

ZOO 365 - CHORDATES

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PHYLUM CHORDATA

The Chordata form one of the most successful phyla of the animal kingdom. Beside occupying various habitats, they have also reached the climax of nervous activity, as illustrated in class Mammalia to which man belongs.

The Chordata are classified into four subphyla:

1. Hemichordata, including acorn-worms,
2. Urochordata, including sea-squirts,
3. Cephalochordata, including Amphioxus, and
4. Craniata or Vertebrata, including lampreys, fishes, amphibians, reptiles, birds and mammals.

The first three subphyla are collectively called the Protochordata, which are entirely marine. Among them, the Cephalochordata are also called the Acrania in contradistinction to the Craniata, being without or with a cranium respectively. The Acrania and Craniata are sometimes grouped together and referred to as the Euchordata.

Whatever diversity of general form their various groups may display, or habitat they occupy, all chordates have a common basic plan of organization. Originally this plan is essentially that of a coelomate, marine, long-bodied, free-swimming creature which displays the following three main features:

- The presence of a notochord, an axial rod of the skeleton, which extends in the dorsal region of the body.
- The central nervous system is tubular, that is, containing a cavity, and lies dorsal to the notochord.
- the anterior part of the alimentary canal- the pharynx- is perforated by a variable number of gill-slits which lead into the gills.

However, these characteristics may be modified to a greater or lesser extent, either early in development or in the adult form. Thus, the notochord may disappear in the postlarva stage as in the adult urochordates, or may be

transformed by the addition of skeletogenous tissues into a jointed backbone or vertebral column, as is characteristic of the Vertebrata. The gills never function at any stage of development of the Amniota (reptiles, birds and mammals) nor in the adult of most Amphibia.

Subphylum

CEPHALOCHORDATA

(ACRANIA)

Amphioxus (= Branchiostoma)

lanceolatus

The lancelet or Amphioxus has received considerable interest from zoologists on account of the fact that this small animal displays all the features of the basic plan of chordate organization in a clear diagrammatic form. The characteristics of this basic plan, referred to above, can well be seen in either a whole mount of this animal or in a T.S. of its pharyngeal region..

Amphioxus is fish-like, about five cm in length. It has the habit of burying itself in the sand during the day, with only its anterior part protruding, but swimming actively during the night.

External features

Examine the provided specimen of Amphioxus, fresh or preserved, with the help of a hand-lens and note.

- The general body form is elongated, pointed at both ends and flattened at each side. The anterior end projects forwards as the rostrum.
- The fins are generally low and continuous with each other: a dorsal, a ventral and a caudal fin. In addition, there are two lateral fins or metapleural folds.
- The mouth lies ventral to the rostrum and is guarded by the oral hood, the anterior edge of which carries long processes, the oral cirri.
- The atriopore is median and ventral, lies at the junction of two metapleural folds and the ventral fin, at about one third of the way along the animal from its posterior end. It is the opening of the atrium.
- The anus lies on the left side, a short distance in front of the posterior end.

- The myotomes are arranged on both sides of the body as metameral blocks of striated muscle fibres, separated by V-shaped partitions of connective tissue, the myosepta or myocommata. Note that the apices of the myosepta are pointing forwards.
- The gonads comprise about 26 pairs, metamericly arranged on both sides of the pharunx. The two sexes are sepatate, but are not externally distinguishable.

Internal Structure

Examine under the microscope a whole mount of Amphioxus, preferably of a young specimen, and note in addition to the above-mentioned points:

- the buccal cavity or vestibule is guarded by the oral hood, at the hinder wall of which lies a vertical transverse partition called the velum which is perforated; its opening is sometimes called the 'enterosome'. The velum carries a number of velar tentacles, and just in front of it there lies a peculiar wheel organ which helps in driving a current of water loaded with food particles into the mouth. Thus., Amphioxus is a ciliary feeder. The closure of the mouth is effected by the folding over of the sides of the oral hood. The oral cirri help during feeding by turning inwards to prevent sand particles from passing into the buccal cavity.
- The notochord is an axial skeletal rod, which extends from the anterior to the posterior end of the body, near to its dorsal side.
- The nerve cord or spinal cord lies just above the notochord and similarly extends from end to end. Pigment may be visible along the cord, which represents eye spots. The cavity of the cord, or the central canal, may be seen in the preparation.
- The pharynx is voluminous region of the alimentary canal which extends from the velum to the beginning of the intestine. Its walls appear like a network on account of the presence in them of gill-bars, of two types: primary and secondary. The former are forked and reach the ventral wall of the pharunx, while the latter are not forked and do not reach that wall. The bars separate the fill-slits, and are all obliquely directed. Cross-bar or synapticalae connect the adjacent primary bars together.

Note the presence of the endostyle as a longitudinal band in the floor of the pharynx, an epipharyngeal groove in the roof, and two peripharyngeal

bands in front linking the endostyle with the epipharyngeal groove. All of these carry dilia which help in the process of feeding.

- The intestine follows the pharynx and gives off a forward blind extension, called the midgut diverticulum, on the right-hand side of the pharynx. The intestine opens posteriorly by the anus.

- The atrium is a cavity which surrounds the pharynx and the anterior part of the intestine. It opens to the exterior by the atriopore.

T.S. of the posterior pharyngeal region

Examine and note:

- The dorsal and lateral fins, with fin rays in the former and lymph spaces in the latter.
- The skin is formed of the epidermis, which is composed of a simple columnar epithelium with goblet cells and covered by a thin cuticle, and of the dermis which is very thin.
- The myotomes and myosepta
- The notochord, with vacuolated cells.
- The spinal cord, with the central canal.
- The pharynx, with primary and secondary gill-bars; the former alone contain portions of the coelom.
- The atrium, around the pharynx.
- The coelom appears as two dorsal canals, one on either side of the epipharyngeal groove. Parts of the coelom are also present in the primary gill-bars, below the endostyle, in the metapleural folds, and around the midgut diverticulum and the gonads.
- The gonads, one pair in the section, lie in the atrium on both sides of the pharynx.
- The midgut diverticulum, on the right side of the pharynx.
- Two lateral dorsal aortae, on the sides of the epipharyngeal groove.

Examine and note:

- Dorsal and lateral fins, skin, myotomes, myosepta, notochord and spinal cord as in preceding section.
- The extension from the atrium.
- The coelom surrounds the intestine. Identify the splanchnopleure and the somatopleure.
- A single dorsal aorta is seen ventral to the notochord, and between three and four subintestinal veins appear on the ventral surface of the intestine.

T.S of the tail region

Examine and note:

- The dorsal and ventral lobes of caudal fin.

- The skin, myotomes, myosepta, notochord and spinal cord as in the two preceding sections.
- The caudal artery and caudal vein appear below the notochord the artery is dorsal to the vein.

How does *Amphioxus* feed and respire?

Subphylum

VERTEBRATA

(CRANIATA)

This subphylum includes the vast majority of chordates. It is characterized as follows: the anterior region of the nerve cord is enlarged to form the brain, with which are connected three pairs of organs of special senses (nose, eyes and ears); the brain is protected by a skeletal box called the cranium (hence the name Craniata), the notochord is transformed by the addition of skeletogenous tissue into a joined backbone or vertebral column (hence the name Vertebrata); there are relatively few gill-slits; there is a heart, ventral in position and composed of at least three chambers; there are two kidneys, of mesodermal origin; and the epidermis is built up of a stratified epithelium, etc.

Vertebrates are classified into two superclasses: the Agnatha and the Gnathostomata.

(1) Superclass AGNATHA

This superclass comprises the first vertebrates which all lack jaws. The majority became extinct (the ostracoderms). The living forms belong to a single class:

Class Cyclostomata

The cyclostomes have a rounded mouth and lack paired appendages. They include the lampreys (order Petromyzontia) and the hag-fishes (order Myxinoidea).

The Lamprey

Petromyzon fluviatilis

There are few species of lamprey, but great zoological interest has been aroused by them on account of their ancestral vertebrate organization.

Like *Amphioxus*, the lamprey is often supplied in the laboratory as a preserved specimen and section taken from various regions of the body.

The adult lamprey measures about 30 cm in length (but may reach 90). Its life-history includes two distinct stages: a larval stage called *Ammocoetes* (or *ammocoete larva*), and the adult. The larva lives in fresh water where it buries itself in the mud and feeds on microscopic organic material (microphagous). The adult is marine and a parasite on fishes. It attaches itself to the body of the fish and rasps off the flesh with its teeth. At rest, the lamprey can be seen holding onto stones by its bucca funnel. In the breeding season the adults leave are developed and, after some time, they metamorphose and go downstram to live in the sea.

Examine the specimen provided and note:

- The body form is eel-like and rounded in front, but becomes bilaterally compressed backwards. The colour of the body is dark brown to blackish above, paler below. The skin is quite smooth and scaleless. In fresh specimens the skin is slimy because of the presence in it of numerous mucus-secreting glands. Through the skin you can see the division of the muscles into myotomes.

Note the median fins. No paired fins are present (a characteristic feature). The body is divided into head, trunk and tail.

- In the head, note the buccal funnel found in front, fringed with papillae and lined with yellowish brown horny teeth. Into the funnel, there projects a protrusible tongue which is also beset with horny teeth. Both sets of teeth are ectodermal and not homologous with the teeth of higher vertebrates. The mouth opening is circular and lies above the tongue.

Behind he buccal funnel are two wyes, not surrounded by eyelids but each covered by a transparent area of skin. On the dorsal surface of the head there lies the single median nostril, immediately followed by a pale area of skin which indicates the position of the pineal eye. Posterior to each eye are seen seven small openings, the outer gill-slits.

- In the trunk, note the presence of two dorsal fins separated by a notch, the second dorsal fin being continuous with the fin around the tail. On the mid-ventral line there lies the cloaca from which projects a slender urinogenital papilla.
- The tail is short, markedly flattened on either side and surrounded by a caudal fin. All median fins are supported by fine

cartilaginous radial; no fin –rays such as those found in fishes, are present.

Write an account of the external features of the lamprey, and point out those which are peculiar to this animal.

Study the internal organizations of *Petromyzon*, using a series of handsections of the body as well as a series of transverse microscopic sections .

Longitudinal hand-section of the head region.

Examine with the help of a hand-lens and note:

The notochord appears as a stiff gelatinous rod, the spinal cord lies above it, and is overlain by myotomes and skin, Seven grillpouches are seen opening externally by seven outer gill-slits, and into the respiratory tube by seven inner gill-slits. And into the respiratory tube by seven inner gill-slits. The tube ends blindly at the posterior end but opens in front into the buccal funnel. (The respiratory tube serves for the passage of the inhaled water, taken through the mouth, into the gill-pouches.) The food passes into the oesophagus which extends dorsal to the respiratory tube.

Note the details of structure of the buccal funnel.

The heart lies in the pericardial cavity just behind the gills and is separated from the rest of the coelom by a transverse septum. Note that the heart is S-shaped and consists of three chambers, a sinus venosus, an auricle, and a ventricle which gives off a ventral aorta that extends forward, below the gills.

Examine with the help of a hand-lens and note: the notochord; spinal cord; myotomes and myosepta; two gill-pouches, one on each side, in between which is seen the dorsal aorta just below notochord, followed ventrally by the oesophagus, respiratory tube and ventral aorta.

Examine and note: the dorsal fin; myotomes and myosepta; spinal cord and notochord; two posterior cardinal veins and the dorsal aorta in between; two kidneys, each showing at its lower end a mesonephric duct; the coelom; the testis suspended by the mesorchium in male, or the ovary suspended by the mesovarium in female (tube ovary is distinguished by its large ova); the intestine as a small tube found ventral to gonad.

Examine and note: the posterior part of dorsal fin (if the section has been taken anteriorly) or the dorsal and ventral lobes of the caudal fin (if the

section has been taken posteriorly); the myotomes and myosepta; spinal cord; notochord, caudal artery and caudal vein.

The brain

Examine the head region from which the skin and the underlying dorsal muscles have been removed away and note the structure of the brain:

The telencephalon is formed of two of two olfactory bulbs and two smaller olfactory lobes (sometimes referred to as cerebral hemispheres). The diencephalon follows, on the roof of the head) and the parapineal body., The mesencephalon shows two optic lobes, and the hindbrain consists of a small cerebellum and a well-developed in the roof of the brain extending from above the diencephalon to the medulla oblongata. This plexus is often severed in the preparation.

Examine through the L.P and note:

-The epidermis is built up of a stratified squamous epithelium (compare with Amphioxus). Distinguish among its component cells: mucus-secreting cells with a basal compressed nucleus, granular cells with a more or less central rounded nucleus and plentiful granules, and club cells which are particularly large, usually have a small flattened nucleus in the middle and clear cytoplasm, and rest on the basement membrane of the epithelium.

Note that the epidermis is covered on the surface by polyhedral cells whose free borders are coloured black and are sometimes referred to as forming a cuticle.

- The dermis is thick (compare with Amphioxus) and built up of a dense connective tissue formed of compact fibres which extend parallel with the surface. This layer is followed by a loose connective tissue which forms the subcutis and contains, close to the compact fibres, numerous melanophres. Blood vessels are also present.

The subcutis is followed by striated skeletal muscles.

The horny teeth

Examine a section of the buccal funnel through the L.P and note the presence of the horny teeth. A horny teeth is indicated by its yellow colour and is seen to consist of a cone of keratinized epidermal cells on the surface. However, the individuality of the cells is almost lost. This is a functioning tooth. A little below it, there is a similar aggregate of cells, taking a similar form and colour. This is a replacing tooth, which will replace the functioning tooth when this wears off and falls down.

T.S. of the trunk region

Examine through the L.P. and note: the dorsal fin supported by cartilaginous radials arranged in a single series; the spinal cord overlain by an adipose tissue forming a “fat column”, the notochord consisting notochord tissue (of large vacuolated cells), notochord epithelium which with its basement membrane form the elastica interna, a thick fibrous sheath and a thin black elastica externa. Note that the notochord is continuous with a layer of connective tissue which also surrounds the spinal cord. Within this tissue there develop cartilaginous nodules which correspond to the basidorsals and interdorsals, both lying dorsal to the notochord on both sides of the spinal cord, and form the incomplete neural arch and interneural arch respectively. Note also two posterior cardinal veins and the dorsal aorta just below the notochord; two kidneys each showing a mesonephric duct; the coelom bounded by the splanchnopleure and somatopleure, the gonad suspended from the dorsal body wall by the mesenteron; the intestine with the spiral valve; the myotomes and myosepta; the skin with its detailed structure.

T.S. of the tail region

Examine through the L.P. and note: the dorsal and ventral lobes of the caudal fin supported by cartilaginous radials; spinal cord; notochord; myotomes and myosepta covered with skin. Below the notochord see the caudal artery and caudal vein. See also the basidorsals or interdorsals.

The ammocoete larva

Examine a whole mount of ammocoetes of lamprey and note:

- The general form is that of an eel-like fish. The head differs from that of the adult, the mouth cavity being surrounded by an upper and a lower lip and containing a number of buccal tentacles (or oral cirri), but devoid of teeth and tongue. At the posterior end of the buccal cavity note the presence of a velum, followed by the pharynx.

In the pharynx note the presence of gill-pouches. The gill-arches and gill-lamellae lie in the wall of these pouches. Along the ventral surface of the pharynx is seen a double strand of mucus-secreting cells known as the endostyle (which will give rise to the thyroid gland of the adult).

Dorsally in the head region note the median nostril and on the side an eye and an auditory organ. Divisions of the brain are also shown.

- The median fin is continuous along the greater part of the body, forming a continuous dorsal and caudal fin. The part of the latter fin which extends along the ventral side of the tail is sometimes considered as a ventral fin. Note the spinal cord and the notochord which extend along nearly the entire length of the body. Note the segmentally arranged myotomes along the sides of the body.

- The heart lies ventrally just posterior to the pharynx and consists of its usual three chambers, which extend in a straight line (compare with adult). The ventral aorta passes forwards from the ventricle below the gills. The dorsal aorta extends below the notochord. Above the heart there is seen the pronephros.

- In the digestive system, follow the pharynx to a narrow oesophagus and this to a wider intestine which opens posteriorly by the anal opening. Just posterior to the heart there lies the liver with a spherical gall-bladder.

In what respects does the ammocoete larva of the lamprey differ from the adult? And what are the points of similarity between it and Amphioxus?

II. Superclass GNATHOSTOMATA

The gnathostomes include the vast majority of vertebrates. They are characterized by having two articulated jaws around the mouth, so that the mouth can be opened and closed.

This superclass comprises the more well known vertebrates which fall into eight classes:

1. Aphetohyoidea, which are entirely extinct.
2. Chondrichthyes, which comprise of dogfishes, sharks, skates and rays
3. Actinopterygii, which comprise the well known market fishes.
4. Crossopterygii or Choanichthyes, which comprise the lung-fishes and some extinct forms
5. Amphibia
6. Reptilia
7. Aves
8. Mammalia.

The first four classes were formerly included in one class, Pisces (fishes). They are all aquatic, with a streamlined body, moving by fins and breathing by gills. The lungs and internal nares are present only in the Crossopterygii. The great majority of fishes possess dermal scales as a protective covering of the body. They also develop peculiar integumentary sense organs for meeting the requirements of the habitat; these organs develop in aquatic and

larval amphibians, but are entirely absent, with their special nerves, from the terrestrial tetrapods. The ear is represented by the inner ear only; and they possess one auricle to the heart, except in the *Crossopterygii* where it is partially divided into two.

The *Chondrichthyes*, as seen in the scheme of classification, are placed near the base of evolutionary scale of vertebrates. Apparently, they are nearer to the ancestors of the vertebrates than any other existing class. Many of their characteristics are, therefore, described as primitive, and enable us to understand well the basic vertebrate organization. It is largely for this reason that they have received considerable attention from zoologists, and hence in laboratory studies.

A. Class CHONDRICHTHYES

This class comprises the well known dogfishes, sharks, skates, and rays. The skeleton is entirely cartilaginous, which may be calcified in places, but true bone is never developed. The body is covered by placoid scales. In the heart there is a conus arteriosus with several transverse rows of valves.

Many of the veins are expanded in the form of large sinuses. The male has two claspers attached to the pelvic fins, there is a cloaca. In the intestine there is a large spiral valve and the coelom communicates with the exterior by abdominal pores.

Most living members of the *Chondrichthyes* are included in the sub-class *Selachii*, of which order *Euselachii* includes most of the living representatives of the class. This order is divided into two suborders: The *Pleurotremata*, with gill-clefts lying on the sides of the head (dogfishes and sharks) and the *Hypotremata*, with gill-clefts on the ventral surface (skates and rays).

B. Class ACTINOPTERYGII

The *Actinopterygii* form the third class of the *Gnathostomata*, but are the last group to evolve among fishes. Since then, they have followed a specialized evolutionary line deviated from the direct line of descent of the *Tetrapoda*. They, together with the *Crossopterygii*, were once known by the name *Osteichthyes*, but this name has recently been abandoned.

The *Actinopterygii* are classified into four orders, the most flourishing of which today is the order *Teleostei*, characterized by a skeleton formed mostly of bone in the adult. This skeleton has undergone considerable reduction during the evolution of this group. Thus the scales have become thin overlapping circular plates of bone (hebe cycloid), and the head shields have become fewer in number and lighter in weight than in their

ancestral forms. An air-bladder, with a hydrostatic function, is present; the specific gravity of the body is nearly equal to that of the surrounding water; the tail is homocercal. There is no spiracle, the gill-slits comprise only four pairs and the gills are covered by an operulum. There are usually separate urinary and genital apertures. The conus arteriosus of the heart and spiral valve of the intestine are both absent.

The importance of the teleostei lies in their abundance, both in number and variety, and the great success which they have achieved in the sea and fresh water. They form an important food source for human consumption.

C. Class AMPHIBIA

The Amphibia are the first vertebrates to emerge from water and adapt themselves partly to life on land. Nearly all of them, however, are still bound to the water medium where they lay their eggs and undergo their early development. Some of them have even reverted completely to aquatic life.

They are characterized by having pentadactyle limbs and a smooth slimy naked skin, and typically they breathe by gills in their larval stages and lungs when adult.

Modern Amphibia are classified into three subclasses: the Urodela (newts and salamanders) with long fish-like bodies, the Anura (frogs and toads) which have lost the tail and become specialized as jumpers and the Apoda which are limbless, blind and specialized as burrowers.

You are already familiar with the morphology, detailed anatomy and histology of a representative amphibian, the toad *Bufo regularis*, which belongs to the highly specialized subclass, The Anura.

D. Class REPTILIA

Reptiles are the first group of terrestrial vertebrates that are well adapted to life on dry land; they do not need to breed in water. Their skin is dry or contains very few glands, and quite distinct from the skin of Amphibia and Mammalia. They are amniotes, that is they form an amnion and other foetal membranes at an early stage of embryonic development, and their kidney is a metanephros.

The importance of reptiles lies in the fact that they have originated from the early Amphibia, and have themselves given rise at an early evolutionary stage to birds on one hand and to mammals on the other hand, through two different offshoots.

Reptiles were once the dominant animal of the world, but most of them have become extinct; the existing reptiles form but a small proportion of the reptiles of the past. Those that are still alive belong to only four orders out of

the seventeen orders of all reptiles extinct and alive. Among the four orders are the Squamata, which are the most successful of them all. They include the lizards (suborder Lacertilia) and snakes (suborder Ophidia). They are characterized by having their bodies completely covered with scales.

E. Class AVES

Birds are the master of the air. They evolved from diapsidan stock and have kept since then many reptilian features, so that sometimes they are described as 'glorified reptiles'. They are the only animals that possess feathers, which like the horny scales of reptiles, are keratinized epidermal products. Some of the horny scales are still present, covering their feet. The fore-limbs are modified into wings, The ancient birds (subclass Arhaecornithes) had teeth on their jaws and a long tail supported by numerous vertebrae. The recent birds (subclass Neornithes) have, except in a few extinct forms, lost the teeth entirely, and have a short tail, a well-developed sternum and reduced hand. They have an extraordinary respiratory system which plays an important role in keeping the body temperature constant. They also have a single right systemic aorta, and very efficient eyes. In the female there is a single ovary and a single oviduct, those of the left side. Birds are divided into nineteen orders of which the order Columbiformes comprises the well known pigeons.

F. Class MAMMLIA

Mammals and birds are principally terrestrial animals which are able to live in various habitats and under severe environmental conditions. This is mainly because these two larger groups have developed a mechanism which keeps their internal composition constant. They are homoiothermal, in contradistinction to all other animal groups which are poikilothermal and which under severe conditions of environment become inactive and hibernate.

Mammals, like birds, have originated from reptiles, but while birds have preserved several reptilian features, mammals have discarded these features to a greater extent.

The class Mammalia is a uniform group, characterized by the possession of hair and mammary or milk glands which secrete milk on which they feed their young. These are born alive and given great care by the parents for a considerable period of time, sometimes for several years as in man. Their highly developed brain and sense organs as well as their motor mechanisms enable them to perceive much of the circumstances under which they live.

The body is lifted off the ground on four legs and is capable of progression on it with great speed.

There is a single bone, the dentary, in the lower jaw, associated with the habit of chewing food; the other lower jaw bones and the quadrate have either been included in the middle ear or disappear. There are four chambers to the heart and a single left systemic aorta (a single right in birds), and there is a muscular diaphragm which plays an important role in breathing. There are principally seven cervical vertebrae only; the dentition is diphyodont and heterodont, and the vertebral centrum ossifies in three centres of ossification, etc.

The class is divided into three principal subclasses, the Prototheria, the Allotheria (extinct) and the Theria. The Theria are further divided into three infraclases, the Pantotheria (extinct), the Metatharia and the Eutheria. So living mammals fall into the three unequal groups, the Prototheria, Metatheria and Eutheria, the last including the majority and more well known of living mammals.