed upon the same principle, but vary exceedingly in their form. Of these, there are five different varieties in the Collection.

In the dog-fishes there are two kinds of teeth ; one, simple and pointed ; the other, with short lateral projections.

Among the voracious sharks the teeth are covered with a strong enamel, and are met with in four different forms.

In the squalus maximus the teeth are very numerous, extremely small, pointed, and placed in parallel rows, about six in number. They are formed upon small vascular pulps which rise from the surface of the gum, and become converted into ivory.

In the saw-fish, the teeth can only be considered as weapons of defence. They are composed of ivory, fixed in the projecting portion of the upper jaw.

Of Gizzards in Fishes.

Fishes whose food is inclosed in shells, have an apparatus for breaking the shells, which is not always placed in the mouth, but sometimes in the stomach, forming a gizzard similar to what has been described in birds.

This structure is most conspicuous in the stomach of the mullet; it is confined to the pyloric portion, the muscular coats of which are extremely thick, while those of the cardiac are very thin.

It is also met with in the Gillaroo trout, in Ireland, although in a less degree. In that fish the form of the stomach is exactly the same as in the salmon and common trout, only having the coats of the pyloric portion two-thirds thicker.

The common trout lives upon the same kind of food occasionally, and swallows stones for the purpose of assisting in breaking the shells; so that it is probable that the coats of the pyloric portion in the Irish trout, acquire their increased thickness from being more constantly employed in this exertion, in like manner as the sea-gull's gizzard becomes encreased in strength after it has lived some time upon grain.

LECTURE VIII.

On the digestive Organs of Worms, and Insects.

In the higher orders of animals the functions of the stomach are so distinct from those of the intestines, and the parts themselves so different in structure, that I have judged it proper to treat of them separately.

In the classes of animals whose stomachs are now under consideration, the stomach and intestine are in many instances not to be distinguished from each other, one oblong cavity serving the purposes of both; and in other instances not less numerous, where the canal is of greater extent, there is no mark to enable us to draw a line of separation between these two parts. I find myself therefore obliged to describe the intestine, where it is met with, along with the stomach, under the general head of the digestive organs; the number of instances in which they are distinct parts not being sufficient to make it necessary, on the present occasion, to go into more minute divisions of the subject.

To enter particularly into an account of the stomachs of all the animals which compose these two very extensive classes of worms and insects, would occupy more than a whole Course of Lectures, and be inconsistent with the plan which has been marked out; I therefore mean to go no further than to describe what I have myself seen, and what the preparations in the Collection illustrate; and even when the subject is thus limited, it is sufficiently abundant for our present consideration.

I shall begin with the stomachs of the worms, and then take up those of the insects.

In animals of the lower orders, as we descend in the scale, we find the mechanism of their bodies becoming more and more simple, till at last we arrive at an animal furnished apparently with no other organs but those fitted for digestion, and the propagation of the species. Without the first, it could not subsist; without the second, its race must become extinct.

Even in such animals the digestive process appears to be carried on as in those of the higher orders, since the cavity, of which the animal consists, we must presume to receive the particular food, and to retain it till it has undergone the necessary changes which render it fit to nourish the animal.

This circumstance becomes more deserving of notice, since no such reservoir is met with in any vegetable, and it points out one of the most marked distinctions between the œconomy of animals and that of plants, respecting their nourishment.

As an instance of an animal of this most simple kind, I shall mention the globular species of hydatid, which consists of a bag containing a liquid having no known aperture, but which is proved to be possessed of life, by having a power of contraction and relaxation; to have received nourishment, by its increasing in dimensions; and to propagate its species, by smaller bags similar to itself growing from its sides.

Although no absolute proof can be given, that the food in the first instance is conveyed into the cavity by passing through its coats, and there rendered fit for the nourishment of the animal, in the absence of such proof, the opinion has every support which can be derived from the closest analogy.

As this is the only species of animal that has no visible aperture leading into the stomach, with which I am acquainted, in this respect it stands alone, forming a distinct division of animals, intermediate between other animals and vegetables, respecting the mode of receiving food. It resembles all other animals in the food being conveyed into a cavity formed for that purpose; it resembles vegetables, in the mode of conveyance of the food into that cavity, which must be by absorption. These animals are met with in the brain of sheep. They feed upon the juices of living animals, which it is natural to believe are more readily converted into nourishment than dead animal matter, requiring less complex organs for that purpose.

There is nothing in nature more wonderful or more difficult to explain than the mode in which these animals are generated in such situations; and as the following facts throw much light upon this subject, I shall mention them here.

The blight in wheat, called by farmers the purples or ear-cockle, is produced by a worm, which is met with in all the stages of growth.

This worm, even when full grown, is scarcely visible to the naked eye; but in the field of the microscope all its parts are readily distinguished. The eggs are seen in the belly, and detected passing out.

The worms, when placed in a drop of water on the field of the microscope, are seen to move briskly about, but if the water is allowed to evaporate, a stain is left on the glass scarcely perceptible, but when water is added they revive and move.

This experiment has been made at intervals of months to the present time, during a period of six years; and whenever it is made, in a few hours the worms become as lively as when first taken from the corn.

This fact, of worms admitting of being dried and returning to life when moistened, was first discovered, I believe, by an Italian, whose name is unknown to me; but these experiments upon a worm living in the juices of plants, which have been made in this country, have not before been continued for so long a period.

When seed-corn has the ear-cockle applied to it and is sown, it becomes inoculated, and the worm grows in its substance and passes along the inside of the stalk in the sap, so as to be found in the seed produced.

This is exactly similar to what must happen in animals in which the tænia hydatigenia and tænia fasciola are met with; and the worm in the aqueous humour of the eye of the horse.

The smut in wheat is a vegetable, a species of fungus, the seeds of which being mixed with the seed-wheat, vegetate in the internal parts of the plant, and pass through several generations before the crop comes to maturity. They are detected at the joints in a state of fructification; they pass up in time and arrive at the new seed, which is found, instead of containing meal, to be filled with these stinking fungi.

The tænia hydatigenia ovalis, found in cysts connected with the liver and kidneys, and in the brains of sheep, forms the first of a second division of animals with respect to their nourishment; that is, of those that receive their food by the mouth, and have no visible mode of throwing off any superfluous part of it, the head being so attached to the part in which the animal feeds, as to appear not to admit of regurgitation. The tænia solium and tænia lata, both met with in the intestines of animals, also belong to this second division ; they have heads and distinct mouths, which in their use exactly resemble those of the tænia hydatigenia ovalis, giving attachment to the animal, and enabling it to draw nourishment from the part to which it is attached.

In the tænia lata and tænia solium, the stomach is not a circumscribed cavity, but is formed into two tubes, which run the whole length of the animal without having any apparent external opening in their course, or at the lower extremity. In the tænia lata these tubes have no lateral communications ; in the solium, they are connected by transverse canals.

The animal which may be given as the first illustration of a third division, or of those which have a power of regurgitating their food, is the fasciola hepatica. It has a mouth, but no regularly-formed head, and therefore has no means of attaching itself to any particular situation ; the stomach consists of a small twisted canal passing from the mouth into the body of the animal, without any apparent opening at the lower extremity. This animal has certainly the power of regurgitating any part of its food.

The animals that belong to this division are exceedingly numerous ; they form several extensive tribes, distinguished from one another by the different habitations which they form for their own defence, and are known by one general name, polypi. It is an animal of this description which forms and inhabits the branches of the corallines, corals, and brainstones ; and there are other species, both in salt and fresh water, which have no such habitation.

In all these, the stomach has only one external opening by which the food is received, and its superfluous or excrementitious parts are regurgitated.

Belonging to this division are the sea-blubbers and the actiniæ: their digestive organs differ, however, considerably in their structure from those already described, as well as from one another; the only real similarity is in having one external opening leading into them.

The sea blubbers or medusæ, of which there is an infinite variety, have one central cavity for receiving the food, and from this go off ramifications leading to every part of the animal, by which means the nutriment is conveyed to them; so that in such animals the stomach not only prepares the food, but forms a reservoir from which it is distributed to all parts of the body, answering the purpose of the heart in the higher orders of animals.

In the smaller medusæ, from the tenderness and transparency of their substance, it is not easy to make out satisfactorily, the facts which I have stated; but I was fortunate enough in the year 1780, while resident in the naval hospital at Plymouth, to catch an enormous blubber, which in its expanded state measured more than three feet in diameter, and was so firm in its texture as to bear examination. It was sent to London, and Mr. Hunter filled the central cavity and many of the tubes with which it communicated, with injection, shewing distinctly the connection between them, One of the portions so injected is preserved in the Collection.

The stomachs of the actiniæ have a very different structure; but from the readiness with which the animal contracts itself into a small form, when handled while alive, and the contracted state in which it is met with after death, the examination of the parts is attended with the utmost difficulty.

In the year 1779, I saw these animals in vast numbers in a large cavern in the rocks upon the coast of Cornwall, which was overflowed by the sea when the tide was in, and was nearly empty at low water. I employed myself in endeavouring to make out the structure of the stomach.

The mouth in its contracted state has the appearance of a long slit, the two lips that form it being closely applied together; but when it is open, it forms a wide circular orifice, and within is seen a large pellucid membranous bag, made up of convolutions or folds; one edge of which is attached below very firmly to the strong muscular substance by which the animal adheres to the rocks; the other is connected to a welt or rim, immediately under and within the external mouth.

This welted rim is exceedingly contractile: the animal has the power of opening it out, and then the appearance within, is that of numerous convolutions of ducts; but this proves only to be formed by the doubled edges of the lateral folds of the membranous bag.

When the rim is completely expanded a cavity is exposed, the capacity of which is equal to the inside of the animal; this cavity is the stomach; the surrounding membrane is loose, and its folds appear to be alternately large and small. The animal can dilate them at pleasure, either separately or together; but this cannot be done after it is dead. Between these, are the openings of the tubes of the external tentacula, through which the animal empties the stomach after having distended it with water. Nothing can be more beautiful than to see one of these animals swell itself out with water, then erect its tentacula by filling them, and throw out the water to a great distance with considerable force from their points.

This operation must answer the purpose of breathing, as it is constantly going on with only short intervals; but the tentacula in their turgid state are also employed for catching the food, which consists partly of sea-snails. They close round them and conduct them into the central opening, which then shuts; and when the soft parts are digested, the shells are thrown out by the same orifice.

If any thing simply touches the tentacula they lay hold of it; but if it presses against them they recede, and almost elude the eye, so completely do they contract. The materials of which these animals are composed have a greater power of contraction than any other with which I am acquainted.

With the actiniæ, I shall conclude the account of this great division of stomachs, comprehending all those which have only one opening externally.

After these, I shall endeavour to describe those stomachs which have an opening at each of their extremities, without being furnished with an intestine, having one uniform appearance throughout the whole canal, so as to make it reasonable to believe whatever office is performed, that it is equally done by every part of the tube.

Of this kind are the stomachs of many worms which are found in the stomachs and intestinal canal of the higher orders of animals. The first which I shall mention is the lumbricus intestinalis.

The lumbricus intestinalis has the mouth opening between three small tubercles, within these is a proboscis a quarter of an inch long, which it has the power of projecting, and by means of it attaches itself to the side of the gut.

The œsophagus is small, and about one-fourth part of the length of the animal; it terminates opposite the external aperture of the oviducts; it then contracts, forming the orifice of the stomach, which is considerably larger than the œsophagus, taking the form of the body of the animal, with a smooth internal surface; and just under the point of the tail is a transverse slit, which is the anus.

In the piked-whale there is a species of lumbricus, some of them seven inches long, some shorter, the head circular, broad, and flattened, with a very narrow neck. The whole head buries itself behind the inner membrane of the gut, and in this way the worm retains itself in its place. The mouth is in the centre of the surface of the circular head, forming a small projection; from this, a canal the size of a common thread extends the whole length of the body, forming the stomach.

Worms of the same kind are met with in other species of whales; and in the intestines of the eider duck, only of a very small size, not more than an inch long; so that these worms appear to be peculiar to the northern seas.

In the ascaris of the horse the stomach has the same form.

In the bott, before it becomes a fly, the stomach is a simple tube of a small size.

In the sea-worm, or animal flower of Barbadoes contained in the coral rocks, the stomach forms one continued tube, extending the whole length of the animal.

In another species, which is enclosed in a soft tubular coat, the stomach has the form of a long intestine. It is thrown into close spiral turns through its whole course, but is one uniform canal.

In the priapism the stomach is still more extended, but has the same uniform appearance throughout the whole canal, which is five or six times the length of the animal. It passes from the mouth nearly to the lower end, then up again, and then turns down to terminate at the anus. It is very much convoluted in its course, and attached to the sides of the body of the animal by thin membranes, which may be called mesentery. The gut does not terminate at the extreme part, but opens into a cavity the whole width of the body, and this cavity opens externally by an orifice which projects inwardly.

In the caterpillar-stage of some insects, such as the silkworm, there is one straight canal passing from the head to the tail, which when full, is nearly as large as the body of the animal. It forms œsophagus and stomach. These caterpillars eat voraciously; but the leaves which pass through them have undergone little change, they only appear browner, and almost dry. In the larva of some of the large moths, the stomach has the same general form as in the priapism, only without convolutions, making a course the length of the animal; then up again to the head; after which it passes down to the anus. Its internal surface is smooth.

Having given so many instances in which the stomach has a tubular form, I shall proceed to the description of stomachs which have a canal proceeding from the stomach, different in its capacity, and evidently fitted for other purposes, than those immediately connected with digestion.

The most simple of this kind, and therefore first to be noticed, is the common leech. This animal has a stomach and an intestine; but the intestine is such, as to have escaped the notice of most anatomists, and appears not to have been perfectly known, even by those who have asserted its existence.

The form of the leech's stomach will be best understood by referring to the annexed engraving;* and as no correct account of the stomach of this animal, so much within every one's reach, has been given, I shall explain the manner in which the parts were so distinctly made out. In a leech that I had caused to be kept without food for a fortnight or three weeks, an injecting pipe was fixed into the mouth, and the cavity of the stomach in this way was distended with proof spirit; after the parts had become hardened by the spirit, they were examined, which could be much more readily done, than when the cavity is distended with blood. The last mode was that adopted by Mr. Hunter, and many preparations so distended are in the Collection.

The stomach is not simply an oval bag, but an oblong cavity of some length, the lower portion of which is divided longitudinally by a middle septum; and in this way two cœca or appendages are formed, communicating with the general cavity; and there is a canal or intestine of very small dimensions, passing down in the duplicature of the septum which divides the cœca from each other; it terminates on the posterior surface by a small transverse orifice, a little way from the extremity of the animal.

This structure of stomach is evidently for the purpose of œconomising the food, by the obstacles opposed to its passing out of the stomach. These indeed, are so great, as almos

* Tab. LXX.

entirely to prevent it from doing so; and the readiness which the animal possesses of disgorging itself, has led into the general mistake of its having no second opening by which the contents of the stomach may be evacuated.

Another mode employed in this animal for œconomising its food is, by the immense valvulæ conniventes of different forms that are met with in the stomach, upon the surfaces of which the food is spread out and retained. In this leech, which was apparently quite empty, and which had been without food, to what extent of time cannot be determined, there was upon almost every one of the valvulæ a small portion of coagulated blood.

There is another set of animals, whose stomachs, in the principle of their structure, so nearly resemble that of the leech, although the form is in many respects different, that I am led to place them under the same head. I am the more induced to do so, as bringing them together throws considerable light upon the use of the cœca, or lateral reservoirs, with which the stomachs are supplied.

This genus of animals was first noticed, I believe, by Sir Joseph Banks in his Voyage round the World; during which he had opportunities of having drawings made of several species while alive; and from him I derive all the information I possess respecting their external form and appearance.

Mr. Hunter had the opportunity of examining the internal structure of two different species, which fortunately I have been able to ascertain to be the same as those Sir Joseph Banks met with; and the annexed engravings of the external and internal parts are derived from these sources.

As many of these animals have a brilliant appearance like cut glass, Sir Joseph Banks gave the name of Dagysa to the genus; some have been since found to emit light.

The following account of a small species of dagysa communicated to Sir Joseph Banks by Mr. Francis Beaufort, is so clear and satisfactory, that I shall give it at length, as a description of the species gemma. This species examined in the microscope, appears to correspond with the larger species in its internal structure; but nothing sufficiently accurate can be ascertained to enable me to describe the form of the stomach, since in such minute objects there are so many sources of error in microscopical observations.

"In April 1806, 20° south of the Line, and not far from the Island of Trinidad, on a remarkably dark and blustry night, the sea appeared in one continued blaze as far as the eye could reach; illuminated by large spots of liquid light floating on the surface, some immersed under water. So strong was the light they emitted, that sitting in the quarter-gallery, I could read a small type with ease; and the sails, and the smallest ropes up to the masts'-heads were distinctly visible. The light being directly under these objects, produced a pleasant optical illusion, the sails appearing convex when concave, and concave when convex.

"In December 1807, (17° north, and 34° west) I succeeded in catching two of those luminous masses: when put into a bucket of salt water, they remained stationary at the bottom, and gave no light, unless the water was violently agitated. On holding one in my hand and gently pressing it, a faint flame seemed to pervade the whole inside; and on each projecting point there seemed to stand a little globule of very vivid light.

" On increasing the pressure its brilliancy likewise increased for a few moments, then gradually declined for some time, as if exhausted by the exertion. It may have been fancy, but at the time, I was convinced that it gave out a sensible degree of warmth to the hand.

" From the orifice in either end, water slowly dropped, a kind of valve seemed to prevent its coming faster, even when gently squeezed. One was immediately put into spirits of wine; and has at this moment precisely the same appearance it had then: the other was left in salt water till morning, when, (probably from the handling it had received) it was quite putrid and discoloured.

" Whether these luminous blubbers have the powers of loco-motion, or owe their continual change of place to the undulation of the sea, I am not certain, as I have never seen them except when there has been a smart breeze and some swell. One fact is remarkable, that when lying to, and passing slowly through a shoal of them, their lights have been extinguished the moment they reached the smooth water under the lee of the ship, which seems almost conclusive, that agitation of the water is necessary to make them display their little lamps.

" I have generally observed, that where the sea has been more than ordinarily bright, a breeze has followed: and though shining particles are to be seen in all parts of the ocean, these large brilliant spots seem limited to the torrid zone.

FRANCIS BEAUFORT."

February, 1808.

The mouth of these dagysæ is a simple orifice, which opens into a cavity within the external covering of the animal. The œsophagus in one species is short, and the stomach appears to be a direct continuation of it, but distinguished by its two lateral cœca, which are coiled in a spiral form, each of them upon itself in the centre; round these the intestine winds, and terminates when it has got beyond them: so that the gut is in fact not so long as one of the cœca of the stomach.

In the other species, the œsophagus is much larger, and the cœca are of considerable length; the course of the intestine is not shewn, but it is evidently very short, more so in proportion than in the first species.*

Next to the dagysæ in the series of structures of digestive organs, are what, I believe, to be known by the name salpæ: but in the classification of these soft sea-animals there is much confusion: every naturalist who has described them, choosing to adopt his own arbitrary divisions into genera, which makes it impossible for me, who am not well versed in what has been published on the external appearances of animals, to attempt to follow them. That I may not, however, lead others into any mistake, I may mention that the salpæ differ from the dagysæ, in not only having an external opening at each end, but also one upon one side.

In these animals the mouth is also within the inner gelatinous covering; the œsophagus is extremely short; and from the stomach, which appears to be coiled upon itself, the intestine passes down to a considerable distance, and terminates in an orifice near the opposite extremity of the animal to that in which the mouth is situated.†

* Tab. LXXI. LXXII. LXXIII.

† Tab. LXXIII.

In another species of those animals with gelatinous coverings, there are at one end two projecting processes and an opening in each, and within this an internal membrane of the same shape, the digestive organs put on a different form from those already described; there being a mouth at the lower part; a short œsophagus swelling into an oviform stomach, which contracts into an intestine, nearly equal in length to that of the dagysa with its cœca; but here no impediments are probably required to the passing of the food; and the stomach and intestine is formed into one regular canal, making a convolution upon itself.

The next animal whose stomach I shall describe, is also one of those with gelatinous coverings. Its form is distinct in the annexed engraving; the stomach and intestine resembles that of the dagysa and salpa, in having the opening of the mouth within the external covering, but not that of the anus. The mouth is very open; the œsophagus extremely short; the stomach swells out, so as to become a distinct organ; and the intestine has a considerable length and opens externally, at the opposite extremity of the animal.*

The stomach of the barnacle differs little from that which was last described, as will be seen by comparing the engravings.†

The stomach and intestine of the echinus form a very close link in the chain to that of the barnacle, only there is a kind of cœcum connected with it.‡

In the oyster, the stomach is a cavity of a less regular form, and the intestine is less uniform in its course.§

In the muscle, the stomach is small; but there is a pecu-

* Tab. LXXIV. † Tab. LXXV. ‡ Tab. LXXVI. § Tab. LXXVII.

liarity in the course of the intestine, the use of which does not belong to the subject of the present Lecture.*

In the sea-snail or doris, the stomach is tubular, and the intestine winds round the cavity of the abdomen, terminating at the lower extremity.

In the land-snail, the stomach has an oval form: and the intestine, which is smaller in proportion than in the doris, makes turns in the liver, and then back upon itself.

The anatomy of this tribe of animals is so well known to the public by the valuable labours of M. Cuvier, that I need not say more upon the subject

The common earthworm may be said to have both a crop and a gizzard. The œsophagus, stomach, and intestine, make one straight canal, extending the whole length of the animal; the stomach consists of a bag, which serves as a reservoir; it has a strong circular ring surrounding it, capable of compressing the food with considerable force, and answering the purpose of a gizzard. The intestine in its course is acted on by the circular rings of the animal; so that it is more contracted at these parts, having a lateral swell in the intermediate portions. Worms eat vegetables, since they are found in the stomach; but as the worm has no teeth, it can only eat those that do not require being cut into pieces. From the quantity of earth met with in their stomachs, this appears to be their principal food. Their mode of feeding is curious. They come out of their holes after rain, leaving only about three inches of the tail in the ground, and eat the moistened earth. On being disturbed they retract themselves entirely; so that they

* Tab. LXXVIII.

shorten the whole body to the length of three inches, the length of the part in the hole.

The sea-mouse or aphrodita, has a stomach of an oval form; and such is the thickness of its coats, that it must be ranked among the gizzards. The intestine goes on in a straight line to the anus; there are lateral canals going off from it, which are peculiar to this animal.

The nereis is a sea-worm, of which there are different species, and the stomach is not in all of them of the same form. It is a curious circumstance that a worm of this kind was presented to me, which had been found at Bermuda, of the enormous length of ten feet; it was so mutilated, that the stomach could not be examined.

In one species of nereis, the gigantea, the stomach is an oval cavity, the coats of which are very strong; within the orifice of the stomach are the teeth, and immediately above them is a projecting fold of the œsophagus, which may be called the orifice of the stomach; the pylorus is very narrow, and projects into the intestine. These parts are seen in the annexed engraving magnified two-thirds beyond the natural size.

In another species which is also represented as large again as in nature, the stomach is more capacious and thinner in its coats. There are teeth attached to the sides of the stomach; the cavity at the lower part has a very glandular structure, and there is a prominent body attached on each side to its external surface. The pylorus projects into the duodenum.*

* Tab. LXXIX.

After the nereis, I shall take the teredo navalis, which corresponds in the form of its stomach with the other teredines.

The œsophagus is very short, and lies on the left side of the neck: the canal swells out and becomes stomach, which in its external appearance is a large bag extending the whole length of the cavity of the abdomen; but when laid open, it is found to have a septum, dividing it longitudinally into two equal portions, except at the lowest part where they communicate, the septum being wanting.

In the teredines examined while alive, the stomachs were empty; but in some preserved specimens they were filled with a yellow pulp, which in the large one shewn in the engraving amounted to ten grains. The pulp when examined by Mr. Hatchett in different ways, proved to be vegetable saw-dust. The intestine has its origin close to the termination of the œsophagus, is extremely small, dilates into a cavity containing a hard white spherical body the size of a pin's head, and then makes a turn upon itself. The course it follows is shewn in the engraving.*

As some teredines bore in wood, and others of a much larger size, as the gigantea, bore in mud, and the parts destroyed are carried through the stomach, it becomes a question whether this vegetable and earthy matter is the animal's real food on which it subsists. When we compare the mode of nourishment of other gelatinous sea-worms with this before us, there is reason to believe that the saw-dust, of whatever kind, serves only as a substance in which the real food procured from the sea is entangled and prevented from escaping too readily from the stomach.

* Tab. LXXX.

The animal of the solen, or razor shell, in its general characters is allied to the myæ; but the intestine, in length and smallness of size, resembles that of the teredines. The body of the animal, when removed from the shell, has a covering, which forms a hollow tube for one-half of its length; the other half is open. From the open part there proceeds a large pendulous proboscis, employed in progressive motion, in the root of which the viscera are placed. The œsophagus is short; the stomach forms an oval bag; the intestine is small and long: it is coiled upon itself, which is not the case in the other molusca. The general appearance of the animal, the shape of the stomach, and the course of the intestines, are shewn in the engravings.*

In the sepia officinalis, the stomach is complex. The œsophagus is very long and small, and enters the stomach at one end; the first cavity is oval, has a cuticular lining, and is plicated through its whole extent. The passage into the second cavity is short, and close to the termination of the œsophagus. This cavity is nearly globular; its internal surface has deep transverse plicæ; the opening into the duodenum is large, but the orifice is filled up by two oval projecting bodies of different sizes, the smaller of which appears to form a valve over another orifice, situated laterally immediately below the pylorus. This lateral orifice communicates with another cavity in the form of a spiral tube, making two turns and a half, like a screw, and terminating in a blind extremity. The spiral tube is largest in the middle, and smallest at its termination. On laying it open, there are found deep transverse folds of the

* Tab. LXXXII.

inner membrane; and on its inside there is a projecting ridge of solid substance running the whole length of the tube, and taking the same spiral course. The intestine is a short straight tube with longitudinal plicæ on its inner surface. Within the anus the ink-bag opens into the gut: this bag is oval, of some extent, and lies in contact with the intestine.*

In the sepia octopodia the œsophagus is small and straight; but about two inches from the mouth there is a lateral dilatation or short cœcum, into which the ducts of two glands open; from this part the œsophagus passes on double its former size for two inches more, then terminates in the stomach, which swells out on the left side into a rounded cavity, being a true gizzard, having its two sides each a quarter of an inch thick, and lined with a cuticle. Immediately beyond the gizzard on the lower side of the canal is situated a spiral appendage, similar to that in the former species, except that the ridge is double, and smaller in proportion to the size of the cavity.

The duodenum goes from the orifice of the stomach, so as to appear to be a continuation of the œsophagus. The duct of the liver opens into the middle of the spiral tube; from which circumstance, and from its resemblance with respect to situation, to the pyloric appendages of the fish, it may be supposed to answer the purpose of the pancreas. The intestine makes one turn, and then another back upon itself, like the duodenum in birds, and then goes straight to the anus. Internally there are four longitudinal rugæ, and the intervening space is villous.

The ink-bag is so imbedded in the liver as to be concealed there; but it has no communication with it, and the duct opens

* Tab. LXXXIII.

into the rectum. The ink secreted in this bag has been said to be thrown out to conceal the animal from its pursuers; but in a future Lecture, I shall endeavour to shew that this secretion is to answer a purpose in the animal œconomy, connected with the functions of the intestines.

On the Teeth of the Vermes.

Having described the digestive organs of a sufficient number of the different genera of vermes to shew an extensive series of structures, I shall, in conformity with the general plan I have adopted, make some observations upon the teeth of this class of animals.

The greater number of the vermes are without teeth; and those which are met with are composed of different materials.

In the leech they are three in number, situated immediately within the lips; they are white, cartilaginous, and rounded on their cutting edge: they are so attached as to be moveable at their base. As soon as the wound is inflicted they fall back, and leave the whole of the mouth open for sucking the blood.

The teeth of the echinus are composed of the same materials as the shell, and are readily seen in the preparation.

Snails of every species have one broad tooth, which is curved and serrated on the edge. It is only met with in the upper jaw; it comes off with the cuticle, and is nearly of the nature of tortoise-shell. Snails eat vegetables, but only when wet.

The teeth of the doris are of a similar structure, one in each jaw.

In the different species of nereis, the teeth appear of the same kind as in the snail, although situated in the stomach;

in one species there are three, with smooth cutting edges; in the other, only two, which are serrated.*

In the teredines, the boring shells or teeth differ from those of all other animals; for instead of being in the mouth, the mouth is within them, as well as the whole head, for which they form a case. They are in texture similar to the shell of the animal, and have each a sharp cutting edge: they are two in number, united together on the back part of the head by a strong digastric muscle; from the middle tendon of which, the muscular fibres go off in a radiated manner, partly to be inserted into the concave surface of the teeth, and partly into a long semi-circular process, projecting from their posterior part.

The teeth are connected on the opposite side of the head by a ligament, from which they are readily separated. At this part there are two small processes, one belonging to the narrow edge of each tooth, where they are joined together.†

From the centre of the head a kind of proboscis projects, which has a vermicular motion when the animal is alive; its extremity has a cuticular covering. in appearance not unlike the cornea of the eye. When this cuticular covering is removed, the cavity under it is found to contain a brown-coloured gelatinous substance, of the form of a Florence-flask, with the rounded end upwards. As this proboscis has no orifice in it, there is reason to believe that its cuticular rounded end adheres to the wood, as a centre-bit while the teeth are in action; and by these means the canal is made perfectly cylindrical. The mouth is a rounded orifice, between the proboscis and digastric muscle.

* Tab. LXXIX. † Tab. LXXXXI.

The beaks of the different species of cuttle-fish are cuticular entirely.

Of the digestive Organs of Insects.

The most simple construction of stomach in the insect tribe which I have met with, is in the pediculus; the food of which being blood, requires less apparatus for its digestion than most other substances.

When a pediculus is kept for some time without food, the body becomes almost transparent, except a dark central line, which is the stomach contracted, only containing a small portion of digested blood. As soon as it is allowed to suck, it voids these contents in a dry state, thus making room for the fresh blood. When the stomach is thus filled, if the animal is placed in the field of a microscope, the canal of the stomach is seen moving with a peristaltic motion, which might be mistaken for the action of the heart, were the blood of insects red; but it is universally white.

The wound which the pediculus makes is not large enough for red blood to escape when the animal is not sucking.

In the crab and lobster the œsophagus is very short, lined with a smooth cuticle. The stomach swells out into a large cavity on the lower or anterior part, and to a greater degree on the two sides than in the middle, so as to form an approach to two cœca.

On the posterior part there is a regular channel into the duodenum. The stomach is lined with a strong cuticular covering, made of the same materials as the external shell, which makes it keep its shape when empty. There is a curious circumstance which takes place in consequence of this structure, which is, that at the time the animal sheds its external shell, it sheds also the lining of the stomach; and may be said to digest its own stomach, or more properly speaking, get rid of it.

The teeth are in the stomach, and are shed along with its crustaceous covering.

The duodenum is a straight small tube, and terminates at the end of the tail.

In the grasshopper, gryllus cristatus, the stomach is only to be distinguished by that end of the canal being the largest. There are six or seven large bags lying on the outside of the stomach parallel to it, the largest next the œsophagus. They are closed at the ends, and have an opening in the middle on one side, by which they communicate with the cavity of the stomach; they contain a curdly substance.

In a large green grasshopper, with small eyes and a long projecting tail, gryllus viridissimus, the œsophagus passes through the neck, and in the thorax grows gradually wider; then contracts, and terminates in a little pyramidal body lined with a horny cuticle, with longitudinal ridges, the edges of which are serrated, and capable of dividing the food before it enters the stomach. The cavity of the stomach has a cœcum on each side, and the pyramidal body projects between them.

In the Cape grasshopper there is a similar structure, only the œsophagus is less pyramidal at its termination; the course of the intestine is very simple. The parts are seen much magnified in the engraving.*

The difference of structure in the stomach of the common grasshopper, and the others arising from the nature of the

* Tab. LXXXIV.

food being different, corresponds to that between the stomachs of the common and the gillaroo trout.

The mole-cricket, in the general structure of its digestive organs, resembles the Cape grasshopper. The œsophagus begins between the roots of the two pincers behind the anterior flap that covers the parts about the mouth. It passes through the head in a horny case ; when arrived at the abdomen it swells out laterally, then forms a pyramidal cavity, whose coats are extremely thick, and the inner surface is covered with cells placed in rows parallel to the cavity.

From the end of the pyramid the cavity of the stomach begins, which becomes dilated, and on the fore and back part incloses the pyramid or gizzard, forming two cœca. From the lower end of the stomach the duodenum passes out nearly straight, but at the lower part becomes twisted upon itself, where it receives the ducts of the liver, then forms the rectum. At each side of the rectum is a white bag, which appears to open at the anus.

In a fly-insect from the South Seas, of which the external form is not preserved, the stomach with its cœca and turns of the intestine are very similar to those of the mole-cricket and grasshopper.

In the silk moths it is curious to observe the change which takes place in the structure and form of the digestive organs, corresponding to the changes in the external form of the insect.

In the caterpillar state, I have mentioned the stomach to be one tube, nearly equal in size. When this is accurately examined, one quarter of an inch may be called œsophagus, as the canal beyond that part becomes thicker in its coats.

One quarter of an inch from the anus there is a contraction: at this part is afterwards the beginning of the intestine.

When the worm begins to spin, the excrement is voided with a little yellow mucus, so as to empty the stomach.

When it comes out of the chrysalis state, the covering of the head, the teeth, and face drop off; the stomach is filled with a little yellow mucus, which is probably its nourishment in the chrysalis state. This mucus is now pushed out of the stomach, and goes along the intestine, which is formed into a straight tube, having a bag or reservoir at the anus in which the mucus is deposited, and the cavity of the stomach is contracted into a small size.

When the moth dies a natural death, the vestiges of the stomach are hardly visible, and are only known by the intestine beginning there. The bag at the anus remains of the same size as when first formed, and contains a brownish fluid, with a white chalky substance in it.

In the queen of the termites, the course of the stomach and intestine closely resembles that in the larva of the large moth, as is seen in the engraving.*

In the labourers, when arrived at the fly-state, the parts put on the appearances represented in the engraving. The intestine is much smaller, which shews the termination of the stomach, not to be distinguished in the queen.*

In the dragon-fly, the stomach is a straight canal, the termination of which is surrounded by a body which is probably the pancreas. The intestine is nearly straight to the anus, which is just under the tail; ducts, which appear to be those of the liver, open into the rectum.

* Tab. LXXXIV.

In the blue-bottle-fly, the œsophagus in the neck is surrounded by a thick, apparently glandular substance. It divides there into two canals of different sizes; the smallest passes down the neck, along the thorax into the abdomen, and then dilates into a large bag which lies across the body. The other canal passes down behind into the abdomen, becomes larger, so as to deserve the name of stomach. It then contracts, becoming intestine, which is thrown into convolutions; it afterwards becomes straight, and receives the ducts of the liver or pancreas. Where the rectum begins there is a valvular structure, below which is a reservoir for the fæces, the coats of which are firmer, and the gut is flattened. On each side is a conical body, the base of which adheres to the side of the gut, but the body itself projects into the cavity with its apex obliquely downwards, on which is the appearance of a number of glandular orifices. The bag into which the first canal from the œsophagus leads, was proved to be a reservoir for food by the following experiment.

Some flies immediately after drinking milk were immersed in spirit. This bag, as well as the stomach, had recent curd in it.

This experiment was repeated with milk, coloured with cochineal, and the result was the same.

In all the bee-tribe the œsophagus begins at the root of the tongue, passes down through the neck and thorax, and as soon as it enters the abdomen dilates into a transparent bag. This is the crop or reservoir, and the contents of this bag are either carried on to the stomach, or regurgitated, at the will of the insect.

This fact was ascertained by catching bees on their return home, when the crop was distended with honey, and a small quantity was found in the stomach. The stomach is a little below, and to the right of the crop, which communicates with it by a tube, the upper end of which rises to some height from the bottom of the crop, and is distinctly seen through its thin coats when full of honey.

The lower end projects downwards into the cavity of the stomach, and forms a valve to prevent the contents of the stomach returning into the crop, which would spoil the honey lodged there.

The stomach has the appearance of an intestine: it passes almost directly down in the middle of the abdomen. Its inner surface is very much encreased, either by circular or spiral valves. The exact termination of the stomach cannot be ascertained; but the canal soon becomes smaller and convoluted.

The intestine makes two or three turns upon itself, and then passes on to its termination at the lower part of the abdomen, where it enlarges forming a reservoir for the fæces, and then contracts a little, just before it opens externally.

In the hornet, the œsophagus is of the size of a large horsehair; the crop, that of a pea, and oviform. Hornets eat meat, ripe fruits, and sugar.

The digestive organs of the wasp are the same as those of the bee; wasps feed upon fruits of the softest and sweetest kinds, as nectarines, cherries, &c.; but they are also fond of such meat as they can divide with their forceps: liver for instance. They eat insects, sugar, and honey; whether they suck flowers is not known. They are seen on the leaves of the cherry-tree; when those leaves are covered with a sweetish substance.

About the beginning of October they are seen in great numbers, both the labourers and males, on the leaves of the willow. When the nest is very strong in labourers, they often, towards the end of September, make an attack on bee-hives, the bees becoming more indolent at that season. They eat not only the honey, but the maggots: they also catch flies, turn up their bellies, and feed upon their entrails.

On the Teeth of Insects.

The teeth of insects resemble so much those of worms, as to make it unnecessary to say much respecting them.

As in worms, they are met with in the mouth, œsophagus, and stomach; and are either cuticular or crustaceous in their texture.

In the Cape grasshopper, they may be said to be placed in the gizzard, and of a horny nature, in transverse rows.

In the mole-cricket they form longitudinal ridges, with serrated edges.

In the crab and lobster their situation is near the pylorus of the stomach. There are two molares, one on each side, so as to oppose each other; their bases are attached to the cuticular lining of the stomach; and immediately beyond these is a single projecting tooth, to keep the food between the others till it is sufficiently masticated. They are composed of the same hard materials as the external crustaceous covering of the insect.

In many of the genera of both of these classes of animals the stomach is employed, not only to digest the food, but to provide an absorbing surface, by means of which, the chyle when formed, may be carried into the general system; and in this respect it differs principally from that of the higher orders of animals.

In others again, many, if not all the complications of this organ, found in the class mammalia, are to be met with; nor is it wonderful that it should be so, since this organ must be adapted to the particular food on which the animal is destined to live; and to whatever class it belongs, the necessary means must be furnished for its preparation and digestion: and although the resources of nature are such, as not to require that those means should he exactly the same, they must bear a considerable degree of analogy to one another.

LECTURE IX.

On the Intestines of Fishes, amphibious Animals, and cold-blooded Animals that breathe Air.

In pursuing our progress in the ascending scale of complexity of structure, there is no course that can be followed which is not liable to some objection; for one organ is often very simple in its form, while most of the others in the same animal are complex; and therefore were we to attempt to bring this simple organ to its proper place in the scale, we should introduce it among parts belonging to a different class of animals, which would too much disturb any general plan of arrangement. The intestines of snakes are on the whole, more simple in their form than those of fishes, and yet it will be proper to begin the present Lecture with the intestines of the latter, more especially as there are some among them in which the structure of these parts is of the most simple kind.

In fishes, the intestinal canal varies exceedingly both in length and structure, but it is in general very short; and in the flying fish (exocætus volitans,) there is no sufficient mark to distinguish it from the stomach; so that I have already described the whole tube as belonging to the latter.

In the crop-fish, the intestine is a simple tube passing down from the posterior surface of the stomach to the anus, making four turns.

The pilchard in this respect is the same as the crop-fish.

In the common eel, the intestine is a simple straight canal, passing down from the curve at the pyloric portion of the stomach to the anus; near the termination there are a few slight convolutions. Its internal surface has fine pulpy plicæ running in a longitudinal direction, but zigzag in their course.

The conger eel resembles the common eel.*

In the zebra eel, the intestine differs from that of the common eel in its internal membrane, having longitudinal ridges, and more of a honey-comb appearance.

In the lamprey eel, the intestine is of the size of a goose quill; it has no convolutions; there are small longitudinal folds through the whole extent.

In the pike, the intestine is twice the length of the abdomen, its internal surface is smooth; within the anus there is a slight valvular projection pointing downwards.†

In the turbot, the intestine makes the same turns as in the pike, but dilates at the upper and lower parts, making a distinct division into three portions, which is not the case in the fishes we have already explained. In conformity with common anatomical language I shall call these duodenum, jejunum, and rectum. The duodenum on the inner surface is villous, slightly plicated longitudinally, the rectum is thinner in its coats, with villi on its internal surface.‡

In the electrical eel, the course of the intestine is very different from that in other eels; it descends on the right side, winds round the cardiac portion of the stomach as high as its orifice, returns back to the lower part, and then passes in a straight direction towards the head, and terminates at the

* Tab. LXXXV. † Tab. LXXXVI. ‡ Tab. LXXXVII.

root of the tongue. This unusual course appears to depend intirely on circumstances unconnected with the uses to which the intestine is applied, being only to give room for the electrical organs. This intestine admits of a division into duodenum, jejunum, and rectum; its internal surface is smooth.*

In the toad-fish, the duodenum at its origin is very large, it makes a turn to the right, there becomes smaller, and may be called jejunum. The intestine then passes down on the right side, up again upon itself, and then down, crossing more to the left behind the stomach, where it swells out to form the rectum, going directly to the anus.†

In the flounder, the duodenum passes down on the left side, crosses the body becoming jejunum, which passes up, then turns down and up again, where it becomes rectum. Its internal surface has a reticulated structure through its whole course.‡

In the whiting, the duodenum bends to the right side. The jejunum makes three turns; at the lower part of the last, there is a valve where the rectum begins. The inner surface is smooth in the jejunum, in the rectum rugous.

In the haddock, the intestine has the same course as in the whiting, but the jejunum is a little more convoluted.§

In the sole, the duodenum bends to the right side. The jejunum makes four turns, the whole length of the abdomen. The lower part of the last forms the rectum, which terminates near the mouth. The inner surface of the intestine is faintly plicated through its whole extent.‖

* Tab. LXXXVIII. † Tab. LXXXIX. ‡ Tab. LXXXIX.
§ Tab. XC. ‖ Tab. XCI.

In the scorpæna horrida, the duodenum passes up to the right, as high as the æsophagus, the jejunum goes down and up again, terminating all at once in the rectum, making an angle like a small cœcum. The rectum is unusually large and long.*

In the gurnet, the intestine makes three turns nearly of the same size.†

In the cod, the duodenum passes up to the right; the jejunum makes three turns, the lower portion of the last swells out, and forms the rectum. In this fish, the anus is more in the middle of the belly than in others, so that the cavity of the abdomen extends nearer the tail, and the intestines pass lower down. The inner surface of the duodenum is honey-combed: in the jejunum are no projecting valves, except one at its termination in the rectum, which points downwards.

In the whiting paulic, the anus has the same situation as in the cod.

The intestines of all the fishes which have been described, have a very similar course, only being longer in some than in others.

In the lophius piscatorius, the intestines are disposed differently, and more like those of land animals, than in any fishes with which I am acquainted. The duodenum begins by a long cœcum, passes down to the right side, becomes much contracted in size, crosses the body, makes six short turns on the left side, then passes over to the right, slightly convoluted, goes up on the right side, and back upon itself to the middle of the body, where it terminates at once in the rectum, which is a large, straight, short intestine.‡

* Tab. XCII. † Tab. XCIII. ‡ Tab. XCIV.

In all the fishes whose intestines I am about to describe, we find them formed upon a different principle from those already explained. The tube is much shorter, and therefore has a very simple course, but the internal membrane is thrown into folds of different breadths, so as to increase the internal surface in a very great degree.

This construction of intestine makes it interfere less with the shape of the fish, as it takes up less room, and the portion containing these valves from having the sides of the intestine so well supported, does not admit of being distended beyond its natural size.

In the salmon, salmon trout, and common trout, the intestine has this structure in a slight degree. The duodenum passes up to the right, then the jejunum goes down, and the lower part is the rectum. The duodenum at its origin is very villous, and tape-worms are found in numbers in the pancreatic cœca. Further on, the intestine becomes plicated, the plicæ short and having a longitudinal direction: lower down, there are small transverse plicæ; the jejunum gradually increases in size, at the largest part there is a broad transverse valve, from which, the transverse plicæ diminish in size. They are twenty-four in all. The internal surface of the rectum is smooth.*

In the sturgeon there is a great length of duodenum, at least of that portion of intestine which has no plicated structure. It makes two considerable turns, one downward, the other up again; its internal surface having a honey-combed structure. Beyond this the jejunum passes down, having a thick spiral projecting valve which is very oblique.

In all the rays and sharks the form of the intestine is nearly

* Tab. XCV. XCVI.

the same. It may be described as a long tube, the upper part of which, or duodenum, is smooth. A spiral valve begins from that part, and is continued through the whole of the jejunum. Beyond this, a cavity is formed, which may be called rectum, and in all of them, I believe, there is a hollow glandular bag communicating with this cavity by a small excretory duct.

In the skate and thornback the spiral valve of the jejunum is so broad, that there is an elastic ligament to keep it in its place.

In the maid, the spiral valve is thin and smooth, it makes ten spiral turns.

In the torpedo and Kingston skate, the spiral valve has a more transverse direction, and passes from right to left; the intermediate space is honey-combed.*

In the dog-fish and blue shark, the turns of the spiral valve are very close upon one another, and have nearly a transverse direction.†

In the squalus maximus, thirty feet six inches long, the jejunum was four feet long, ten inches in diameter; the spiral valve so strong and close, as to give the whole an appearance of solidity, like a small cask. At the lower end of the jejunum the termination of the spiral valve formed a projection resembling the leaves of a rose not quite blown. The rectum was two feet long. The glandular bag attached to it was reticulated upon its inner surface with deep indentations, and the coats so thick that the cavity could not contain more than a pint, although the bag externally appeared more than double that size. The excretory duct was very long and exceedingly small.

* Tab. XCVII. † Tab. XCVIII.

This appendage common to most cartilaginous fishes in its situation bears a great analogy to the ink-bag in the cuttle-fishes, and its use is evidently to supply the rectum with a secretion of a particular kind.

As fishes form the first class of animals in which the intestines have been considered as a distinct subject, and as their coats are nearly of the same kind with those met with in all the higher classes, I shall give in this place, a general description of these coats.

The internal membrane varies exceedingly in the different parts of the intestine, as has been explained, and requires a particular description in each kind of intestine. On the outside of this, is a layer of circular muscular fibres, and over it another of longitudinal fibres: these, like the other parts of the body are connected together by means of cellular membrane. The outer coat is the membrane that lines the general cavity of the abdomen, which having a smooth polished surface, allows the intestine to move with facility among the other parts. This coat forms only a partial covering, being wanting on the posterior part, to admit the blood-vessels and absorbents to pass in its duplicature.

The food when it leaves the stomach, passes in consequence of the contraction of the pyloric portion of that viscus into the duodenum, and in doing so, stretches the hollow muscle to make room for it; this part so dilated is thus brought into a proper state to act upon its contents, and by its contraction send them further on. By a succession of these actions, which has received the term peristaltic motion, the contents of the intestine are carried along very irregularly in point of time, till the indigestible part is voided at the anus.

The uses of the intestinal canal, I am led to believe, are much more extensive than has been commonly imagined; and as we are now for the first time entering upon this subject, and are about to prosecute it through the higher classes of animals in which the parts are more complex, I think it right to call your particular attention to the facts which will be stated, that you may the better understand the conclusions which will be afterwards drawn from them.

That the office of the intestinal canal is to give a sufficient surface on which the chyle may be exposed to the absorbents, is sufficiently established: that different secretions are poured into it, and mixed with the contents, for the purpose of stimulating the muscles, and making the absorbents more active; as well as to make the necessary combinations of the different ingredients of which the food is composed, to prevent putrefaction, is well understood; but there also is reason to believe, that the lower intestines have an office not hitherto adverted to; which is extracting from their contents a secondary kind of nourishment.

The evidence from which this opinion is formed, is partly to be collected from the course of the intestines in the present class, and that immediately below it; but more especially from what is met with in animals of the higher classes.

The glandular appendages met with in the different species of cuttle-fish, in the rays, and sharks, form secretions which are evidently intended to produce some effect upon the contents of the intestine: and the length of this lower portion, as well as the delicate structure of the internal membrane by which it is lined, make it evident that it is to answer some purpose beyond that of a reservoir.

Of the Intestines of amphibious Animals.

In the truly amphibious animals the intestine is more simple in its form than in fishes. It makes many turns or convolutions in its passage downwards from the stomach to the anus, towards the lower part its capacity becomes enlarged, and its course straight. It admits of a division into three portions: the duodenum, or that next the stomach; the convoluted part, or the jejunum; and the wide lower part, or the rectum. The coats are very delicate, and there are no valvulæ conniventes the internal membrane.

It is deserving of observation, that there being only two species or genera of amphibious animals, one living principally on animal, the other on vegetable food, the intestines in both have the same general structure, so that no marks can be pointed out, by which they may be distinguished. The only mode of accounting for this, is, that the processes carried on in the stomachs and intestines of these animals is so slow, that the continuance of the contents in the canal, in that which lives upon vegetable food, is a compensation for the greater extent of intestine which appears to be required in other classes of animals.

Of the Intestines of Snakes.

In snakes, as in the truly amphibious animals, the intestine becomes loose from its origin at the pylorus. It is of different lengths in different genera. In the water-snake it is uncommonly long, and is curled upon itself, making numerous convolutions.

In all snakes there are longitudinal plicæ or valvulæ conniventes, which are more strongly marked in some genera than in others; and the lower portion is much larger than the rest of the canal, and it passes to the anus in a straight line.

In a large African snake there is a long cœcum, not met with in others.

Of the Intestines of Lizards

In the newt and warted lizard, the intestinal canal is similar to that in the snake.*

In the draco-volans, the small intestines are of the same length, and there is a contraction where the rectum begins; this last part is five or six times larger or more capacious than the rest.

In the crocodile, the intestine when it leaves the stomach passes to the right side, for about four inches; is then folded back upon itself for about two inches; it afterwards passes behind the other folds, adhering to the posterior parts, crosses the spine a little below the root of the mesentery, and becomes loose. It is small in size and thin in its coats, till within three inches of the anus, where it becomes suddenly larger, and the coats very strong; it goes on straight to the anus. The plicæ or valvulæ conniventes are longitudinal.

In most animals of this tribe the rectum is not continued to the external opening, but terminates in a valvular orifice, about two inches higher up, in a cavity common to it and the external vagina in the female.

The camelion differs from the lizards that live upon animal food, in having a short cœcum, which is not the case in the intestines of the animals of this class which have been described.

In the scincus and iguana, which live upon vegetable food,

* Tab. XCIX.

there is a marked difference in the formation of the intestines from that in the lizards that live upon animal food.

In the scincus which I examined, the small intestine was fifteen inches long, near the stomach three-quarters of an inch in diameter, and encreasing in size in the course of thirteen inches to one inch and a quarter; and there a sudden contractionwas met with, the gut again became dilated, and gradually diminished in size, till it terminated by a small orifice in a large intestine, so that the division between the two was very distinct, and a blind end was formed of half the diameter of the gut.*

This part in the intestines of the scincus, as well as the camelion, in compliance with the common terms in use by anatomists, I shall call cœcum; the gut beyond it, properly speaking, is the same as the rectum in the other lizards, being only three inches long.

In the broad-tailed iguana, the duodenum turns to the right side, and then a little upwards. About an inch from the pylorus it receives the gall-ducts from the liver; it then passes on, being about five-eighths of an inch in diameter: it continues nearly of the same size for seventeen inches, and terminates by a small orifice in the colon, which is above an inch and a half in diameter. The cœcum is larger than in the scincus, being about three-quarters of an inch, and the part beyond may be called colon, as it is eleven inches long; this makes several turns upon itself, diminishes in size during its course, and the rectum commences by a slight contraction. It is three inches long, five-eighths of an inch in diameter, and terminates by a broad valve a little within the external anus.†

* Tab. XCIX. † Tab. C.

There are plicæ or valvulæ conniventes in a longitudinal direction, beginning immediately beyond the valve of the pylorus, and continued to the orifice leading into the colon. The inner membrane of the colon is smooth, the coats thin; there are no glands to be seen either in the colon or rectum. The colon contained seeds of a similar kind to what were met with in the stomach. In this species of lizard we have the first instance of a distinct colon and rectum.

The common iguana from the West Indies has an intestinal canal, similar to that of the broad-tailed iguana, except that in the beginning of the colon there are transverse valves; those nearest the cœcum being the broadest and strongest.

When the structure of these parts is compared with that of the intestines of the crocodile and lizards that live upon animal food, there is an apparatus evidently connected with some changes which vegetable substances are required to go through after having undergone the process of digestion, which are not provided for in the intestines of lizards that live on animal food.

In the frog, the intestine is very simple; the duodenum passes up from the lower end of the stomach as high as the cardiac orifice, then turns to the right, and may be said to form the jejunum, which makes one wide convolution or turn upon itself in the middle line of the body. It dilates suddenly into the rectum, which is very capacious, and passes in a straight line to the anus.

In the toad, the principal difference is, that the contraction between the jejunum and rectum exists in a greater degree.

In the tadpole of the bull-frog, the duodenum goes up from what must be supposed to be the bottom of the stomach, as high as the cardiac orifice, then back upon itself; at the lower part it makes the outer turn of a large coil of six turns into the centre and back again: behind this, it makes a smaller turn, then passes upwards in a straight line to the left of the stomach, and bends directly down to the anus, forming rectum. In all this course its size is nearly the same.*

From seeing a length and course of intestine so unlike any thing belonging to the toad and frog, I was desirous of acquiring some information of the habits of life of this animal, but have met with nothing at all satisfactory respecting it.

From the appearance of the intestine there is every reason to believe, that its food, of whatever kind, is procured with difficulty, and is of a vegetable nature,

Of the turtles that live upon animal food, (in consequence of their not being fit for the table,) few opportunities occur of examining their internal structure.

In the small species from the Muskito shore, which feeds upon worms, the intestines are very simple: the duodenum makes a turn on the right side, then becomes jejunum, making several loose convolutions in the left side, crosses the body to the right, and passes directly back again to the middle of the body, where it forms rectum; there is no cœcum.†

In the turtle brought from the West Indies, which lives upon vegetable food, the duodenum passes first to the right side, then becomes a loose intestine, and continues so till it terminates by a contraction in the colon or rectum, which is fixed in its situation in the middle line of the body, and goes directly down to the cavity common to the oviducts and the urine, which is some inches long. There are no plicæ or

* Tab. CI.

† Tab. CII.

valvulæ conniventes, but a villous surface, with a zigzag figure upon it.

In a tortoise from Germany, the duodenum becomes immediately a loose intestine attached to a mesentery, which carries the intestine or jejunum rather to the left. The cœcum is in the middle line of the body, very short; as the large portion is short and straight, it must be called rectum, not colon.

This is very similar to what is met with in the scincus and iguana.

In a land-tortoise from South Carolina, the shell of which measured in length two feet four and a half inches, the duodenum measured one foot; the jejunum three feet one inch; and the colon and rectum five feet one inch. The duodenum passes down the right side fixed to the mesocolon; then becomes loose; the mesentery passes obliquely up to the left, and terminates immediately behind the stomach in the cœcum, which is simply a pouch with an oblique valvular opening. The course of the intestine is shewn in the engraving.* The internal surface of the duodenum is loculated, the coats thin; the internal surface of the jejunum is plicated. The inner membrane of the colon and rectum is smooth; the portion of the rectum common to the urine and oviducts is six inches in length.

The animal had not taken food for two months, and the small intestines were empty; but the colon was full of coloured costive fæces.

In another species, theduodennm passes down the right side, then becomes loose, forming the jejunum, which passes over to the left, and back again towards the right, where it enters

* Tab. CII.

the cœcum, which is very short. The colon passes first down to the right, then up the right side; crosses the body very large, afterwards returns smaller to the middle of the body, where it becomes the rectum, and goes down to the anus.*

In a tortoise from South America, the duodenum passes down the right side connected closely to the lungs, and ascending colon ; and near the lower part becomes loose, forming the jejunum, which makes one large sweep round. When in the right side again it enters the cœcum, which lies in a sulcus in the lower edge of the right lobe of the liver ; it makes a turn upon itself, and then receives the jejunum, and becomes the colon, which passes a little farther down, and makes a turn up before the duodenum ; from thence passes to the left behind the stomach, becoming very large. It then makes a quick turn across the spine to the right, then back to the middle of the body, where it turns down to form the rectum, which is a common cavity, as in the other species.†

The plicæ or valvulæ conniventes in the small intestines, are longitudinal; there are none in the colon.

Having shewn the different structures, as well as the varieties that are met with, both in the course and length of the intestines belonging to the classes of cold-blooded animals, I shall not at present make any observations on the functions they are intended to perform, since that will be better done, after the same parts in the higher orders of animals have been examined; but it will be proper to observe, that the internal surface to which the contents are exposed in their passage, is smaller than that of the intestines of the animals not yet described.

* Tab. CII. † Tab. CIII.

This is to be explained by the slowness with which every operation connected with digestion in these animals is performed, and an equal degree of slowness of the passage of the food after digestion is compleated; so that the length of time the contents are allowed to remain, makes it unnecessary that there should be a large extent of surface over which they are to pass; but even under these circumstances, the intestines which are to receive vegetable food are much longer than those in which animal matter is contained.

LECTURE X.

On the Intestines of Birds.

HAVING described the intestines of cold-blooded animals, both those that live in water and upon land, I shall now proceed to the intestines of birds, and of the class mammalia. These animals differ materially from the former, in having a power of generating heat, and consequently having the actions of the animal œconomy more actively carried on. It is from these last that we shall be enabled to acquire such information as is more immediately applicable to the physiology of the human body, although the knowledge of the structure of the lower orders is by no means devoid of much useful instruction.

In giving these Lectures, I am desirous of confining myself as much as possible to facts; and in comparative anatomy, they are not to be acquired without much labour and perseverance; but when once an extensive series is collected and arranged, the first and most important step will be accomplished towards the advancement of physiological knowledge. I have still two Lectures besides the present, to give upon intestines, and as the detail of facts is often tedious, I must rely upon your patience and indulgence, being more desirous of conveying instruction than affording amusement.

Upon this particular subject I have bestowed much pains, and have collected a considerable number of materials; but it requires more leisure; health less impaired; and a mind upon which there are fewer other demands than I possess, to follow the same path; and when these Lectures are finished, I shall with much satisfaction resign this Chair, to one who is abundantly qualified to prosecute these enquiries into the internal structure of the most curious, as well as the most noble of the works of the Almighty Creator.

In birds, the intestinal canal is in many respects more complex than in those which have been described.

As in the snakes and lizards, the intestine is thinner in its coats than in any other animals, in birds it is thicker, in proportion to the size of the body.

In birds, whether carnivorous, or living on vegetable food, the duodenum follows one uniform course. It passes down for some inches on the right side, and is then bent back upon itself, and the parts are kept in this situation by a broad thin connecting membrane, which fills up the space between the two portions. This mode of union is peculiar to the bird, and the membrane may be called the meso-duodenum.

In many birds there are similar connecting membranes between other portions of the small intestines.

Another distinguishing peculiarity in the intestines of birds, is a muscular band running longitudinally the whole length of the canal, opposite to the attachment of the mesentery. The edges of this band are insensibly lost in the coats of the intestine. Its probable use is, by its contraction, to facilitate the passage of the contents of the intestine through those parts which are so closely bent upon themselves, that without such a contrivance, a stoppage of the contents might be produced in the angles formed by the turns of the intestine.

Their internal surface has no spiral valve, as in fishes, nor any plicæ, either longitudinal or transverse. It has only a villous appearance; and although it has commonly, near its termination, lateral processes called cœca, they are of a different kind from those of the turtle or camelion, more nearly resembling the gland and ink-bag in the cuttle fish, and the gland connected with the intestine of the shark.

In some carnivorous birds the cœca are so short, as hardly to deserve the name; in others they are entirely wanting, Those birds which have the cœca very short, have loose excrements, and have the power of throwing them to a great distance, which birds with long cœca have not. Hence, when the common fowl has loose excrements, the feathers are soiled.

In birds, the ducts of the liver and pancreas open into the duodenum at a greater distance from the stomach than in other animals; this distance is commonly about twelve inches.

The cœca in birds differ from that in the tortoise. In both, however, they form a valve to prevent regurgitation of the contents of the lower bowel. In the bird there is no actual valve, the orifice of the intestine being in a line with the gut below, but the orifices of the cœca are open, and their coats so thick as to press the sides of the orifice of the intestine together.

The intestine in birds terminates considerably within the verge of the external orifice, and at that part there is a valve. The cavity beyond this valve is common to the semen, the urine, and fœces; they all pass through it, but none of them remain there.

The external orifice in the bird comes almost to the last bone of the tail, and is consequently raised and depressed along with the tail, the bones of which admit of a great deal of motion. This allows the excrement to be thrown to a considerable distance, so as to prevent the feathers under the tail from being soiled. This power is greater in some than others, and is most remarkable in those whose fœces are loose.

In considering the intestines of this class of animals, we find that those belonging to birds which feed on fruits and soft vegetable substances, have no cœca (the common pidgeon excepted) and therefore may be considered of the most simple kind, and deserving the first place in the present arrangement.

The large wattle-bird from the South Seas has an intestine of the most simple form; the duodenum is short, it makes three turns; the jejunum is then attached to a mesentery, and afterwards passes up behind the gizzard to form the rectum. There are no cœca nor any enlargement at the termination of the rectum. The whole intestine is unusually short and wide. Many stones of a red fruit deprived of their pulpy covering were found in the intestine, and the fruit in its intire state was found in the gizzard.

In the Brasilian dove, the duodenum is the same as in the wattle-bird; the jejunum then makes a long fold upon itself closely connected; this is rolled upon itself in a circular form. The intestine then makes a shorter fold upon itself, and afterwards goes to form the rectum, there being no cœcum.

In the small East Indian dove the intestines have a similar course.

In the blue-crown pigeon from the East Indies, the duodenum has the common course; the jejunum then passes towards the back, on the right side, becoming a loose intestine for about nine inches, having a broad mesentery; at the termination of which there is a fold of intestine nearly a foot long, the two portions of which are three-eighths of an inch asunder, united by a fatty cellular membrane. It has also a mesentery common to both; one edge attached to these intestines, the other loose, and this by being the shortest, makes the intestine form an irregular arch. Along the loose edge of the mesentery pass the blood-vessels that supply the intestine. This fold is coiled upon itself. The intestine then makes a second fold, seven inches long, the two portions of it being half an inch apart, with blood-vessels ramifying on the intermediate membrane. The intestine then passes down, and may be called rectum. There are no cœca. At the anus there is a considerable reservoir.

In the common pigeon and white dove, the intestines differ only in there being two small very short cœca.

There are some differences in the turns of the intestine of the dove from those of the pigeon, which are not of importance; the circumstance deserves, however, to be noticed.

In the macaw, the duodenum has the common course; the jejunum then passes down and is folded upon itself. At the root of the mesentery, there is another fold unconnected with the former; there is then a shorter fold connected with the first, and another connected with the second, after which, the intestine makes a third connected with the first; then, an unconnected fold of some length, from the termination of which, the intestine adheres closely to the right side of the gizzard, passes to the back, and forms the rectum. There is no cœcum. The anus is very large.

Next in point of simplicity to the intestines of birds that live on fruits and different kinds of pulse, are those of birds of prey. They have, in general, cœca, but extremely short.

In the eagle, the duodenum, after making the third turn, connected by a meso-duodenum, of the form which I have described, is continued into the jejunum, which passes down on the right side, becoming a loose intestine attached to a mesentery, the edge of which is scolloped, so as to throw the intestine into convolutions. The jejunum diminishes in size, passes up the left side, is attached to the posterior surface of the gizzard, afterwards passes down and makes a loose turn upon itself, is thrown into convolutions, and then becomes the rectum; the beginnning of which is marked by short cœca. The whole length of the intestine is twice that of the whole bird, and four times the length of the body or trunk. The anus is very large.

In the kite, the course of the intestine differs from that in the eagle, in its making a short turn upon itself after leaving the mesentery before it passes up to be connected to the posterior surface of the gizzard.

The rectum is only about three inches long, and terminates by a valvular orifice, the sides of which fit so closely that when the parts are viewed from the external anus, no opening can be observed. The intestines are three times the length of the whole bird, and six times that of its body.

In the hawk, the principal peculiarity is, that the cœca are only three-eighths of an inch long; so that they are rather to be considered as a mark of the termination of the small intestine, than to answer any essential purpose. The rectum terminates by a projecting orifice like that of the os tincæ.

In the vulture, the turns of the duodenum are not so closely united as in the eagle, but the course of the intestine is the same. In all these birds, the duct of the liver opens into the duodenum, near its termination. In the vulture there is no cœcum whatever. The rectum is very large.

In birds that live upon fish, the intestines very much resemble birds of prey in the shortness of the cœca.

In the pelican from the West Indies, the duodenum makes one long fold upon itself, and a second, which is shorter; it then becomes the jejunum, being attached to a mesentery; is smaller in size, and from the mesentery having deep scollops, the intestine makes many convolutions, some of which are larger than others; the last is the longest, and towards its termination it becomes more closely attached to the root of the mesentery; it then goes down to form the rectum. The cœca are about an inch and quarter long.

In the pelican from Arabia, the second turn of the duodenum goes much higher on the right side of the stomach than the pylorus, and the jejunum makes a sweep down the right side, then towards the left, and upwards, forming an oblong spiral turn within itself; it then passes back on the outside, attached to a mesentery, and becomes a loose intestine. The mesentery extends to the left side, and has deep scollops. The jejunum makes a long fold upon itself; the last part of which passes higher up behind the stomach to the root of the mesentery, and bends down close to the back to form the rectum. The cœca are two inches long; the rectum is very short, as well as the whole intestine.

The opening of the rectum into the cavity at the anus is oblique.*

* Tab. CIV.

This difference in the windings of the intestine in the Arabian pelican, must arise from there being a greater necessity in that bird to œconomise its nourishment, than in the West Indian species, which, in the Gulph of Mexico, has a more ample supply of its natural food.

In the cormorant, the intestines are every where nearly of the same size, except the rectum, which is larger than the rest. Their length is about four feet; that of the cœca, half an inch. The inner membrane has a villous surface, and glands are readily distinguished upon it.

The bittern and heron have only one cœcum. In the crane the turns of the intestines are shewn in the engraving.*

In the large sea-gull, the duodenum makes the usual turns, and then becomes jejunum, attached to a mesentery, at the termination of which, it is connected with the posterior surface of the stomach; and from thence it goes to form the rectum, which is only about two inches long. The cœca are half an inch long. The whole intestines are scarcely four times the length of the body, or twice that of the whole bird. In the soland-goose they form oblong folds.†

In the little auk, the intestines are five times the length of the body. The dilatation at the termination of the rectum, is large in proportion to the size of the bird.‡

The owl is introduced into this place, although a bird of prey, in consequence of its intestines having more convolutions, and the cœca being longer than in any of the carnivorous or piscivorous birds which have been described. The duodenum in the owl passes down the right side, then up again as high as the liver, then down towards the back.

* Tab. CV. † Tab. CVI. ‡ Tab. CVII.

From this part, which may be called the third turn, it may be considered as jejunum, being less closely attached; but there is a broad scolloped middle mesentery, which divides into three distinct folds; the first, the shortest; the second, the longest; and the third, has the cœca lying on each side of it. This fold ends close to the back, and there the rectum begins. The intestine is extremely small at this part, not larger than one of the cœca; and the rectum is about the size of the intestine and the two cœca taken together. The cœca appear, in length, to bear the same proportion to the bird as they do in the common fowl, in which each of them is eight inches long. The lower part of the rectum swells out into a globular cavity, and there terminates.

In the raven, crow, and rook, the intestines bear so great a similarity as not to require a separate description. The duodenum is large compared with the size of the gizzard; it passes down on the right side two inches and a half, returns upon itself, inclosing the pancreas in the fold. It receives the biliary duct, then passes backward, forming a coil from right to left of three turns and a half, and then returns in the opposite direction, making the same number of turns close to the others, but behind them. It then becomes visible, accompanying the duodenum, round which it passes, going behind it close up to the gizzard, and then forms the rectum. The intestine diminishes gradually from the gizzard to the cœca. In the raven they are longer than in the crow and rook, but not larger, and the rectum is not so large. The cœca are one-quarter of an inch long.

The sea mew lives partly on fishes, artly on worms. The

Tab. CVII.

turns of the intestines bear a close resemblance to those of the crow.*

In the ardea argilla of Bengal, the intestines are unusually small in size; the small intestines in the specimen which I examined, were nine feet six inches long; the cœca three-eighths of an inch; the rectum six inches.†

After those birds which live principally, if not wholly upon other animals, I shall describe the intestines of those, whose food is partly animal and partly vegetable.

The bustard has been already proved to be of that description. In this bird, after the third turn of the duodenum, the jejunum makes one similar to it, and afterwards one twice as long, being in the specimen which I examined rather more than a foot, and a little wider in diameter than the others. This last turn adheres to the duodenum, and the cœca open into it. The rectum is loose, large, and nearly a foot long; it dilates at the anus; but not as in birds in general, equally all round, but only on the posterior part. The rectum is larger than in any other bird which I have examined but the ostrich. The internal membrane of the rectum is villous, but that of the dilated part is smooth.

In the turkey, pheasant, partridge, and fowl, the intestines have a general resemblance. In the common fowl the duodenum passes down from the posterior part of the gizzard ten inches, and then returns again upon itself till it reaches the under surface of the liver, where it receives the ductus cysticus and hepaticus, separately; and immediately below,

* Tab. CVIII. † Tab. CIX.

that of the pancreas. The intestine then becomes smaller, and is attached to a mesentery. The length of the intestines to the cœca in the specimen which I examined, was five feet seven inches; the rectum two and a half. Each cœcum was eight inches long. In a chick five days old, each cœcum was two inches. The internal surface of the cœca is rugous at the upper end; the rugæ run into each other, and are lost in a smooth surface, about three inches from the termination of the cœcum in the rectum: where the small intestine opens into the rectum between the cœca, there is a kind of valvular orifice. The intestine has a smooth villous surface; in the rectum there are slight longitudinal rugæ. The intestine is six feet long, or eight times the length of the body of the bird.

The quan-bird is about the size of a pheasant, and resembles it in the shape of the head and bill; its claws are longer, more like those of the crow. The duodenum is wide; the fold upon itself in one specimen was only two inches long. In another, three. The jejunum takes its course backwards in the right side, and becomes a loose intestine attached to a mesentery, and afterwards to the posterior surface of the gizzard near the beginning of the duodenum; it then passes up behind the root of the mesentery, to which it is firmly connected; it then receives the openings of the cœca, and forms the rectum. The cœca were nearly three inches long, and small in diameter. The intestines were wide and short, not being more than four times the length of the body of the bird. The contents of the cœca were of the consistence of thick cream, and as black as ink, in appearance totally different from any thing met with in the other portions of the intestine.

In the duck tribe, the turns of the intestine are in some measure peculiar to themselves, neither resembling those met with in the granivorous birds, nor in those that graze.

In the Muscovy-drake, the duodenum has the common course; the jejunum passes back on the right side, and makes a short fold on itself with an intermediate mesentery, then becomes apparently loose: but even this part forms short folds. After this, it forms three distinct folds, all parallel to one another, attached at the end next the mesentery, but loose at the other. There are two cœca, each about the length of the last fold, with which they are connected. They are thin in their coats, the rectum becoming gradually smaller to its termination at the anus.

In the common duck, the hepatic and pancreatic ducts open into the duodenum, about twelve inches from the gizzard, as in the fowl. The jejunum was seven feet long, the rectum five inches. The cœca on the outer curve were nine inches long, the other eight. The cœca are slightly rugous at their upper end, they are widest in their middle, forming a double cone. They contained in the middle, a quantity of dark-coloured fæces, mixed with a strong mucus; the fæces were the same as in the lower end of the small intestines and rectum. In a duckling a week old, the cœca were each three inches long.

The orifice of the small intestine into the rectum is projecting and valvular: so that regurgitation from the rectum would more readily take place into the cœca than into the jejunum. The small intestines through their whole course have their internal surface smooth and villous, without any distinct glands. The rectum has rugæ in a longitudinal direction, of a singular appearance. The length of the body or trunk of the bird was eight inches and a half; so that the intestines were ten times its length.*

The grazing birds have a still different form of the convolutions of the intestines; and it is proper to observe in this place, that these will be found hereafter, to have a correspondence with the peculiar course of the colon in ruminating animals.

In the goose, the duodenum has the usual course; the intestine then makes a fold upon itself eight inches long; afterwards four folds upon itself, with one central mesentery to the whole. To the last of these the cœca are attached; and where these open, the rectum begins.†

The intestines vary but little in size from the duodenum to the cœca. The small intestines were seven feet long, the rectum about seven inches.

The internal membrane of the small intestines is smooth and villous, without valvulæ conniventes. Each cœcum is ten inches long, nearly equal in size throughout. On its internal surface are six longitudinal rugæ, running from the extreme end towards the rectum, but gradually lost in a smooth villous surface, about three inches before the cœcum terminates. It contained a small quantity of mucus, growing yellower as it approached towards the rectum, and resembling in appearance the general contents of the intestines. In a gosling three weeks old, each cœcum was seven inches long, the coats thinner than those of the other intestines. In the rectum were two sets of rugæ taking an oblique direction, each pair meeting in a central line directly opposite to the termination of the small intestine in the rectum. There were no distinct glands any where.

* Tab. CX.   † Tab. CXI.

In the wild swan, the duodenum makes the usual fold, the jejunum then passes down making a fold upon itself, and then up again. It turns over the edge of the mesentery and down on its opposite side, then up again, and forms a turn encircling the whole, so that the duodenum makes one fold in its proper meso-duodenum, and the jejunum afterwards makes three folds in the mesentery, and then three folds in nearly a similar manner upon another mesentery, where it is attached to the two cœca, and there the intestine enlarges, and passes down the back to the anus.

In this bird the intestine is longer from the part where the cœca enter it to the anus, than common, being eight inches, and six inches of its internal surface have a number of transverse rugæ, and the lower two inches are lined with a cuticle, and have longitudinal plicæ; while the inner surface of the jejunum is only villous.

This makes a natural division of what in other birds is properly rectum, into two parts, to one of which may be given the name of colon, and that of rectum to the other.

The cœca were eight inches long, they contained a pulpy green coloured substance in their middle part, but were quite empty for an inch at least towards the two extremities.*

The intestines of the brent goose resemble those of the swan; the cœca were six inches long, and serpentine in their course.

In a flamingo which was shot in the East Indies, the duodenum passed out as usual and made a turn to the left for four inches, then back again upon itself. At the termination of this fold, it began making spiral turns close on one another,

* Tab. CXII.

ten in number, becoming less and less in circumference. In the centre, the intestine turned round and made similar circles in the opposite direction; having arrived at the upper part, it emerged, and formed the rectum.

The cœca were four inches long, blunt at the end, involved in the folds of the small intestine; the colon and rectum may be said to be the whole length of the cavity of the abdomen; the latter enlarged very much in passing to the anus.

As the walking birds, which are not provided with wings to raise them into the air, form so complete a series among themselves with respect to thelr gizzards, as has been already shewn; and as they will now be found to do so equally with respect to their intestines, I have reserved them for this place to complete the present series.

I shall consider them in the same order, respecting the intestines, as I did formerly respecting their gizzards.

The cassowary I examined from the island of Java, had its duodenum of unusual width, being two inches and a half in diameter for four inches of its length; it then contracted to one inch and a half in diameter, and passed down in the right side seven inches and a half, then was folded as usual upon itself for nine inches and a half, after which it became jejunum, being attached to a mesentery. The gall ducts entered the duodenum two inches before it becomes jejunum, at which part it was two inches in diameter. The mesentery was broad, of an oval form, and terminated upon the spine nearly as high as the origin of the duodenum; and there the colon began, three inches in diameter, attached by a loose mesocolon, and went down straight to the anus. The cœca were six inches long, a quarter of an inch in diameter, and widest towards the blind extremity.

The duodenum was one foot five inches long; the jejunum three feet seven inches; the colon and the rectum one foot; the whole six feet. The internal surface of the duodenum had long villi. On the inner surface of the jejunum were longitudinal rugæ and short villi. The inner surface of the colon had short villi and longitudinal rugæ.

In the cassowary from New South Wales, the duodenum passed down nine inches, and back upon itself: it was about one inch and three quarters in diameter; its internal surface was slightly honey-combed.

The gall-ducts entered eighteen inches from the pylorus, just where the duodenum terminates. The jejunum became loose, attached to a mesentery through its whole course, about one inch and a quarter in diameter. The intestine suddenly enlarged, forming a colon three inches before it was joined by the cœca, which were only two inches long, half an inch in diameter, with a smooth inner surface. The colon and rectum were two inches in diameter, with a smooth inner surface.

The duodennm was eighteen inches long; the jejunum ten feet seven inches; the colon and rectum thirteen inches; in all, thirteen feet two inches.

In the South American ostrich the duodenum passed down twelve inches, and back again fourteen, attached to one of the cœca; its inner surface was honey-combed.

The jejunum was attached to a mesentery. Its inner surface was slightly honey-combed; it was one inch in diameter. Where it terminated there was a loose valvular projection on each side, thickened at the point.

The cœca were three feet ten inches long.

The colon was one inch three-eighths in diameter, its internal surface was not rugous, but was rendered rough by innumerable projections. Orifices of glands were interspersed over the surface.

The duodenum and jejunum were ten feet seven inches; the colon and the rectum one foot eight inches in length.

The inner surface of the duodenum was smooth, but that of the jejunum was reticulated.

The cœca were two inches in diameter in the middle, which was the widest part; half an inch at the point, which was the smallest. On their inner surface they have a loculated appearance, and valvulæ conniventes three inches and a half broad, which go only half round, but alternately, so as to pass with their terminations between each other.

In the African ostrich the duodenum passed down about thirteen inches, and then back again as high as the gizzard, but in its course made a fold upon itself.

The hepatic duct entered the duodenum about an inch from the gizzard, in this respect differing from the usual situation in other birds. The jejunum passed down behind, attached to a mesentery on its right edge. In its course it became looser, till it was entirely so. When it left this mesentery, it passed up behind its root, and there the cœca, two feet nine inches each, opened into it, having been attached to each side of the intestine for the whole length of the last turn, as well as to the posterior surface of the duodenum. Here the colon might be said to begin, which became a loose intestine diminishing in size from the openings of the cœca till it reached the pelvis, where it might be called rectum, but still forming convolutions upon a loose broad meso-rectum.

The duodenum was two feet six inches; the jejunum, twenty-four feet six inches; the colon and the rectum, forty-five feet three inches: the whole, seventy-two feet three inches.

The internal surface of the duodenum had slight serpentine rugæ made up of papillæ, in the direction of the intestine, (so faint as to be scarcely visible to the naked eye), for the extent of two inches; beyond which the surface was more smooth, but with a magnifying glass the serpentine rugæ could be traced to the openings of the cœca. Where the jejunum joined the cœca it was three-quarters of an inch in diameter.

The cœca were nearly of the same size; largest in the middle where the intestine passed, they had the appearance of a colon folded on itself, three inches in diameter for one foot of each cœcum, then tapering to a point. They had the same loculated appearance externally as the colon; they terminated in small vermiform extremities. Internally they had transverse valvulæ.

Where the colon left the cœca it was one inch and a quarter in diameter, and increased to two inches.

The internal surface of the colon for fourteen feet from the entrance of the cœca was loculated, and had valvulæ conniventes in a transverse direction. These valvulæ did not go quite round, but indigitated, like those in the cœca of the South American ostrich.

From the termination of the valvulæ conniventes to the anus, which was thirty-one feet three inches, the intestine continued of the same capacity, and was thin in its coats.

In the jejunum, the contents were of a pulpy consistence, and of a dark yellow colour. In the valvular portion of the colon they were very thick, and of a dark green colour. In the part beyond the valves they were broken into distinct portions. Corn in its entire state was found in the colon; so that even in the ostrich, grain of that size escape sometimes the action of the gizzard.

I shall here close my description of the intestines of birds, not meaning to do more than to shew the principal varieties in structure that have come within my knowledge, without attempting to grasp at the whole of so comprehensive a subject. What I have stated, will be sufficient to explain the general principle upon which the intestinal canal in birds is formed, and enable us to form some idea of the uses to which it is applied, which seem to exceed those that are attributed to it. When we contemplate the various forms of intestine which have been explained, and the different convolutions which they make, we are disposed to attribute some wise purpose to every part of such conformation. The turns of the duodenum in different birds bear a great resemblance, whatever be the nature of their food; and the biliary ducts, which in the other classes of animals open into it near the pylorus, enter commonly at the distance of twelve inches from the stomach. These circumstances, combined with others, confirm the opinion, that the duodenum in birds answers the same purpose as the pyloric portion of the stomach in other animals.

The jejunum has the lacteal vessels opening upon its inner surface for the absorption of the chyle; but the uses of the other parts have not hitherto been explained. We cannot for a moment suppose, that as soon as the process of digestion is completed, and the chyle spread over the inner surface of the intestines to be taken up by the lacteals, that the lower portion of the intestine, and all the remains of the aliment are to answer no other purpose in the animal œconomy, but are to be thrown as refuse out of the body.

When we see the intestines of birds which feed upon ripe fruits, and animal food, have a simple form; while those of granivorous birds are more complex, and those of grazing birds still more so; and these differences as great, if not greater in the lower part of the intestine than in the rest of the canal: when we see that there are no cœca to those more simple intestines, or cœca so small, that they seem as if intended to give an appearance of uniformity; while in the others, these cœca have an increased length, have peculiar secretions, and those very abundant; when we see that into these cœca, as reservoirs, a portion of the contents of the intestine is conveyed, and remains there a considerable time: and when all these circumstances are brought into one point of view, we must be inclined to suspect, that the remains of the food, from which the nutriment has been extracted by digestion, may undergo a second process in the lower bowels, by means of which some further supplies may be procured for the support of the animal œconomy in cases of emergency.

For the proof of such an œconomising principle in the intestines of birds, it is only necessary to compare the intestines in the four kinds of walking birds that have been described.

In the cassowary of Java, that lives in the most fertile country on the globe, no œconomy is necessary; the jejunum is three feet seven inches; the cœca are only six inches; the colon and rectum one foot.

In the cassowary from New South Wales, a country less luxuriant, the jejunum is ten feet ten inches; the cœca two inches; the colon and rectum ten inches.

In the South American ostrich, where the food is less abundant, the jejunum is nine feet; the cœca, three feet ten inches, and their internal structure is very complex; the colon and the rectum are one foot eight inches in length.

In the African ostrich that lives in the Desert, the jejunum is twenty-four feet six inches; the cœca two feet nine inches each, with a complicated internal surface: the colon and the rectum forty-five feet three inches.

In the cassowaries which have little occasion for œconomy, the colon does not exceed a foot, nor the cœca six inches.

In the African ostrich, which requires the greatest degree of œconomy to enable it to subsist, the colon is forty-five times, and the two cœca more than five times the length of the colon of the cassowary; so that in fact, the colon and cœca of the African ostrich are fifty times the length of the colon and cœca of the cassowary from Java.

From this single fact, it is evident that the cœca and colon are of most use when the provisions are most scanty.

But the mode in which the contents of these appendages to the digestive organs are rendered productive of nutriment to the animal, I shall not attempt to explain, till I have gone through my account of the intestines of the animals belonging to the class mammalia.

I shall close the subject of the present Lecture by adverting to the wise provisions of nature, by which animals are instrumental to the increase of the vegetable creation: and thus while they are destroying for their own support, so many vegetable productions, they are converting a great proportion of what they devour into a species of manure, under which vegetation proceeds with the greatest degree of luxuriancy.

Pigeons' dung and hens' dung are much sought after as manure. Many persons keep pigeons for the sake of their dung, which far exceeds in its effects all the dung of quadrupeds; so in fact would be the dung of other birds, if it could be collected.

Rooks' dung constantly produces the rankest weeds under the trees on which they build. The dung of sea-fowl, brought from their breeding places in South America, called guma, is perhaps the most fertilising substance that can be used. Some persons have made a calculation, and have persuaded themselves that it would pay its freight to England, if it could be procured on this side of the American continent.

The seeds which pass through the intestines of birds, have their readiness for vegetating much quickened. The berries called haws, from which the white thorn is produced, must be buried in the earth for a whole year before they are ready to sow; they will not vegetate till the second year, unless they have passed through the bowels of a bird. If a person wishes to raise them quickly, he feeds his turkeys with the haws in the autumn and sows their dung: the crop rises in the spring, instead of waiting a whole year.

LECTURE XI.

On the Intestines of Quadrupeds.

THE form of the intestines in the class mammalia is so various, and the difference in structure in the different tribes is so strongly marked, that it becomes necessary to simplify the subject, by dividing it into subdivisions, beginning with the intestines of quadrupeds nearest allied to those of the bird, and ending with those which are the furthest removed.

The first subdivision will comprehend all the intestines which have cœca formed upon the same principle as those in birds.

The second, all intestines which have no such appendage as a cœcum.

The third, all intestines which have a cœcum, forming a portion of the intestinal canal.

Of Intestines which have Cœca resembling those of Birds.

The only species of animal which has cœca exactly the same as in the bird, is the myrmecophaga didactyla, one of the ant-eaters; which proves what I have already stated, that the ant-eaters, with respect to their digestive organs, both stomachs and intestines, form the intermediate link between birds and quadrupeds.

In this animal, the duodenum passes down on the right side and across the body, becoming larger towards its termination; at that part there is a sudden contraction, and the intestine becomes attached to a narrow mesentery, which becomes gradually broader. The ilium passes over to the left immediately under the stomach, and ends in the colon, which begins by being dilated to more than three times the size of the ilium; and from the rounded end of this dilatation go off two small cœca, one on each side, one-quarter of an inch long, and one-eighth wide. The colon and the rectum take a straight course to the anus, and are only about three inches long, which exactly corresponds with what is met with in the bird.

The duodenum in the instance which I examined was seven inches long; the jejunum, eleven inches and a half.

The other animals that have a cœcum of this description, belong to the newly-discovered country of New South Wales. That the ornithorhynchi should have this peculiarity, is little surprising; as we have already stated on a former occasion, that the stomach of these animals was more like those of the bird than of the quadruped. But we also find it in two other genera, the koala and wombat, whose stomachs are of the same form with those of other quadrupeds; and in whom therefore it was natural to expect a resemblance with respect to the intestines also.

In some birds I have stated the cœcum to be single, and in the animals just mentioned it is always single, and it does not appear to receive into its cavity any portion of the contents of the intestine; in this respect being analogous to the short cœca in birds, and to the glandular appendage met with in cartilaginous fishes.

In the ornithorhynchus paradoxus, the duodenum makes a turn in the right side, then crosses the spine, and becomes a loose intestine attached to a mesentery of considerable breadth. At the origin of the colon there is an appendage two inches and a half long, and a quarter of an inch in diameter; it goes off from the side of the intestine with which it communicates. The sides of the cavity of the cœcum are cellular. The intestine at this part has no valve, no enlargement, nor any character by which it is to be distinguished; and on its inner surface there are ten rows of small glands, which commence at the orifice of the cœcum, and are placed along the inner membrane of the colon at equal distances from one another, for a considerable length of its canal.

The colon passes up the right side, then crosses the body, fixed in its situation by the omentum ; in the left side it becomes the rectum, which increases in size, and at the anus is very large.

In the duodenum there are valvulæ conniventes, whose direction is transverse; but none are met with in the loose intestines, which we shall call here, (in conformity with established custom in the names given to the small intestines in the human body) the jejunum and ilium: under the first of these names including the upper half; and under the second, the lower half. The inner surface of the intestines is studded over with glands.

The small intestines in the instance which I examined, measured four feet four inches; the colon and rectum one foot four inches. The whole length of the animal from the point of the bill to the extremity of the tail, was seventeen inches and a half.

In the ornithorhynchus hystrix the general appearance of the intestines is the same as in the paradoxus; but although the animal was larger and the intestines longer, the cœcum was shorter, being only one quarter of an inch long.

The internal surface of the duodenum had a corrugated appearance, but no regular valvulæ conniventes. The cavity of the cœcum was not loculated; there were no regular rows of glands in the colon, but ten or twelve placed irregularly round the orifice of the cœcum, and several others in different parts of the inner membrane of the colon.

In the instance which I examined the small intestines were seven feet long, the colon and the rectum two feet. The length of the animal was seventeen inches from the point of the mouth to the point of the tail.

In the wombat, another of the uncommon animals from New South Wales, very different in its external appearance from the ornithorhynchi, there is the same remarkable peculiarity in the intestines, an appendicular cœcum.

In the wombat, the duodenum makes the usual turn on the right side, crosses the body, and forms the jejunum by becoming a loose intestine. At the termination of the ilium there is an appendix two inches long, the size of a small quill, which is the cœcum. The great intestine has three longitudinal bands, which give it the same sacculated appearance as is observed in the colon of the human body.

The coats of all the intestines are unusually thin; and between the coats of the duodenum are scattered small pellucid glandular bodies in clusters, at irregular distances, principally on the side to which the mesentery is attached. On the inner surface of the colon are clusters of glands in different parts:

more prominent than those in the small intestines. There are no glands in the rectum, and no appearance any where of valvulæ conniventes.

The length of the small intestines in the specimen which I examined was thirteen feet; of the colon and the rectum, eleven feet. The length of the animal was two feet.

The koala has exactly the same form of intestines as the wombat. In the ant-eaters, as well as the ornithorhynchus paradoxus, the intestines are short, their food being animal; but in the wombat and koala, that live upon roots and fruits, they are longer, in the proportion of three to one, even when compared with those of the hystrix, which are the longest.

Of the Intestines of Quadrupeds which have no Cœca.

In my explanation of the structure of the stomachs of the animals belonging to the class mammalia, I treated separately of those belonging to animals that live upon land, and those that inhabit the ocean; their difference in form making such a distinction necessary.

In treating of the intestines, we find the similarity between them in land and sea animals to be so great, as to make it proper that they should be considered under the same head; and we shall find, in the subdivisions I have adopted, that the intestines of some of the whale tribe will be included in the present series, and some of them in that which will follow it.

In the generality of the animals in which the intestines have no cœcum, the food is principally animal; and in most of them, at the verge of the anus, there are two bags from which secretions are produced, consisting of mucus impregnated with different kinds and degrees of a strong scent. These are not peculiar to animals without cœca, but are met with in others of the carnivorous tribes. As one of the uses of the secretion appears to be the defence of the verge of the fundament from the acrid quality of the fæces formed from animal food, I think proper to describe the bags along with the intestines, of which they appear to be appendages.

It is difficult to arrange a series of intestines belonging to animals that differ so widely from one another in most other respects, although they agree in this point. I shall begin with the manis pentadactyla, which is the next in order among the ant-eaters to that which I last described. In this species of ant-eater from Sumatra, the duodenum passes down the right side, and becomes attached to the mesentery without crossing the spine. The jejunum goes on the right side of the mesentery. The ilium passes up the opposite edge nearly as high as the stomach, and then bends quickly down to form the rectum. The intestines are short.

At the anus are two bags which contain a yellow mucus; on the surface are two projections, not unlike the cotyledons of the uterus of ruminating animals. All round the anus under the skin are small glands whose ducts open externally; and when the gland is squeezed, the secretion is forced out of the consistence of paint in a bladder; in each duct hairs grow with their points projecting beyond the external orifice, so that they become conductors to the secretion.

In the armadillo with nine bands, the intestine follows the same course as in the human body, only that there is no cœcum nor enlargement of the colon. On the internal surface there is no appearance of valvulæ conniventes, but in different places there is an indistinct glandular structure. The rectum is formed by a sudden dilatation of the gut, in the hollow of the sacrum; there are two pyriform bags at the anus, containing a cheese-like mucus. About half an inch from the anus is a circle of orifices, belonging to the excretory ducts of glands.

In the specimen which I examined the intestines measured eleven feet; which was six times the length of the animal.

In the hedge-hog, the intestines resemble those of the armadillo, and were found to be between six and seven times the length of the animal.

In the bear, the duodenum goes down to the right, then passes behind the root of the mesentery. The whole canal is one continued tube, there being no cœcum, no colon, nor any valvulæ conniventes on the internal surface. There are two small anal bags. The intestines are eight times the length of the animal.

The intestines of the stoat closely resemble those of the bear.

In the badger also, the intestines resemble those of the bear. In the ilium there are very large congeries of glands. There are two oblong bags at the anus; of which the half next the verge is covered with a thick glandular structure. The intestines are nine times the length of the animal.

In the martin-cat, the intestines resemble those of the badger; they are three times the length of the animal. There are the same bags at the anus.

In the rackoon there is no regular colon, but the intestine enlarges at the part where it is usually met with; and there is a valvular structure, but too slight to prevent regurgitation. The course of the intestine resembles that of the colon, but the connections are not by broad surfaces. The coats of this portion are stronger than those of the others. This intestine, corresponding to the colon and rectum, is rather more than a foot long. The bags at the anus have the same peculiarities as in the badger, but in a less degree. The intestines are seven lengths of the animal.

In the ferret, the intestines have the same course as in the human body; but there is no cœcum. Where the intestine passes up before the root of the mesentery, it does not adhere closely to it, but has a shorter meso-colon than any where else. The whole intestines measured three times and a half the length of the animal; the colon and the rectum making the half portion. The anal bags contained a yellow fœtid mucus.

The swash, with respect to the intestines, resembles the ferret.

The mole also in this respect resembles the ferret, but the intestines are seven times the length of the animal, and there are no bags at the anus.

In the otter, the course of the intestines is the same as in the ferret; they have no valvulæ conniventes, and are three times and a quarter the length of the animal. At the anus are two large bags covered by the sphincter muscle, with openings at the verge of the anus. They are covered by a glandular structure, and have a number of follicles round them. The contents which come out are partly yellowish, partly white, and very rancid.

In tbe sea-otter the intestines have the same course, without any valvulæ conniventes. They are twelve times the length of the animal, the whole being fifty-two feet, of which the part corresponding to the colon and rectum makes only fifteen inches. There are no bags at the anus; such secretions not being necessary to animals that dung under water. It is curious, that in the common otter the intestines should be only ten feet eight inches, while those of the sea-otter are fifty-two. This leads to the belief, that the sea-otter must have much more occasion to œconomise the food at particular seasons of the year than the other.

The wolverine in its intestines resembles the otter, only that the duodenum, between the pylorus and the entrance of the ducts of the liver, is very glandular.

In the small bottle-nose whale the duodenum is not bound down, but the intestine becomes almost immediately loose. The rectum, as it passes down the back, is fixed between the two kidneys. The intestinal canal was one bundred and eight feet long. The whale, which was a young one, measured seven feet and a half, so that they were fifteen times the length of the animal.

In a specimen of the large bottle-nose whale, described by Dale, twenty-four feet nine inches long, the duodenum upon leaving the pylorus was found to swell out to form a large cavity, into which the ducts of the liver open; it then became gradually smaller, and made a sudden turn upon itself to the left, and afterwards was one continued canal to the anus. It was nearly of the same size (about an inch and a half in diameter) through its whole course. It had no cœcum.

The internal membrane was thrown into, or formed large cells; those towards the bottom were subdivided into smaller ones. The orifices were downwards, and so valvular, that water could hardly be made to pass upwards. This appearance began faintly in the duodenum, and terminated near the anus. The intestines were short, compared with those of the small bottle-nose whale. This is readily explained by the internal structure being such, as greatly to encrease the surface. The warm-blooded animals that live in the ocean, probably from that circumstance alone, require a greater power of œconomising the food, since the very action of keeping up the animal heat may require an additional supply of nourishment.

In the skunk, the duodenum passes down on the right side, having a broad mesentery, and becomes fastened to the psoas muscle and meso-rectum. This attachment is loose; the intestine is then connected to a mesentery till it becomes the rectum: this last part is distinguished by its size and the thickness of its coats. On each side of the anus are placed the musk-bags; the ducts enter the rectum just within the verge of the anus; each duct terminating in a small nipple, with a prepuce which conceals it. The bags contain a yellow pungent fluid, which makes the eyes water when exposed to it.

In the musk-rat, there is no attachment of the duodenum; so that the intestine through its whole course is connected to a mesentery.

In the English bat the intestine was five inches long, while the animal was one inch and three-quarters, which is not three times the length of the animal. There are two bags at the anus.

In a vampyre bat nine inches long, the intestines were seven feet two inches long; so that the intestines are nine times and a half the length of the animal.

This is a curious circumstance, as the difference in the length of intestine in the two kinds of bat, must arise from the food in the one being animal, the other vegetable. The nature of the food of the vampyre-bat has been already explained.

The dor-mouse has also the intestines of great length, corresponding to the kind of food. The length of the animal which I examined, from nose to tail, was two inches and three-quarters. The intestines were sixteen inches; which is nearly six times the length of the animal. There was no cœcum, and the whole canal had one uniform appearance.

In the bradypus didactylus, (cauda nulla) of Linnæus, the duodenum passes down on the right side, attached to the right of the mesentery, very much convoluted, but the convolutions being very short. The intestine gradually bends towards the left, behind the mesentery, and then forwards coming to the right again, and forming the colon without a cœcum. The colon takes a turn towards the left on the opposite edge of the mesentery, and then down the loins to the anus. Where the colon begins there is a valve; and there is another about the middle: a third near the anus. Below the last there is a dilatation, as in the bird.

In the stomach were found leaves, seeds, twigs, and the inner rind of the bark, shewing the kind of food the animal lives upon.

Having described the intestines of so large a number of the animals which have no cœcum, I may observe that the greater part of them are animals that sleep during the winter, as the bear, hedge-hog, dor-mouse; or that burrow, as the mole, wombat, and koala; or are of indolent habits, as the bat and bradypus didactylus: this leads us to the consideration of the office of the intestines in sleeping animals, during the different seasons of the year; to see how far such information will assist us in explaining this particular construction of intestine.

The following observations were made upon the hedge-hog by Mr. Hunter.

In April, the stomach contained grubs in a state not unlike chopped hay; and sometimes blades of grass not chewed.

In May, June, July, and August, the contents of the stomach were principally the common caterpillars found on cabbages, with a variety of other insects, mixed with what had the appearance of chopped hay.

In October, the contents were principally the wings of black beetles and other insects; and a blade of unchewed grass.

In the intestines during these months there was nothing but the fæces which remain after digestion.

In the months of November, December, January, February, and March, no food was met with in the stomach; but in March its internal membrane was covered over with mucus, of the consistence of cream. In all these months the contents of the intestines were a substance resembling the meconium found in the intestines of the fœtus; and this in larger quantity as the winter advanced. It does not regularly fill the intestine: but is found in different parts of the canal. In the rectum there was a greenish substance; the urinary bladder was full of urine.

In the month of October the hedge-hog is very fat, having a thick layer of adipose substance every where under the skin, except on the head and legs. A bed of fat incloses the kidneys. The omentum and mesentery contain fat, but are not loaded with it.

In the month of February the fat under the skin is thinly spread, and of a yellow colour; and very little remains in the omentum, mesentery, or surrounding the kidneys.

In such animals as are obliged to have their intestinal canal completely emptied for several months in the year, there is an evident advantage in having them so constructed as readily to admit of every part of the contents being evacuated; and as these animals only feed during the summer months when provisions are in abundance, there is no occasion for œconomising the food, either in the stomach or intestines. This will explain why such animals have no cœcum nor colon; the intestines forming one continued canal without interruption. In those of indolent habits the intestines are shorter than in many other animals; but where the food is entirely vegetable, as in the vampyre bat, and in the dor-mouse, there is a greater length of intestine, as well as in the animals that live in the ocean.

It is a curious circumstance that the fat of the hedge-hog is laid up in store, principally immediately under the skin, that being the situation in which it is met with in infancy, where there is the greatest demand for it to be absorbed to supply the growth of the young animal.

Of the Intestines of Animals with Cœca, forming part of the Intestinal Canal.

As the greater part of the animals of the class mammalia have intestines of this kind, it will tend to simplify the subject very much to divide them into three distinct series:

First, those of animals with a short colon.

Second, those of animals with a long and loose colon.

Third, those of quadrupeds in which the convolutions of the colon are very much confined in their situation.

Of the Intestines of Animals with a short Colon.

In the truly carnivorous animals the colon is not only shorter, but the whole of the intestinal canal is less extensive than in those animals which feed upon vegetables, in which a cœcum is met with. I shall therefore begin with a description of the intestines of the lion tribe, which may be considered as the most truly carnivorous of quadupeds.

In the lion the duodenum is long and loose, having a broad thin meso-duodenum. Where it passes across the spine, it is attached to it by a thin doubling of the peritonæum, which is attached to the right kidney, to the liver, and to the meso-colon on the left, having a semi-lunar form, the concave edge upwards. There is also an attachment to the root of the mesentery at its posterior part, which is firmer than the other. The intestine then becomes loose, being attached to a mesentery.

The ilium enters the colon on the right side where the cœcum is situated. The colon passes very high up in the abdomen, but does not cross it in a regular manner; and when it has reached the left side, has a broad meso-colon, and passes down in the middle line of the body into the pelvis. The meso-colon is a continuation of the mesentery, so that the colon is every where as loose as the other intestines; in this respect it forms a nearer approach to the course of the intestines of those animals that have no cœcum.

The small intestines are rather more than four times the length of the animal; the colon about two-thirds, and the cœcum three inches. The coats of the intestine are thick and strong, not flexible and soft in their texture; the internal surface is uniformly smooth, having no valvulæ conniventes. There are two bags at the side of the anus, similar to those described in animals without a cœcum.

In the leopard, the intestines resemble those of the lion. The cœcum is one inch and a quarter long; the two bags at the side of the anus are as large as walnuts, covered by the sphincter muscle. When cut into, there are seen two white spots on the inside, which appear to be glandular, but very small in size. The orifices of the ducts of these glands which open into the rectum, have the appearance of the os tincæ of the human uterus.*

The shargoss, which is about the size of a fox, is nearly allied to the lynx. Its intestines in their course are very similar to the lion. The small intestines are only once and two-thirds the length of the animal; the colon is two-thirds, which is longer in proportion to the others than in the lion.

The tiger, the lynx, and the cat, have their intestines resembling those of the lion.

The hyæna differs only from the lion, in the cœcum being longer.

The gennetta forms a remove from the cat, and is nearer the hyæna. The duodenum passes down the right side nearly to the pelvis, bending round the root of the mesentery to the left, where it becomes loose, attached to the edge of the mesentery, approaches to the right, and then passes up on the fore-part of the root of the mesentery closely connected to it, in the same manner as the duodenum is behind; so that they appear to cross each other. When it has reached the left

* Tab. CXIII.

again, it passes down towards the pelvis, and enters into the colon. The cœcum, which is short, lies on the left of the small intestine, and in the direction of the rectum, which becomes straight from the point of the cœcum.

At the sides of the anus are two bags; of which the inner coat is like white silk in appearance; there is a glandular part in each; the ducts open just in the verge of the anus. The bags contain a yellow fœtid liquor, in which there is a thick part that falls to the bottom. These are independent of the musk-bags.

In the civette, the intestines are more loosely attached than in the genette, the duodenum going down the right side without crossing the body, and then attached to the mesentery, which terminates rather in the left side, and there the cœcum is situated, and the gut goes straight down, being unusually short, and deserves the name of rectum rather than colon.

There are bags at the anus as in the genette, besides the musk-bags.

In the seal, the duodenum passes to the right and downwards, and is bent so much towards the stomach as to be attached to it a ittle; as it passes down the right side, it lies upon the right lobe of the liver, and at the lower part upon the kidney; it then makes a turn upwards behind the mesentery to the left. In this course it has a small mesentery; when it comes out from behind the great mesentery, it is attached to the meso-colon and becomes a loose intestine. The small intestines terminate in the cœcum which lies behind the curvature of the stomach and before the portion of duodenum, which passes to the left.

The cœcum is two inches long, not large in proportion to the ilium. The colon, as it rises from so high a part of the abdomen, cannot ascend; it passes to the left, then dips into the pelvis and forms the rectum. The small intestines are sixteen times the length of the animal. The colon is only one-half its length. There are no bags at the anus. The seal corresponds with the other sea animals in the length of its intestines. The sea cow has intestines similar to those of the seal.

In the piked-whale the duodenum passes down the right side, then over the kidney, then to the left side behind the ascending colon and root of the mesentery, and there it becomes jejunum, attached to a mesentery. The ilium in the lower part of the abdomen before its termination, makes a turn towards the right and upwards round the edge of the mesentery, then passes upon the right as high as the kidneys, where it enters the colon. The cœcum lies on the lower end of the right kidney. The colon passes obliquely upwards; and when as high as the stomach in the middle line of the body, crosses to the left, and passes down with a broad mesocolon; it lies on the left kidney, then in the middle line of the body, lower down. It is situated in the female behind the uterus. The last five inches of the rectum are contracted, having a cuticular lining of a soft nature, and studded with glands.

The anus is very small. The inner surface of the duodenum has longitudinal valvulæ conniventes at some distance from each other, with transverse folds uniting them together.

The inner membrane of the jejunum and ilium is thrown into irregular rugæ, which are longitudinal, but follow a serpentine course.

The colon and the rectum have very flat rugæ ; the length of the small intestines is twenty-eight yards and a half; the cœcum is seven inches; the colon two yards and three-quarters. The length of the animal was five yards two-thirds; so that the intestines are six times its length.

In the fox, the duodenum makes a sudden turn down on the right side before the right kidney, then goes across the spine to the left; is more fixed to the root of the mesentery, and to the meso-colon, where it is going to become meso-rectum: it then becomes a loose intestine; towards the right the ilium enters the cœcum, and adheres to it for about two inches. The cœcum is folded upon itself, and is not bound down to the psoas muscle, but is closely connected to the root of the mesentery.

The colon passes across the spine to the left, then down, leaving a long meso-colon, and forms the rectum. At each side of the anus there is a cavity of the size of a pigeon's egg, lined with a cuticle; these have each an opening just at the side of the anus, where there are two or three hairs.

The length of the small intestines was eight feet; the cœcum four inches; the colon one foot four inches; only four times the length of the animal.

In the wolf the small intestines were fifteen feet; the cœcum eleven inches; the colon two feet: their course the same as in the fox.

In the dog the intestines are the same as in the wolf. It is remarkable, that the intestines are shorter in the fox than the wolf, making it in this respect a nearer approach to the lion and beasts of prey.

In the American opossum the duodenum passes down on the right side, but soon crosses the spine to the left, where it becomes a loose intestine. The ilium termidates in the colon on the right side. The cœcum is three inches long, and in general straight; but in one instance it was bent, having a meso-cœcum. The colon passes up the right side, across the body and down the left side, having no attachment but the meso-colon, which is very loose. The small intestines are unusually wide and short, being only three feet nine inches; the cœcum three inches; the colon nine inches. There are two bags at the anus, which open by small long ducts, terminating in points close to the verge. Their contents are partly liquid, and partly of a more solid substance.

In a species of opossum of the size of a rabbit, the duodenum passed to the right, and then down, having a mesentery, became more fixed to the back, and afterwards loose. The mesentery was long and narrow; the jejunum and the ilium, short. The ilium entered the cœcum high up on the right. The cœcum was of considerable length. The colon passed almost immediately down to form the rectum. It had a longitudinal band opposite the meso-colon, and probably one where attached to it.

In the following series, the intestines of those animals are described first which approach the monkey tribe; then those of monkeys; and lastly, those of man.

The lemur tardigradus ecaudatus, has the duodenum as usual; it then passes a little way to the left to become loose. The ilium enters the colon on the right. The cœcum is about one inch and a half long, not pyramidal. The colon passes up the right side; and where it is going to cross the body, makes a slight fold on itself, and then passes to the left and down to the pelvis, lying close to the back, having a sigmoid flexure, and then it becomes the rectum.

The small intestines are short, and have no valvulæ conniventes; in this respect corresponding to the habits of the animal.

In the lemur vittatus, the duodenum passes to the right and then downwards, without crossing to the left. The cœcum is about one inch and a half long, and terminates almost in a point like the human appendix cœci vermiformis.

The colon makes turns upon itself, one within the other, before it becomes the rectum. The animal has therefore a greater power of œconomising the food.

In the sanguine, the duodenum is not covered by the root of the mesentery, but only adheres to the angle of the meso-colon and loins, becoming loose on the left side; and the ilium enters the colon on the right. The colon passes up the right side, crosses to the left, and from thence passes down into the pelvis, having no attachment but to the meso-colon, which is shortest at the right side where it is going to make the turn. There are two longitudinal bands, one on the edge next the meso-colon. and the other on the opposite edge. The small intestines are twice the length of the animal. The colon is once its length.

In the following animals, the intestines are shorter than in many which have been described.

In the mocock, the duodenum is short and more closely attached as it crosses the spine, in this respect forming an approach to the monkey; but the attachment is not to the spine itself, or the kidney, but to the ascending colon.

The ilium passes into the cœcum on the right side. The cœcum is seven inches long, and small; towards the blind end it is a little bent, having a narrow meso-cœcum, but is quite unattached.

The colon is of the same size as the largest part of the cœcum; it is attached to the psoas muscle, a little below the transverse turn of the duodenum, but not so much as in man. The ascending colon is attached to the right edge of the mesentery, so as to lie more loose in the abdomen even than in the monkey.

The colon makes a transverse arch, attached to the root of the mesentery, the duodenum and the pylorus; but it becomes looser as it passes to the left side, and is bent back upon itself nearly its whole length, and is fixed by a narrow mesentery. It is folded back again upon itself to the left, attached to the former turn, but does not go so far, nor is it in contact with it; then it passes back towards the spine upon the left of the root of the mesentery, to which it is attached, and goes down the loins in the middle line of the body to form the rectum.

About the beginning the colon is formed into pouches by something like ligamentous bands, and this part is the largest; but this appearance is not continued further.

There are no valvulæ conniventes in the small intestines; they are three times the length of the body. The colon is one-half its length.

In the long-tailed monkey, the intestines are very nearly the same as in man; the mesentery is thinner, and the meso-colon is looser; so that the colon is only bound down at the beginning of the transverse arch, and that chiefly to the duodenum. There is an appendix cœci of a pyramidal form, and about half an inch long.

The small intestines were seven feet four inches long; the colon one foot eight inches. The length of the animal was two feet two inches. There were small valvulæ conniventes in the duodenum and jejunum.

In another monkey, the appendix cœci was entirely wanting; and there were no valvulæ conniventes in any part of the small intestines.

In a large black monkey the appendix cœci was three inches long, and half an inch in diameter.

In the baboon, the only thing in which the intestines differ from those in man, is that the appendix cœci and valvulæ conniventes are wanting; the cœcum is looser, and the mesocolon is longer.

In man, the course of the intestines is so well known to the greater part of my audience, as to make a description unnecessary; but the followiug facts respecting their comparative length in the different stages of growth, may not be so familiar.

In a man five feet seven inches high, the small intestines were twenty-five feet nine inches; the colon and rectum six feet: five times and one-half the man's length.

In a man five feet high, the small intestines were twenty-three feet; the colon and rectum four feet: five times and one-third the man's height.

In a child three feet one inch high, the small intestines were twenty feet one inch; the colon and rectum three feet: seven times and one-half the child's height.

In a child one foot nine inches high, the small intestines were thirteen feet; the colon and rectum one foot eight inches: eight times and one-third the child's height.

In a child one foot four inches high, the small intestines were thirteen feet two inches; the colon and rectum one foot eight inches: eleven times and one-eighth the child's height; so that the intestines during growth, are longer in proportion to the size of the body than afterwards.

Of the Intestines of Animals with a long and loose Colon.

The animals whose intestines I am about to describe, have chissel-teeth in a greater or less degree, and form a series intermediate between that to which man belongs, and that formed by animals that ruminate: they all feed upon vegetable substances of different kinds; the cœcum is in general long; and the colon commonly long, loose, and small in size; and the fæces while passing through it become more divided, and take on a more solid form than in the colon of the animals which have been described.

The first of the chissel-teethed animals whose intestines I shall describe, is the marmotte. This animal is the only one of those that have a cœcum that sleep during the winter, and yet differs very little from the other animals with chissel-teeth in the course of the intestines. The cœcum we find to be rather shorter as well as the colon. Nothing can shew more strongly the principle in nature of the structure of animals running imperceptibly into one another, than this animal having a cœcum, and belonging to the tribe of animals which sleep during the winter; which have none.

In the marmotte, the duodenum is long and loose; as it passes down it is attached to the first angle of the colon, then to the right side of the ascending colon round which it passes, and comes out at the left side, forming the jejunum. The cœcum is large, lying upon the fore-part of the spine just above the pelvis, a little bent upon itself, having a narrow meso-cœcum. Its appearance is as if it were quilted: it was three inches and a half long. The colon is of the same size as the cœcum, passes up the same side, but soon becomes narrow and small: it then makes a loose tnrn upon itself eight inches long, only connected to the descending duodenum, and to itself by a narrow meso-colon; after which it makes another turn half the length of the former; from thence it passes down the left side to the pelvis, becoming much stronger in its coats, with a broad meso-colon. Where it makes the first turn the fæces are soft, but are beginning to be divided into separate portions, and then become harder and harder towards the rectum. This forms an approach to the division of the fæces into small distinct portions met with in the colon of ruminating animals.

The termination of the rectum is about three-quarters of an inch above the anus; the lower part is surrounded by glands resembliug those met with more externally in the hare and rabbit. The small intestines were seven feet nine inches; the colon and rectum were three feet ten inches; which is about seven lengths of the animal.

The duodenum is large at its origin, and somewhat sacculated. This appearance is produced by the contraction at the pylorus, and one in the duodenum, where its canal is suddenly diminished; and then the intestine becomes loose, not passing so low down the right side as is usual in quadrupeds, but only making a fold on itself; then passing under the root of the mesentery, where it adheres, and down just below the lower end of the kidney, to which part it has a thin membranous attachment. It is doubled upon itself for a little way, then convoluted, and passes to the left behind the meso-colon, and afterwards becomes loose. These intestines are very small. The cœcum is very large, about an inch and a half in diameter, thickest where the ilium enters it, which is in the left side at the lower end of the kidney. It adheres there, and makes an arch downwards across the brim of the pelvis towards the right side, becoming smaller, and making two or three loose turns.

In all this course it is only connected to the lower and right edge of the mesentery. There are three longitudinal bands beginning at the apex of the cœcum, and running through its whole length to its termination, where two unite into one, leaving only two. About an inch and a half from the entrance of the ilium, the colon becomes suddenly small, is bent back upon the cœcum, and is attached to it by a thin membrane about an inch broad, for nearly two-thirds of the length of the cœcum, becoming smaller and smaller, and at the smallest part is half an inch in diameter. It leaves the cœcum and ascends, attached to the right edge of the mesentery near its root, and where the duodenum is connected to it, then makes a double fold upon itself, and crosses the root of the mesentery on its anterior surface to the left side, adhering closely to the mesentery.

The colon then becomes loose, having a broad meso-colon and meso-rectum, and is thrown into convolutions; but at the lower part it is straight. In this last part the fæces are divided into small portions.

The small intestines are seven times the length of the body of the animal: the cœcum more than two-thirds; the colon and rectum four times. On the skin round the verge of the anus are sebaceous glands; and that part is sometimes so much drawn in, as to appear to be the anus itself.

In the la paca (of Buffon), the duodenum swells out, projecting above the pylorus like a cœcum, and that part is very glandular; it then becomes much smaller and passes to the right. In its course downwards it gets behind the ascending colon, to which it is attached; it then ascends a little, and crosses the spine behind the mesentery, becoming a loose intestine.

The small intestines are very long; the ilium enters the colon in the lower part of the belly, nearly in the middle line, The cœcum is very large, long, and conical; the point lies on the left side: from thence it passes behind the mesentery in a spiral course to the right, then makes a sweep downwards and crosses the pelvis again. At this part the ilium enters. When the cœcum is blown up, it forms one complete spiral turn and a half. From the left, the colon again makes another turn to the right upon that which was last described, adhering to it by a narrow meso-colon. At this last bend it diminishes in size, and continues to do so to the right; it is there thrown into longitudinal folds, and then passes up the right side, adhering to the duodenum, and makes two complete spiral turns upon itself; then passes out upon itself again; it crosses the spine closely connected to the fore part of the root of the mesentery, and becomes attached towards the left of the mesentery by a long meso-colon; it is very loose; is thrown into a number of small folds: it passes from thence down the left side to form the rectum.

In the porcupine, the duodenum passes down on the right side, attached to the ascending colon for nearly a foot in length;

is then attached to the root of the mesentery on the same side, gets behind it, and on the left side becomes loose on the edge of the mesentery. The cœcum is a foot long, conical, with three longitudinal bands, as in the Guinea pig. The course of the colon also resembles that of the Guinea pig. The small intestines have no valvulæ conniventes. They are nearly four feet long. The ilium is dilated just before it enters the colon; and there is a fold of internal membrane on one side, forming an imperfect valve. There are clusters of glands in the lower part of the ilium, and in the cœcum at different distances, from half an inch to an inch asunder; these are not met with in the duodenum, jejunum, or colon.

The length of the colon is nearly ten feet. In the cœcum the contents are in a half fluid state, but they enter the colon in the form of small pellets: these, at first, are soft, but acquire consistence as they pass on, and are hard at the anus. There are no bags at the anus.

In the rat, the duodenum passes down the right side with a long mesentery, then passes to the left, and up by the side of the rectum to the root of the mesentery. It is attached to the rectum by a narrow membrane, also to the root of the mesentery; then passes forward round its left edge, and becomes loose and convoluted.

The ilium enters the colon before the spine, and a little to the right. The cœcum is turned towards the right, is about one inch and a half long, a little bent, and near an inch in diameter.

The colon is a little convoluted at its origin, where it passes behind the ilium to the right, and up that side attached to the right edge of the mesentery, through its whole length; then passes before the root of the mesentery to the left, closely connected to it; from thence down into the pelvis, nearly in the middle line of the spine. At the beginning of the colon there is a thickening, and kind of stricture, and the fæces begin to be divided at this part. The small intestines were two feet ten inches in length; the colon and rectum nine inches.

In the flying squirrel, the duodenum from its origin is loose, till it passes upwards to cross the spine; it is then attached to the root of the mesentery and to the spine, by a thin membrane, and it then becomes again loose. The ilium enters the colon in the middle line of the body; and the cœcum lies chiefly on the left side: it is about two inches long and bent upon itself, having a narrow meso-cœcum.

The colon on the right side makes a fold upon itself, about two inches long, and then crosses the spine, making at that part a slight fold; then passes down to the anus.

In the grey Virginia squirrel, the pylorus is bent up, and the duodenum passes down to get to the right side. It becomes loose, forming the jejunum, which has a long mesentery, passes down to the brim of the pelvis, then up, and behind the mesentery to the left; to the root of which it is there closely connected.

In the English squirrel, the duodenum is attached to the vertebræ of the loins and psoas muscle by a very thin membrane, which is connected to the meso-colon. This is also the case in the fox-squirrel: the intestine then becomes loose, forming the jejunum; and on the right side enters the colon. The cœcum is large, but smallest next the insertion of the ilium. The colon passes up the right side, attached to the right edge of the mesentery by a thin meso-colon, and also to the meso-duodenum. The colon when it goes to the left makes a fold upon itself five inches long; and when it has just crossed the mesentery, to which it is closely attached, it makes another fold of the same length. From thence it passes down into the pelvis, having a long meso-colon.

The small intestines are seven times the length of the body of the animal, The cœcum is one-half; the colon twice its length.

In the beaver, the duodenum passes down nearly to the pelvis; then turns up by the side of the rectum, adhering to it during its course; then gets on the left of the mesentery, where it becomes a loose intestine. The ilium enters the colon in the middle line of the body, just above the pelvis. The cœcum passes to the right, and makes a sudden turn upwards towards the left behind the mesentery; so that the apex of the cœcum lies on the left side.

The cœcum is wide at the entrance of the ilium, and tapers to a point at the apex. It is twelve inches long.

The colon passes to the left side, then makes a sudden turn upon itself, the two portions adhering together and crossing the pelvis; it then adheres to the right curve of the cœcum, crosses the lower curve of the duodenum, then is attached to the meso-duodenum, and makes two small folds on itself; from thence it crosses the root of the mesentery, and passes down on the left of the duodenum to the pelvis. These folds resemble those met with after the colon crosses the spine in the Guinea pig. The rectum is carried down along the lower part of the tail beyond the pelvis, before it terminates in the anus, which termination is bent down from the tail.

The small intestines were eighteen feet long. They have no valvulæ conniventes nor glandular structures. The cœcum has two longitudinal bands and a puckered appearance; a circular fold of the internal membrane marks the beginning of the colon. Several clusters of two or three or more glands, are scattered between the coats of the cœcum at different distances.

The colon was three feet six inches long. It has three longitudinal bands and a puckered appearance. Clusters of glands, like those in the cœcum, are scattered along at different distances as far as the rectum. Above seventy of these were counted.

In this animal, the fat is principally under the skin, hardly any being met with in the abdomen, or in the interstices of the muscles.

In the hare, the duodenum is loose, having a broad mesentery, and is very long, for when it passes down the right side, it makes a loose fold upon itself, five or six inches long, connected by a broad meso-duodenum; the last part of this fold, before it crosses the spine, is attached to the rectum by a thin membrane for nearly three inches, and where it crosses, it is attached to the root of the mesentery, and then becomes a loose intestine.

The ilium, before it enters the colon, passes for seven inches between it and the cœcum, attached to both the whole length; just before its termination, it dilates into a bag.

The cœcum is two feet long, and has a kind of spiral valve, which begins indeed in the colon, making two turns just beyond the entrance of the ilium, and goes on through the greater part of the cœcum. The cœcum gradually diminishes in size, and the smaller portion is towards the extremity for three or four inches; it has no valvular structure.

The colon, immediately beyond the entrance of the ilium, makes a sudden turn upon itself with a very short meso-colon, then passes a little way along with the ilium, becomes small, makes a fold upon itself; at this part it has two bands, which, at the beginning of the colon, are very faint. It afterwards makes another fold, in which the two bands are lost. It joins the descending part of the duodenum, in whose curve it lies, passes to the right behind the stomach, to which it adheres, crosses the body to the left, adheres to the duodenum going behind the root of the mesentery, and forms the rectum.

The small intestines were eleven feet six inches long; the colon and rectum were five feet.

In the rabbit, the intestines resemble those of the hare; the cœcum is eighteen inches, and makes two spiral turns upon itself: its internal structure is as in the hare. The small intestines were eight feet, the colon and rectum three feet in length.

In le cabiai the duodenum passes down the right side, adhering to the cœcum, then winds round the root of the mesentery, and gets upon the left of it. In this course, it describes nearly the segment of a circle, and is so connected to the parts behind, that it cannot be said to have a meso-duodenum.

The ilium is attached to the cœcum for nearly twelve inches before it enters the colon by a membrane, which appears to be a continuation of the mesentery. This membrane becomes gradually narrower towards the insertion, and there the ilium adheres to the cœcum. It enters on the left side, and there the cœcum is very large; it passes to the right, crosses the pelvis, and passes up to the liver; adheres to the duodenum, then goes across the body close to the stomach, and terminates there in a blunt point. Near the smallest end there are two ligaments, but on the wider part there are five. It was one foot five inches long.

The colon is large at the beginning, but soon becomes smaller; it is reflected to the right on the forepart of the cœcum, connected to it by a thin membrane, which gradually becomes narrower, till at last it adheres to the cœcum, follows it through all its turns nearly to the tip; it then turns back upon itself for the same length, after which it passes to the left and becomes loose, with a long meso-colon, making several convolutions upon the iliacus internus muscle, then it forms the rectum. The fæces are as soft as dough.

The small intestines were twenty-seven feet six inches, the colon and rectum eight feet in length.

In the jumping mouse, the duodenum passes down on the right side as low as the pelvis, connected to the ascending colon, then up to the left behind the mesentery, and becomes loose, forming the jejunum. The ilium enters the colon upon the spine. The cœcum is four inches long, large at the entrance of the ilium, and tapering to a point which lies loose in the pelvis, but the other part makes a spiral turn round the entrance of the ilium.

The colon is largest at its origin, makes a turn upwards, is attached to the first turn of the cœcum by a meso-colon, passes a little up on the right side, makes a fold upon itself about an inch and a half, crosses the spine, and makes another short fold; from thence it passes down to the anus.

In the jerboa, the duodenum passes to the right side, attached to the upper surface of the transverse arch of the colon; when as low as the os ilium, it makes a turn up to the left behind the mesentery, where it becomes loose, forming the jejunum. The ilium adheres to the cœcum for some way before it enters the colon, which it does as low as the pelvis in the middle line of the body.

The cœcum passes upwards on the right of the mesentery, terminating in an oblique point, which is curved.

The colon winds round the cœcum, and follows it nearly its whole course, attached by a narrow meso-colon, but towards the two extremities, it adheres by close contact; where the colon leaves the cœcum, it makes a convolution, then a fold upon itself five inches long, then crosses the spine attached to the duodenum, then makes a turn one inch long upon itself, and passes down the left side to the pelvis, having a long meso-colon. The rectum, as it comes out of the pelvis, is bent downward, and opens externally about two inches from the tail.

About half an inch further on, between the legs, is another opening similar to the anus, and passing in the same direction, leading to a double cul de sac between the rectum and the bulb of the urethra, lined with a white silky cuticle, on which hairs grow. The two blind ends are glandular, and secrete a white mucus.

In the kanguroo, the duodenum is large, passes down the right side, crosses the body, then contracts and forms the jejunum. The mesentery is long and delicate; the cœcum is on the right side, and has two longitudinal bands, which give it a puckered appearance; these are blended together at its apex.

There are several clusters of glands at regular distances from each other on its internal surface. The colon passes up the right side, crosses the body, and on the left side forms the rectum. The colon has three longitudinal bands, is very much puckered, the meso-colon is very long, and there are large appendiculæ epiploicæ. The small intestines were twenty-six feet and a half long ; the colon and rectum were nine feet and a half.

I have now described the structure and course of the intestines in those genera of the class mammalia, which have an appendage like the cœca in birds ; in those in which there is no cœcum ; in those also with a cœcum, at the beginning of the colon, short in carnivorus animals, and long in the tribes which live wholly upon vegetable food : but my task is not yet completed, as the course of the intestines of a very extensive series of animals remains unexplained, in which are comprehended all those that are obliged to ruminate their food. The consideration of the intestines of the various genera of ruminants, is all that is wanting to make this curious and complex chain of structures completely understood, and comprehends all that I mean to lay before you upon this branch of comparative anatomy.

LECTURE XII.

On the Intestines of Quadrupeds, in which the Convolutions of the Colon are confined to their situation.

THE greater number of the quadrupeds which compose this series, are those that ruminate; but this circumstance of the colon being confined to its situation, is not entirely peculiar to them; indeed, it is met with in some of the animals already described,—as the paca: but that animal is so nearly allied to the Guinea-pig, and the animals with chissel teeth, that I gave it a place with them. Under the present head, may be included the intestines of the horse, elephant, and the hog tribe, as well as the ruminants.

After all that has been already said of the small intestines, I need not enter into a very minute account of them at present; and even with respect to the course of the colon, to which I wish particularly to draw your attention, you will learn more from the engravings than from any description; and by comparing them together, the nature of the different variations will be better understood.

In the horse, the duodenum passes down on the right side, and at the lower part becomes a little convoluted and loose; it then crosses the spine behind the root of the mesentery, becoming the jejunum; immediately before this part of the duodenum is the union of the colon with the cœcum. The duodenum, jejunum, and ilium, have no valvulæ conniventes.

The ilium enters the colon, leaving a portion of two feet in length, which forms the cœcum, and is bent upon the colon. The cœcum has four bands, is about a foot in diameter, and terminates in a narrow point. It is connected to the colon by a meso-cœcum, and lies principally on the right side. The colon at the beginning is attached to the root of the mesentery, and lies between it and the transverse portion of the duodenum; is very small, having no ligaments, and makes a slight turn upon itself on the side of the angle between it and the cœcum. It becomes loose in the cavity of the abdomen, has four ligaments, and is in this state for the length of five feet; then becomes smaller, and makes another turn upon itself, and the two portions are united by a narrow meso-colon; towards the end of this turn it becomes larger, crosses the abdomen near the root of the mesentery. On the left side it contracts all at once, and is continued of an uniform size, with two strong longitudinal bands; in the latter part it has a loose meso-colon, and is thrown into convolutions.

This part, in the instance which I examined, was about twelve feet long; the size of the first turns of the colon, often varies very much from the irregular contraction of the muscular fibres.*

The small intestines were fifty-six feet long. The colon and rectum were twenty-one feet; the cœcum, two and a half feet.

In the ass, the course of the intestines is the same as in the horse. The small intestines were forty feet, the colon and rectum seventeen feet long.

In the zebra, the intestines are the same as in the ass. The small intestines were thirty-six feet and a half; the colon

* Tab. CXIV.

and rectum, were nineteen and a half; the cœcum was two and a half.*

In the elephant, the intestines are formed upon the same principle. The small intestines were thirty-eight feet, the colon and rectum twenty and a half, the cœcum one and a half.

In the tapir there is an evident resemblance in the course of the colon to that of the horse, as is satisfactorily seen in the engraving. The principal difference is the cœcum pointing downwards, and the colon being small at its origin, but it afterwards swells out.†

I have brought together the description of the course of the colon of these five genera of animals, since there are peculiarities common to them not met with in other animals. The cœcum is very wide, and is situated nearly in the middle line of the body. The colon for some length is of the size of the cœcum, and has a fold of considerable length, the two portions of which are closely connected together; so that the colon is to be considered in some measure as a reservoir, in which the contents may be detained. This observation is however more applicable to the first portion of the colon, than to the rest of that intestine.

In the hog, the intestines more nearly resemble those of ruminating animals, and in this respect may be considered as forming an intermediate link between them and the tapir. They resemble the tapir in the turns they make, being on the edge of the meso-colon, not in it, as in ruminants, and differ from both in the turns, being transverse respecting the body of the animal instead of longitudinal.

* Tab. CXV. † Tab. CXVI.

The duodenum passes directly downwards before the right kidney, attached to a loose thin mesentery; then makes a turn and crosses the spine, getting behind the ascending part of the colon, adhering to it as it passes obliquely upwards, and winds round the colon: and when on the left it passes forwards and becomes loose.

In all this course it adheres to the rectum and neighbouring parts.

The jejunum and ilium are nearly of one uniform size, and much convoluted in their folds. They have no valvulæ conniventes. At the lower part of the cavity of the belly the ilium passes backwards towards the spine, and enters the colon on the right iliacus internus muscle. The small intestines are twenty times the length of the body of the animal. The cœcum is four inches long, and one in diameter; it lies upon the urinary bladder, and is attached through its whole length to the ilium by a thin mesentery; it lies loose in the cavity of the abdomen, its blind end being turned directly forwards.

The colon at its origin is attached to the spine; from thence passes up on the left side just before the left kidney as high as the stomach; then makes a turn towards the right, where it forms a circle, and makes five spiral turns like a screw upon itself. It is then bent backwards, passing between the former turns: in this retrograde course it approaches the centre of the screw, so as to be entirely hid; then makes a quick turn upwards, adhering to itself and the left kidney, as high as the first spiral turn; from thence it crosses the spine immediately before the mesentery, adhering to the lower edge of the pancreas, and as it were enclosing the fore part of the mesentery; then passes down the right side before the duodenum, and afterwards behind the bladder to force the rectum. These turns of the colon are, respecting situation, the reverse of what I have met with in any other animal. The spiral turns are singular, and are to the left of all the other intestines. The colon is not large in proportion to the rest of the canal; it has no longitudinal bands, but is sacculated: this arises from its adhering by a broad surface to the parts to which it is connected; so that the adhesion is shorter than the intestine. Its length is five times that of the animal.*

In the pecari, the spiral turns of the colon are three instead of five: this may arise from the luxuriancy of climate in which the animal lives, making length of colon less necessary. The fæces are in some degree knotted; but not so much so, as in the goat and deer.

The first of the truly ruminating animals whose intestines I shall describe, is the nyl-ghau. The duodenum first passes upwards towards the liver, and becomes firmly connected to its vessels; then downwards on the right side very low, having a meso-duodenum of considerable length, which becomes narrower in the loins; from thence it passes obliquely upwards towards the left, behind the mesentery, and becomes loose.

The ilium enters the colon on the right side. The cœcum is a foot and a half long, and ten inches in circumference.

The colon at its beginning is larger than at any other part; is a little folded on itself: then passes upwards, becoming smaller and smaller, makes six spiral turns; then runs in between the laminæ of the mesentery in its middle; passes upwards towards the left; then crosses the fore part of the mesentery attached to it, making a fold upon itself in the

* Tab. CXVII.

meso-duodenum; then in crossing, is attached to the posterior surface of the omentum; and immediately above the beginning of the jejunum in the left side, passes down with a meso-rectum to the anus.

In the bonassus, the duodenum passes backwards, and makes a quick turn downwards along the loins; at the lower part it passes behind the other intestines adhering to them; makes a slight turn upwards, and then becomes loose. The ilium enters the colon on the right side: the cœcum is bent upon the beginning of the colon, and adheres closely through its whole length.

The colon passes to the right, and then makes a turn to the left: in this way it makes three complete turns; after which, its windings are so irregular, and so closely connected together, as to baffle description.

The rectum passes down upon the spine.

In the bullock, the duodenum passes down the right side as low as the pelvis, making small convolutions, then a sudden turn along the spine on the side of the rectum; and when as high as the root of the mesentery, forms the jejunum, which, just before its termination, joins the cœcum, and runs along it till it enters the colon; for the turns of which, I may refer to the engraving.*

In the East Indian bull, the duodenum passes to the right, and down that side attached to the first descending turn of the colon, in a serpentine course; then crosses the spine, winding round the first and posterior turn of the colon; then up the left side between the colon and rectum, becoming

* Tab. CXVIII.

loose where the rectum begins: the course of the colon is seen in the engraving.*

In the camel, the duodenum passes down the right side, long and convoluted, then up, and crosses the body behind the rectum. The course of the colon is shewn in the engraving.† The small intestines were seventy-one feet; the colon and rectum fifty-six; the cœcum three feet.

In the sheep, the convolutions of the colon are fewer than in the goat; I have therefore taken them next in order; and the turns peculiar to this genus are represented in the engraving.‡

In the Vienna sheep, the convolutions of the colon, which are shewn in the engraving, are found to be more complex than in the common sheep, shewing evidently, that either constantly or occasionally, there is a greater length of colon required in them for œconomising the food.§

In the goat, the duodenum begins on the right side, passes back round the third cavity of the stomach, adhering to the angle between it and the second by a meso-duodenum; it then passes down on the right side, making a fold upon itself, attached to the end of the pancreas; then passes behind the mesentery, and comes out to form the jejunum.

The duodenum, jejunum, and ilium, are remarkably small. The ilium is the largest, and more so towards the termination.

The cœcum is about nine inches long, and four in circumference. It is connected by an uniting membrane to the ilium through its whole length.

The course of the colon is shewn in the engraving. The

* Tab. CXIX. † Tab. CXX. ‡ Tab. CXXI. § Tab. CXXII.

convolutions are not only more numerous than in the sheep, but the cœcum is a much larger reservoir.

The small intestines have no valvulæ conniventes; they are ten times the length of the animal; the colon and rectum are three times and a half. When the contents of the colon are examined, they are found uniform till they arrive at the first spiral turn of the colon; they are then divided into separate portions.*

In the antelope, the turns of the colon are less complex than in the deer; they have, therefore, the next place in the present arrangement; and as the ring-horned antelope has the most simple form of colon, it comes first in this order.

The turns of the colon are shewn in the engraving. The length of the animal from the horns to the anus was three feet three inches; the small intestines were forty-four feet; the cœcum nine inches; the colon sixteen feet.†

In the antelope, the turns of the colon are not in the mesocolon, as in the goat, but loose, more oblong, and some longer than others. Towards the centre they are less regular. A general idea is given of them by the engraving. It is evident that the pasture of the ring-horned antelope in the places destined for its food, is richer than that of the common antelope.‡

In the deer tribe there is great variety; and in the present arrangement, where the turns of the colon are equally complex, or nearly so, those with the smallest cœcum have the lower, or first place. Of those which I have to describe, this falls to the little deer from Carolina, of which the turns of the colon are shewn in the engraving.§

* Tab. CXXIII. † Tab. CXXIV. ‡ Tab. CXXV. § Tab. CXXVI.

In the small deer from Prince of Wales's Island in the East Indies, which differs from the rest of its tribe in having no third cavity to the stomach, the cœcum is larger, longer, and the rectum of unusual size, although the course of the colon is nearly the same, as will be seen in the engraving.*

In a small animal of the deer kind, smaller than that from Prince of Wales's Island, and resembling it in the gall-bladder and other respects, the turns of the colon are different, although in no very great degree; but the difference is sufficiently strongly marked to demonstrate, that nature deviates from any particular structure, whenever a variety of the same animal is produced: and the annexed engraving is to shew this particular fact.†

In the hog-deer from the East Indies, the turns of the colon are more extensive than in the species already described.‡

In the East Indian deer, they are probably not more extensive, but put on a different form.§

In the common deer, the duodenum almost immediately upon leaving the stomach crosses the body to the left side, without any mesentery. The mesentery of the jejunum and ilium, instead of being oblique, is almost horizontal. The ilium enters the colon, not upon the edge where the meso-colon is attached, but upon the anterior surface, and is attached to the cœcum by a meso-colon.

The cœcum is one foot long. The course of the colon is shewn to differ from that in others of the deer tribe, in the turns being horizontal instead of perpendicular.‖

* Tab. CXXVII. † Tab. CXXVIII. ‡ Tab. CXXIX.
§ Tab. CXXX. ‖ Tab. CXXXI.

In the rein-deer, the turns of the colon are complex beyond those of any others of the tribe: the necessity of their being so is very obvious, since in that animal, during a part of the year at least, the greatest œconomy respecting the food is required. The duodenum, soon after its origin, makes a slight fold upon itself, attached to the first ascending turn of the colon, then crosses the body obliquely behind the mesentery along with the posterior turns of the colon. When as high on the left side as its origin on the right, it becomes jejunum, attaches itself to the edge of the mesentery, along which it passes downwards, and towards the right again, making short convolutions, and before the ilium enters the colon it rises higher in the abdomen, the whole taking a circuitous course, and on the right side it terminates.

The cœcum was one foot and a half long; the blind end of it lies in the pelvis.

To see the turns of the colon, the mesentery and small intestines must be turned aside, as the turns of the colon are on the posterior surface of the meso-colon.*

* Tab. CXXXII.

On the Functions of the lower Intestines.

Having at last completed the description of the intestinal canal in all the classes of the animal kingdom, from the most simple that can be imagined, to the most complex of the ruminating quadrupeds; I am led to bring before you, some observations respecting the purposes for which the lower portion of this canal is intended by Nature.

In taking a review of the intestinal canal in all the different classes of animals, we find invariably, that there is a greater length of this tube than is necessary to answer the two uses which are generally allowed to belong to it; namely, the affording a surface upon which the chyle may be spread, and from thence carried by the absorbents into the circulation; and the forming a reservoir for containing the refuse of the food, till it is voided out of the body.

The necessity of an extensive reservoir in land animals is obvious; but this is not the case in the whale tribe, which inhabit the ocean; and yet in these last the colon is of an enormous length; from which it would appear, that there is some other use to which, in them, this portion of the canal is adapted.

The numerous glandular structures, whose secretions are mixed with the contents of the colon, render it probable, that in all animals, there is some process going on in it, and that it answers some other purpose besides that of being a reservoir. These glands are particularly conspicuous at the cœcum; and in some animals the cœcum does not form a part of the canal, but only supplies it with its secretions. Of this description is the cœcum of the ornithorynchi, the cœca in birds of prey, the appendix cœci of the human colon, and the glandular bag in the whole of the shark tribe, to which the ink bag of the different species of cuttle fish appear to be analogous in its use. The cœca in birds are studded with glands; and in one instance I have mentioned the secretions to resemble the ink of the cuttle fish.

Another argument in favour of this opinion respecting the functions of the colon, may be derived from the contrivances employed to prevent the contents from too hastily passing along the canal. These vary in different animals; they are most remarkable in the cœca of birds, in which the contents, when once they have been received, may be detained for an indefinite length of time; and in ruminating animals, in which the windings of the gut make the passage of its contents unusually slow.

In animals whose food is vegetable, and contains little nourishment, the colon is longer, and the means of retarding the progress of its contents are greater than in those which live on animal food, or have the means of procuring a plentiful supply; and from this it is probable, that the process which is carried on in the colon, is connected with the nourishment of the animal.

It is unnecesary, after what has been stated in the preceding Lectures, to give more than one illustration of this in the class mammalia, and one in the class of birds.

In the lion, the colon and cœcum are three feet eight inches long; in the goat, they are twenty feet nine inches, although the animal is so much smaller in size than the lion.

In the eagle, each of the cœca is a quarter of an inch long, and the rectum four inches. In the wild swan, each of the cœca is eight inches long, and the rectum eight inches.

There is, however, a much stronger evidence in favour of the length, and other contrivances in the structure of the colon, being for the purpose of extracting nourishment from its contents; which is, that the colon in animals that live upon the same species of food, is of a greater length in proportion to the scantiness of the supply. Among quadrupeds, this may be illustrated by the length of the colon in the elephant, being only twenty feet six inches, while in the dromedary it is forty-two. The first inhabits the fertile woods of Asia; the latter, the arid deserts of Arabia. It is still more strikingly contrasted among birds. The cassowary of Java, which lives amid a most luxuriant supply of food, has a colon of one foot in length, and two cœca, each of which is six inches long, and one quarter of an inch in diameter. The African ostrich, on the other hand, which inhabits a country where the supply of food is very scanty, has the colon forty-five feet long, each of the cœca two feet nine inches, and at the widest part three inches in diameter; and in addition, there are broad valvulæ conniventes both in the colon and cœca. These remarkable facts and striking analogies, make it clear that some process goes on in the colon, from which a secondary supply of nourishment is produced.

The circumstance of ambergrise, which contains sixty per cent. of fat, being found in immense quantities in the lower intestine of spermaceti whales, and never higher than seven feet from the anus, is an undeniable proof of fat being met with in the intestines; and as ambergrise is only met with in whales out of health, it is most probably collected there in consequence of the absorbents not doing their duty in taking it into the constitution.

Ambergrise is found in lumps from fourteen to more than one hundred pounds each; it is not to be distinguished from the fæces till, by exposure to the air, it grows hard. A lump has been found in the sea, weighing one hundred and eighty-two pounds.*

In whales, there is a greater demand for fat than in other animals, both as to nourishment, and to support their weight in the water; and in them the colon is unusually long.

The following case, communicated to me by my friend Dr. Babington, shews that fat in a liquid form is sometimes detected passing off with the fæces.

Elizabeth Ryder, four and a half years old, had been healthy for six months after her birth, when she became thin, had a sallow complexion, and was liable to jaundice; at a year and a half old her belly was tumid, and she had great weakness in her back and limbs, for which complaint Dr. Babington was first consulted. At three years old, the mother observed something to come from her as she walked across the room, which when examined, was found to be fat in a liquid state, which concreted when cold. Ever since that time to the present, she has voided at intervals of ten or fourteen days, the quantity of from one to three ounces, sometimes pure, at others mixed with fæces. When voided, it has an unusually yellow tinge, and is quite fluid, like oil. Her appetite is good as well as her spirits, and her flesh firm; her belly rather tumid, but not hard. She is subject to occasional griping, her urine natural, and she sleeps well.

* Vide Phil. Trans. for 1783.

In a diseased state of the human colon, lumps of a fatty nature are often voided, and are called scybala; these appear to resemble the ambergrise met with in the rectum of the spermaceti whales.

The similarity between fat and adipocere, led me to ascertain the circumstances under which dead bodies have been converted into that substance, and compare them with those of the contents of the colon. The following history will explain what these circumstances are.

Mary Howard, aged 44, died on the 12th of May, 1790, and was buried in a grave ten feet deep, at the east end of Shoreditch church-yard; ten feet to the east of the great common sewer, which runs north and south, and which has always a current of water in it, the usual level of which is eight feet below the surface of the ground, or two feet above the level of the coffins in the graves.

In August 1811, the body was taken up, with some others buried near it, for the purpose of building a vault, and the flesh in all of them was found completely converted into adipocere, or spermaceti.

In Stowe's History of London, this part of Shoreditch is stated to be a morass, and since that time the ground has been raised eight feet. The clerk and the grave-digger observe, that at the full and new moon the water in the sewer rises two feet; and at these times there is water found in the graves, which at other times are dry.

Dead bodies, in a state bordering upon putrefaction, being converted into adipocere by the application of water and the exclusion of the external air, makes it probable that the solid contents of the colon, retained in the lateral loculated structure, and having water constantly applied to them may undergo the same process.

In those animals that sleep during the winter, fat is deposited in different parts of the body in a shorter time than in others that live upon the same food; and in such animals the intestines have an unusual length. In the bear they are thirty-three feet long; while in the lion they are only twenty-four. Adipocere is formed in the shortest time, when the materials are placed in a current of water; and in the bear and most of the sleeping animals, in consequence of there being no cœcum, and the intestines not confined to their situation, the fluids pass more readily than in other animals: so that the solid contents may be said to be deposited on the banks of running streams.

To see how far the contents of the colon in the living body are converted into fat by being retained there, or by other means, I instituted the following experiments. A duck was kept seven days without an evacuation from the bowels, so as to place the cœca under nearly the same circumstances as when diseased. The duck was killed, and the cœca examined. They were found completely distended with a substance of the consistence of soft clay.

The intestine immediately above the cœca was empty. The rectum was much distended; its contents had a softer consistence than those of the cœca.

The contents of the cœca were divided into two portions of one drachm each, and comparative experiments were made upon them, and upon similar quantities of the contents of the rectum, by Mr. W. Brande.

Expt. 1. One drachm of the contents of the cœcum was completely immersed in half an ounce of water, and kept for seven days in a temperature varying from 40° to 60°. At the end of that time, warm water was poured upon it, but no appearance of fat could be perceived.

Expt. 2. The same quantity of the contents of the cœcum was immersed in water, in which there was one-fifteenth part of nitric acid, and kept under the same circumstances as in the former experiment: in seven days, warm water being poured upon it separated a portion of oily matter, which concreted when cold, and appeared to be one-eighth of the whole mass.

Expt. 3. Portions of the contents of the rectum were treated in the same way as in experiment 1 and 2. That in water became putrid very rapidly, and shewed no appearance of fat. The other in the dilute nitric acid was more dissolved than in experiment 2. Considerable extrications of gas took place, but there was no appearance of fat.

By these experiments, one-eighth part of the contents of the cœcum, after being confined there for some days, was readily converted into fat by nitric acid; but the contents of the rectum were not.

While engaged in this enquiry, I had the opportunity of dissecting a wild swan. The contents of the cœca were of a bright green colour. This led me to propose to Mr. Brande, to ascertain by experiment, whether an admixture of bile had any effect upon the process of converting animal substance into fat.

The following experiments were made by Mr. Brande upon this subject.

Expt. 1. He took two portions of human muscle of the same size, and digested one of them in human bile, the other in water, both placed in the temperature of 100.° In the first day the muscle in the bile underwent no change.

On the second day it became soft in texture, and had a slightly fœtid smell.

On the third day it became more fœtid and yellow.

On the fourth day it had the smell of excrement, was flabby, very putrid, and fatty upon the surface.

The portion of muscle digested in water had undergone no other change in the four days, but becoming slightly putrid; and there was no appearance of fat whatever.

Expt. 2. A similar experiment to that with the human bile was made with a small portion of beef, and ox's bile; and the results were exactly similar.

Exp. 3. The last experiment was repeated in the temperature of 60°. In four days the beef became slightly fœtid, and of a yellow colour; in six days, more fœtid, but there was no appearance of fatty matter.

Expt. 4. A portion of beef cut into pieces, was digested in ox's bile at the temperature of 100°. At the end of the fourth day the putrefaction was more advanced than in expeperiment 2. The beef was washed and heated upon paper, but no greasy stain was produced.

From these experiments, bile appears to assist in converting animal substance into fat: and the temperature of 100°, or nearly so, is favourable for that process. The fat is produced just as putrefaction is beginning to take place; and if the substance goes rapidly into putrefaction, no fat is formed. It is deserving of observation, that the smell peculiar to fæces, so different from that of putrid matter, is produced during the process.

Having so far succeeded in changing animal matter into fat, by adding bile to it out of the body, I was desirous of ascertaining whether this process could be detected going on in the human intestines; and being in attendance upon a gentleman of advanced age, who had been six days without an evacuation from the bowels, I did not let slip the opportunity of his having a costive stool deeply tinged with bile, to make the experiment.

The excrement was put into water, and kept heated for three hours to a temperature above 100.° When the water was allowed to cool, a film was formed upon the surface, which appeared to be of an oily nature, and Mr. Brande ascertained it to be so. The quantity was not great, but quite sufficient to ascertain the fact. Next day, the fæces having subsided, the fatty film was much more conspicuous.

From the evidence which has been adduced, it is rendered more than probable, that fat is formed in the lower portion of the intestines; and from thence is carried through the medium of the circulating blood, to be deposited in almost every part of the body. When there is a great demand for it, as in youth, for carrying on growth, it is laid immediately under the skin, or in the neighbourhood of the abdomen. When not likely to be wanted, as in old age, it is deposited in the interstices of the fasciculi of muscular fibres, to make up in bulk for the wasting of these organs.

There appear to be no direct channels by which any superabundance of it can be thrown out of the body; so that when the supply exceeds the consumption, its accumulation becomes a disease, and frequently a very distressing one.

That fat should be formed in the lower intestines, and not by a secretion, is conformable to the general analogy of nature: we find that it is capable of being readily formed by a simple chemical process independently of life; and it seems to be a rule of the animal œconomy, that the laws peculiar to life should not be employed when the mechanical or chemical laws of matter will answer the purpose.

The following fact of the muscular structure of a living animal having been converted into adipocere: and the very valuable discovery of my friend and fellow-labourer in Animal Chemistry, that fat, spermaceti, and adipocere, are in reality the same substance, make no small addition to the collateral evidence in favour of the lower intestines being the elaboratory in which fat is formed.

My Dear Friend,

"I have received a letter from Mr. Charles Bathurst, surgeon of Strood near Rochester, in which he states, that a sheep was killed in December 1812, the muscular parts of which, when cut up, were discovered to have been entirely converted into fat, with the exception of a few streaks of muscle in the shoulders and neck.

"The change appears to have commenced in the muscles of the back, which, together with the legs, had become an entire mass of fat; distinct however from the common external fat, by being of a different texture, and of a very pale brownish, yellow colour.

"The sheep was a wether, about two years old, of the Romney Marsh breed, and was fed with other sheep in a rich marshy pasture.

"It did not apparently labour under any disease, excepting that for about six weeks before it was killed, it shewed signs of great debility; and was, therefore, suspected to have received some injury in the back, although it now appears that this suspicion was without foundation.

"During this debility, it however continued to feed; and when driven to the butcher's at Strood, it was, as I am informed, still able to walk four miles out of six.

"In fleece, size, and general contour of its form, I do not learn that it exhibited any singularity; nor that its viscera appeared to differ from those of other sheep.

"Mr. Bathurst, when he sent me the account of this very extraordinary fact, also obligingly sent me a steak which had been cut from the loin; and which, as you will perceive, has not undergone any change, although it has been hung up in the air for many months, without having had salt applied, or any thing else done to preserve it from putrefaction.

"Since this steak came into my possession, I have been induced to make some experiments on part of it, taking care however, in the removal of this part, not to mutilate a specimen so very singular as, in my opinion, to deserve a place in the Museum of the College of Surgeons; and to which, through your hands, I beg leave to present it.

I.

"A thin slice, including the common external fat, with the ligament which was under it, and a portion of the fatty substance which had originally been muscle, was boiled for about an hour in a glass matrass filled with water.

"The common fat became softened, transparent; and after the separation of the grease, a portion of common cellular substance remained.

"The ligament lost its horny and transparent appearance, swelled much, and became white and semi-transparent, so as to resemble albumen recently coagulated.

"The fatty substance originating from muscle, was gradually diminished in size during the boiling, but did not lose its shape; and when nearly the whole of the grease had been thus separated, there remained a tough, opaque, buff-coloured substance, apparently devoid of fibres; and which much resembled a thin shaving of close-grained buff leather.

"This substance did not appear susceptible of putrefaction; and had all those characters, which in former investigations, I have observed to be possessed by bodies consisting of indurated and organised albumen.

"When cold, the fat which had coagulated on the surface of the water was collected, and was found not to differ in any respect from common grease or tallow.

"Lastly, The liquor was examined by tannin and other methods, but not any vestige of gelatine was obtained.

II.

"In order to ascertain in some measure the proportion of the buff-coloured substance, I repeatedly heated a thin slice, weighing twenty grains, upon a leaf of platina; and between each time of heating, I pressed it between folds of thick filtering paper, so as progressively to absorb the whole of the grease. The remaining substance weighed rather more than two grains; and therefore the proportion of the grease to that of the buff-coloured substance may be estimated at about nine-tenths; which proportion I found to be very similar in some comparative experiments which I made upon common mutton fat.

III.

" A portion of the fatty substance was digested in boiling acetic acid: and when cold, the fat which was separated, did not appear to have suffered any change, excepting that it had become rather harder and more brittle.

" The acid liquor afforded a considerable precipitate of phosphate of lead, by the addition of solution of acetite of lead.

IV.

" Some of the fatty substance was digested in boiling alcohol; and when it had settled and become perfectly transparent, the clear hot liquor was cautiously poured into a glass vessel. This, as it progressively cooled, lost its transparency; and the whole of the fat in solution was gradually deposited in the form of small grains on the sides and bottom of the glass.

The same experiment was repeated, excepting that the liquor was poured on a filtre, through which it passed transparent, but became white and thick as soon as it dropped into the glass; and the fat which had been dissolved, was thus separated as in the former experiment.

" It has, I believe, been stated by all chemical authors up to the present time, that fat is insoluble in alcohol; whilst spermaceti and adipocere are dissolved in it when heated, and are subsequently deposited as the alcohol becomes cold; so that the solubility of the two latter in boiling alcohol has been considered as a principal chemical character by which they are distinguished from common fat.

The results of the previous experiments therefore surprised me; and notwithstanding that in other respects I could not distinguish any difference between the substance in question and common animal fat; yet from its solubility in boiling alcohol, I was inclined to suspect some real peculiarity. I thought it right, however, to try the effects of boiling alcohol upon common mutton fat and tallow: when I found that they were both, in like manner, dissolved by it, and were also deposited in proportion as the alcohol became cold. Moreover, this effect was produced, whether I employed the common alcohol of the shops, or some which had been very highly rectified. It appears, therefore, that (however the mistake may have arisen), it is certain, that common fat is soluble in boiling alcohol, as well as spermaceti and adipocere.

" The results of the above experiments indicate, that the substance into which the muscular parts have been converted, is common animal fat or tallow; that during this change the muscular fibres have been nearly, if not quite destroyed. That the portion which has not been converted into fat, has become a dense albuminous substance, very different in appearance from cellular membrane;—that the gelatine usually present in animal muscle, does not exist in the fatty substance; and that the chemical distinction between common animal fat, spermaceti, and adipocere, as far as relates to the effects of heated alcohol upon these substances, has been hitherto erroneously stated.

Believe me,

Dear Sir Everard,

your's with sincere regard,

CHARLES HATCHETT.

If it is once admitted that the contents of the lower intestines are converted into fat by means of bile, it will throw considerable light upon the nourishment derived from glysters; a fact well ascertained, but which could not, without this knowledge, be explained.

It will also account for the wasting of the body, which so invariably attends upon all complaints of the lower bowels, in which the contents are not retained.

It will account for the turns of the colon varying so much in different animals.

Such a property in the bile will explain the formation of fatty concretions in the gall bladder, so commonly met with, as they may be produced by the action of the bile on the mucus secreted in the gall bladder.

It will also enable us to understand the following effects, of bile being excluded from the intestines.

A child was born at the full time, of the usual size, and lived for several months, but never appeared to increase in size, although it fed heartily, and had regular stools. The food appeared perfectly digested. There was no bile in the stools, and the skin was of a dark yellowish-brown colour. I saw the child while alive, and was struck with its want of growth, and its having no fat under the skin, which made it appear longer than new-born children generally are.

Upon examining the body after death, the only malformation met with was, that there was no gall-bladder, and no duct leading from the liver into the duodenum.

From what happened in this case, a supply of fat seems necessary for growth; for the child was by no means wasted in its muscles, which it must have been, had the constitution not been supplied with nourishment.

The disease called the rot, in sheep, is produced by worms breeding in the large gall-ducts of the liver, and consuming the bile, by which the intestines ought to be supplied. Under such disease the animal is always lean: to render it fat, it is not necessary that the liver should be restored to a healthy state; all that is required for that purpose is destroying the worms; for as soon as their number is very much reduced, and a sufficient supply of bile is carried to the intestines, the animal is readily fattened, and fit to be brought to market.

Having come to the conclusion of the present Course of Lectures, I beg leave to resign the honourable office of Professor of Comparative Anatomy, which has been conferred upon me, not having leisure further to prosecute its laborious duties.

In accepting it, I was desirous of paying a tribute to the memory of the Founder of the Collection, and of shewing a readiness to use my utmost exertions for the benefit of the College. In resigning it, I have much satisfaction in knowing that the duties will fall upon a Member of the College, whose energies, and whose zeal in the cause of science, will stimulate him to do justice to the invaluable Collection from whence his materials are to be drawn, and make him ambitious to answer the expectations of his country, which has raised so noble an edifice for its reception, as well as desirous to encrease the reputation of this College, by which it is so liberally endowed.

END OF VOL. I.

London: Printed by W. Bulmer and Co.
Cleveland-row, St. James's.

[illegible]