



Comparative methods of digestion, circulation & respiration in fishes, amphibians & mammals

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COMPARATIVE METHODS

OF

DIGESTION, CIRCULATION & RESPIRATION

IN

FISHES,

AMPHIBIA & MAMMALS.

GEELONG :

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PREFACE.

THIS little book—a compilation from the most recent authorities—is intended to supply, in a condensed form, the knowledge required, in addition to HUXLEY'S Lessons, from Candidates for Honours in Physiology at Matriculation. I publish it in the hope that it may prove of some service to Students until a better work appears. I have to thank Professor W. BALDWIN SPENCER, of Melbourne University, for revising the proof and suggesting some alterations and additions.

J. BRACEBRIDGE WILSON, M.A., F.L.S.



DIGESTION.

FISHES.

IN Fishes the teeth show more variation than in any other class of Vertebrates. Some are without teeth altogether ; in others, most of the bones which form the cavity of the mouth may bear teeth, as may also the hyoid and branchial arches. In others again, teeth are fixed in some portion of the membrane of the mouth, without being supported by bone or cartilage. The teeth may be few or numerous, in a single, double, or triple series ; or they may form bands or patches. In form the teeth of fishes may be cylindrical, conical, straight, or curved, pointed, or truncated at the top like the incisors of mammals. They may have one cusp or be bi- or tri-cuspid, or have their margins serrated. In other forms the teeth form a pavement, are rounded in form, and serve to crush shell-fish, crustacea, &c.

Good examples of incisor teeth may be noted in the common "Leather-Jacket." The Murray Cod and Murray Perch present a

number of bands of fine conical teeth, called *villi*form teeth. In the Rays we find the teeth to consist of broad flat plates adapted for crushing. The Dog-fish has small teeth, arranged in rows, having their points directed backwards. In the Bream there are 4—6 conical teeth in the front part of the mouth, and three or more rows of crushing teeth in the upper and lower jaws.

The teeth of fishes are constantly shed and renewed throughout life.

Salivary glands are absent.

Gills etc
The oesophagus is usually wide and short. The stomach is in the form of a bent tube or canal, one half being the cardiac, the other the pyloric portion ; or with the cardiac division prolonged into a long blind sac.

The duodenum receives the bile and pancreatic juice, and also includes the openings of the the pyloric appendages. These appendages are pouches, sometimes wide, sometimes narrow, occasionally very numerous, and are intended either for purposes of secretion or to increase the absorbing surface. The remaining part of the intestinal tube is either straight and short, as in some fishes, or long and folded, as in others ; or, as in the Sharks, Rays, and Sturgeons, the intestine contains a spiral ridge or valve.

Fishes possess a liver, pancreas, and spleen, and a highly developed lymphatic system. Their liver is large and rich in oil,

and is usually provided with a gall-bladder and bile duct. In all animals of lower organisation the bile is mingled with the venous blood, but in fishes we find a portal circulation, the venous blood of the intestine passing through the capillaries of the liver, and being returned to the heart by one or more veins corresponding to the inferior vena cava and opening into the *sinus venosus*.

A M P H I B I A .

The teeth in amphibia are fewer than in fishes, and of more uniform character. They consist of enamel and dentine on a bony base, and lie deeply embedded in the mucous membrane. In shape they are narrowed above and slightly curved, ending in either a single or double apex. New teeth are continually formed during life to replace those that are worn or broken away.

In the amphibia no distinct salivary glands have yet been observed.

The oesophagus is usually short. The stomach is elongated. The intestine is never very long, the convolutions being few and simple. There is a marked distinction between the small and large intestine.

The duodenum is bent at a sharp angle with the stomach. It consists of a short somewhat straight tube, running forwards from the pyloric constriction nearly parallel to the stomach. The

amphibia possess a liver, with gall bladder, and a bile duct opening into the duodenum. The pancreas lies between the stomach and duodenum, and its duct enters the bile duct. Their lymphatic system is well developed, and is characterised by the existence of two pairs of receptacles with the power of rhythmical contraction. These are commonly called lymphatic hearts.

M A M M A L I A.

In mammals, as a rule, incisor, canine, and grinding teeth or molars, are present. These are embedded in sockets or *alveoli*. There are no teeth on the palate. Instead of a continuous succession as in lower forms, there is only one change, the first or milk-teeth being replaced by a stronger or more fully developed permanent dentition. In the Cetacea and Edentata there is no change. In the former all the teeth are similar in form.

The mammalia are furnished with salivary glands, except the Cetacea, who, from the nature of their food and surroundings, do not need the secretion. In the horse, sheep, and ox there are special glands, in addition to the ordinary salivary glands; and in all vegetable feeders the secretion is poured out in large quantities.

The oesophagus is long and muscular, traversing the chest and piercing the diaphragm.

The stomach is either simple, as in man and most mammals; complex, as in the kangaroo; or compound, as in the ruminant

animals. In the latter the stomach consists of four distinct cavities. The first and largest, called the paunch, is lined with shaggy villi, and first receives the partially-chewed food. The second cavity is smaller. Its walls are covered with polygonal cavities. The third, also small, has its lining membrane arranged in thin plates placed lengthways. The fourth division, which is somewhat larger than the second or third, is pear-shaped, and is lined with very numerous folds of mucous membrane.

The œsophagus has an opening into the paunch, and also, independently, into the three other stomachs. Ruminating animals have the power of throwing portions of the food from the paunch into the second division of the stomach, and from that back into the mouth. After a second more thorough mastication, it is once more passed through the œsophagus to the third and fourth divisions. It is in the latter that the process of digestion is principally performed. In vegetable feeders the small intestine is long, and furnished with numerous folds and villi; the cæcum also is large.

Of the secretions concerned in digestion, the saliva is chiefly of importance to moisten the food and prepare it for the act of swallowing. The principal function of the acid gastric juice, in addition to the formation of peptones from proteids by the action of the ferment called pepsin, is to arrest putrid fermentation, and kill micro-organisms, which inevitably reach

the stomach with the food. The pancreatic juice acts on all three main kinds of food, turning proteids to peptones, starches to sugar, and fats to glycerin and fatty acids. The intestinal juice is rich in carbonate of soda. It neutralises the acids, and emulsifies fat. Bile promotes the absorption of fats, and is in some degree antiseptic.

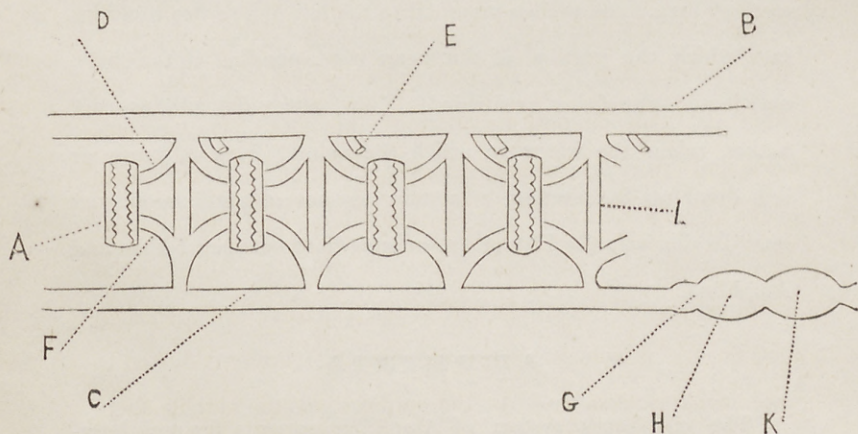
CIRCULATION.

FISHES.

The heart in fishes consists essentially of a single large thin-walled auricle, and a single powerful muscular ventricle. It is venous or branchial only; performing the office of the pulmonic auricle and ventricle, which form the right half of the heart in man and the higher vertebrata. The ventricle is prolonged into a tubular structure known as the *conus arteriosus*, which contains several rows of valves. This is aborted in the Teleostei, or bony fishes, in which the proximal end of the branchial artery is dilated to form a *bulbus arteriosus*. At the entrance to the auricle there is a cavity called the *sinus venosus*, into which the veins pour their blood, and from which the blood passes into the auricle. There is no systemic heart, answering to the left auricle and

ventricle of the higher vertebrates. The capillaries of the branchiae unite to form a vessel corresponding to the branchial arch which lies between each pair of branchial or gill-clefts. These vessels all unite on the dorsal surface of the alimentary tract to form a median vessel, the dorsal aorta, from which the various arteries pass to the different parts of the body.

In the Dipnoi (*e.g.*, *Ceratodus*, the Mud-fish of Queensland) there are two distinct auricles, one of which contains purified blood from the swim-bladder modified into a lung. With this exception, all the cavities in the heart of fishes are of the same branchial character, driving venous blood to the branchial arches.



Diagrammatic representation of the branchial circulation of a fish.

A, gill-cleft; B, dorsal aorta; C, branchial artery; D, efferent branchial vessel; E, blood vessels of the other side joining the dorsal aorta; F, afferent branchial vessel; G, bulbus arteriosus; H, ventricle; K, auricle; L, ductus Botalli.

The liver receives the blood from the intestinal veins by means of a portal vein, which is a contractile tube.

In most fishes there is a renal-portal circulation, the caudal vein breaking up into capillaries in the kidneys, and the blood passing from the kidneys into veins, in addition to the hepatic-portal system, formed by the vessels which return the venous blood from the alimentary canal, pancreas, and spleen, breaking up into capillaries in the liver. In eels there are, near the end of the tail, additional contractile cavities or venous hearts.

In the Dipnoi, as mentioned above, the swim-bladder is modified so as to form a rudimentary organ of respiration or lung. Blood is taken from the last of the efferent branchial blood vessels to the "lung," and thence returned to the left of the two divisions into which the portion of the heart corresponding to the single auricle of other fishes is divided. Thus, when the gills are not acting, when the water in which the animal lives is more or less dried up in summer, a certain amount of purification goes on. In this way the Dipnoi are intermediate between Fishes and Amphibia.

A M P H I B I A .

The circulatory system of Amphibia presents features intermediate between fishes and the higher vertebrates. The heart consists of three cavities: a right auricle, which receives the venous blood; a left auricle, into which the blood flows from the

lungs after oxygenation ; and a single ventricle, which receives blood from both auricles, and from which both pulmonary and aortic arteries take their origin. It is evident, therefore, that the lungs receive partially arterialized blood, and that impure or partially venous blood is driven through the body. There is, in the amphibian heart, the same tendency to repetition of cavities which obtains in fishes. In addition to the right auricle there is a cavity, called the *sinus venosus*, which receives the systemic veins. The aortic arches also originate in a cavity answering to the *conus arteriosus* of cartilaginous fishes (*e.g.*, shark). This cavity is divided into two halves by a spiral valve, which is attached dorsally and has a free ventral edge. One half communicates with the carotid and systemic arches, the other with the pulmonary arch. The opening into the ventricle is guarded by two semi-lunar valves, which have their free margins attached to the wall of the tube by chordæ tendineæ.

In the lymphatic system there are no lymphatic glands, but there are two pairs of lymph hearts, which pump lymph into the adjacent veins.

M A M M A L I A.

The heart in mammals consists of four distinct cavities, two auricles, and two ventricles. The right auriculo-ventricular valve is tendinous like the left, and furnished with *chordæ tendineæ*, and papillary muscles. The aorta is single. The mode in which the large vessels are given off varies in different mammals. The

branches proceed to all parts of the body. In certain mammals there is a peculiar vascular structure, in which an artery breaks up into a network of small parallel or convoluted vessels. In the *Cetacea* this occurs in the intercostals, and is adapted for holding a large quantity of oxygenated blood to serve during prolonged immersion.

The impure blood is usually returned to the heart, as in man, by two *venæ cavæ*. In some of the diving animals, such as seals, there is a dilatation of the *vena cava*, resembling the *sinus venosus* of fishes and amphibia. The pure or oxygenated blood is returned to the heart from the lungs by the pulmonary veins, which open into the left auricle, from which the blood passes into the left ventricle, and from this the single aortic arch arises.

In *Cetacea* the veins are without valves. In various parts of the body they are split up into a network or plexus, the object of which structure is probably to delay the circulating blood while the animal is beneath the surface.

Mammals have a portal circulation through the liver, but no renal-portal circulation. The kidneys are supplied with arterial blood only, and their veins open directly into the inferior *vena cava*.

RESPIRATION.

FISHES.

Fishes breathe air, dissolved in water, by means of gills or branchiæ. The water is received by the mouth, driven by a swallowing action to the gills, and expelled by the gill-openings.

In the cartilaginous fishes the gill clefts open directly on to the surface of the body, whilst in the osseous fishes they are covered over by a special development known as the *operculum*. Gills or branchiæ consist essentially of folds of the mucous membrane of the gill cavity, in which capillary blood vessels are distributed. The heart drives the blood through the branchial artery to the branchial arches. The vessels from all the branchial arches unite and form the aorta, which corresponds to the aorta of the mammalia. The details of structure vary in different families of fishes, but the principle is the same in all. The venous blood is exposed in a network of capillaries to streams of water. The walls of the capillaries are so formed as to allow the chemical interchange between the blood charged with carbonic dioxide, and the air dissolved in the water.

Many fishes are furnished with a peculiar organ, called an air-bladder. This, although not actually an organ of respiration in all cases, represents by its origin and position the lungs of the higher vertebrates, and in the Dipnoi actually performs the function of a lung. These bladders, being filled with gas, serve to regulate the specific gravity of the fish, and perhaps may in some cases enable it to rise or sink as occasion may serve. In the Dipnoi, e.g., *Ceratodus*, the mud-fish, the air-bladder is so modified as to approach in function to the lungs of the air-breathing amphibia.

A M P H I B I A .

The respiratory as well as the circulatory organs of the amphibia show them to be connecting links between the gill-breathing fishes and the lung-breathing higher vertebrates. In all cases they possess two lung sacs, either simple, or provided with cellular spaces ; but, in addition to these, they have always, either in the larval state, or in the adult animal, three or four pairs of gills. These sometimes project from the neck in tufts or fringes, some-

times are contained in a cavity covered by a fold of skin with an external opening.

In the frog, during larval development, both forms of branchiae are present. The tufts projecting from the side of the neck are first developed. These gradually atrophy, and as they do so the branchial folds on the walls of the gill-clefts appear. At first the gill-clefts open, as in cartilaginous fishes, directly to the exterior; but, as development goes on, they become covered over by an operculum, much as in the case of osseous fishes.

As the amphibia have neither diaphragm nor ribs, the act of respiration cannot be performed in the usual way. There is a special adaptation of the muscles of the throat and the hyoid bone, and the nostrils are furnished with valves. In breathing, the mouth being kept shut, the ~~raising~~ ^{depressing} of the hyoid bone draws air into the mouth through the nostrils. When the throat muscles contract, the air first presses against and closes the nostril valves, and is then forced into the lungs. In expiration the elasticity of the lung-wall expels the air, aided by the contraction of the abdominal muscles. As long as respiration is carried on only by gills, the structure of the heart and arterial trunks resemble that in fishes. When pulmonary respiration begins, the auricle becomes divided into right and left chambers; the right receiving the veins from the body, the left those from the lungs. The ventricle continues single.

M A M M A L I A.

It is not necessary to describe the respiratory organs of the mammals, seeing that the structure of the lungs, the mechanism of respiration, and the arrangement of the pulmonary vessels do not materially differ in most cases from what can be studied in the human body. The *Cetacea*, however, present peculiarities worthy of note. Their lungs are very spacious, and extend far backward, like the swimming bladder of fishes. High up on the skull there is a single or double nasal aperture, which leads straight down into the nasal cavities. These extend in the form of a nasal canal, which at the soft palate can be shut off from the pharynx by a sphincter muscle. The expired aqueous vapour, when driven through the blow-holes, condenses into a cloud, giving rise to the popular, but erroneous, notion that whales spout a column of water from their nostrils.

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