But, in Amphioxus, the head retains throughout life a segmentation comparable to that of the rest of the body, while, in the higher Vertebrata, almost all traces of these distinct segments are very early lost.

The saurischian pubis left juts forward, and its ischium points backward. The ornithischian pubis and ischium right both point backward. The ornithischians were all herbivorous, and included some of the most interesting-looking dinosaurs. Ornithischian dinosaurs include three suborders: Ornithopoda , Marginocephalia and Thyreophora. The famous carnivorous dinosaurs were from the saurischian order, as were the largest herbivorous dinosaurs. The saurischian dinosaurs include two suborders: The first vertebrates to evolve true flight were the pterosaurs, flying archosaurian reptiles. After the discovery of pterosaur fossils in the 18th century, it was thought that pterosaurs were a failed experiment in flight; a humorous mishap; or that they were simply gliders, too weak to fly. More recent studies have revealed that pterosaurs were definitely proficient flyers, and were no evolutionary failure; as a group they lasted about million years about as long as birds have! Pterosaurs are thought to be derived from a bipedal, cursorial running archosaur in the late Triassic period about million years ago. No other phylogenetic hypothesis has withstood examination; however, the early history of pterosaurs is not yet fully understood because of their poor fossil record in the Triassic period. We can infer that the origin of flight in pterosaurs fits the "ground up" evolutionary scenario, supported by the fact that pterosaurs had no evident arboreal adaptations. The pterosaur wing was supported by an elongated fourth digit imagine having a "pinky finger" several feet long, and using that to fly! Pterosaurs had other morphological adaptations for flight as a keeled sternum for the attachment of flight muscles, a short and stout humerus the first arm bone , and hollow but strong limb and skull bones. Pterosaurs also had modified scales that were wing-supporting fibers, and that possibly formed hairlike structures to provide insulation -- bird feathers are analogous to the wing fibers of pterosaurs, and both are thought to possibly have been evolved originally for the primary purpose of thermoregulation which implies, but does not prove, that both pterosaurs and the earliest birds were endothermic. Early pterosaurs such as Dimorphodon had long tails that assisted balance, but later pterosaurs had no tails, and may have been more adept flyers. Temporal fenestration has long been used to classify amniotes. Taxa such as Anapsida, Diapsida, Euryapsida, and Synapsida were named after their type of temporal fenestration. Temporal fenestra are large holes in the side of the skull. The function of these holes has long been debated. Many believe that they allow muscles to expand and to lengthen. The resulting greater bulk of muscles results in a stronger jaw musculature, and the longer muscle fibers allow an increase in the gape.

Chapter 2 : Protochordate | invertebrate | www.nxgvision.com

AMPHIOXUS or LANCELET, a small, marine creature, neither fish nor worm, but something between the two, which is the simplest example of the Vertebrate type of structure.

Advanced Search Abstract The cephalochordates, commonly known as amphioxus or lancelets, are now considered the most basal chordate group, and the studies of these organisms therefore offer important insights into various levels of evolutionary biology. In the past two decades, the investigation of amphioxus developmental biology has provided key knowledge for understanding the basic patterning mechanisms of chordates. Comparative genome studies of vertebrates and amphioxus have uncovered clear evidence supporting the hypothesis of two-round whole-genome duplication thought to have occurred early in vertebrate evolution and have shed light on the evolution of morphological novelties in the complex vertebrate body plan. Complementary to the amphioxus genome-sequencing project, a large collection of expressed sequence tags ESTs has been generated for amphioxus in recent years; this valuable collection represents a rich resource for gene discovery, expression profiling and molecular developmental studies in the amphioxus model. Here, we review previous EST analyses and available cDNA resources in amphioxus and discuss their value for use in evolutionary and developmental studies. We also discuss the potential advantages of applying high-throughput, next-generation sequencing NGS technologies to the field of amphioxus research. Together with Tunicata and Vertebrata, they constitute the phylum Chordata. All chordates share several key characteristics, including a dorsal nerve chord, a notochord, segmented somites and pharyngeal gill slits. Unlike most tunicates whose larvae undergo drastic metamorphosis and lose many chordate characteristics as they become sessile in adulthood, the adult body plan of amphioxus remains highly similar to that of vertebrates Figure 1 A. Furthermore, the embryology of amphioxus is more comparable to that of vertebrates [1]. Therefore, cephalochordates were traditionally considered the closest relatives to vertebrates. Recent molecular phylogenetic analyses, however, have indicated that tunicates are in fact the closest sister group to vertebrates and that cephalochordates actually represent the most basal group within the chordate lineage [2â€"4]. Therefore, amphioxus represents a key model system for understanding both conserved chordate developmental mechanisms and the evolutionary origins of the complex vertebrate body plan. For this reason, the genome of the amphioxus Branchiostoma floridae was sequenced and published in [5 , 6], and the draft genome has become a rich source for comparative genomics and developmental studies in this organism. View large Download slide Adult and embryonic stages of the amphioxus B. A Photograph of a living adult female animal left lateral view and a corresponding diagram of the major anatomical features of amphioxus. B Unfertilized egg; C gastrula; D neurula; E h larva. To facilitate gene identification and verification of gene model predictions in the draft genome, a large collection of B. In this review, we first provide a historical overview of EST studies that were performed prior to the completion of the B. We next describe the large-scale EST analysis of B. We also discuss the applications of the B. Finally, we conclude with a discussion of the use of high-throughput next-generation DNA sequencing NGS technologies in the amphioxus model, focusing on the potential applications for future transcriptome analysis. Historical overview of amphioxus EST analyses Before the amphioxus genome-sequencing project, several studies had exploited EST surveys as a low-cost alternative to full genome sequencing to elucidate the tissue specific and developmental gene expression profiles of amphioxus and to investigate gene duplication events during vertebrate evolution. EST studies have been carried out by various research groups and with different amphioxus species, including the most widely used Florida amphioxus B. It should be noted that the Asian amphioxus was originally named Branchiostoma belcheri, and later a subspecies status Branchiostoma belcheri tsingtauense was recognized for the population distributed along the northern Chinese coast and in Japan [9 , 10]. However, recent studies have clearly demonstrated that the amphioxus population of the Asian-Pacific coast is comprised of two morphologically and genetically distinct species, B. For clarity, the northern Asian-Pacific coast subspecies is now called B. Based on the location of the Asian amphioxus collection sites, we suspect that some of the EST studies [13 , 14] did not actually collect samples from the

southern species B. To avoid confusion, we henceforth will refer to B. EST analysis was used to provide a first glimpse of the genes expressed in the amphioxus notochord [14]. The notochord is the defining characteristic of the Chordata phylum. In vertebrates, the notochord is a transient embryonic structure derived from the dorsal axial mesoderm that serves as an important signaling center, secreting various signals necessary for patterning the dorsal–ventral and left–right axes of the vertebrate body plan [15]. The notochord also functions as an axial skeletal structure in developing embryos before it is replaced by the vertebrae [15]. Unlike vertebrates, amphioxus retain the notochord throughout their lives and never develop vertebrae. Suzuki and Satoh [14] dissected the notochord tissues and isolated notochord cells from approximately B. Interestingly, with the exception of bFGF, they did not detect homologs of any known signaling molecules in their EST data. This finding is probably due to differences in the developmental stage assayed, as the Suzuki and Satoh library is derived from adult notochord cells, while most known signaling molecules primarily function during embryonic stages and are therefore not likely to be highly expressed in the adult stage. Additionally, the limited number of ESTs sequenced in this study may have been insufficient to detect low abundance transcripts. In fact, later large-scale EST analyses of different developmental stages of the Florida amphioxus B. Moreover, the expression surveys with in situ hybridization indicated that many of these genes are expressed in either the notochord or in its precursor in amphioxus embryos [16], suggesting a conserved organizer function for amphioxus dorsal axial mesoderm. In , Mou et al. In addition to identifying many genes coding for common metazoan structural and enzymatic housekeeping proteins, Mao et al. Thus, their EST analysis provided a preliminary global view of the genes expressed during this important developmental stage in amphioxus. In another study, Panopoulou et al. Without whole-genome sequencing data, they attempted to compile a substantial amphioxus gene set to address the long-debated two rounds of whole-genome duplication 2R hypothesis of early vertebrate genome evolution [18]. After assembling their amphioxus ESTs into consensus sequences and assigning them to orthologous groups with genes from human, mouse, ascidian, Caenorhabditis elegans, Drosophila, and yeast, they estimated the extent of gene duplication at the transition from invertebrates to vertebrates. They found that on average, humans and mice have 2. The authors therefore concluded at least one large genome duplication event occurred at the origin of vertebrates and that subsequent smaller scale duplications may have also occurred during the course of vertebrate evolution. However, this estimation of gene-copy ratio could be complicated by possible gene loss in vertebrate lineages after gene duplication events [19] or gene duplication events unique to the amphioxus lineage [20–23]. Later, the amphioxus genome-sequencing project provided more definitive information about the extent of whole-genome duplication during early vertebrate evolution. When whole-genome sequence data from the Florida amphioxus B. More interestingly, when mapped to human chromosomes, each putative ancestral chordate linkage group corresponded to large segments on four different human chromosomes [6]. This quadruple conserved synteny pattern strongly suggests that two rounds of whole-genome duplication occurred in the vertebrate lineage. Five non-normalized cDNA libraries were prepared from unfertilized eggs, gastrula, neurula, h larvae Figure 1 B–E , and mixed male and female mature adults. Together with the aforementioned ESTs from B. Because the previous clustering analysis did not include this second set of EST data [7], we reanalyzed the data and provided some updates on the status of the current B. To date, we have obtained ESTs from these five B. This finding suggests that more than half of the predicted genes are either not expressed in the developmental stages analyzed in this EST analysis, or that they are expressed at such a low level that their transcripts could not be detected. Of note, the number of cDNA clusters is larger than the number of protein-coding loci 21 predicted from the draft genome sequence [6]. This result is likely due in part to the existence of alternatively spliced isoforms of specific genes in amphioxus [24]. Unlike genome-sequencing coverage, it is not straightforward to extrapolate the coverage of the EST data to the entire transcriptome because the exact number of different transcript isoforms produced by each gene is not known in amphioxus. We applied mathematical models to this plot to estimate the maximum diversity of amphioxus transcript species through extrapolation [25]. The model predicts that the amphioxus transcriptome contains a maximum of 79 unique transcripts, and many transcripts are predicted to be rare species that would only be identify by sequencing a considerable number of ESTs. A comprehensive analysis of mouse full-length

cDNAs from the FANTOM project has identified more than independent transcripts [26], and the data suggested that the total number of transcripts is at least one order of magnitude larger than the estimated number of protein-coding genes 22 in the mouse genome. A recent study using a transcript-tagging technique and the NGS platform identified more than unique tag sequences from the cheetah skin transcriptome [27]. It should be noted that non-coding RNAs either polyadenylated or non-polyadenylated are now recognized to contribute a significant portion of reads to transcriptome data [28 , 29]. This finding may also explain in part the large difference between the number of predicted protein-coding genes in amphioxus and the number of transcripts. Further comprehensive analysis of amphioxus full-length transcripts and detailed annotation of different classes of non-coding RNAs in this organism will help determine the relative contribution of non-coding RNAs to the amphioxus transcriptome. View large Download slide Clustering analysis of current B. The curve has not reached its plateau due to the continuous discovery of many singleton clusters. As embryonic development proceeds, the embryos and larvae begin to express additional transcript species. Numbers of ESTs from five B.

Chapter 3 : Details - A student's text-book of zoology, - Biodiversity Heritage Library

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The invertebrate that can model for vertebrates I know you came here to learn about amphioxus, but first, a song. This song was regularly taught to undergrads at various universities in the past see history here , new articles suggest that it may be wrong! The lancelets retain all normal chordate features, including dorsal nerve cord with support from a notochord, gill slits, myomeres for muscular structure, and a post-anal tail. Previous work on invertebrates has yielded crucial information for developmental biology and the understanding of conserved signal cascades. A main reason that invertebrates are so elucidative is their smaller genome size with decreased duplication. This allows the easier identification of genes that are evolutionary conserved. Conservation and amphioxus as a model The structure of the amphioxus tail bud has been related to the development of the vertebrate tail bud. Both organisms generate the neural tube, somites, and posterior portions of the notochord. The development of the tail bud is controversial, as it is unclear whether it is a continuation of gastrulation or is separate from the formation of the trunk. The latter view was established in studies on chicks and mice, with the results suggesting that the tail bud is a blastema of pluripotent mesenchymal cells. This means the tail bud retains the ability to differentiate into multiple tissues. The other side of the argument is derived from the use of frogs as a model organism, which shows that the tail bud is pre-partioned and an extension of gastrulation. Several genes, including Wnts are preserved and expressed in the tail buds of both vertebrates and amphioxus see Figure 2 below. The expression of these Wnts can compensate for each other, with their genes being partially overlapped in ampioxus and xenopus. These genes are responsible for tail elongation and tail formation. The conserved interaction of these genes suggests that amphoxious structures can offer insight for vertebrate homologs. Gene expression in amphioxus bud development. Similarly, the pharynx formation of amphioxus offers unique insight to the role of endoderm and neural crest in vertebrates. Primarily, amphioxus do not have neural crests or derivatives, allowing separation between what is caused due to pharyngeal endoderm patterning and what is neural crest. When amphioxus were exposed to retinoic acid, the same chemical that is in Accutane and causes craniofacial birth defects when taken early in pregnancy, they expressed a similar phenotype. This defect has also been exhibited in mice, chicks, and quail, with its cause identified as the retinoic acid shifting the pharynx anteriorly. The affected downstream genes are in the Pax family, and the amphioxus genome has no duplication in this region. Both amphioxus and vertebrates expressed Pax1 and Pax9 genes in their pharyngeal endoderm, exhibiting roles in the prevention of tissue fusion and promoting cell proliferation. The final morphological element of invertebrate development that can be examined through the use of amphioxus as a model organism is neural crest formation. This is an interesting use of an amphioxus, as they do not have a neural crest! The neurulation, however, is related to several vertebrates including frogs, birds, and mammals; this conserved process is the formation of the dorsal ectoderm into a neural plate. This conserved gene patterning between an organism that does not form a neural crest and one that does has raised questions about the true function of these genes. The answer to these inconsistencies are accounted by the location of the gene expression, like the FoxD gene which is expressed in the edges of the non-neural plate of amphioxus and in the neural crest of vertebrates. Genetic experiments in amphioxus are inhibited by the lack of continuous breeding, currently, but this element is rapidly changing. While there are obvious differences in the actual processes, certain elements are easily translatable, making a simply invertebrate easily translatable in the lab. The amphioxus model has several benefits not explained here but is mentioned in the article that this is based on including the importance of the implications of the use of amphioxus as a genomic model and the evolution of processes throughout increasing species complexity. Existing research has suggested that there is a strong relationship between the formation of the amphioxus and vertebral tail buds. Wnt expression around the formation of these buds varies between the two organisms, but Wnts can compensate for each other in the same pathway, explaining evolved variation. The explanation of the separation of regulation behind this

development can be shown in Figure 5 below Minguillon et al.

Chapter 4 : Phylum Chordata, Subphylum Cephalochordata

The phylum Chordata comprises cephalochordates (amphioxus or lancelets), urochordates (tunicates), and vertebrates. These three groups share several characteristic features, including a notochord, dorsal hollow neural tube, gill slits, and endostyle (Fig. 1), and are thought to have diverged from a common ancestor during or prior to the Cambrian explosion.

Their fins are thin and supported by spines. There are over 30, species representing more than half of all living vertebrates. They are an important part of the human diet in many areas of the world and, in affluent nations, support a large sports fishing industry. Although the earliest bony fishes may have appeared late in the Silurian period , their fossils become abundant in freshwater deposits of the Devonian period. In addition to gills, these fishes had a pair of pouched outgrowths from the pharynx which served as lungs. They were inflated with air taken in through the mouth and may have provided a backup gas exchange organ when the water became too warm and stagnant to carry enough dissolved oxygen. Their kidneys were adapted for the hypotonic environment in which they lived. Some migrated to the oceans. In this more stable environment, their lungs became transformed into a swim bladder with which they could alter buoyancy. Their kidneys became transformed as well adapting them to their new â€" hypertonic â€" surroundings. Coelacanths were long thought to have become extinct at the end of the Mesozoic era, some 70 million years ago. But in December , a living coelacanth, Latimeria chalumnae, was pulled up from the depths of the ocean off the east coast of Africa. Since then, over additional specimens have been caught. The nostrils of bony fishes open only to the outside and are used for smelling. Some of the lobe-finned fishes developed internal openings to their nostrils. This made it possible to breath air with the mouth closed as modern lungfishes do. Judging from present-day lungfishes, two other significant adaptations evolved in this group: This permitted a partial separation of oxygenated blood returning from the lung s and the deoxygenated blood returning from the rest of the body. This mechanism is highly-developed in the African and South American lungfishes. While in the water, these fishes excrete their waste nitrogen as ammonia, just as most ray-finned fishes do. In time of drought, these animals burrow in the mud and switch to urea production. These rare modern lobe-finned fishes are the sole survivors of once-flourishing groups that also gave rise to the tetrapods â€" the four-legged vertebrates. In the Devonian perhaps as early as million years ago , the paired fins of some sarcopterygians moved under the body and developed limbs complete with digits. This enabled them to venture out on land. So once again, evolution was opportunistic giving rise to the first land vertebrates, the amphibians. The figure shows the relationship between the bones of two tetrapod forelegs and the pectoral fin of a sarcopterygian. Amphibians With their bony limbs and lungs inherited from their lobe-finned ancestors, amphibians were so successful during the Carboniferous Mississippian and Pennsylvanian periods that these periods are known as the Age of Amphibians. The Carboniferous was followed by the Permian, when the earth became colder and dryer. The fortunes of the amphibians began to decline until only three groups â€" totaling about species â€" remain today: As the name suggests, amphibians are only semiterrestrial: Their skin is soft and moist so they are at risk of desiccation in dry surroundings. Link to descriptions of the heart and kidneys of amphibians. Amniotes Amniota Some million years ago in the Pennsylvanian , some amphibians evolved the ability to lay shelled, yolk-filled eggs. The embryo developing within the egg produces 4 extraembryonic membranes: A shelled egg is just as impervious to sperm as to water, so its arrival coincided with the development of internal fertilization. The early aminotes soon diverged into two major lines of descent: With the arrival of the cold, dry Permian, reptiles were well-adapted to survive because of their development of a shelled, yolk-filled egg which could be deposited on land without danger of drying out. The photo courtesy of the Carolina Biological Supply Company shows an American chameleon emerging from its egg. Other adaptations that enabled the reptiles to flourish for the next million years were: This group developed the ability to convert their nitrogenous waste into uric acid. Uric acid is almost insoluble in water so its excretion involves little loss of water. It is the whitish paste that pigeons leave on statues. This modification largely freed the diapsids and their descendants from a dependence on drinking water; the water in their food is usually sufficient. Diapsid evolution soon produced: Link to illustrated discussion of the lizard kidney thecodonts. Thecodonts were able

to run fast by rising up on their hind legs, which became larger than their front legs, and using their long tail for balance. The group diversified into: The dominance of the reptiles during the Mesozoic era has giving it the name, the Age of Reptiles. Feathers are the feature that most clearly distinguishes the birds from their dinosaur ancestors. These scaly skin outgrowths provide a light, strong surface for the wings; heat insulation, making it possible to be small but still warm-blooded.

The lancelets â€" also known as amphioxi (singular, amphioxus) consist of about 32 species of fish-like marine chordates in the order www.nxgvision.com are distributed in shallow and coastal temperate (as far north as Norway), subtropical and tropical seas around the world, usually found half-buried in sand.

The ordinal name for the genera and species of Amphioxus is Cephalochorda, the term referring to the extension of the primary backbone or notochord to the anterior extremity of the body; the family name is Branchiostomidae. The amount of generic divergence exhibited by the members of this family is not great in the mass, but is of singular interest in detail. There are two principal genera - I. Branchiostoma Costa, having paired sexual organs gonadic pouches ; 2. Heteropleuron Kirkaldy, with unilateral gonads. Of these, the former includes two subgenera, Amphioxus s. Yarrell and Dolichorhynchus Willey. The species belonging to the genus Heteropleuron are divided among the three subgenera Paramphioxus Haeckel, Epigonichthys Peters, and Asymmetron Andrews. The generic characters are based upon definite modifications of form which affect the entire facies of the animals, while the specific diagnoses depend upon minor characters, such as the number of myotomes or muscle-segments. Habits and Distribution With regard to its habits, all that need be said here is that while Amphioxus is an expert swimmer when occasion requires, yet it spends most of its time burrowing in the sand, in which, when at rest, it lies buried with head protruding and mouth wide agape. Its food consists of microscopic organisms and organic particles; these are drawn into the mouth FIG. Slightly altered from Kirkaldy. Amphioxus favours a littoral habitat, and rarely if ever descends below the fathom line. Species occur in all seas of the temperate, tropical and subtropical zones. The European species, A. A recently described species, Dolichorhynchus indicus, characterized by the great length of the praeoral lobe or snout, has been dredged in the Indian Ocean. I Lateral view of adult, to show general form, the myomeres, fin rays and gonads. The perforated pharyngeal region has then been detached from the adherent epipleura or opercular folds wall of atrial or branchial chamber by cutting the fluted pharyngo-pleural membrane d, and separated by a vertical cut from the intestinal region. Lettering as in 2. Asymmetron lucayanum is the Bahaman representative of the family, with a subspecies, A. The Peruvian species, Branchiostoma elongatum, with nearly eighty myotomes, cannot at present be assigned to its proper subgenus. External Form The following description, unless otherwise stated, refers to A. Amphioxus is a small fish-like creature attaining a maximum length of about 3 in. The body is narrow, laterally compressed and pointed at both ends. The main musculature can be seen through the thin skin to be divided into about sixty pairs of muscle-segments myotomes by means of comma-shaped dissepiments, the myocommas, which stretch between the skin and the central skeletal axis of the body. These myotomes enable it to swim rapidly with characteristic serpentine undulations of the body, the movements being effected by the alternate contraction and relaxation of the longitudinal muscles on both sides. Apparently correlated with this peculiar locomotion is the anatomical fact of the alteration of the myotomes on the two sides. Symmetrical at their first appearance in the embryo, the somites from which the myotomes are derived early undergo a certain distortion, the effect of which is to carry the somites of the left side forwards through the length of one half-segment. For example, the twenty-seventh myotome of the left side is placed opposite to the twenty-sixth myocomma of the right side. The back of the body is occupied by a crest, called the dorsal fin, consisting of a hollow ridge, the cavity of which is divided into about compartments or fin chambers, into each of which, with the exception of those near the anterior and posterior end of the body, projects a stout pillar composed of characteristic laminar tissue, the fin ray. The dorsal crest is continued round both extremities, becoming expanded to form the rostral fin in front and the caudal fin behind. Even in external view, careful inspection will show that the body is divisible into four regions, namely, cephalic, atrial, abdominal and caudal. The cephalic region includes the rostrum or praeoral [[Right Fig]]. Section through region of atrio-coelomic canals, v. Section in front of mouth; the right and left sides are transposed. As already stated, the notochord extends beyond the mouth to the tip of the rostrum. The mouth consists of two portions, an outer vestibule and an inner apertura oris; the latter is surrounded by a sphincter muscle, which forms the so-called velum. The vestibule of the mouth is the space bounded by the oral hood;

this arises by secondary downgrowth of lid-like folds over the true oral aperture, and is provided with a fringe of tentacular cirri, each of which is supported by a solid skeletal axis. The oral hood with its cirri has a special nerve supply and musculature by which the cirri can be either spread out, or bent inwards so that those of one side may interdigitate with those of the other, thus completely closing the entrance to the mouth. The velum is also provided with a circlet of twelve tantacles in some species sixteen which hang backwards into the pharynx; these are the velar tentacles. The atrial region extends from the mouth over about twothirds of the length of the body, terminating at a large median ventral aperture, the atriopore; this is the excurrent orifice for the respiratory current of water and also serves for the evacuation of the generative products. This region is really the branchiogenital region, although the fact is not apparent in external view. The ventral side of the body in the atrial region is broad and convex, so that the body presents the appearance of a spherical triangle in transverse section, the apex being formed by the dorsal fin and the angles bordered by two hollow folds, the metapleural folds, each of which contains a continuous longitudinal lymph-space, the metapleural canal. In the genus Branchiostoma the metapleural folds terminate symmetrically shortly behind the atriopore, but in Heteropleuron the right metapleur passes uninterruptedly into the median crest of the ventral fin fig. In this connexion it may also be mentioned that in all cases the right half of the oral hood is directly continuous with the rostral fin fig. The abdominal region comprises a short stretch of body between atriopore and anus, the termination of the alimentary canal. It is characterized by the presence of a special development of the lophioderm or median fin-system, namely, the ventral fin, which is composed of two portions, a lower keel-like portion, which underlies an upper chambered portion, each chamber containing typically a pair of gelatinous fin rays. Finally, the caudal region comprises the post-anal division of the trunk. The keel of the ventral fin is continued past the anus into the expanded caudal fin, and so it happens that the anal opening is displaced from the middle line to the left side of the fin. In Asymmetron the caudal region is remarkable for the curious elongation of the notochord, which is produced far beyond the last of the myotomes. Alimentary, Respiratory and Excretory Systems. The alimentary canal is a perfectly straight tube lined throughout by ciliated epithelium. As food particles pass in through the mouth they become enveloped in a slimy substance secreted by the endostyle and conveyed down the gut by the action of the vibratile cilia as a continuous food-rope, the peristaltic movements of the gut-wall being very feeble. The first part of the alimentary canal consists of the pharynx or branchial sac, the side walls of which are perforated by upwards of sixty pairs of elongated slits, the gill-clefts. Each primary gill-cleft becomes divided into two by a tongue-bar which grows down secondarily from the upper wall of the cleft and fuses with the ventral wall. New clefts continue to form at the posterior end of the pharynx during the adult life of the animal. The gill-clefts open directly from the cavity of the pharynx into that of the atrium, and so give egress to the respiratory current which enters the mouth with the food fig. The atrium or atrial chamber is a peripharyngeal cavity of secondary origin effecting the enclosure of the gill-clefts, which in the larva opened directly to the exterior. The atrium is thus analogous to the opercular cavity of fishes and tadpoles, and, as stated above, remains in communication with the exterior by means of the atriopore. The primary and secondary bars which separate and divide the successive gill-clefts from one another are traversed by blood-vessels which run from a simple tubular contractile ventral branchial vessel along the bars into a dorsal aorta. The ventral branchial vessel lies below the hypobranchial groove or endostyle, and is the representative of a heart. As water for respiration streams through the clefts, gaseous interchange takes place between the circulating colourless blood and the percolating water. The pharynx projects freely into the atrium; it is surrounded at the sides and below by the continuous atrial cavity, but dorsally it is held in position in two ways. First, its dorsal wall which is grooved to form the hyperpharyngeal groove is closely adherent to the sheath of the notochord; and secondly, the pharynx is attached through the intermediation of the primary bars. These are suspended to the muscular bodywall by a double membrane, called the ligamentum denticulatum, which forms at once the roof of the atrial chamber and the floor of a persistent portion of the original body-cavity or coelom the dorsal coelomic canal on each side of the pharynx. The ligamentum denticulatum is thus lined on one side by the epiblastic atrial epithelium, and on the other by mesoblastic coelomic epithelium. Now this ligament is inserted into the primary bars some distance below the upper limits of the gill-clefts, and it therefore follows that, corresponding with each

tongue-bar, the atrial cavity is produced upward beyond the insertion of the ligament into a series of bags or pockets, which may be called the atrial pouches. At the top of each of these pouches there is a minute orifice, the aperture of a small tubule lying above each pouch in the dorsal coelom. These tubules are the excretory tubules or nephridia. They communicate with the coelom by several openings or nephrostomes, and with the atrium by a single opening in each case, the nephridiopore. It is important to emphasize the fact that in Amphioxus the excretory tubules are co-extensive with the gill-clefts. The perforated pharynx terminates some distance in front of the atriopore. At the level of its posterior end a pair of funnel-shaped pouches of the atrium are produced forwards into the dorsal coelom. These are the atrial coelomic funnels or brown funnels, so called on account of the characteristic pigmentation of their walls. There are reasons for supposing that these funnels are vestiges of an ancient excretory system, which has given way by substitution to the excretory tubules described above. In the same region of the body, namely, close behind the pharynx, a large diverticulum is given off from the ventral side of the gut. This is the hepatic caecum fig. Although within the atrial cavity, it is separated from the latter by a narrow coelomic space, bounded towards the atrium by coelomic and atrial epithelium. No food passes into the hepatic caecum, which has been definitely shown on embryological and physiological grounds to be the simplest persistent form of the vertebrate liver. This notochord represents the persistent primordial skeletal axis which, in the higher Craniata though not so in the lower , gives way by substitution to the segmented vertebral column. Immediately above the notochord there lies another FIG. After Rathke, slightly altered. In this species the atrium is produced as an asymmetrical blind pouch behind the atriopore as far as the anus. This cord is neither elastic nor solid, but consists of nerve tissue, fibres and ganglion cells, surrounding a small central canal. For the sake of uniformity in nomenclature this nerve-cord may be called the neurochord. It is the central nervous system, and contains within itself the elements of the brain and spinal marrow of higher forms. The neurochord tapers towards its posterior end, where it is coextensive with the notochord, but ends abruptly in front, some distance behind the tip of the snout. The neurochord attains its greatest thickness not at its anterior end but some way behind this region; but the central canal dilates at the anterior extremity to form a thin-walled cerebral vesicle, in the front wall of which there is an aggregation of dark pigment cells constituting an eyespot, visible through the transparent skin fig. There are two pairs of specialized cerebral nerves innervating the praeoral lobe, and provided with peripheral ganglia placed near the termination of the smaller branches. Corresponding with each pair of myotomes, and subject to the same alternation, two pairs of spinal nerves arise from the neurochord, namely, a right and left pair of compact dorsal sensory roots without ganglionic enlargement, and a right and left pair of ventral motor roots composed of loose fibres issuing separately from the neurochord and passing directly to their termination on the muscle-plates of the myotomes. The first dorsal spinal nerve coincides in position with the myocomma which separates the first myotome from the second on each side, and thereafter the successive dorsal roots pass through the substance of the myocommata on their way to the skin; they are therefore septal or intersegmental in position. The ventral roots, on the contrary, are myal or segmental in position. In addition to the cerebral eyespot there are large numbers of minute black pigmented bodies beside and below the central canal of theneuro chord, commencing from the level of the third myotome. It has been determined that these bodies are of the nature of eyes Becheraugen, R. Hesse , each consisting of two cells, a cup-shaped pigment cell and a triangular retinal cell. These may be called the spinal eyes, and it is said that they are disposed in such a way as to receive illumination preferentially from the right side, although this fact has no relation with the side upon which Amphioxus may lie upon the sand. When kept in captivity the animal often lies upon one side on the surface of the sand, but on either side indifferently. Over the cerebral eye there is a small orifice placed to the left of the base of the cephalic fin, leading into a pit which extends from the surface of the body to the surface of the cerebral vesicle; this is known as A. At the breeding season the walls of the pouches burst and the sexual elements pass into the atrium, whence they are discharged through the atriopore into the water, where fertilization takes place.

Characteristics Of Vertebrata- In this lesson, Iftekhar Khan explains about the complete characteristics of vertebrates. The functional units of vertebrates have been discussed entirely in this unit.

Reproductive systems[edit] Nearly all vertebrates undergo sexual reproduction. They produce haploid gametes by meiosis. The smaller, motile gametes are spermatozoa and the larger, non-motile gametes are ova. These fuse by the process of fertilisation to form diploid zygotes , which develop into new individuals. Inbreeding[edit] During sexual reproduction, mating with a close relative inbreeding often leads to inbreeding depression. Inbreeding depression is considered to be largely due to expression of deleterious recessive mutations. In several species of fish, inbreeding was found to decrease reproductive success. Numerous inbreeding avoidance mechanisms operating prior to mating have been described. Toads and many other amphibians display breeding site fidelity. Individuals that return to natal ponds to breed will likely encounter siblings as potential mates. Although incest is possible, Bufo americanus siblings rarely mate. Advertisement vocalizations by males appear to serve as cues by which females recognize their kin. In guppies, a post-copulatory mechanism of inbreeding avoidance occurs based on competition between sperm of rival males for achieving fertilization. Active selection of sperm by females appears to occur in a manner that enhances female fitness. Outcrossing[edit] Mating with unrelated or distantly related members of the same species is generally thought to provide the advantage of masking deleterious recessive mutations in progeny [52] and see Heterosis. Vertebrates have evolved numerous diverse mechanisms for avoiding close inbreeding and promoting outcrossing [53] and see Inbreeding avoidance. Outcrossing as a way of avoiding inbreeding depression, has been especially well studied in birds. For instance, inbreeding depression occurs in the great tit when the offspring are produced as a result of a mating between close relatives. In natural populations of the great tit Parus major , inbreeding is avoided by dispersal of individuals from their birthplace, which reduces the chance of mating with a close relative. However, there are ecological and demographic constraints on extra pair matings. The first is through dispersal, and the second is by avoiding familiar group members as mates. Within their group, individuals only acquire breeding positions when the opposite-sex breeder is unrelated. Cooperative breeding in birds typically occurs when offspring, usually males, delay dispersal from their natal group in order to remain with the family to help rear younger kin. Parthenogenesis[edit] Parthenogenesis is a natural form of reproduction in which growth and development of embryos occur without fertilization. Reproduction in squamate reptiles is ordinarily sexual, with males having a ZZ pair of sex determining chromosomes, and females a ZW pair. However, various species, including the Colombian Rainbow boa Epicrates maurus , Agkistrodon contortrix copperhead snake and Agkistrodon piscivorus cotton mouth snake can also reproduce by facultative parthenogenesis -that is, they are capable of switching from a sexual mode of reproduction to an asexual mode- resulting in production of WW female progeny. Mole salamanders are an ancient 2. As a result, the mature eggs produced subsequent to the two meiotic divisions have the same ploidy as the somatic cells of the female salamander. Synapsis and recombination during meiotic prophase I in these unisexual females is thought to ordinarily occur between identical sister chromosomes and occasionally between homologous chromosomes. Thus little, if any, genetic variation is produced. Recombination between homeologous chromosomes occurs only rarely, if at all. However, meiosis may have been maintained during evolution by the efficient recombinational repair of DNA damages that meiosis provides, an advantage that could be realized at each generation. The capacity for selfing in these fishes has apparently persisted for at least several hundred thousand years.

Chapter 7 : Amphioxus - Encyclopedia Britannica - Bible Encyclopedia

MAJOR CLADES OF THE VERTEBRATA: 1. Animals with a hollow dorsal nerve cord, notochord, and pharyngeal gill slits. 2. Brain encapsulated, or at least partially so, by a cartilaginous or bony cranium.

Depending on the exact species involved, the maximum length of lancelets is typically 2. A relatively poorly developed tail fin is present, so they are not especially good swimmers. While they do possess some cartilage -like material stiffening the gill slits , mouth, and tail, they have no true skeleton. Also like vertebrates, the muscles are arranged in blocks called myomeres. Unlike vertebrates, the dorsal nerve cord is not protected by bone but by a simpler notochord made up of a cylinder of cells that are closely packed to form a toughened rod. The lancelet notochord, unlike the vertebrate spine , extends into the head. The nerve cord is only slightly larger in the head region than in the rest of the body, so that lancelets do not appear to possess a true brain. However, developmental gene expression and transmission electron microscopy indicate the presence of a diencephalic forebrain , a possible midbrain , and a hindbrain. The frontal eye is widely thought to be light-sensitive, although this has not been confirmed by electrophysiological measurement. The lamellar body, a possible homologue of the pineal body, was once thought to be light-sensitive, although this has been called into question. All of these organs and structures are located in the neural tube, with the frontal eye at the front, followed by the lamellar body, the Joseph cells, and the Hesse organs. These cells bear the opsin melanopsin. The Hesse organs also known as dorsal ocelli consist of a photoreceptor cell surrounded by a band of microvill and bearing melanopsin, but half enveloped by a cup-shaped pigment cell. Both the Joseph cells and Hesse organs are in the neural tube, the Joseph cells forming a dorsal column, the Hesse organs in the ventral part along the length of the tube. The frontal eye, which expresses the PAX6 gene, has been proposed as the homolog of vertebrate paired eyes, the pigment cup as the homolog of the RPE retinal pigment epithelium , the putative photoreceptors as homologs of vertebrate rods and cones , and Row 2 neurons as homologs of the retinal ganglion cells. Its cells contain the pigment melanin. The cells are flask-shaped, with long, slender ciliary processes one cilium per cell. The main bodies of the cells lie outside of the pigment cup, while the cilia extend into the pigment cup before turning and exiting. The cells bear the opsin c-opsin 1, except for a few which carry c-opsin 3. Cells of all four rows have axons that project into the left and right ventrolateral nerves. The tegmental neuropil has been compared with locomotor control regions of the vertebrate hypothalamus , where paracrine release modulates locomotor patterns such as feeding and swimming. Water passes from the mouth into the large pharynx , which is lined by numerous gill-slits. Ciliary action pushes the mucus in a film over the surface of the gill slits, trapping suspended food particles as it does so. The mucus is collected in a second, dorsal, groove, and passed back to the rest of the digestive tract. Having passed through the gill slits, the water enters an atrium surrounding the pharynx, then exits the body via the atriopore. In larvae the action is mediated by the pharyngeal muscles while in the adult animal it is accomplished by atrial contraction. The hepatic caecum , a single blind-ending caecum , branches off from the underside of the gut, with a lining able to phagocytize the food particles, a feature not found in vertebrates. Although it performs many functions of a liver, it is not considered a true liver but a homolog of the vertebrate liver. The circulatory system does resemble that of primitive fish in its general layout, but is much simpler, and does not include a heart. There are no blood cells, and no haemoglobin. Also unlike vertebrates, there are numerous, segmented gonads. By lancelets had become a model organism. By the midth century they had fallen out of favor for a variety of reasons, including a decline of comparative anatomy and embryology, and due to the belief that lancelets were more derived than they appeared, e. Newer research suggests this is not the case. The Cephalochordata is the most basal subphylum of the chordates, [35] while the sister group of the vertebrates are the tunicates , previously known as the urochordates. Genetic studies have come to separate conclusions on their divergence, with some suggesting that Asymmetron diverged from other lancelets more than million years ago and others with higher statistic support that it occurred about 42 million years ago. Other sources recognize about thirty species.

Chapter 8 : Chordate - Wikipedia

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References Abstract For the last two centuries, the cephalochordates, commonly known as lancelets or amphioxus, have been central to investigate the evolutionary genesis of vertebrates. At first, by classical morphologists fascinated by their odd but at the same time familiar anatomical traits and later by molecular biologists giving the first insights into their slow evolving nature. The present data available not only holds amphioxus as an organism of preternatural importance within the tree of life but also boosts its potential to untangle the molecular basis underlying the vertebrate complexity. This is a walk through the past and present of the amphioxus field merging morphological and molecular data in linkage with the fossil record and the modern vertebrates. The resulting picture is drawn together with comparative maps of genome organisation, gastrulation and the origin of the vertebrate organiser, neurulation and the origin of the neural crest, and shared signalling mechanisms between vertebrates and amphioxus during development. Cephalochordates occupy at present the key phylogenetic position to get insights into the invertebrate–vertebrate transition and the evolutionary genesis of vertebrates. The amphioxus genome appears to be the best surrogate available for the ancestral chordate genome regarding the gene content, gene structure and chromosomal organisation. The amphioxus prototypical body plan with respect to vertebrates facilitates the comparative analysis and linkage between invertebrates and vertebrates. Comparative anatomy of fossils, cephalochordates and vertebrates. Although Haikouella fossils remarkably resemble modern cephalochordates the pharyngeal denticles where indicated approaches them to vertebrates. After Mallatt and Chen and Holland et al.. Schematic representation of macrosynteny between the B. The 17 CLGs identified in the B. The gene content and organisation is in most of the cases clearly conserved between B. Such conservation permits to recognise gene losses or chromosomal reorganisations, amongst other genomic events. The example given in b shows the loss of the gene of interest red in one of the human chromosomes 5 , the loss of a surrounding gene blue in another human chromosome 20 and different arrangements of the paralogous regions, including a local reorganisation of the surrounding genes see tandem in pink, orange and blue in chromosome The ordering of surrounding genes pink, orange, blue, yellow and green is also an example of microsynteny. Phylogenetic relationship between vertebrate an invertebrate chordates. Although the first molecular phylogenies located amphioxus as the sister group of vertebrates a , the more recent analyses of bigger sets of genomic data place amphioxus in the pivotal position at the root of all chordates. Comparative representation of the gastrula organiser in vertebrates and amphioxus. In both cases the vegetal pole is the initial point of invagination, where the blastopore will remain open. Based on references Yu et al. Commonalities of Hox regulation between vertebrates and amphioxus. Graded pink represents the RA gradient, with a rostral limit coincident with the most anterior Hox expression and a caudal limit partially overlapped with Cdx expression. In the anterior region, Fgf signalling represses the RA front generating a Hox free region devoid of segmentation. Based on references Schubert et al. Territorial differences and common molecular players during the formation of the neural tube in vertebrates and amphioxus. The major difference lies on the neural crest territory at the edges of the neural plate light yellow. In vertebrates a the neural crest territory is separating the nonneural E from the neural ectoderm NP , whereas in amphioxus b the nonneural ectoderm E simply closes over the neural ectoderm NP light yellow territory is represented where it conceptually should be located. Although the molecular machinery to set the neural crest borders is common between amphioxus and vertebrates, only one neural crest specifier, Snail, is equally restricted in the equivalent region in amphioxus. The notochord underlying the neural plate has been removed for clarity. Based on references Holland and Yu et al.. International Journal of Biological Sciences 2: Boorman CJ and Shimeld SM Pitx homeobox genes in Ciona and amphioxus show left–right asymmetry is a conserved chordate character and define the ascidian adenohypophysis. Evolution and Development 4: Theory in Biosciences Napoli, Azzolino, pp 49–” Darwin C On the Origin of the Species. Disk J Yunnanozoon and the ancestry of chordates. Acta Paleontologica

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Chapter 9 : PHYLUM VERTEBRATA

Subphylum Cephalochordata (Amphioxus or Lancet). Amphioxus (Branchiostoma lanceolata) is the most commonly studied member of the www.nxgvision.com the other members of this subphylum, it is a small, fish-like animal found in shallow marine waters in many parts of the world.

We find in Amphioxus the essential vertebrate features reduced to their simplest expression and, in addition, somewhat distorted. There are wide differences from that vertebrate plan with which the reader may now be considered familiar. There are no limbs. But two lowly vertebrates, the hag-fish and lamprey, have no limbs and a continuous fin. There is, as we shall see more clearly, a structure, the respiratory atrium, not apparently represented in the true vertebrate types, at least in their adult stages. There is no distinct heart, only a debateable brain, quite without the typical division into three primary vesicles, no skull, no structures whatever of cartilage or bone, no genital ducts, no kidneys at all resembling those of the vertebrata, no pancreas, no spleen; apparently no sympathetic chain, no paired sense organs, eyes, ears, or nasal sacs, in all of which points we have striking differences from all true vertebrata; and such a characteristic vertebrate peculiarity as the pineal gland we can only say is represented very doubtfully by the eye spot. The vertebral column is devoid of vertebrae; it is throughout life a rod of gelatinous tissue, the notochord Figure 1, n. Such a rod is precursor to the vertebral column in the true vertebrates, but, except in such lowly forms as the lamprey, is usually replaced, partially e. On this account the following classification is sometimes made of those animals which have a notochord: Having the notochord reaching in front of the brain. Having the notochord reaching anteriorly to the mid-brain, a brain of three primary vesicles and a skull. Having the notochord confined to the tail. The anterior end of the notochord in the developing rabbit or dog lies where the middle of the basisphenoid bone is destined to be. Figure 1, Sheet 19, shows the general anatomy of Amphioxus. We recognise four important points of resemblance to the earlier phases of the higher and the permanent structure of the lower members of the vertebrata, and it is these that justify the inclusion of amphioxus in this volume. In the next, just above it at s. Thirdly, the pharynx ph. The [so-called] hyoidean apertures are not equivalent to the similarly-named parts of the vertebrata. Behind the pharynx the intestine int. The circulation is peculiarly reduced Figure 2. The cardiac aorta c. There is no -distinct- heart, but the whole of the cardiac aorta is contractile, and at the bases of the aortic arches that run up the bars there are contractile dilatations that assist in the propulsion of the blood. Dorsal to the pharynx, as in fishes, there is a pair of dorsal aorta d. A portal vein p. Thence hepatic veins hep. The coelom, or body cavity, of Amphioxus lies, of course, as in the vertebrata, between the intestinal wall and the body walls, and, just as in the vertebrata, it is largely reduced where gill slits occur. But matters are rather complicated by the presence of an atrial cavity round the pharynx, which is not certainly represented in the vertebrata, and which the student is at first apt to call the body cavity, although it is entirely distinct and different from that space. The mutual relation of the two will become apparent after a study of Figures 10, 11, 12 Sheet Figure 10 gives diagrammatically a section of a very young stage of Amphioxus; P is the pharynx portion of the alimentary canal, coe. The gill slits, by which P. Next Figure 11 shows the invagination at. In Figure 12, at. Now imagine the gill slits perforated, as shown by the double-headed arrow in Figure Figure 3, on Sheet 20, is a less diagrammatic representation of a cross-section of the pharyngeal region vide Figure 1, Sheet The student should compare Figure 3, Sheet 20, and Figure 12, Sheet The atrium and metapleural canals are easily recognised in both. In Figure 3 the coelom is much cut up by the gill slits, and we have remaining of it a the dorsal coelomic canals d. The atrial cavity remains open to the exterior at one point, the atrial pore at. The method of examining cross-sections is an extremely convenient one in the study of such a type as Amphioxus. The student should very carefully go over and copy the six sections on Sheet 20, comparing Figure 1 as he goes. He should do this before reading what follows. One little matter must be borne in mind. These figures are merely vintended to convey the great structural ideas, and they are considerably simplified; they must not be regarded as a substitute for the examination of microscopic sections. The] -For instance, the body-wall- muscles of Amphioxus are arranged in bundles bent sharply in an arrow shape, the point forward. If we compare the nervous system of amphioxus with that of any vertebrate,

we find at once a number of striking differences. In the first place, the skeletal covering of it, the cranium and the neural arches of vertebrae, are represented only by a greatly simplified connective tissue. In the next, a simple and slight anterior dilatation alone represents the brain. A patch of black pigment anterior to this e. There is a ciliated funnel, c. Figure 1, Sheet 19 , opening on the left side, which has been assumed to be olfactory in its functions, and in the mouth chamber a ciliated pit c. The ventral fissure of the spinal cord is absent. The dorsal nerves are without ganglia, and do not come off in pairs, but alternately, one to the left, then one to the right, one to the left, one to the right, and so on. The ventral nerves are very short, more numerous than the dorsal, and never unite with these latter to form mixed nerves. The student will observe that here, just as in the case of the ciliated funnel and anus, the Amphioxus is not strictly symmetrical, but twisted, as it were, and so departs from the general rule of at least external bilateral symmetry obtaining among the vertebrates. It habitually lies on one side in the mud of the sea bottom, and it is probable that this external asymmetry is due to this habit, so that too much classificatory importance must not be attached to it. The soles and other related fish, for instance, are twisted and asymmetrical, through a similar specific habit, to such an extent that both eyes lie on one side of the animal. No kidney on the vertebrate pattern is found, but the following structures have, among others, been suggested as renal organs: The reproductive organs Figure 4, Sheet 20, g. Thence they escape either by gill-slits, pharynx and mouth, or, more generally, through the atrial pore. The animals, like all the vertebrata, are dioecious, i. The vertebrate thyroid, early in development, is certainly an open and long narrow groove in the ventral side of the pharynx. The hyper-pharyngeal groove h. The student is advised to revise this chapter before proceeding, and to schedule carefully the anatomical features under the headings of 1. The Development of Amphioxus Section The development of amphioxus, studied completely, is at once one of the most alluring and difficult tasks in the way of the zoologist; but certain of its earlier and most obvious fasts may very conveniently be taken into consideration now. The phenomena of the extrusion of polar bodies and fertilization are treated of later, and will, therefore, not be considered now. We will start our description with an egg-cell, which has escaped, of course, since there are no genital ducts, by rupture of the parent, has been fertilized by the male element, and is about to develop into a young amphioxus. It is simply a single cell, with some power of amoeboid motion, a single nucleus and nucleolus; and in amphioxus its protoplasm is clear and transparent. Frequently ova are loaded with granules of food store yolk , which enable the young animal to go far with its development before it is hatched and has to begin fending for itself. The first thing to be seen in the developing cell is a deepening circular groove Figure 1, Sheet 21 , which divides the ovum into two parts. Another groove then cuts at right angles to this subdividing the two into four Figure 2. Another groove, at right angles to both the former, follows, making the four eight Figure 3. And so subdivision goes on. The whole process is called segmentation or cleavage. At the end of segmentation we get a hollow sphere of small cells, the cells separating from one another centrally and enclosing a cavity as the process proceeds. This is the blastosphere, shown diagrammatically in Figure 4, and of which an internal view, rather truer to the facts of the case as regards shape, is given as Figure 5. The central cavity is the segmentation cavity s. Invagination follows Figure 6. In this process a portion of the blastosphere wall is the tucked into the rest, as indicated by the arrow, so that a two-layered sack is formed. The outer layer of this double-walled sac is called the epiblast. For the present we will give the inner lining no special term. The young amphioxus has, at this stage, which is called the gastrula stage, a curious parallelism with such a lowly form as the Hydra of our ditches. This latter creature, like the gastrula, consists essentially of two layers of cells, an outer protective and sensory layer, and an inner digestive one; it has a primordial intestine, or archenteron, and its mouth is sometimes regarded as being a blastopore. All animals that have little yolk, and start early in life for themselves, pass through a gastrula stage, substantially the same as this of amphioxus. The anus is perforated later near the region occupied at this stage by the blastopore. Hence the anterior end of the future amphioxus, the head end, is pointing towards the Figure 6, and the letters ep. Note first that the epiblast along the mid-dorsal line is sinking in to form what is called the neural plate n. Now, at Figure 8, a slightly later stage is represented, and at 9 i. The remainder of the epiblast constitutes the epidermis. Reverting to Figure 7 ii. This is the notochord compare Figures 8 and 9. Finally, we note two series of buds of cells, one on either side of the archenteron in Figure 7 ii. In 8 these buds have become hollow

vesicles, growing out from it, the coelomic pouches. They are further developed in 9; and in 9 ii. They finally appear to? Hence, in considering the structure of amphioxus, we have three series of cells from which its tissues are developed: Walls of the coelomic pouches, which form a an inner lining to the epiblast, b an outer coating to the hypoblast, and c the mesentery m. This is the mesoblast. The lining of the mesenteron, or hypoblast.