Lesson №26

EVOLUTION OF ORGAN SYSTEMS (PART I)

Biogenetic law, A. N. Severtsov's theory about phylembryogeneses

In 1866 Ernst Haeckel formulated a biogenetic law: *ontogenesis is short and quick recapitulation of phylogenesis conditioned by peculiarities of heredity and adaptability*.

Ch. Darvin confirmed the association between onto- and phylogenesis (phylogeny) and developed theory of **recapitulations**: during ontogenesis an organism goes through the same stages as the ancestral species did in evolution.

Further research showed that the biogenetic law is valid only in general: none of development stages of an embryo completely repeats characters of ancestors. Ontogenesis repeats not the structure adult ancestors, but their embryos.

A. N. Severtsov elaborated the theory of phylembryogeneses. This theory explains connection between ontogenesis and phylogenesis. A **phylembryogenesis** is an embryonic reconstruction that is preserved in adults and has adaptive nature. There are 3 types of phylembryogeneses:

1) **archallaxis** is an early deviation from ancestral developmental pattern that occurs at the moment of an organ formation (an example is development of a hair coat in mammals). Mutated genes get involved in morphogenesis since its beginning and make the new course for development of the organ (recapitulations are absent);

2) **deviation** is changes in the course of morphogenesis that begin in its middle (an example is development of scales in reptiles). Initially morphogenesis goes according to ancestral patterns (partial recapitulation) but later mutated genes activate and make new course for the organ's development.

3) **anabolia** is an additional development of the organ (a two-chambered heart into a four-chamber heart). At first all stages of the organ development recapitulate, and then mutated genes activate to form new character.

In some congenital malformations the body acquire characteristics of another orders or classes of chordates. They appear due to ontophylogenetic mechanisms such as recapitulations and parallelisms. **Recapitulations** occur as a result of incomplete anabolia or its absence. Examples of such disorders are three-chambered heart, preservation of embryonic vessels, two aortal arches, arrested development of kidneys, duplication of ureters. **Parallelism** is independent development of similar characters in closely related species during their evolution (human and animals that have similar origin). An example of parallelism in the human is polymastia (abnormal number of nipples).

Phylogenesis of the nervous system in chordates.

The nervous system originates from ectoderm, is forms in the form of a tube.

Basic directions of evolution:

1. Differentiation of the nerve tube into the brain and the spinal cord.

2. Evolution of the brain:

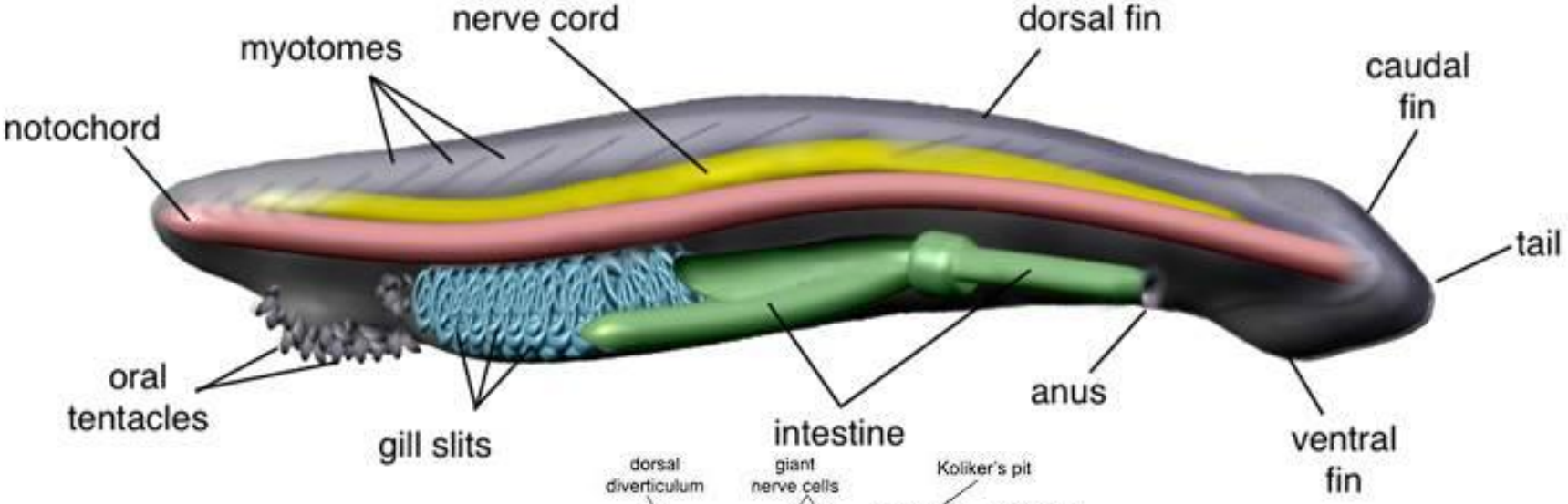
a) transformation of 3 cerebral vesicles into 5 cerebral vesicles and therefore 5 brain regions;

b) appearance of the brain cortex and enlargement of its surface due to its sulci (grooves) and gyri (folds);

c) transformation of the ichthyopsidian brain type into sauropsidian one and ultimately into mammalian brain.

3. Differentiation of the peripheral nervous system.

In the lancelet the CNS is presented by a nerve tube. Its anterior part is dilated and has an olfactory pit. Photosensitive cells (Hesse organs) are located throughout the whole length of the tube.



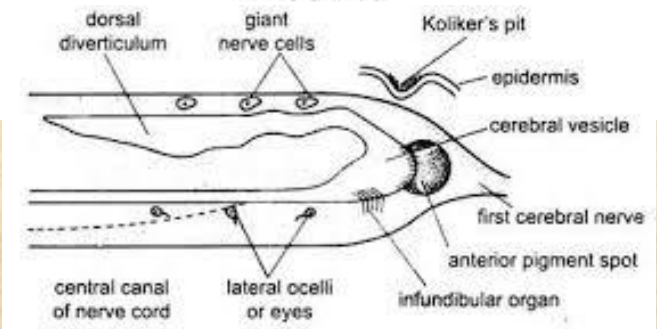
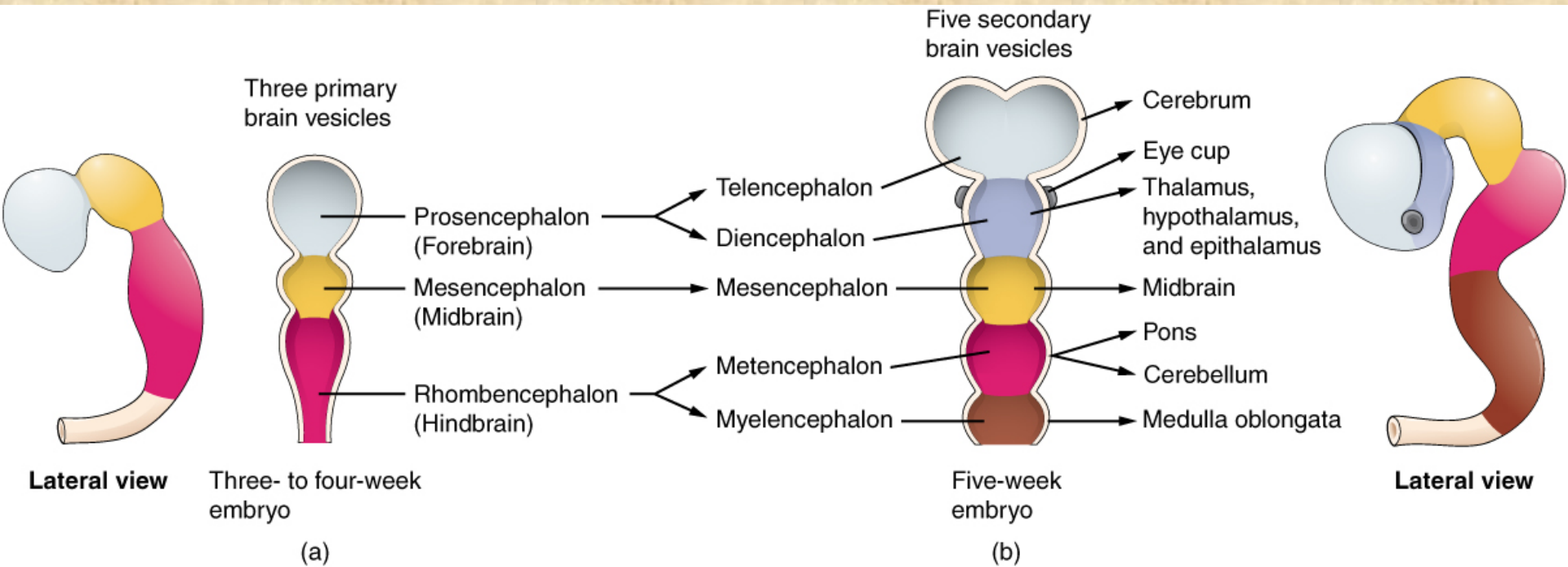
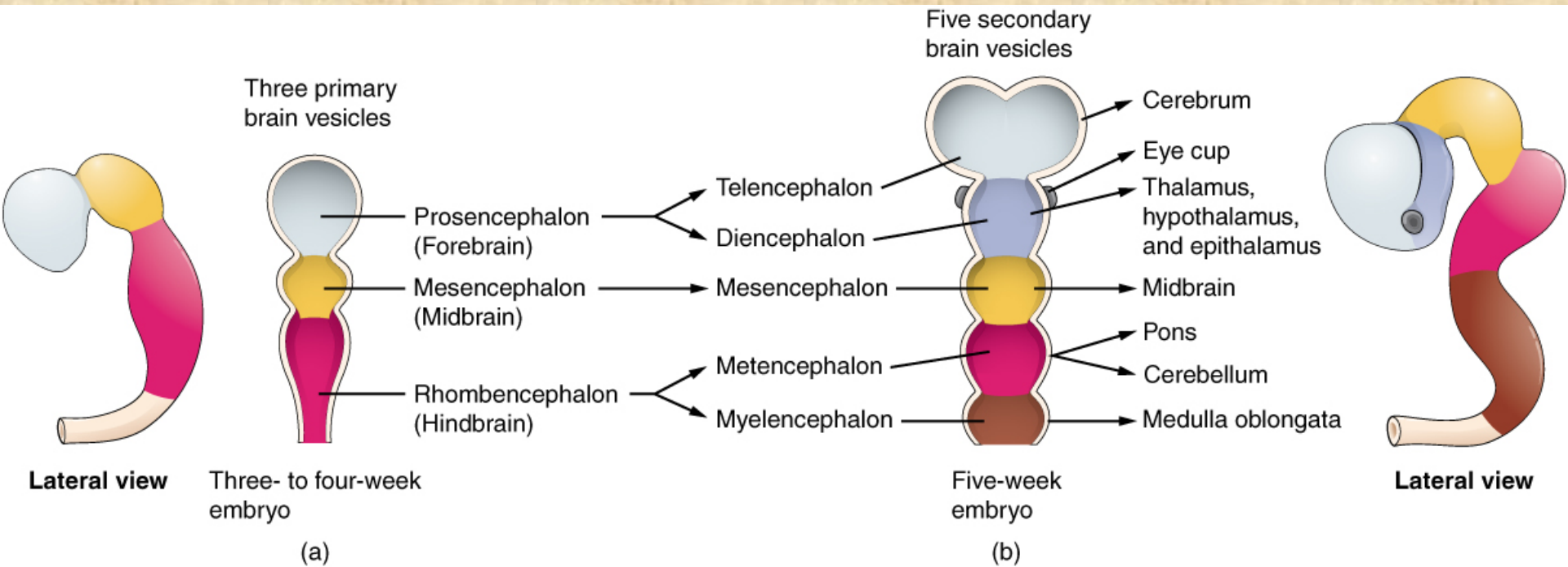


Fig. 6.26. *Branchiostoma*. V.L.S. of anterior part of nerve cord.

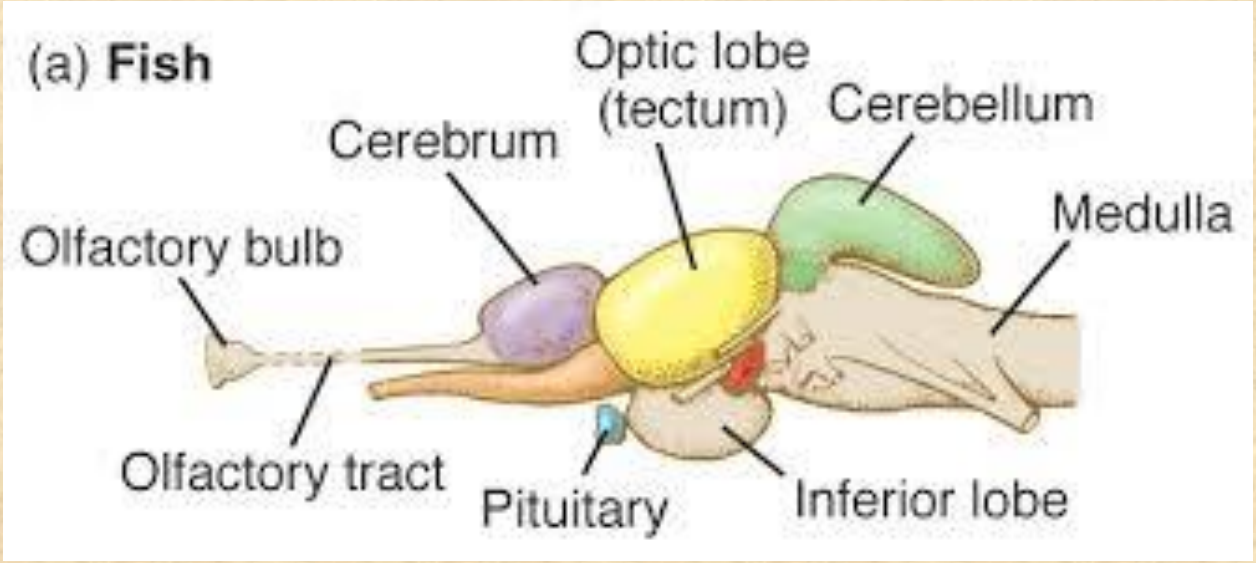
The brain of mammals consists of 5 regions. It undergoes same stages during its formation. At first the nerve tube is formed and 3 cerebral vesicles appear at its anterior end: forebrain (prosencephalon), midbrain (mesencephalon) and hindbrain (rhombencephalon).

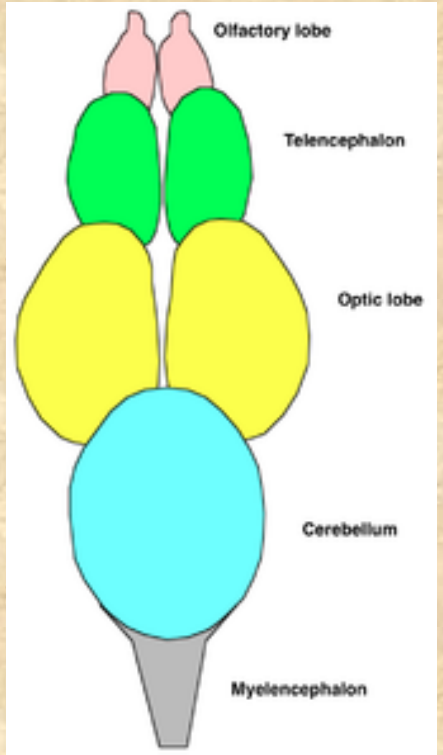


Then the forebrain and hindbrain divide to form 5 cerebral vesicles, each will transform into a certain brain region: endbrain (*telencephalon*), interbrain (*diencephalon*), midbrain (*mesencephalon*), afterbrain (*metencephalon*) and medulla oblongata (*myelencephalon*). There are cavities in the bran (cerebral ventricles) that continue into the spinal cord as the spinal canal. The part of the brain located above the ventricles is called the *roof* (mantle) and the part below is the *floor* of the brain.

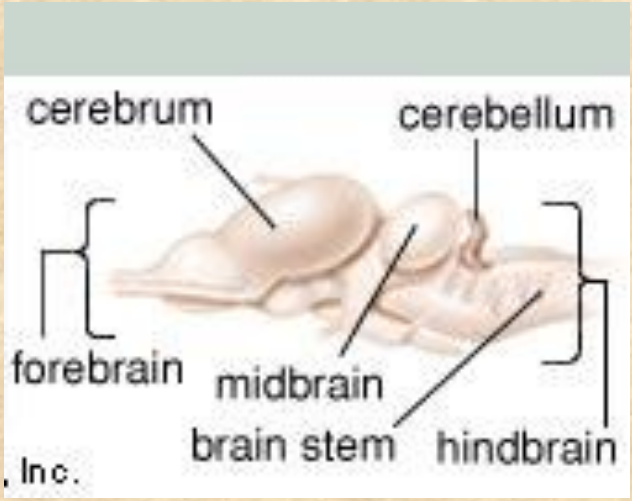


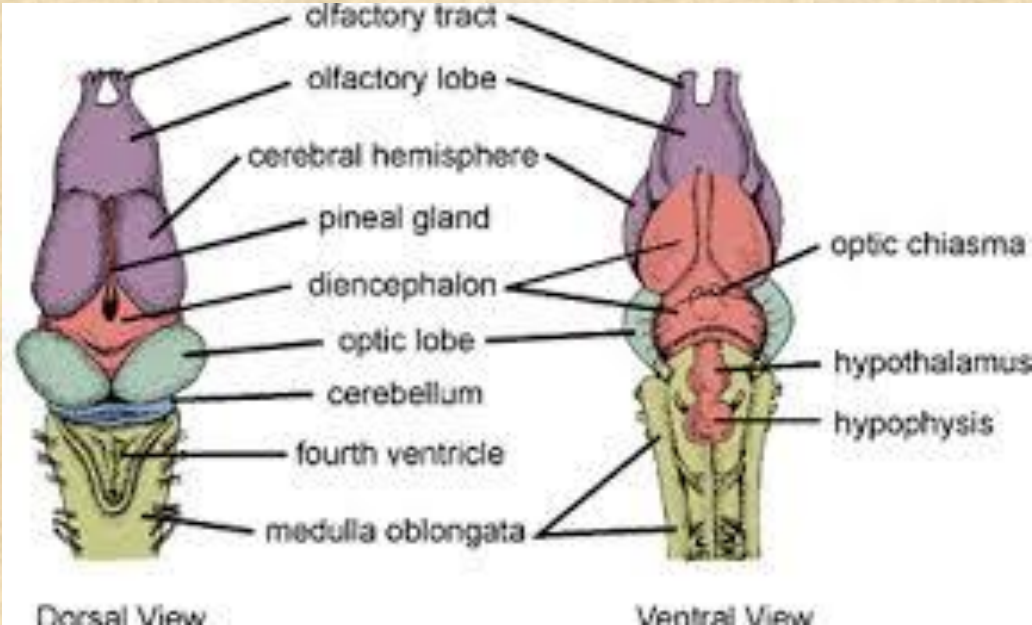
The brain of **fishes** is small. The endbrain is not divided into hemispheres. The roof is epithelial; the floor of the brain is presented by striate bodies. Olfactory lobes are small. The interbrain is presented by the thalamus and hypothalamus. The middle brain is large, it is an integrating center (*ichthyopsidian* type of the brain). A flexure appears in the area of the midbrain. The cerebellum is developed well. There are 10 pairs of cranial nerves.



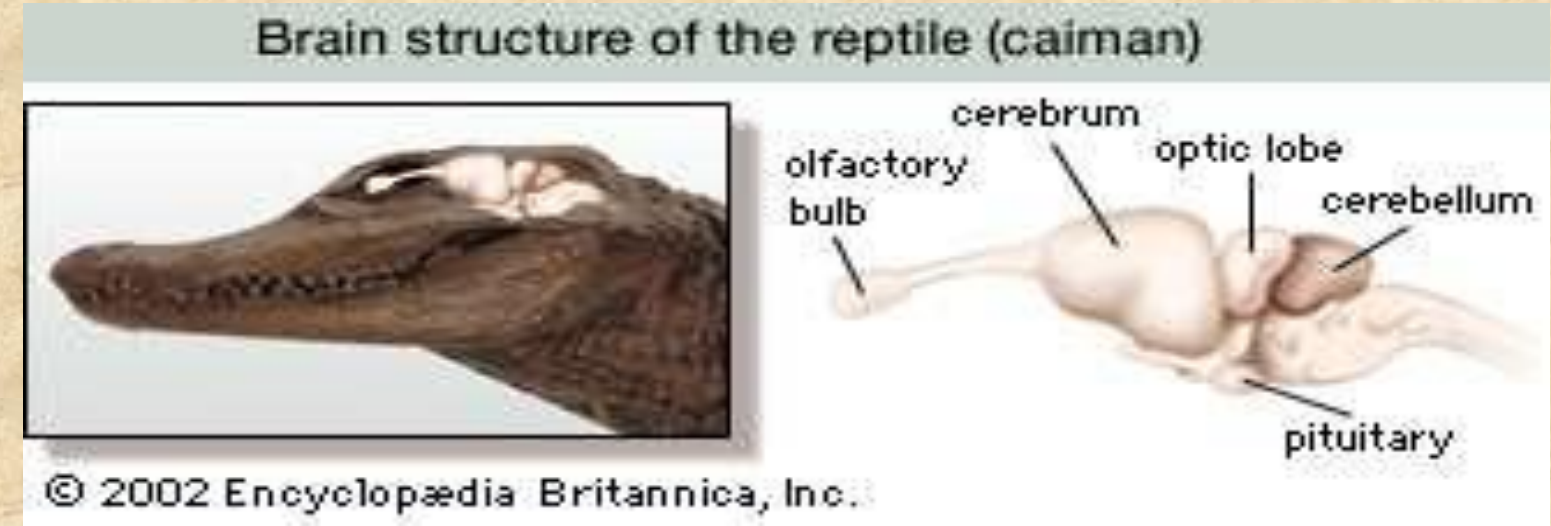


In **amphibians:** 1) the volume of the forebrain increases; 2) the endbrain divide into 2 hemispheres; 3) nervous tissue appears in the brain roof; 4) striated bodies are well developed. Olfactory lobes are separated from the hemispheres. The interbrain is presented by the thalamus and hypothalamus. The midbrain is large and still serves as the integrating center. The cerebellum is poorly developed. The medulla oblongata is developed same as in fish. There are 10 pairs of cranial nerves.



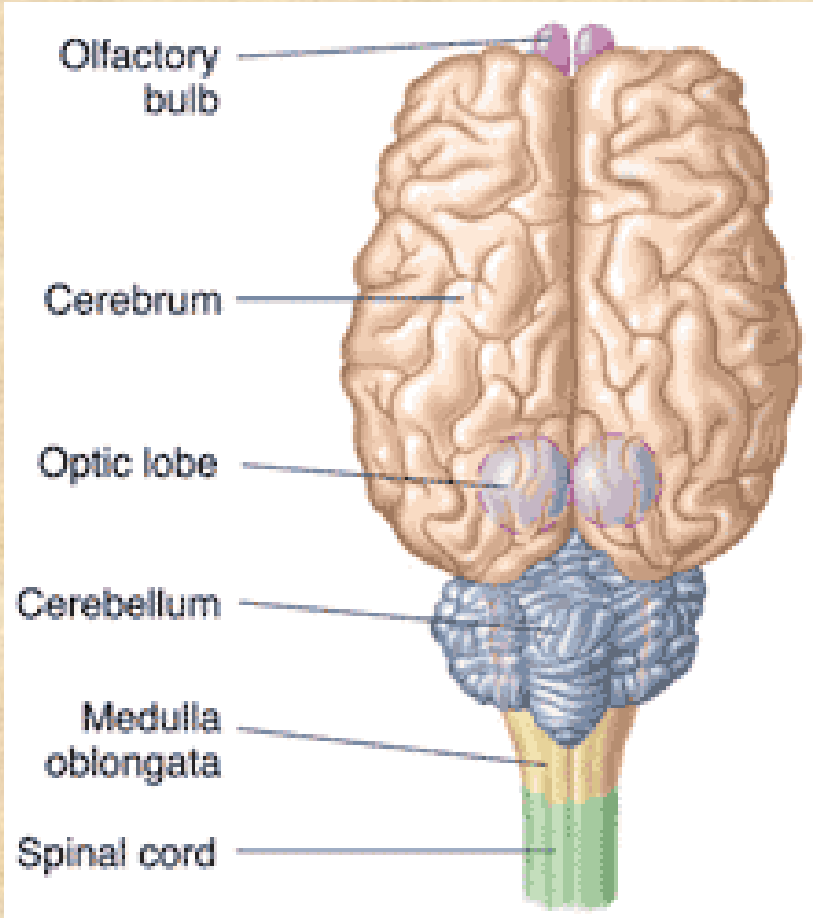


In **reptiles** the forebrain is the largest brain region. Large olfactory lobes are differentiated, parietal lobes are separated. Hemispheres of the brain have primordial cortex on their lateral surfaces. The structure of the cortex is primitive (3 layers of cells) — *archipallium*. The striated bodies of the forebrain is the integrating center. Such type of the brain is called *sauropsidian (striatal)*. The size of the midbrain is diminished (it is no longer the integrating center of the brain). The cerebellum is considerably larger. The medulla oblongata forms a sharp flexure in the vertical plane. There are 12 pairs of cranial nerves.

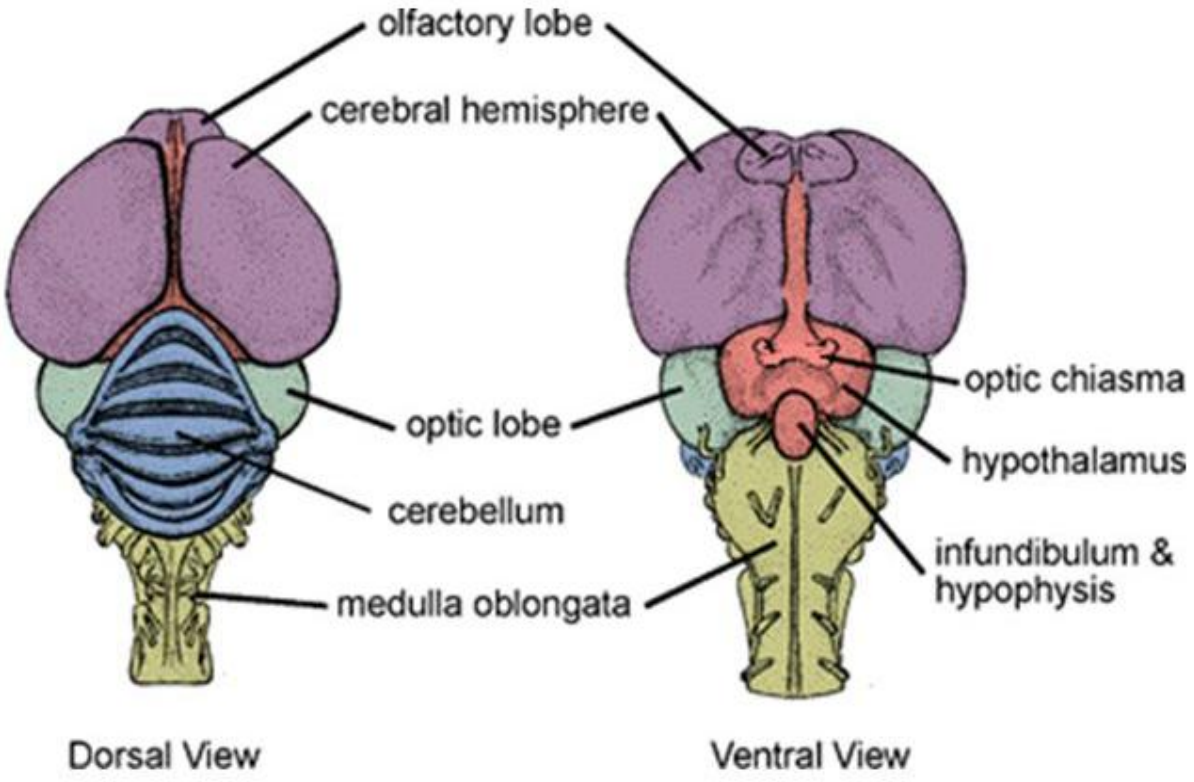


In **mammals** the forebrain reaches maximal development due to the secondary cortex (*neopallium*). In lower mammals the surface of the cortex is smooth, in higher mammals it has sulci and gyri. The secondary cortex is an integrating center (mammalian type of the brain). The forebrain covers the intermediate brain. The size of the midbrain decrease.

This region consists of quadrigemina (2 superior colliculi are subcortical centers of vision, 2 inferior colliculi are subcortical centers of hearing).



The cerebellum is considerably larger. It is differentiated into two hemispheres with the vermis in the middle. The brain has 12 cranial nerves. There are 3 flexures of the brain: 1) cephalic flexure at the level of the midbrain, 2) cervical flexure in the region where the medulla oblongata passes into the spinal cord, 3) pontine flexure in the area of the hindbrain.



Ontophylogenetic etiology of brain malformations (causes are recapitulations): anencephaly, rachischisis, undifferentiation of hemispheres, incomplete separation of hemispheres of the telencephalon (prosencephalia); ichthyopsidian or sauropsidian types of the brain, oligogyria, pachygyria, agyria.

Rachischisis: failure of neurulation; i.e., the neural tube does not close

Rachischisis: spinal cord
Cranioschisis: brain

Craniorachischisis: brain & cord

Phylogenesis of the digestive system of chordates

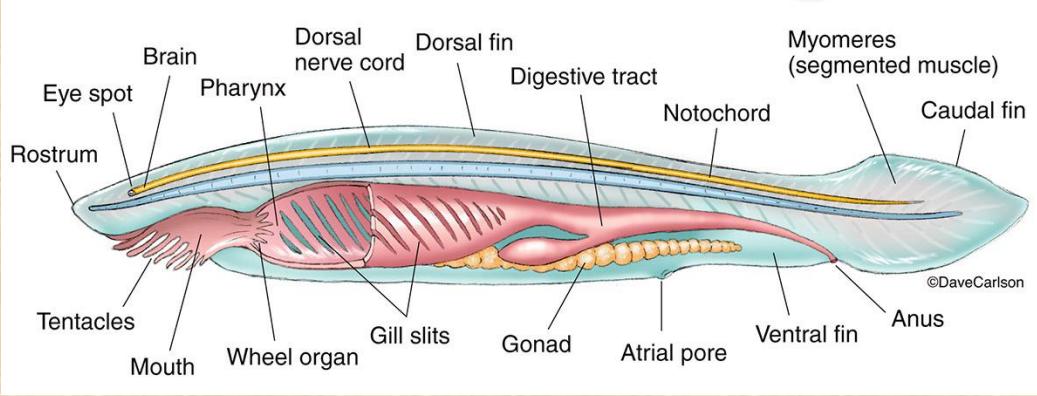
The digestive system originate from the entoderm, its beginning and ending regions develop from the ectoderm.

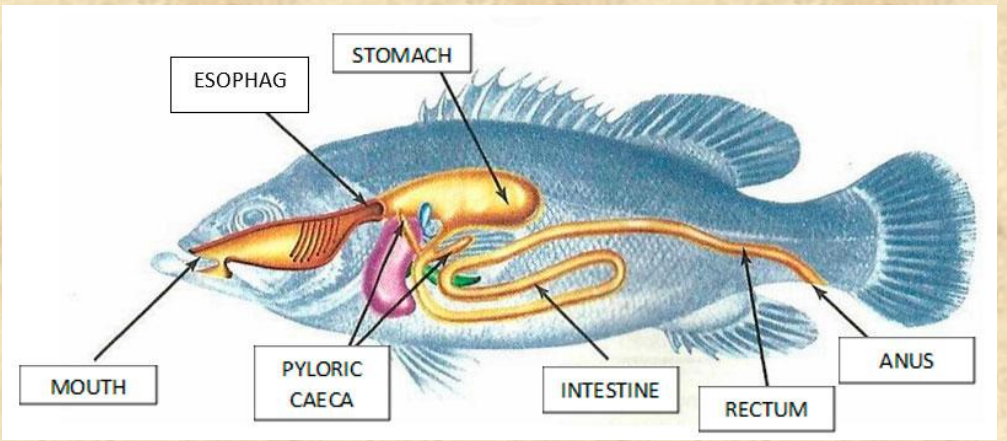
Basic directions of evolution:

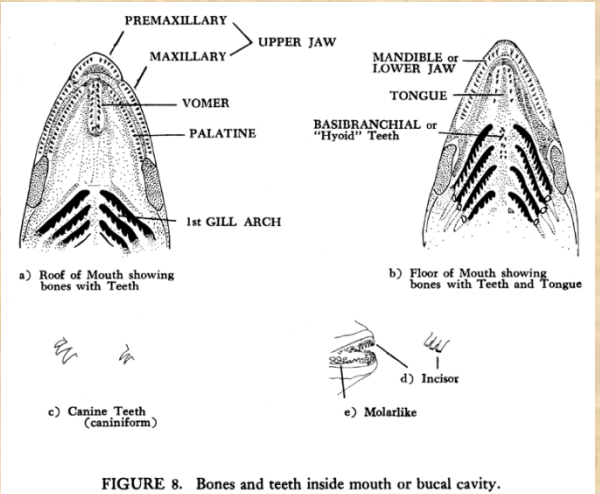
1. Differentiation of the alimentary tube into regions.
2. Appearance of digestive glands.
3. Appearance of teeth and their differentiation.
4. Enlargement of the absorption surface due to the elongation of the intestine and appearance of villi.

Lancelet's digestive system is presented by a straight tube that is differentiated into a pharynx and intestine. The pharynx has gill slits. The alimentary tube forms a hepatic cecum.

Fishes have jaws with homogenous teeth (homodontous animals). There are an esophagus, stomach, small and large intestines. The liver is well developed; there is a gallbladder. The pancreas is differentiated poorly.

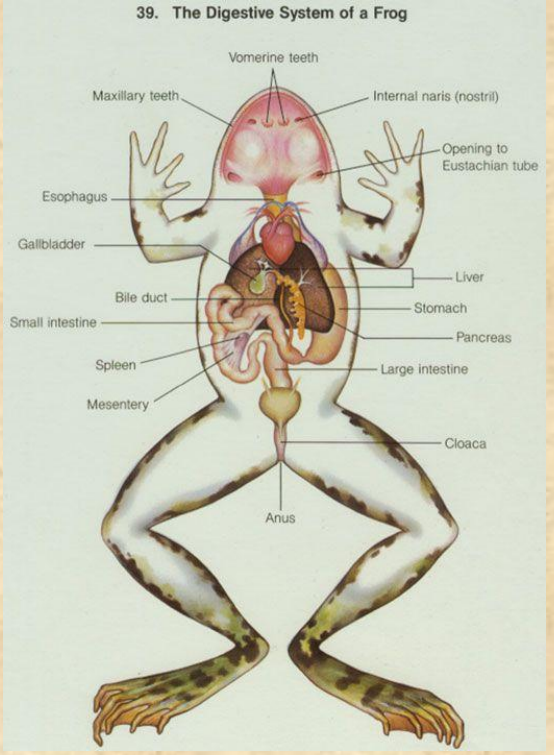






Amphibians have an oropharyngeal cavity with homogenous teeth, esophagus, stomach, small and large intestine, liver, pancreas. A muscular tongue and salivary glands appear. There are no enzymes in saliva. Amphibians have a duodenum and rectum. The intestine ends with a cloaca.

Reptiles has an oral cavity that is separated from the pharynx, walls of the stomach are thick. There is a primordial cecum, the intestine becomes longer and ends with a cloaca.



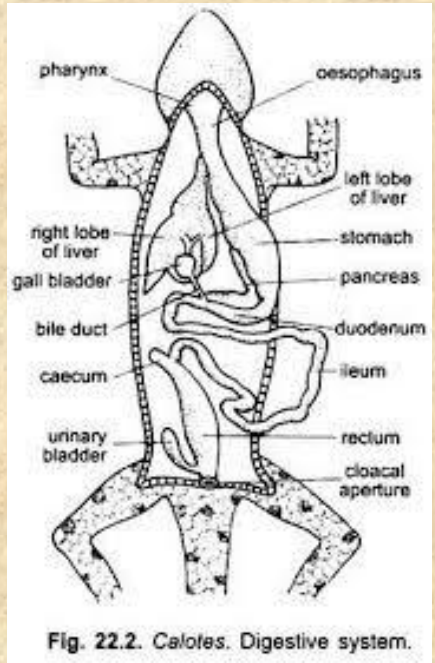
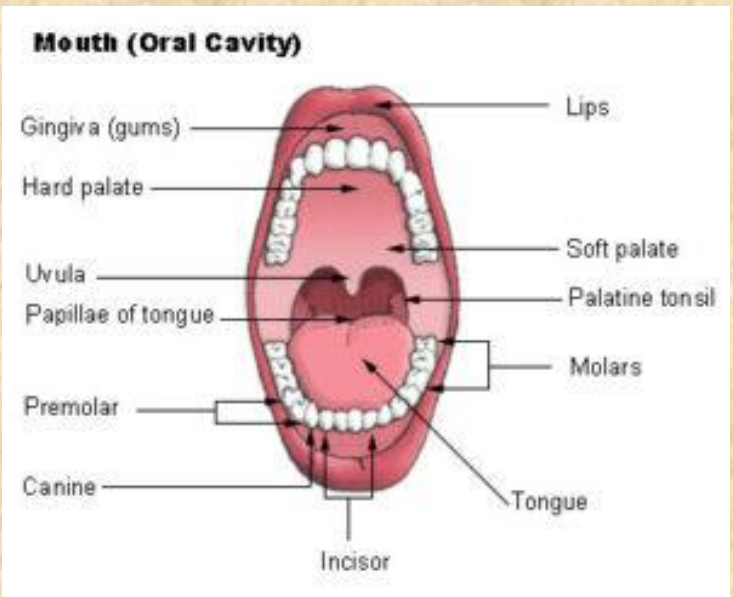
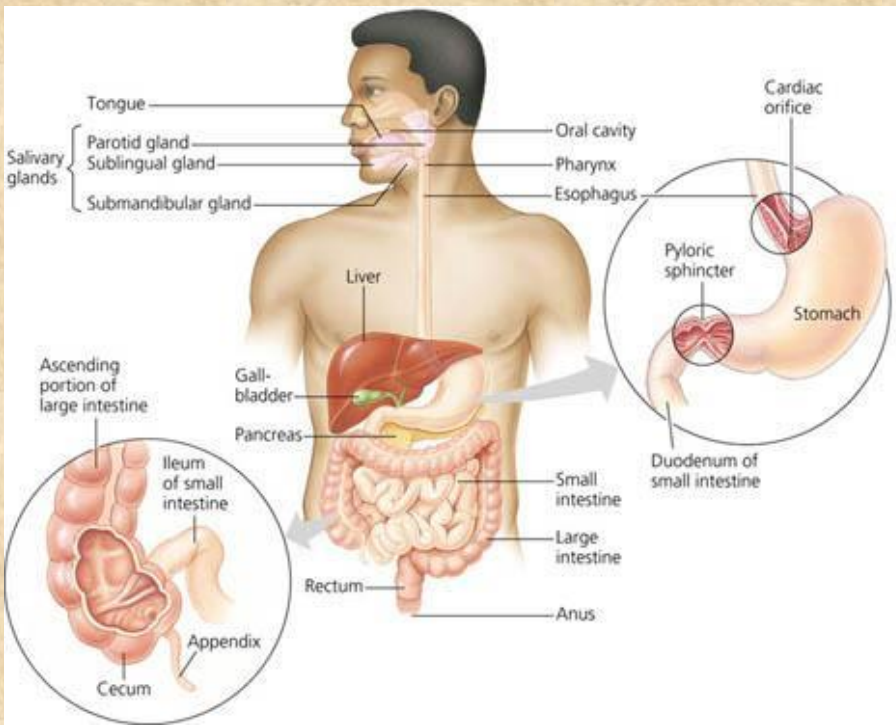
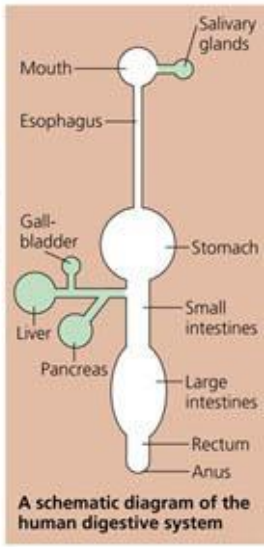


Fig. 22.2. *Calotes*. Digestive system.

Mammals are heterodonts (have incisors, canines and molars); lips appeared. The saliva contains enzymes. The intestine is differentiated into a small and large intestine, the caecum is well developed and has an appendix. The rectum ends with an anal opening. The mucous membrane of the intestine has a great number of folds, the small intestine has villi.







Ontophyloigenetic etiology of malformations of the digestive system: homodontous teeth, extra teeth, tricuspid structure of molars, forked tongue, cervical fistulae (rupture gill pouch), aplasia and hypoplasia, additional lobes of the liver and pancreas, shortening of the intestine, heterotopy of pancreatic tissue in the wall of the small intestine or stomach, persistence of the cloaca.

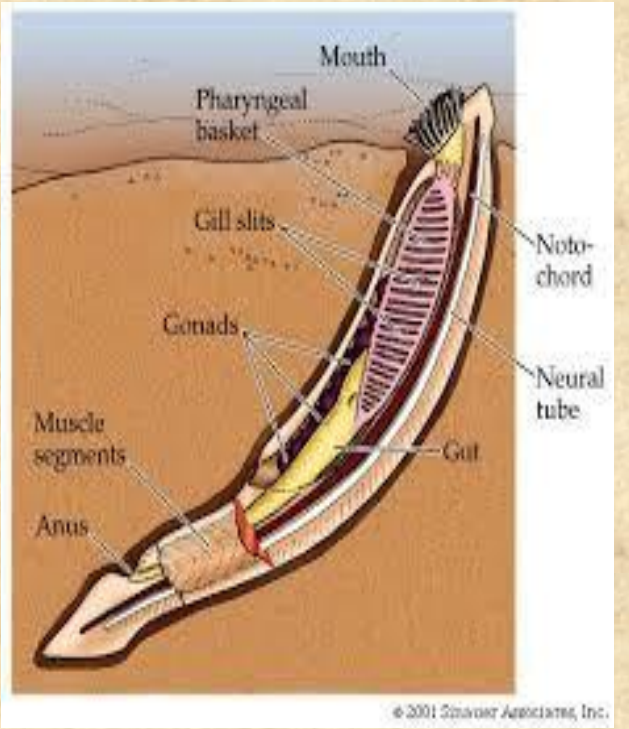
Phylogenesis of the respiratory system of chordates

The respiratory system has an entodermal origin.

Basic directions of evolution of the respiratory system:

1. Transformation of interbranchial septa of lancelets into the gill apparatus of fishes.
2. Enlargement of the respiratory surface due to gill filaments; formation of gill capillaries.
3. Transformation of the gill apparatus into terrestrial respiratory organs (lungs).
4. Development and differentiation of respiratory tract, formation of a bronchial tree.
5. Enlargement of the respiratory surface of the lungs; formation of the chest and appearance of the diaphragm.

A **lancelet** has 100–150 pairs of interbranchial septa piercing the pharynx and gas exchange takes place in their vessels. These are afferent branchial artery and efferent branchial artery. There are no branchial capillaries. Water enters through the mouth into the throat, passes through the gill slits, in the gill arteries there is gas exchange. The blood is saturated with oxygen and carries it to the organs.



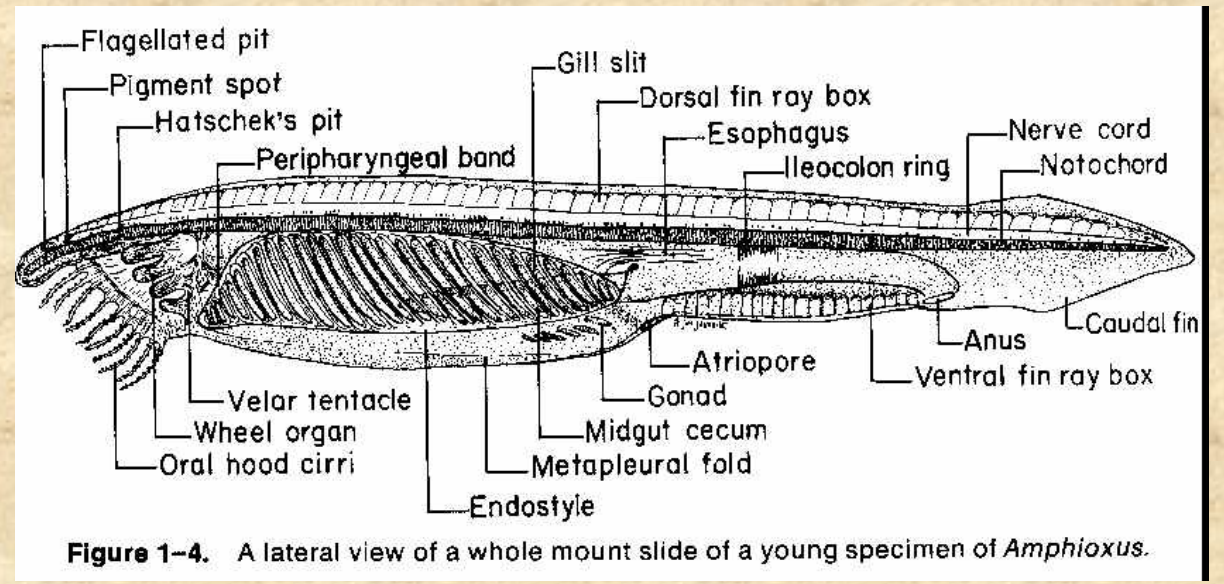
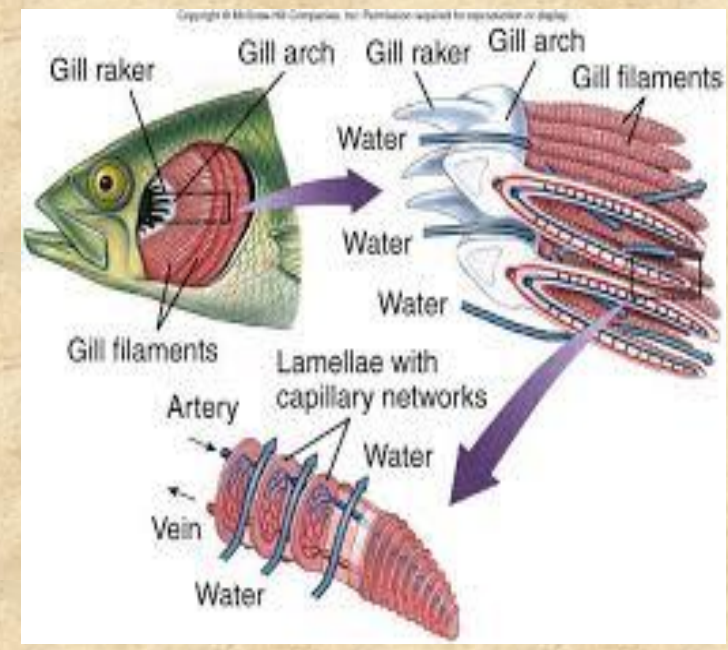


Figure 1–4. A lateral view of a whole mount slide of a young specimen of *Amphioxus.*

Fishes have branchiae (gills) in the anterior part of the pharynx. Gas exchange takes place in the capillaries of gill filaments. *Crossopterygians* acquired organs able to breath with air – paired outgrowth of the pharyngeal wall at the abdominal side. They are anlages of lungs of terrestrial vertebrates.



Anura amphibians have a laryngotracheal chamber, in caudate amphibians it separates into the larynx and trachea; arytenoid cartilages and vocal folds appear in the pharynx. Anurans have septa in the lungs. The lungs of caudates are presented by two thin-walled sacs without septa. Ventilation of the lungs is low and skin participates in respiration.

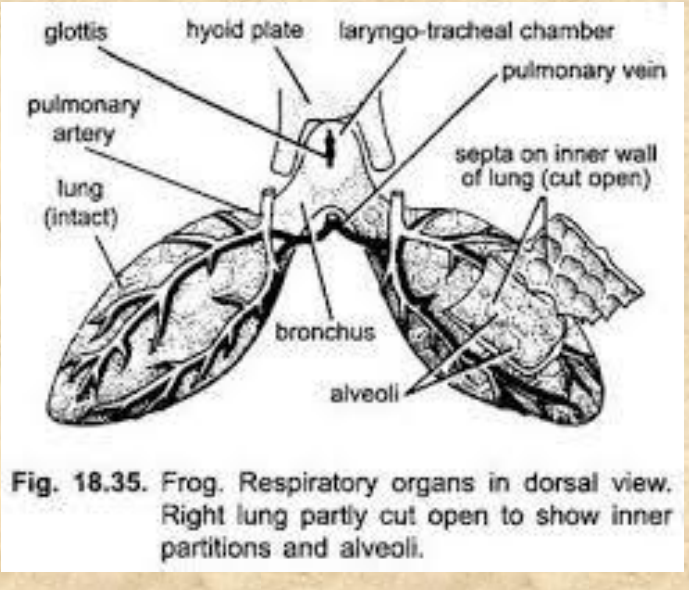
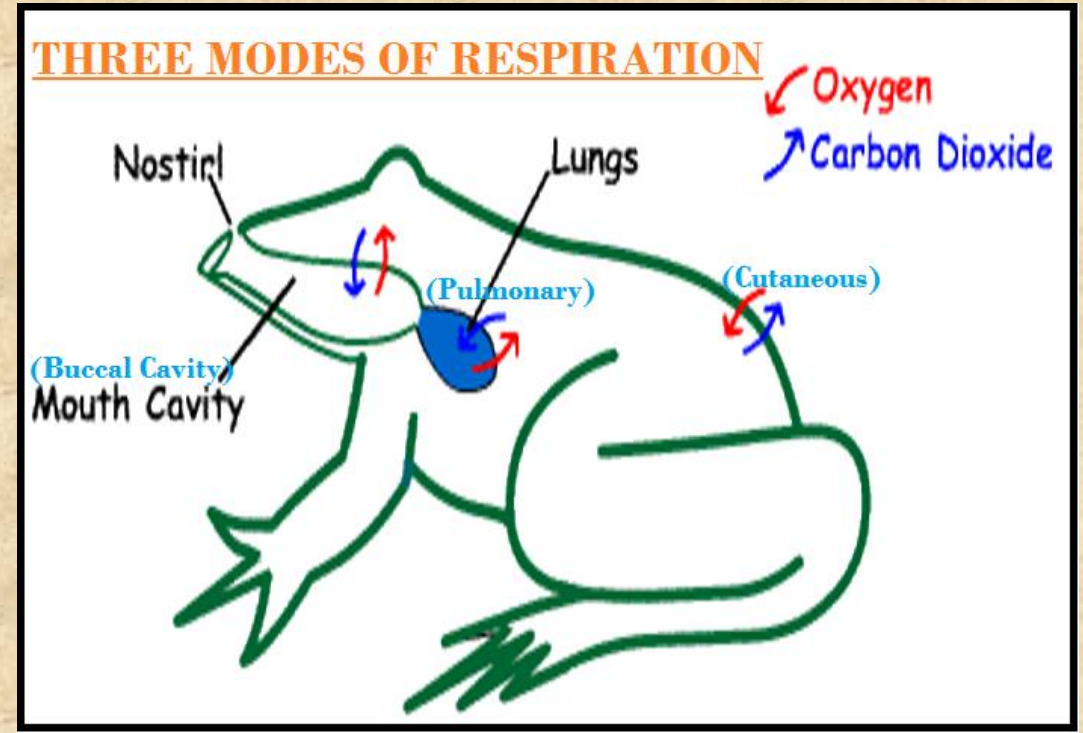
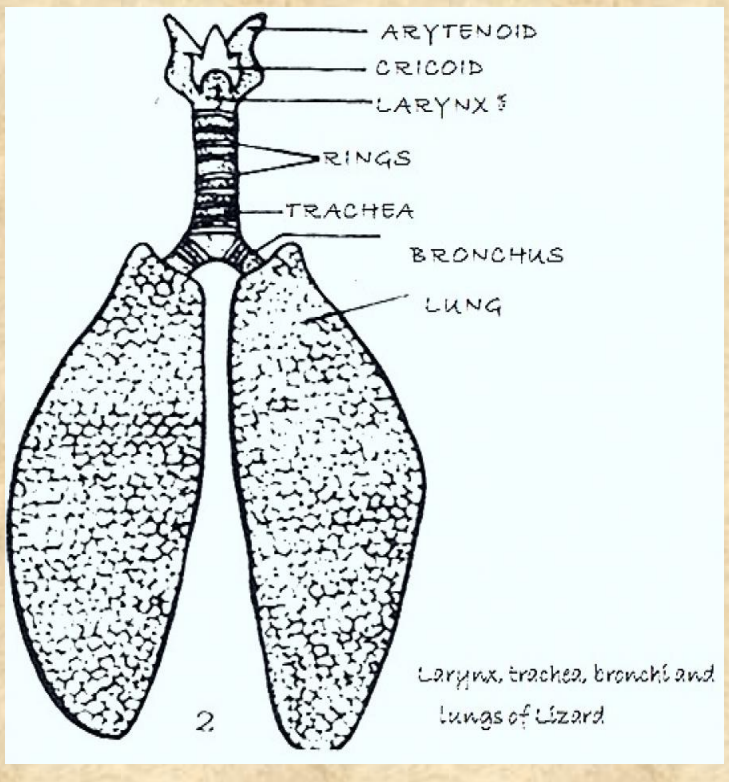
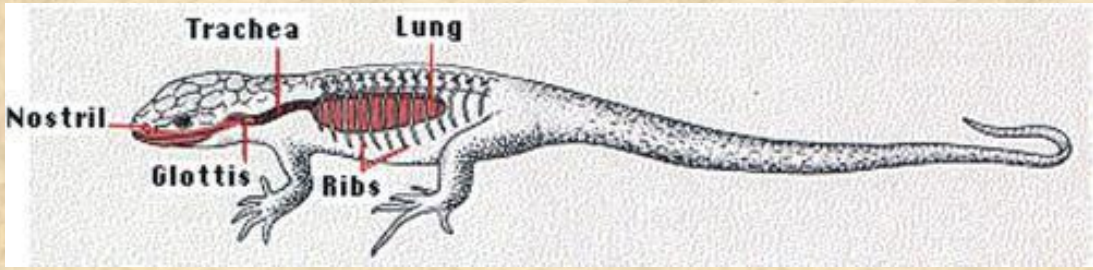


Fig. 18.35. Frog. Respiratory organs in dorsal view. Right lung partly cut open to show inner partitions and alveoli.

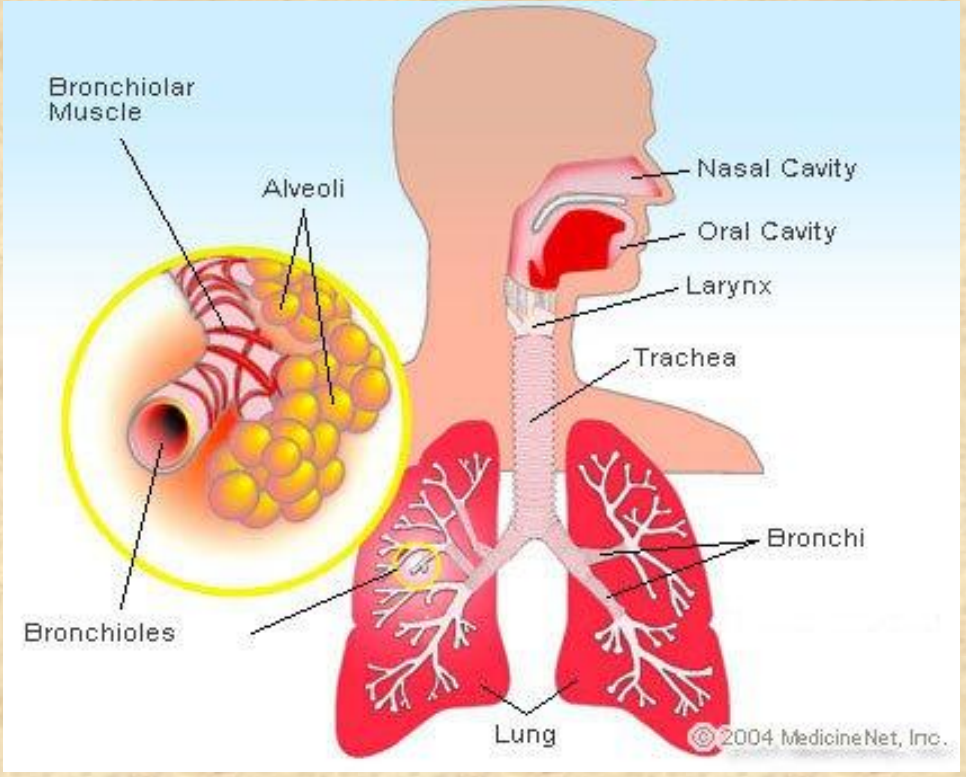


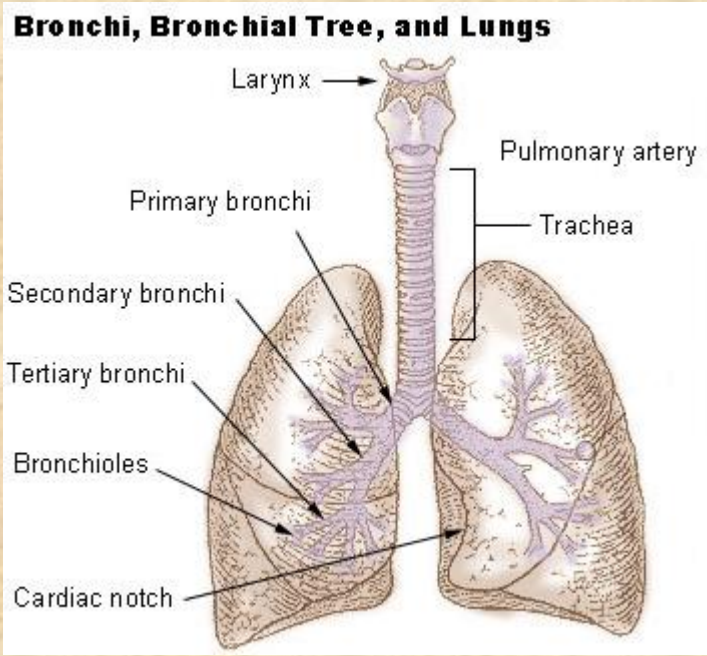
In **reptiles** the respiratory surface of the lungs is increased by honeycomb shaped structures alveoli with blood vessels. There are extrapulmonary bronchi; cricoid cartilage appears in the pharynx, cartilaginous rings appear in the trachea. There is a chest. Ribs are movably connected to the spine and breastbone, there are intercostal muscles.





In **mammals** appear the nasal cavity, nasopharynx. Thyroid cartilage appear in the larynx. Bronchial tree is formed. Bronchioles and alveoli considerably increase the respiratory surface (the number of alveoli is up to 500 million). The chest is separated from the abdominal cavity by the diaphragm and takes part in respiration.



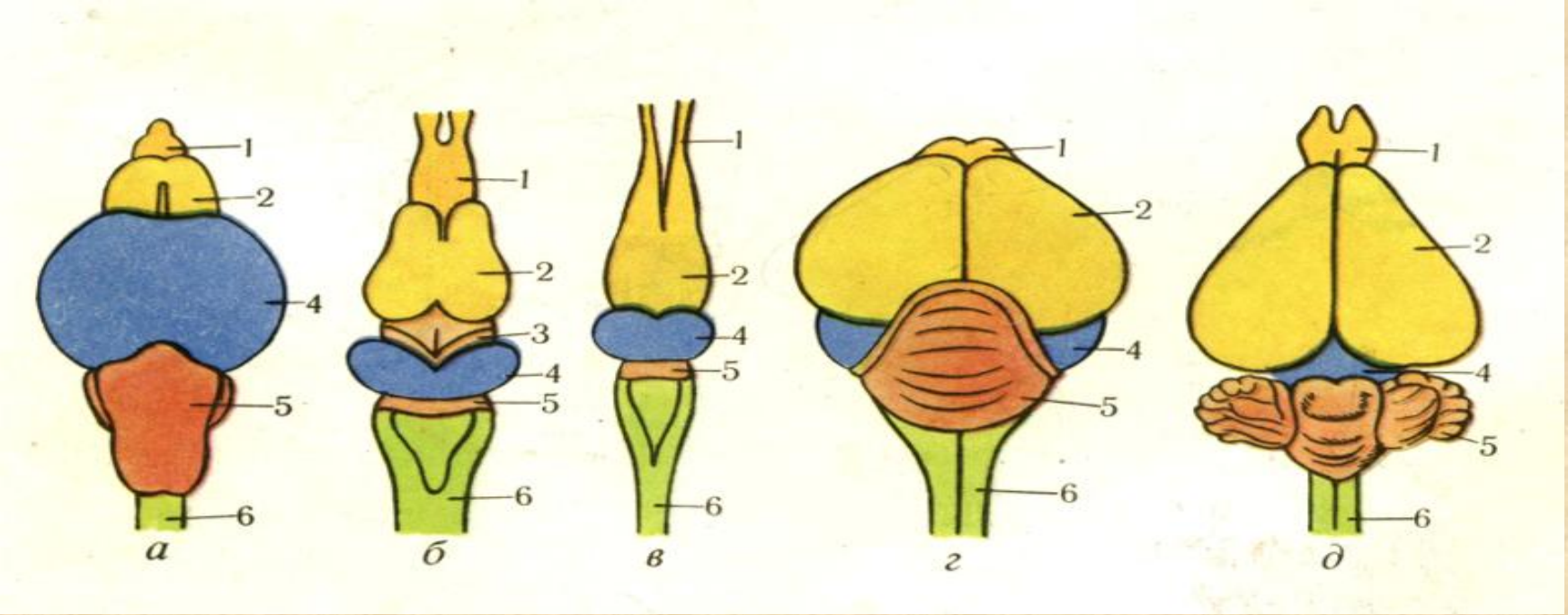


Ontophylogenetic etiology of malformations of the respiratory system: underdevelopment of the pharynx or lungs, esophagotracheal fistula, cystic lung hypoplasia, abnormal branching of bronchi, hypoplasia of the diaphragm, etc.

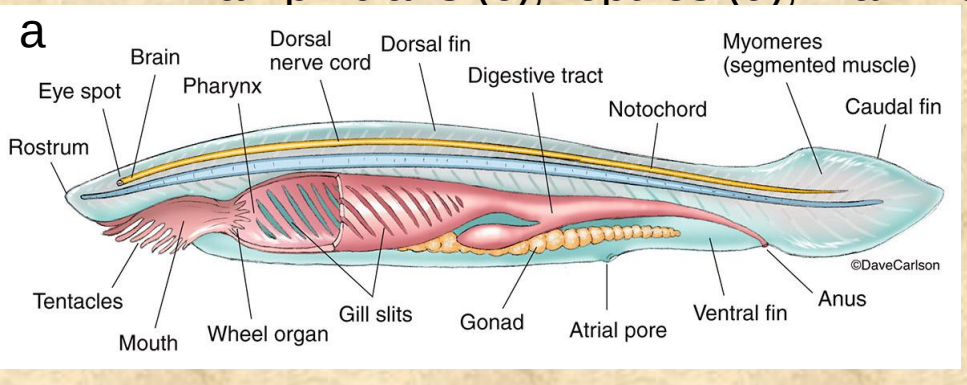
Draw in your drawing books:

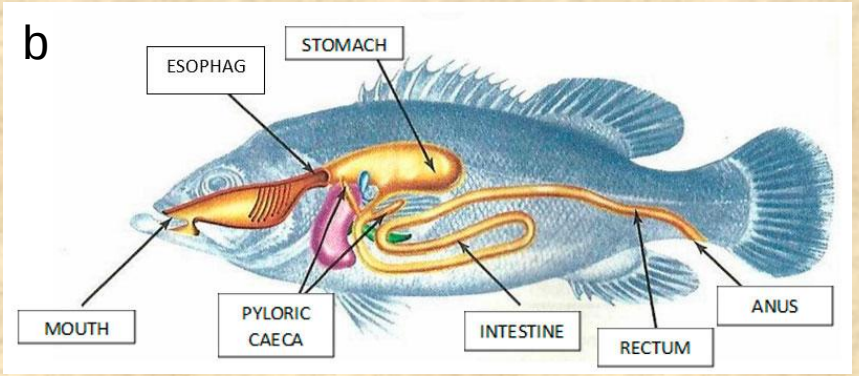
1. A diagram of the structure of the brain of fish (*а*), amphibians (*б*), reptiles (*в*), mammals (*д*). Designate:

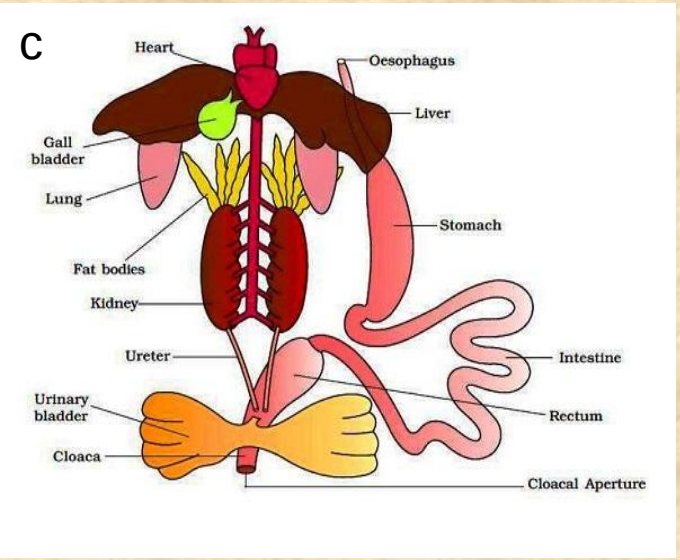
1 – olfactory lobes, 2 – forebrain, 3 – diencephalon, 4 - midbrain, 5 – cerebellum, 6 – medulla oblongata



2. A diagram of the structure of the digestive system of lancelet (a), fish (b), amphibians (c), reptiles (d), mammals (e).







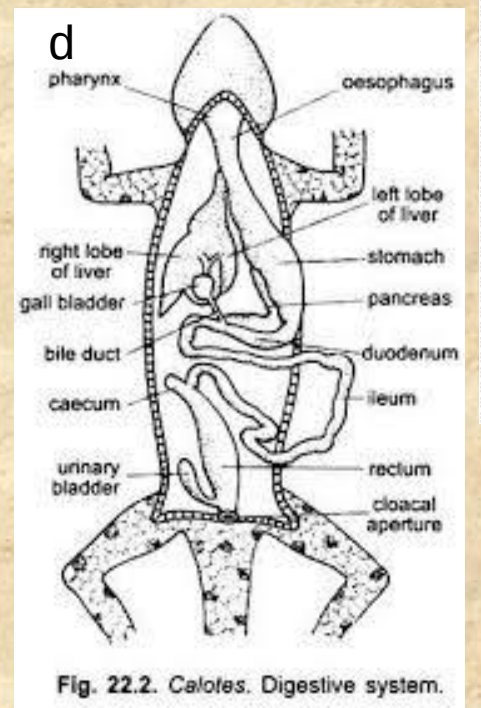
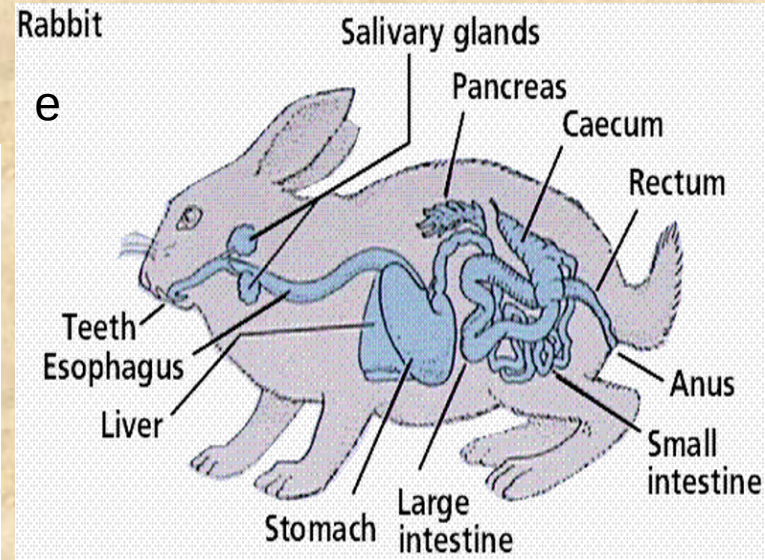
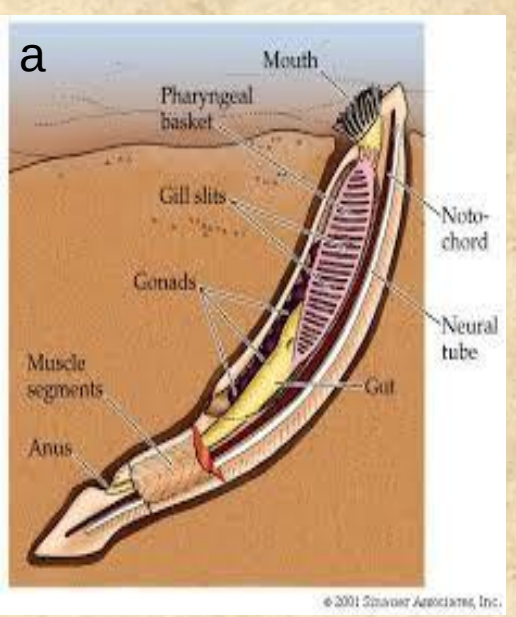
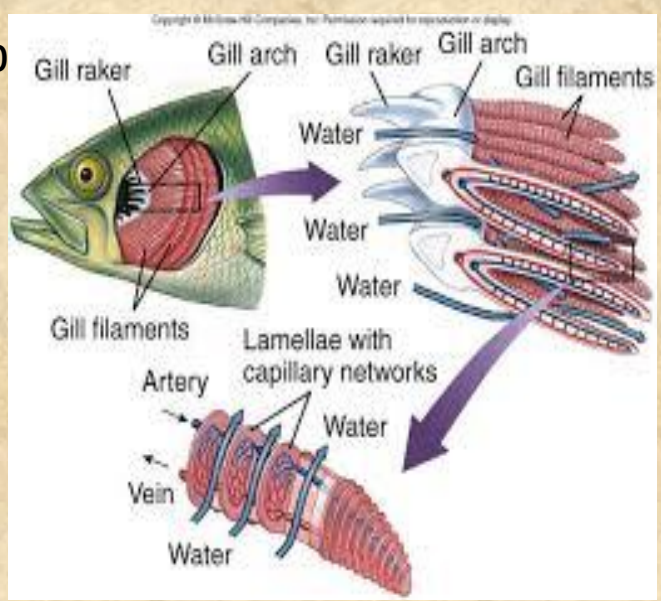


Fig. 22.2. *Calotes*. Digestive system.



A diagram of the structure of the respiratory organs of lancelet (a), fish (b), amphibians (c), reptiles (d), mammals (e).





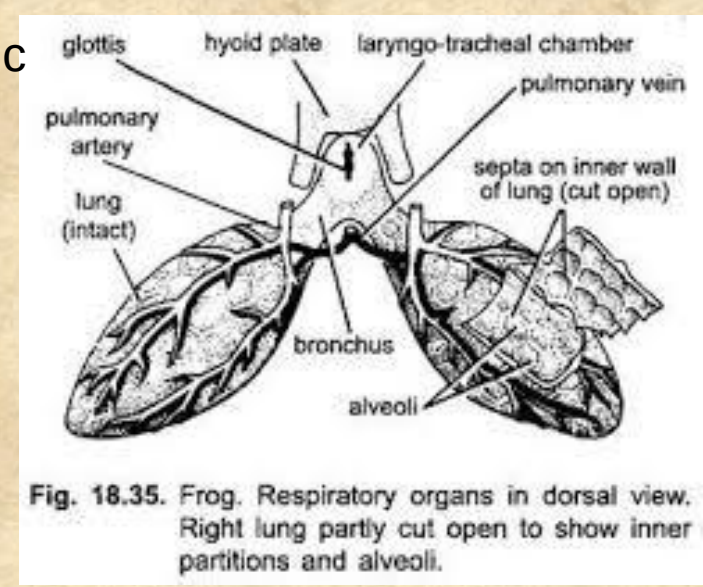


Fig. 18.35. Frog. Respiratory organs in dorsal view. Right lung partly cut open to show inner partitions and alveoli.