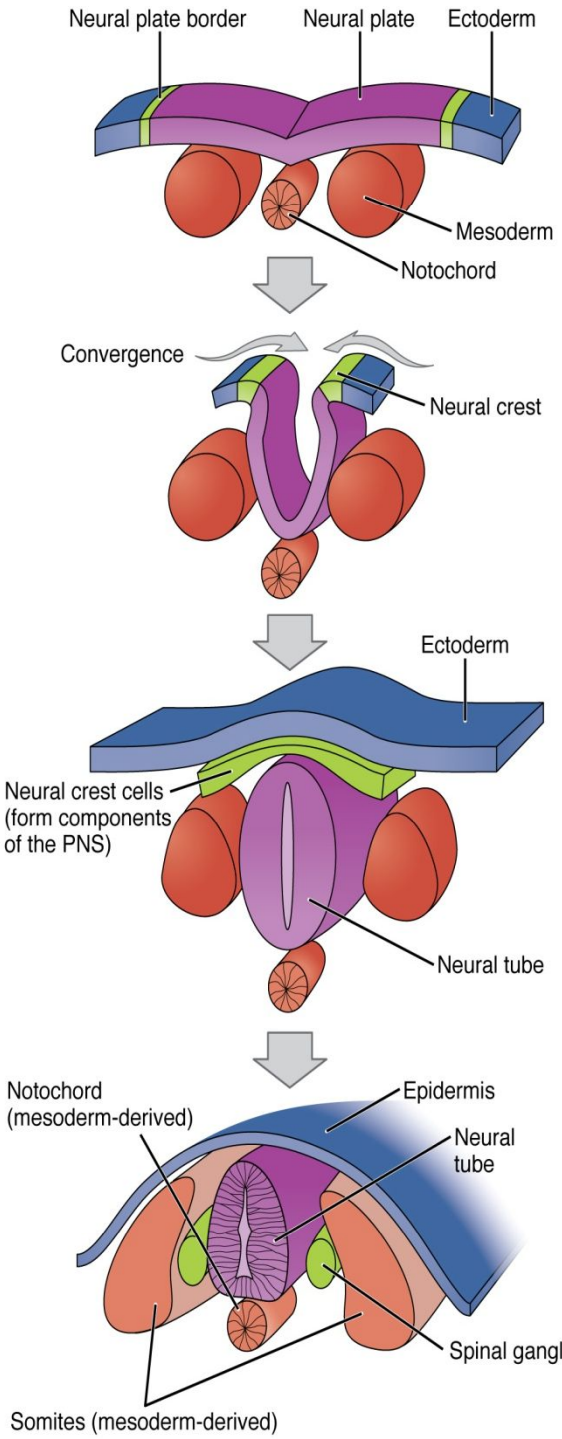
FROG BRAIN DEVELOPMENT

- 0 hours - fertilization of the egg
- 1 hours - formation of the gray crescent due to pigment migration
- 3.5 hours - early cleavage
- 4.5 hours - blastula stage(coeloblastula with eccentric blastocoel
- 26 hours - gastrulation
  - 26 hours - early crescent shaped dorsal lip
  - 34 hours middle semicircular blastoporal lip
  - 42 hours late circular blastoporal lip
- 50 hours - neurulation
  - 50 hours - early medullary plate
  - 62 hours - middle neural folds converging
  - 67 hours - late neural tube formed and ciliation of embryo

- **84 hours** - tail bud stage(early organogeny)
- **96 hours** - muscular response to tactile stimulation
- **118 hours** - early heart beat, development of gill buds
- **140 hours** - hatching and gill circulation
- **162 hours** - mouth opens and cornea becomes transparent
- **192 hours** - tail fin circulation established
- **216 hours** - degeneration of external gills, formation of operculum, development of embryonic teeth
- **240 hours** - opercular fold over brachial chamber except for spiracle and internal gills
- **255 hours** - prolonged larval stage with refinement of organs
- **270 hours** - development of hindlimbs, internal development of forelimbs in opercular cavity
- **275 hours** - projection of forelimbs through operculum, left side first
- **280 hours** - absorption of the tail and reduction in size of the gut
- **284 hours** - metamorphosis complete, emergence from water as miniature, air breathing frog

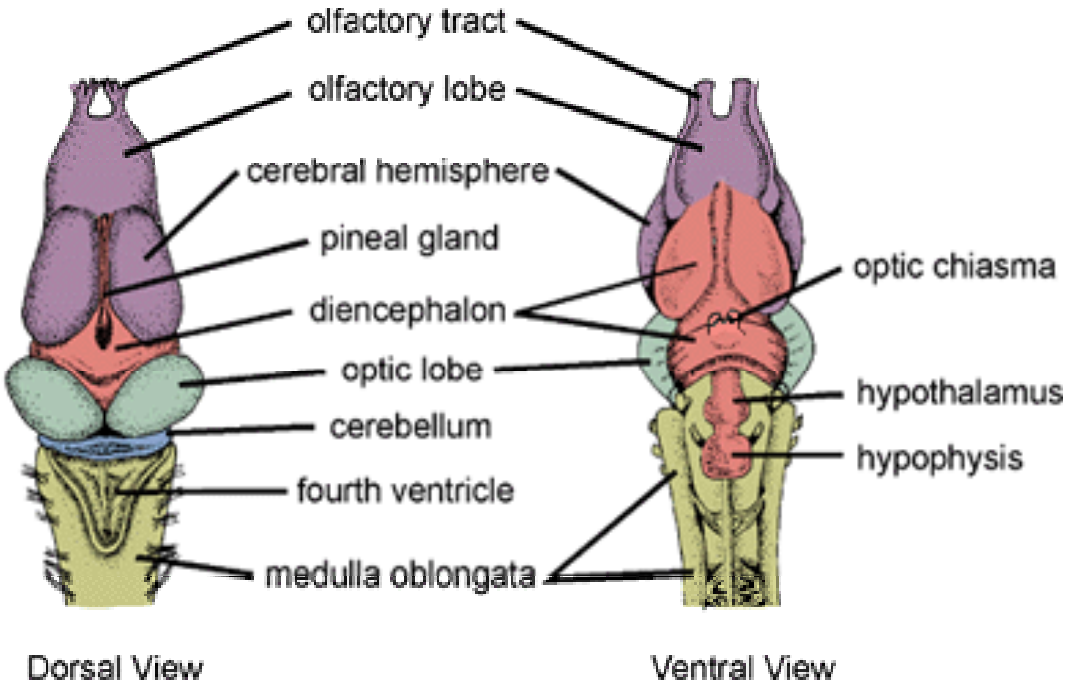


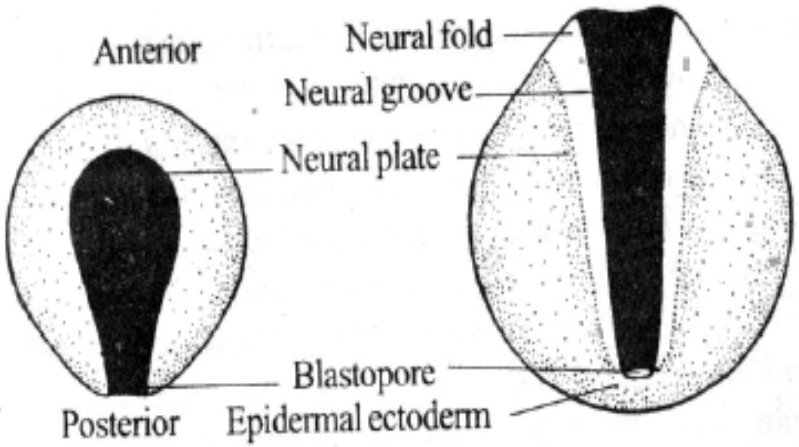
(1) Neuroectodermal tissues differentiate from the ectoderm and thicken into the neural plate. The neural plate border separates the ectoderm from the neural plate.

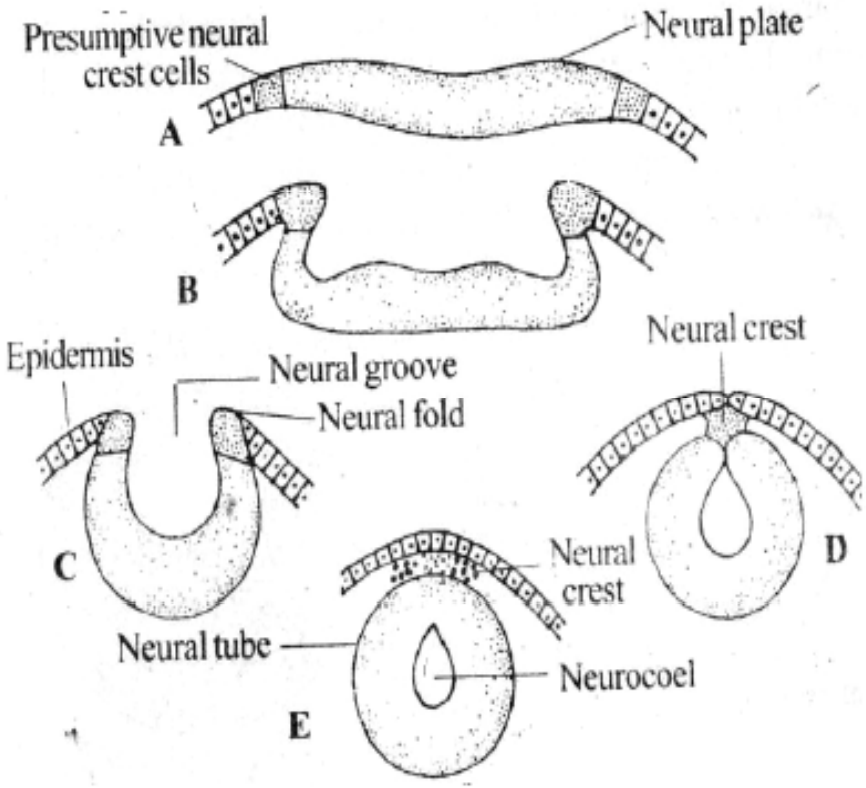
(2) The neural plate bends dorsally, with the two ends eventually joining at the neural plate borders, which are now referred to as the neural crest.

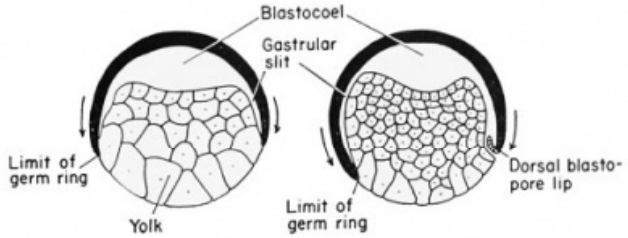
(3) The closure of the neural tube disconnects the neural crest from the epidermis. Neural crest cells differentiate to form most of the peripheral nervous system.

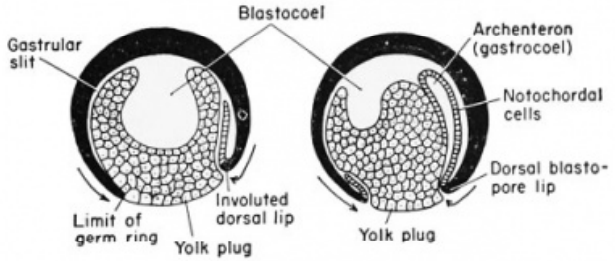
(4) The notochord degenerates and only persists as the nucleus pulposus of the intervertebral discs. Other mesoderm cells differentiate into the somites, the precursors of the axial skeleton and skeletal muscle.

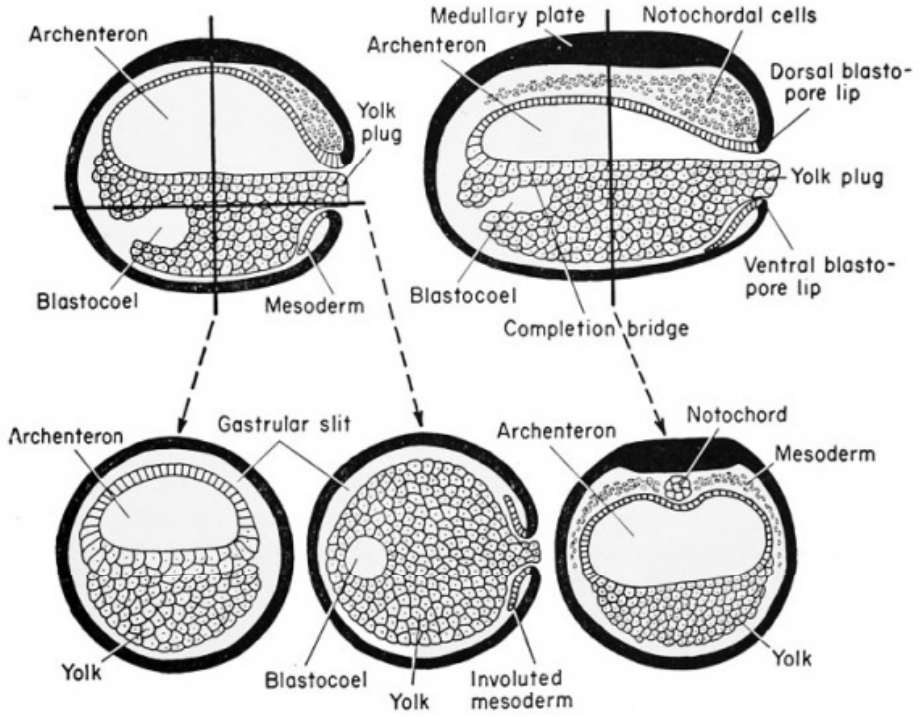

olfactory tract
olfactory lobe
cerebral hemisphere
pineal gland
diencephalon
optic lobe
cerebellum
fourth ventricle
medulla oblongata
optic chiasma
hypothalamus
hypophysis
Dorsal View
Ventral View

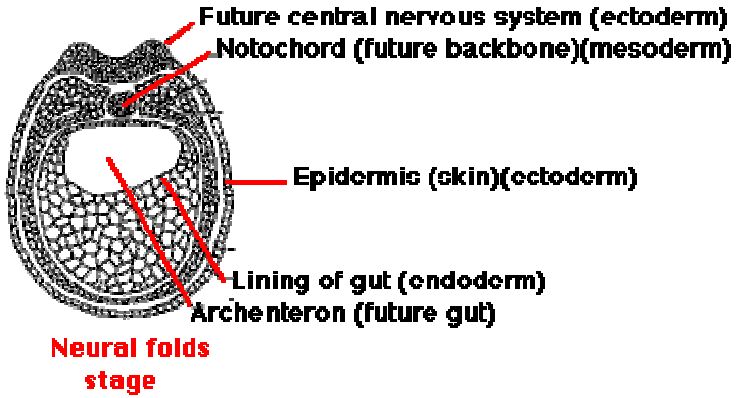

Anterior
Neural fold
Neural groove
Neural plate
Blastopore
Posterior
Epidermal ectoderm

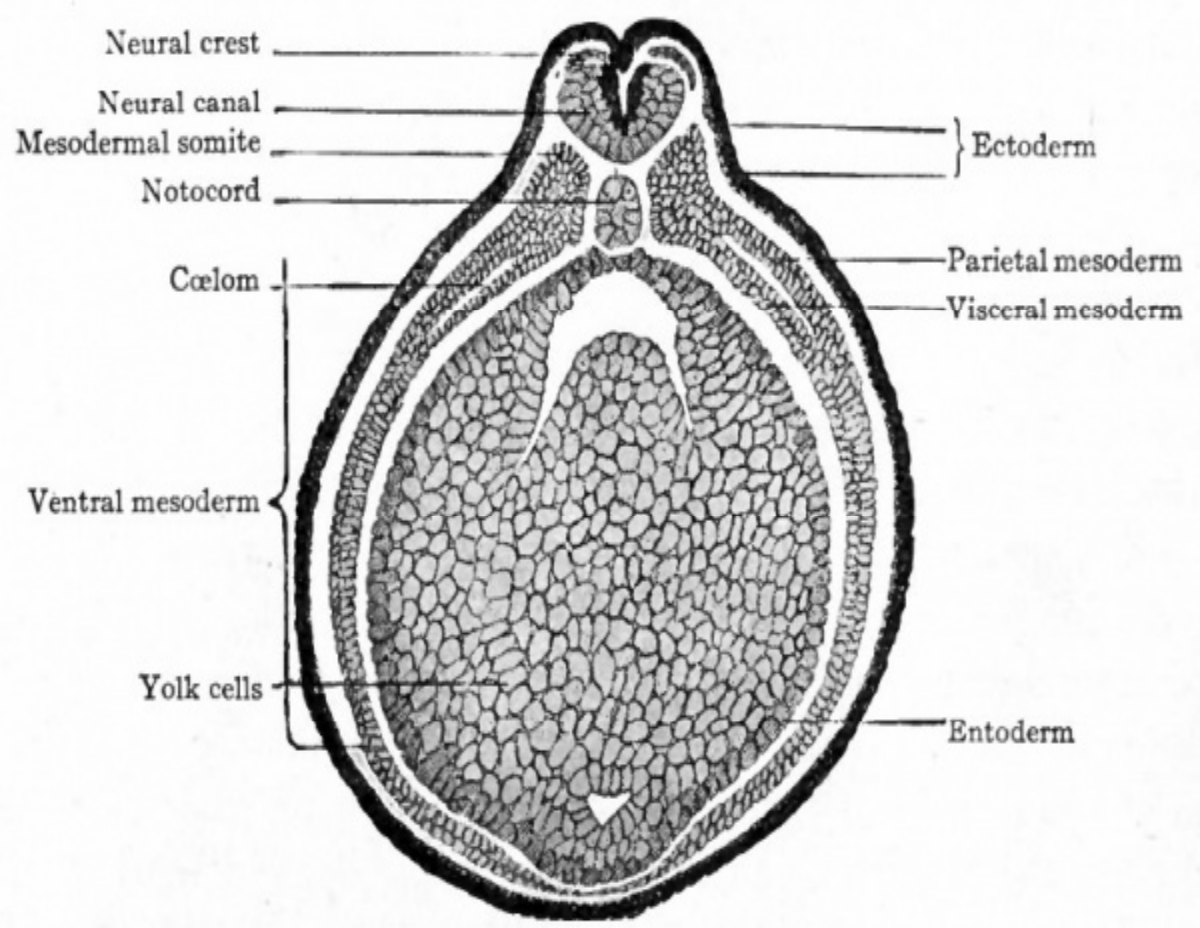

Presumptive neural crest cells
Neural plate
A
B
Epidermis
Neural groove
Neural fold
Neural crest
C
D
Neural crest
Neural tube
Neurocoel
E


Blastocoel
Gastrular slit
Limit of germ ring
Yolk
Limit of germ ring
Dorsal blasto-pore lip


Blastocoel
Gastrular slit
Archenteron (gastrocoel)
Notochordal cells
Dorsal blasto-pore lip
Involuted dorsal lip
Limit of germ ring
Yolk plug
Yolk plug

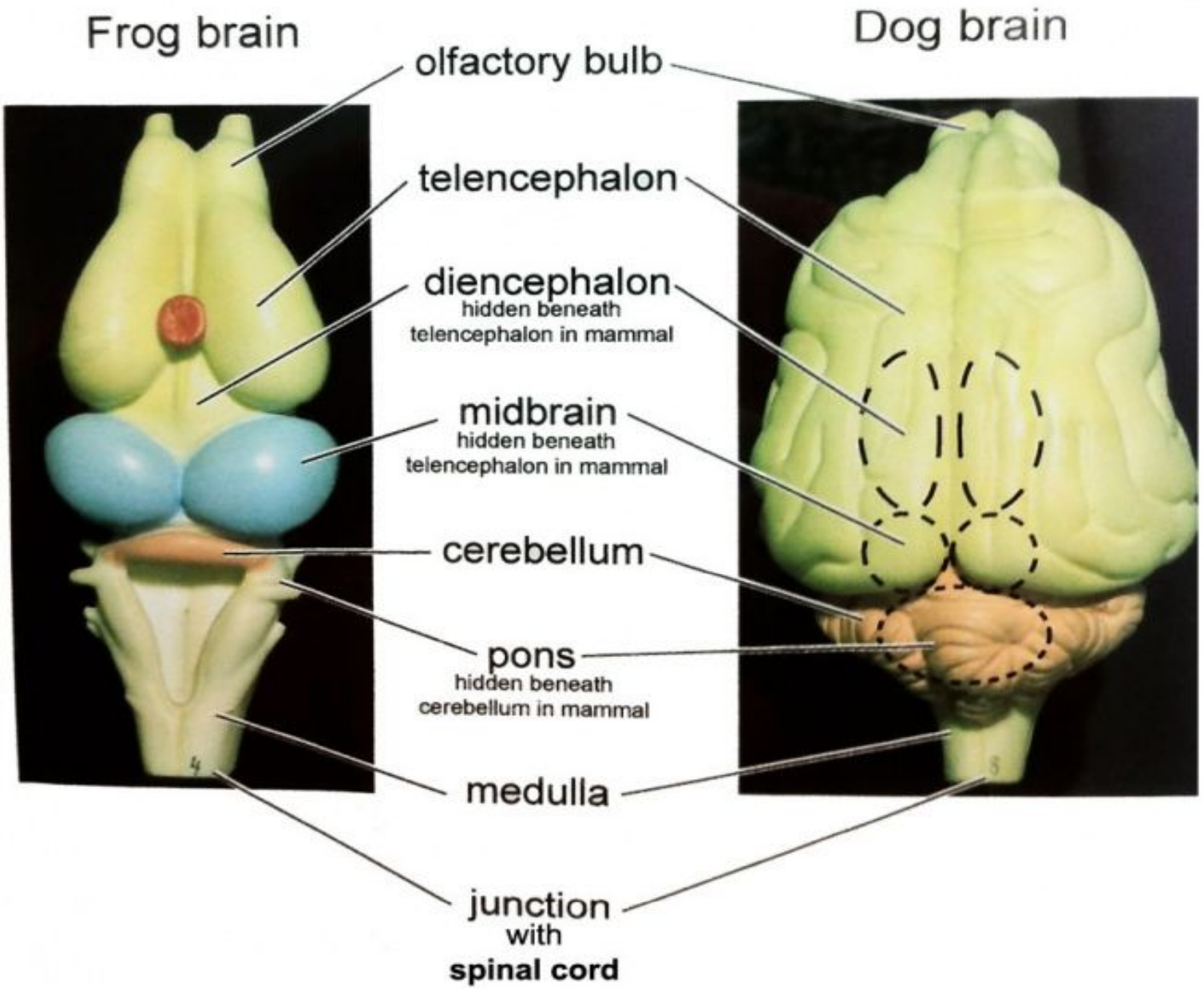

Archenteron
Yolk plug
Blastocoel
Mesoderm
Medullary plate
Notochordal cells
Archenteron
Dorsal blasto-pore lip
Yolk plug
Ventral blasto-pore lip
Blastocoel
Completion bridge
Archenteron
Gastrular slit
Yolk
Blastocoel
Yolk
Involuted mesoderm
Archenteron
Notochord
Mesoderm
Yolk

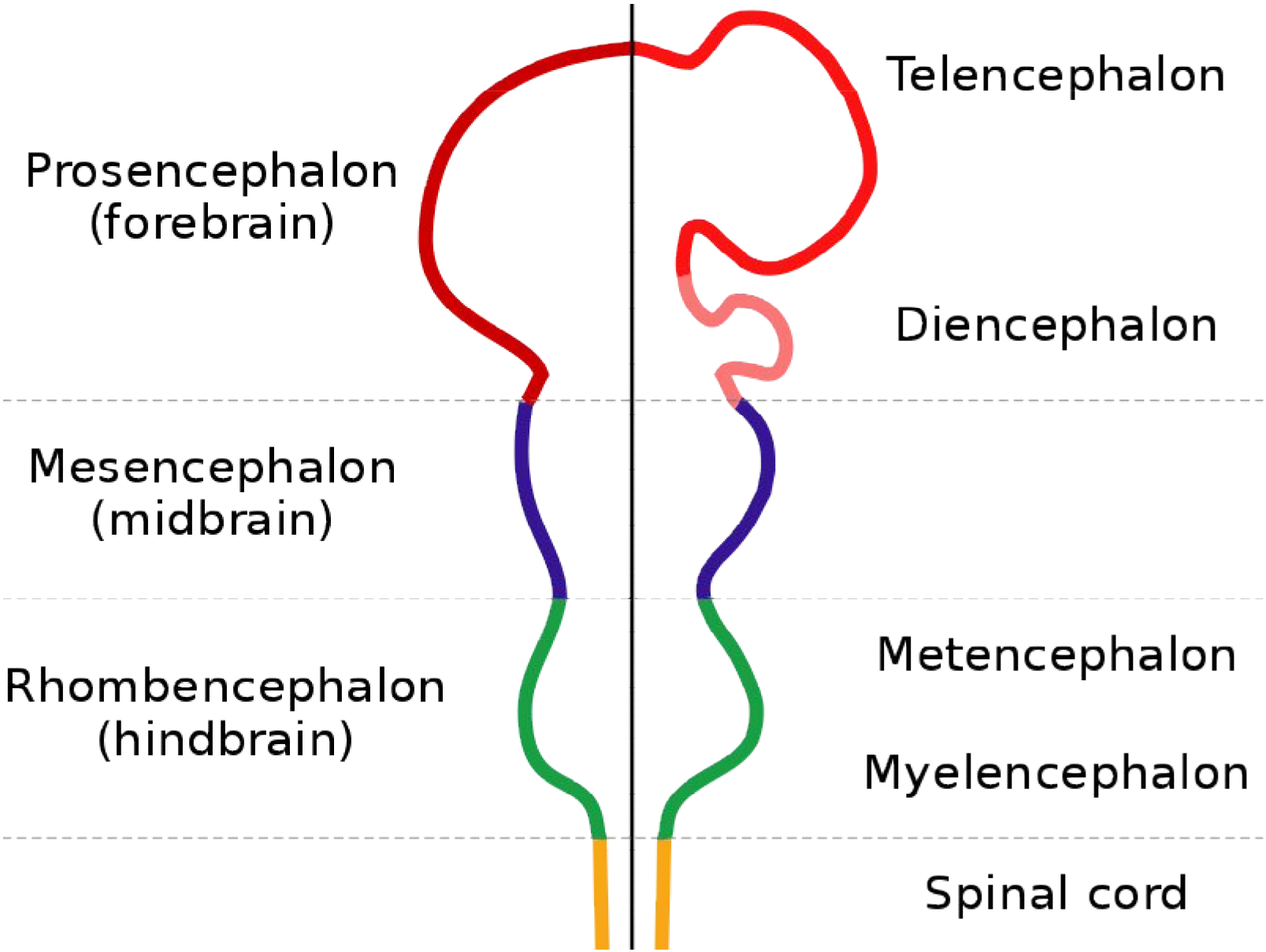

Future central nervous system (ectoderm)
Notochord (future backbone)(mesoderm)
Epidermis (skin)(ectoderm)
Lining of gut (endoderm)
Archenteron (future gut)
Neural folds stage

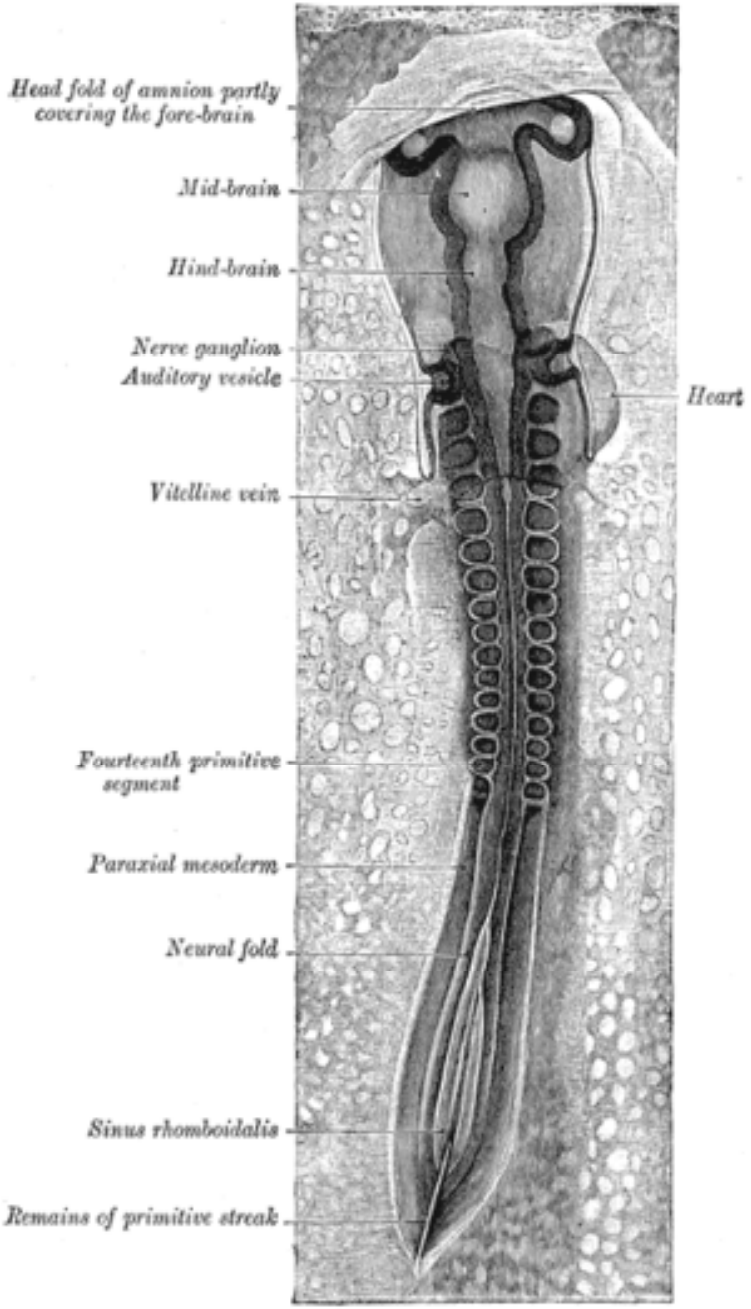

Neural crest
Neural canal
Mesodermal somite
Notocord
Cœlom
Ventral mesoderm
Yolk cells
Ectoderm
Parietal mesoderm
Visceral mesoderm
Entoderm

Forebrain or prosencephalon is the rostral-most (forward-most) portion of the brain. The forebrain, the midbrain (mesencephalon), and hindbrain (rhombencephalon) are the three primary portions of the brain during early development of the central nervous system.

At the five-vesicle stage, the forebrain separates into the diencephalon (thalamus, hypothalamus, subthalamus, epithalamus, and pretectum) and the telencephalon which develops into the cerebrum. The cerebrum consists of the cerebral cortex, underlying white matter, and the basal ganglia.


Frog brain
Dog brain
olfactory bulb
telencephalon
diencephalon
hidden beneath
telencephalon in mammal
midbrain
hidden beneath
telencephalon in mammal
cerebellum
pons
hidden beneath
cerebellum in mammal
medulla
junction
with
spinal cord


Telencephalon
Prosencephalon
(forebrain)
Diencephalon
Mesencephalon
(midbrain)
Metencephalon
Rhombencephalon
(hindbrain)
Myelencephalon
Spinal cord


Head fold of amnion partly covering the fore-brain
Mid-brain
Hind-brain
Nerve ganglion
Auditory vesicle
Vitelline vein
Fourteenth primitive segment
Paraxial mesoderm
Neural fold
Sinus rhomboidalis
Remains of primitive streak
Heart

The anterior part of neural tube is distinguished as encephalon which develops into various parts of the brain through thickening, thinning, evagination and invagination.

The primary embryonic brain of the frog has three main subdivisions called prosencephalon (forebrain), mesencephalon (midbrain) and rhombencephalon (hindbrain). The cavities of three primary divisions are known as prosocoel, mesocoel and rhombocoel.

Prosencephalon

- The prosencephalon becomes further subdivided into two regions, the telencephalon and the diencephalon.
- At the posterior limit of prosencephalon the brain bends ventrally around the anterior end of the notochord to form cranial flexure which remains as a prominent feature of brain of vertebrates.
- The area of cranial flexure thickens to develop the tuberculum posterius that marks the posterior limt of forebrain ventrally.

- **The most anterior division of the forebrain is the telencephalon with its original cavity, the telocoel.**
- **The anterior limit of telencephalon is the lamina terminalis which will separate the future cerebral hemispheres by a longitudinal groove.**
- **Actually, the lamina terminalis represents the anterior fused neuroporal area.**

- **The telencephalon is the embryonic cerebrum. Its cavity expands laterally to give rise to the right (first) and left (second) lateral ventricles and the surrounding thick-walled cerebral hemispheres, at about the 12 mm. stage.**
- **These ventricles are laterally compressed. In the frog the cerebral hemispheres are first differentiated at the 7 mm. stage but never become very large.**
- **The two telencephalic vesicles are partially constricted off from each other but remain connected by way of the tubular foramen of Monro, which opens into the common (intermediate) third ventricle.**
- **The third ventricle overlaps and connects the telocoel and the diocoel.**

- **The roof of the cerebral lobes thickens to give rise to cortex or pallium and the floor and sides of which form the corpora striata.**
- **The olfactory lobes arise as a pair of evaginations from the anteroventral part of telencephalon.**
- **Subsequently, they become fused medially. The nerves originating from the olfactory lobes innervate the nasal epithelium or olfactory placode.**
- **The ventricle enclosed by the olfactory lobe is called olfactocoel.**

Diencephalon (Thalamencephalon or Between-brain).

- The structural derivatives of this diencephalon include the posterior commissure, just anterior to the dorsal limit of the mesencephalon. Anterior to this is the epiphyseal recess, and the dorso-medial saccular outgrowth known as the epiphysis.
- This continues to grow forward and becomes separated from the brain as a small knob of cells which remain in the adult as the brow spot.
- It is presumably homologous to the pineal gland of higher vertebrates.

- **The optic vesicles begin to develop very early as ventro-lateral outgrowths of the diocoel.**
- **The expansion of the diocoel provides a temporary and slight thinning of the walls of the optic vesicles.**
- **However, as these vesicles make contact with the lateral head ectoderm, that portion of the vesicle in contact begins to thicken and then invaginate to form a 2-layered optic cup.**
- **The most lateral and invaginated portion of the cup will become the retina, the medial layer will become the pigmented layer of the eye, and the connecting and somewhat constricted tube the optic stalk.**
- **The nervous elements of this optic stalk will join in the optic chiasma which contains the optic nerve fiber tracts from the two sides.**
- **The stalk will develop around an inverted groove (the choroid fissure) which will contain, within the groove, accessory nerves and blood vessels which feed the retina.**

Mesencephalon(Midbrain)

- **This portion of the brain functions largely as a pathway of nerve tracts between theanterior prosencephalon and the posterior rhombencephalon.**
- **These tracts are found principally within the paired ventro-lateral thickenings of the walls and floor on either side of the tuberculum posterius.**
- **They are known as the crura cerebri.**
- **The original dorsal thickening becomes subdivided by a median fissure into paired dorsolateral thickenings. These are known as the optic lobes or corpora bigeniina.**

- They do not reach their full development until the time of metamorphosis.
- Anterior to these lobes is the posterior commissure.
- From the posterior limits of the mesencephalon and optic lobes may be seen the valvulae cerebelli and the fourth pair of cranial nerves (trochlear) which emerge from the dorso lateral wall.
- The original cavity of the midbrain (mesocoel) connects the rhombocoel (fourth ventricle) with the third ventricle which becomes narrow and is known as the aqueduct of Sylvius.

Rhombencephalon (Hindbrain)

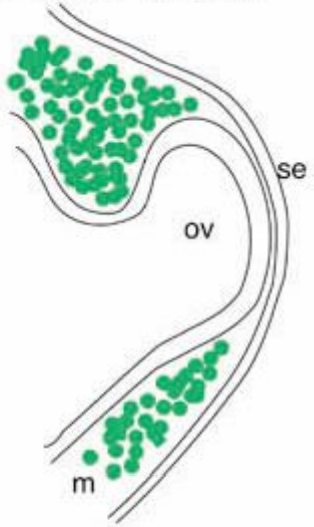
- **This portion of the brain is clearly marked off from the mesencephalon by a transverse constriction in the roof of the brain, at the posterior limit of the dorsal thickening.**
- **It is not clearly divided farther. There appears a slight transverse thickening in the roof of the rhombencephalon which corresponds to the metencephalon of higher forms and develops into the small cerebellum.**
- **Posterior to this the roof becomes broad, thin, and vascular, and folds into the rhombocoel (fourth ventricle) as the posterior choroid plexus.**

- **The ventral and ventro lateral walls of the rhombencephalon are known as the medulla oblongata from which arise the cranial nerves V to X inclusive.**
- **The walls become thickened by fibers which form numerous pathways from the brain and cord.**
- **The rhombocoel or cavity of the hindbrain is known as the communicates posteriorly with the central canal of the spinal cord and anteriorly with the aqueduct of Sylvius of the mesencephalon.**
-

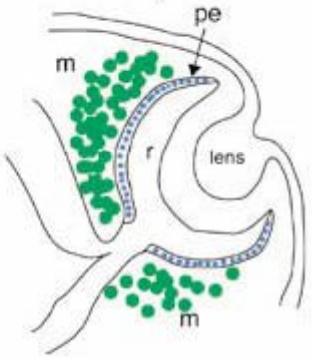
Development of Eye

- **The eye is a photoreceptor. It is an ectodermal derivative.**
- **Its development begins even at the gastrulation stage.**
- **However the first sign of eye formation appears with the development of two optic vesicles from the lateral walls of the embryonic diencephalon.**

Isolate optic vesicle



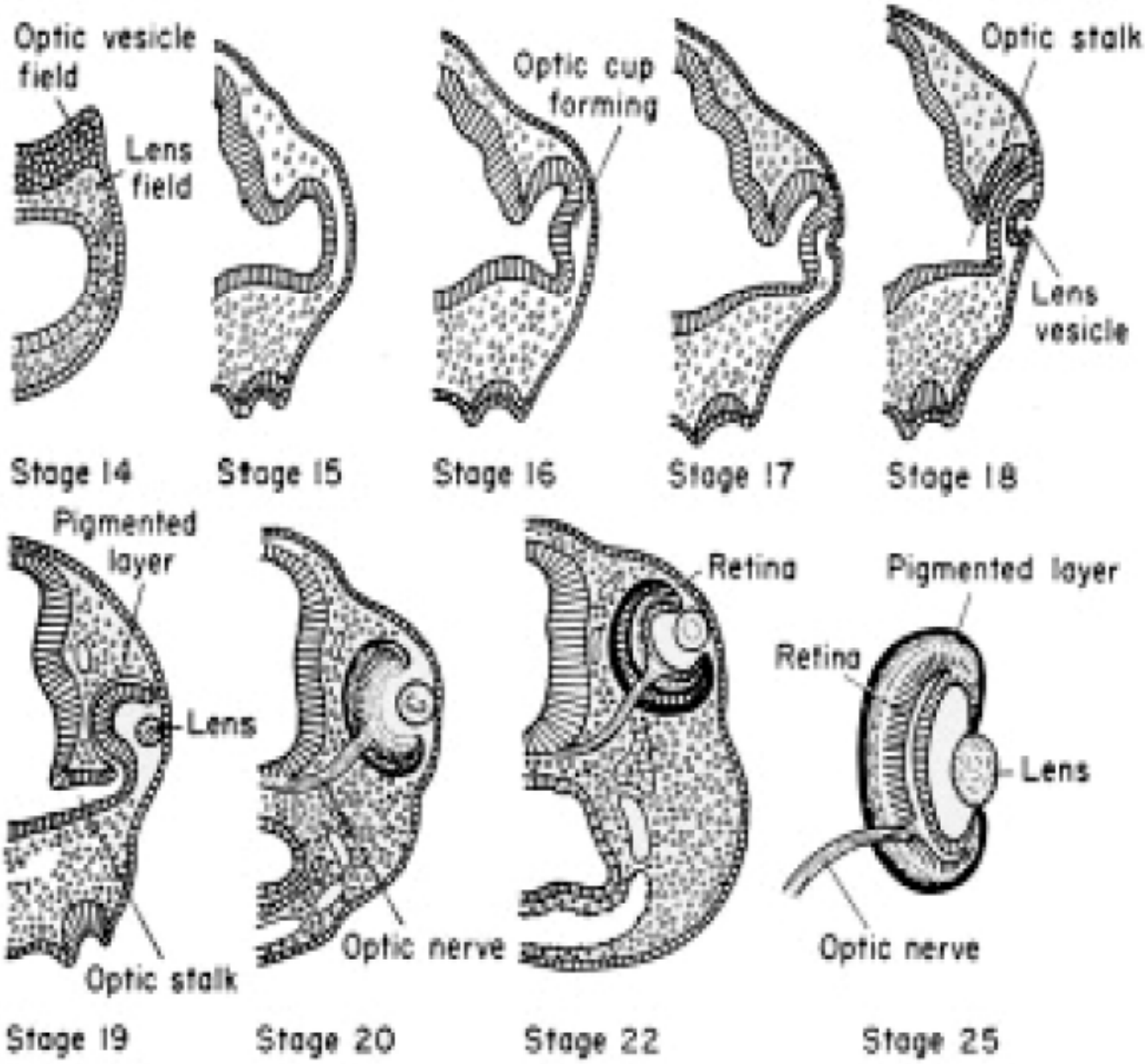
Culture overnight

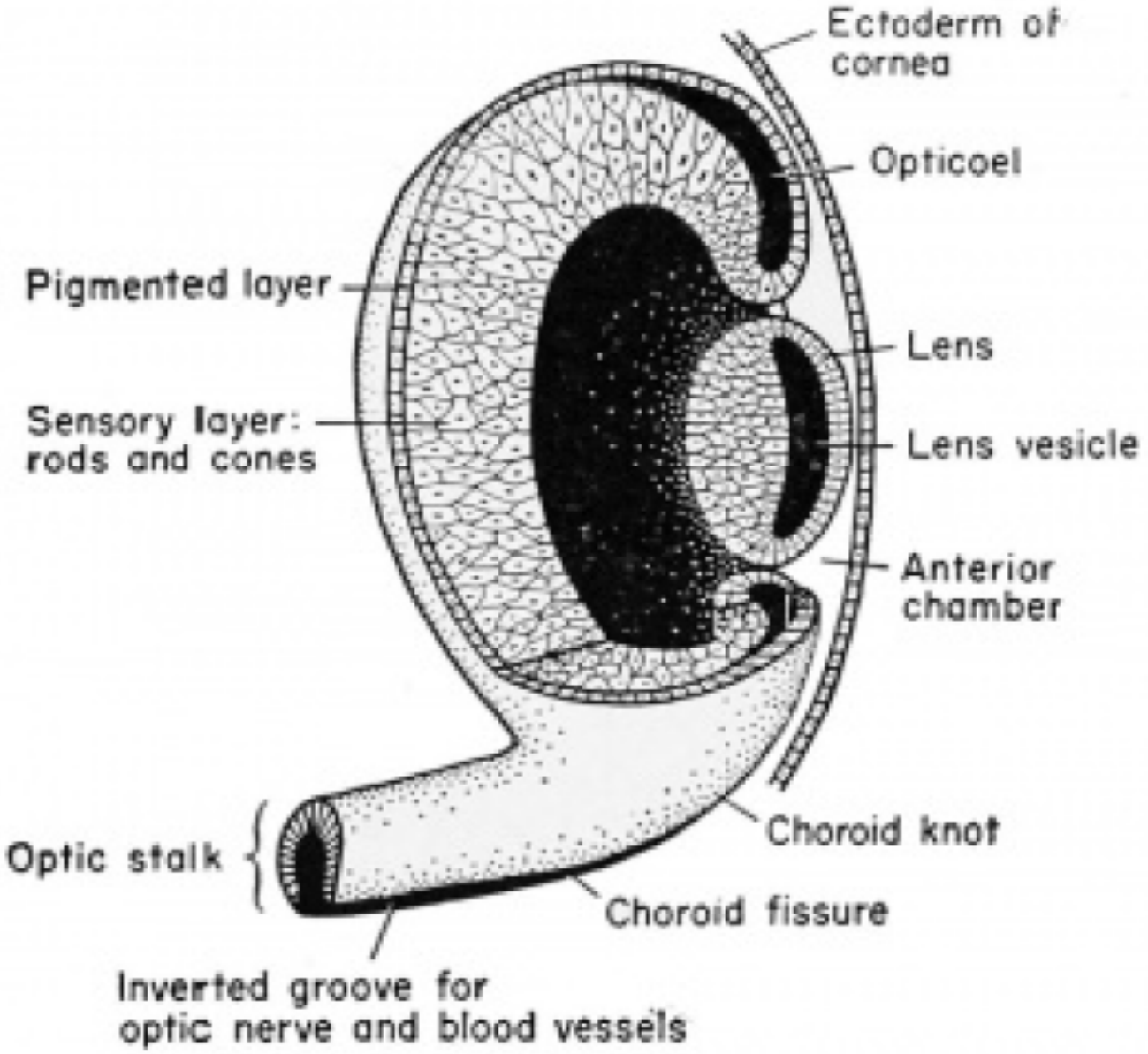


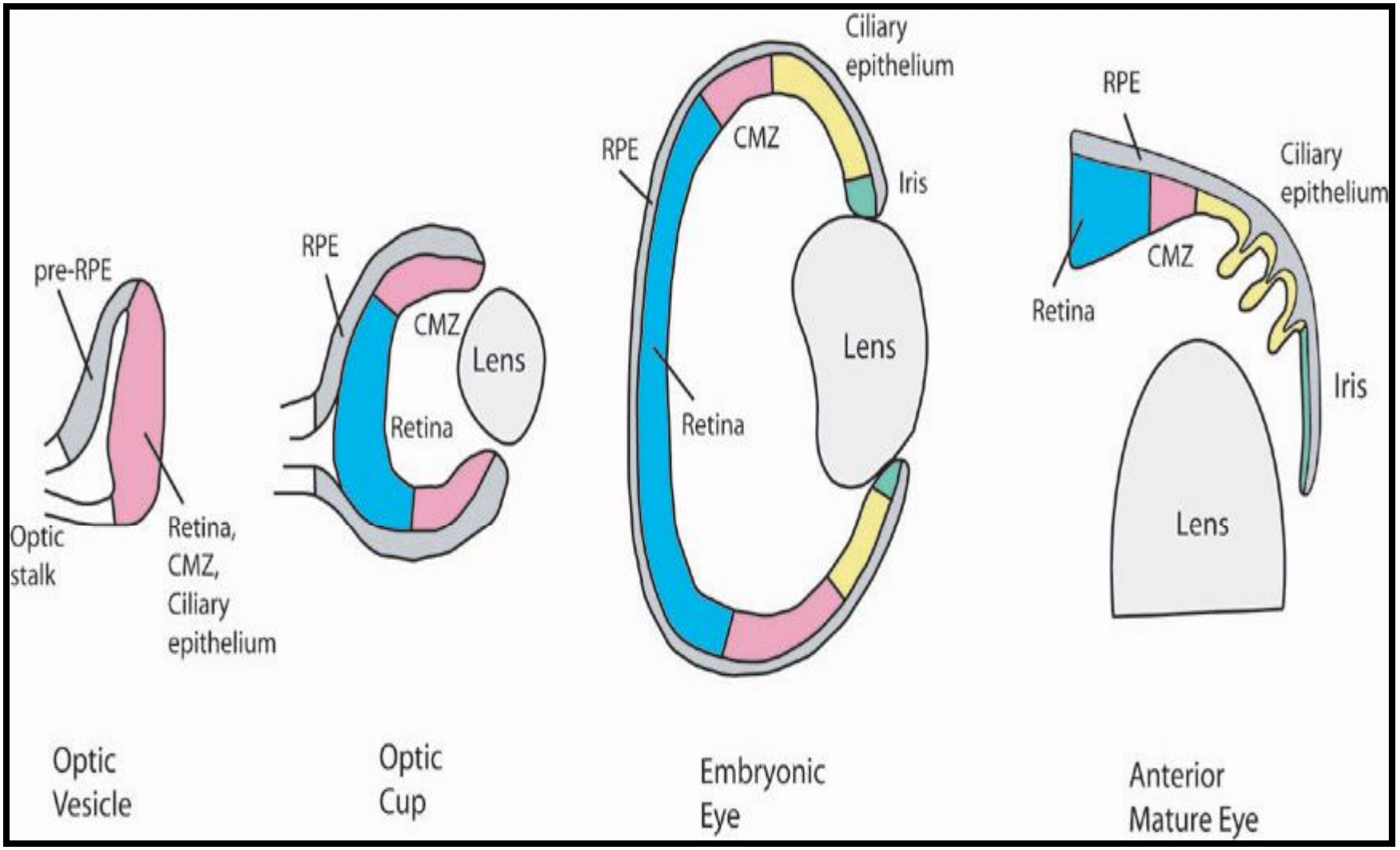
Analyze explants with ISH and IHC

Formation of optic cup

- **The eyes develop as two lateral outgrowths of the prosencephalon called optic vesicles. The cavity of the optic vesicle is called optocoel.**
- **The connection of the optic vesicle with the brain becomes a narrow stalk like structure called optic stalk.**
- **The optic stalk becomes connected with the ventral side of the optic vesicle rather than at its centre. The optic vesicles extend outward and reach the ectoderm.**
- **The wall of the optic vesicle next to the ectoderm is gradually flattened and later invaginates to form a double walled cup called optic cup.**
- **The optic cup consists of two layers. The inner layer (derived by invagination) gives rise to the nervous region, the retina.**


Optic vesicle field
Lens field
Optic cup forming
Optic stalk
Lens vesicle
Stage 14
Stage 15
Stage 16
Stage 17
Stage 18
Pigmented layer
Lens
Optic stalk
Optic nerve
Retina
Pigmented layer
Retina
Lens
Optic nerve
Stage 19
Stage 20
Stage 22
Stage 25


Ectoderm of cornea
Opticoel
Pigmented layer
Lens
Sensory layer: rods and cones
Lens vesicle
Anterior chamber
Choroid knot
Optic stalk
Choroid fissure
Inverted groove for optic nerve and blood vessels


pre-RPE
Optic stalk
Retina, CMZ, Ciliary epithelium
Optic Vesicle
RPE
CMZ
Lens
Retina
Optic Cup
Ciliary epithelium
RPE
CMZ
Iris
Lens
Retina
Embryonic Eye
RPE
Ciliary epithelium
CMZ
Retina
Iris
Lens
Anterior Mature Eye

- **The outer layer will be a thin, black pigmented layer for the absorption of light. Initially the opening of cup is very large. Soon its rim bends inward and converges, so that the opening is reduced.**
- **This opening is called the pupil. The rim of the optic cup surrounding the pupil becomes the iris.**
- **Later on, large amount of pigment is deposited in the outer epithelial layer of iris. A groove extends along the ventral side of the optic cup.**
- **It is called the choroid fissure. It extends to the middle of optic stalk. It serves for the entry of blood vessels and mesenchyme cells into the posterior chamber of eye.**

- **The retina develops a membrane on its inner most surface called the internal limiting membrane.**
- **The outermost cells of the neurosensory retina differentiate into rods and cones.**
- **The inner cells of the retina differentiate into neuroblasts or nerve cells.**

Development of lens

- **When the lateral surface of the growing optic vesicle comes in contact with the ectoderm it gives off stimulus of some kind, which causes the ectodermal cells to elongate, forming a disc shaped thickening.**
- **This is called the lens placode or lens rudiment.**
- **It curves into a cup and finally separates from the ectoderm. The free edges of the cup fuse to form a globular hollow lens vesicle.**
- **The lens vesicle comes to lie in the cavity of the optic cup.**

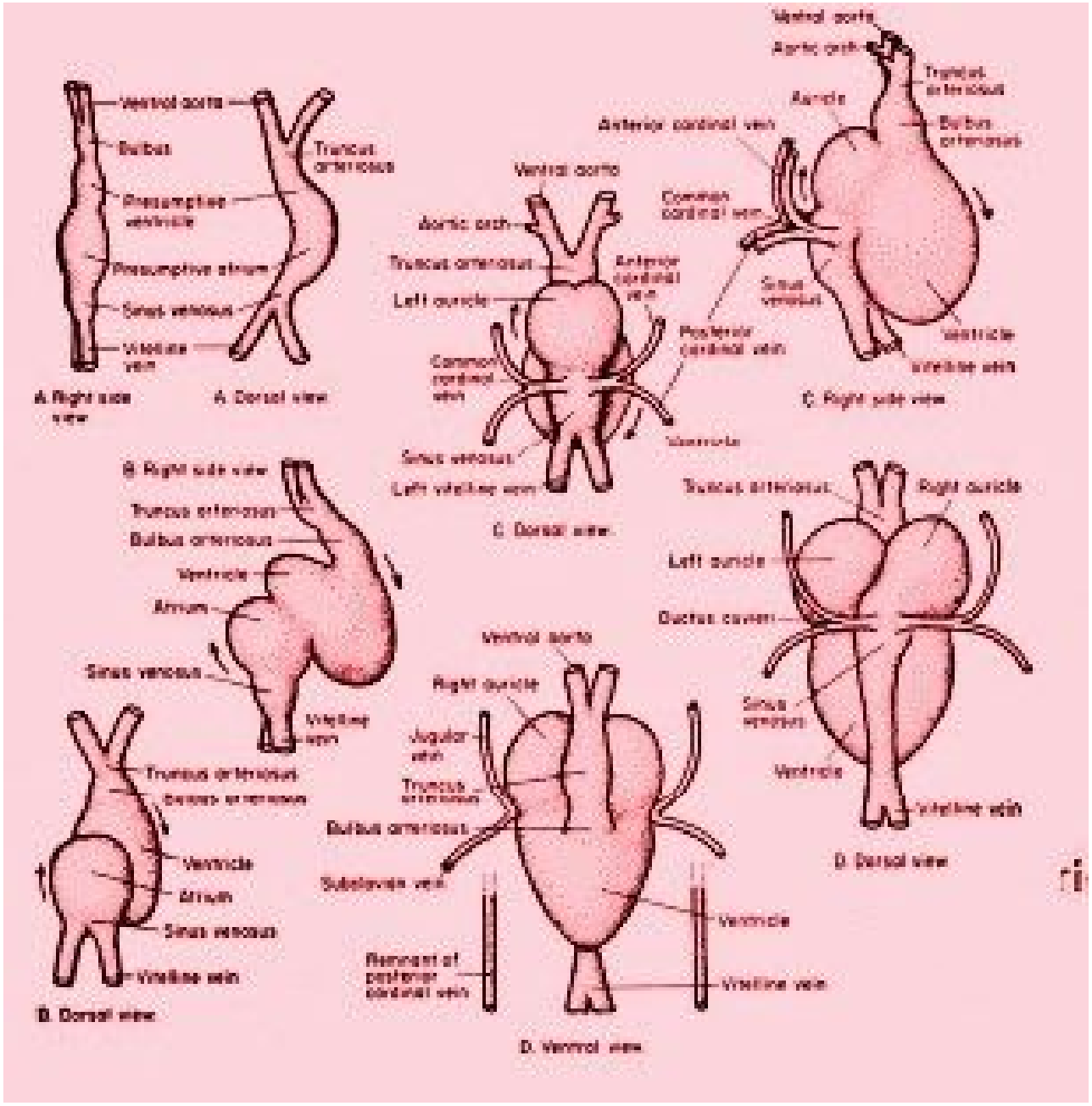
- **The cells of the inner side of the lens vesicle elongate, become columnar and are finally transformed into long fibres.**
- **Their nuclei degenerate and cytoplasm becomes hard and transparent making it refractile. These cells are called lens fibres.**
- **The outer layer of the lens remains unchanged and becomes the lens epithelium.**
- **The junction between the lens fibres and the lens epithelium represents the growing point of lens.**

- **Here the epithelial cells are continuously transformed into lens fibres.**
- **When the lens is formed, the free margin of optic cup touches the edges of the lens and grows in front forming iris.**
- **Thus lens hangs in the opening of optic cup.**
- **Soon after the development of lens the overlying ectoderm closes over and differentiates to become the cornea.**
- **It is continuous with the skin. The transformation of the skin into cornea is caused by an induction arising from the optic cup and lens.**
- **The ectodermal cells covering cornea form an extremely thin, transparent membrane**

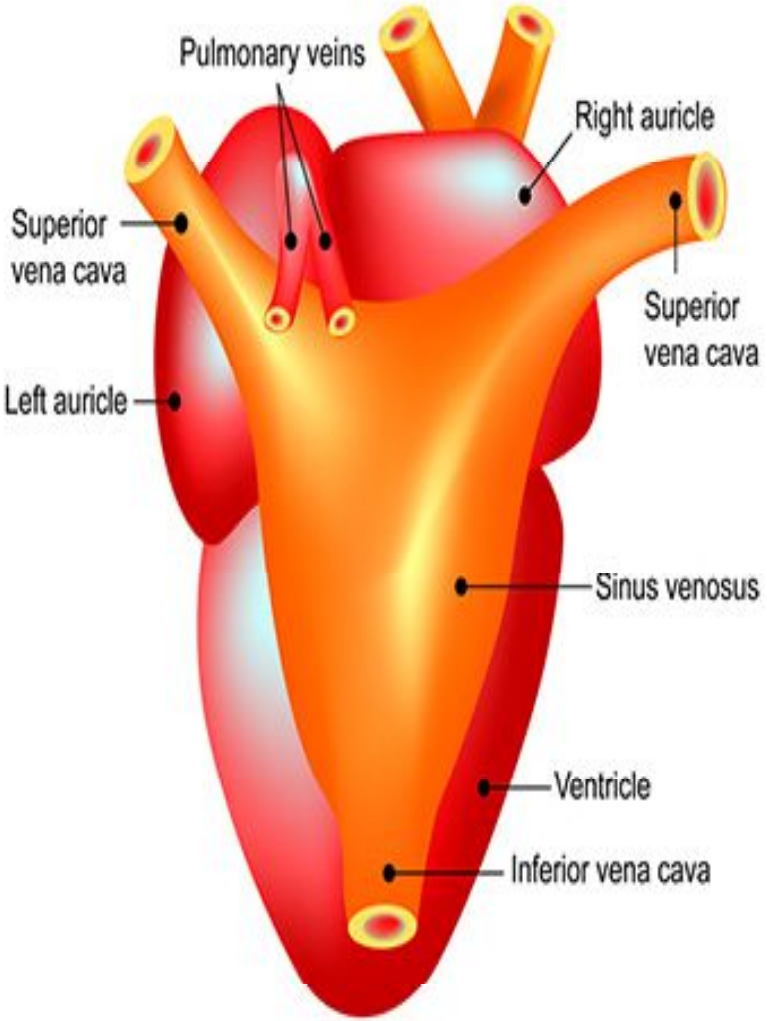
- **This is known as conjunctiva of the eye ball.**
- **In adult this becomes continuous with the inner lining of upper and lower eyelids.**
- **The space between lens vesicle and the overlying presumptive anterior epithelium of cornea represents the anterior chamber.**
- **It contains cellular material called anterior vitreous body.**
- **The choroid and sclerotic coat of eye develop from the mesenchyme cells accumulating around the eye ball.**

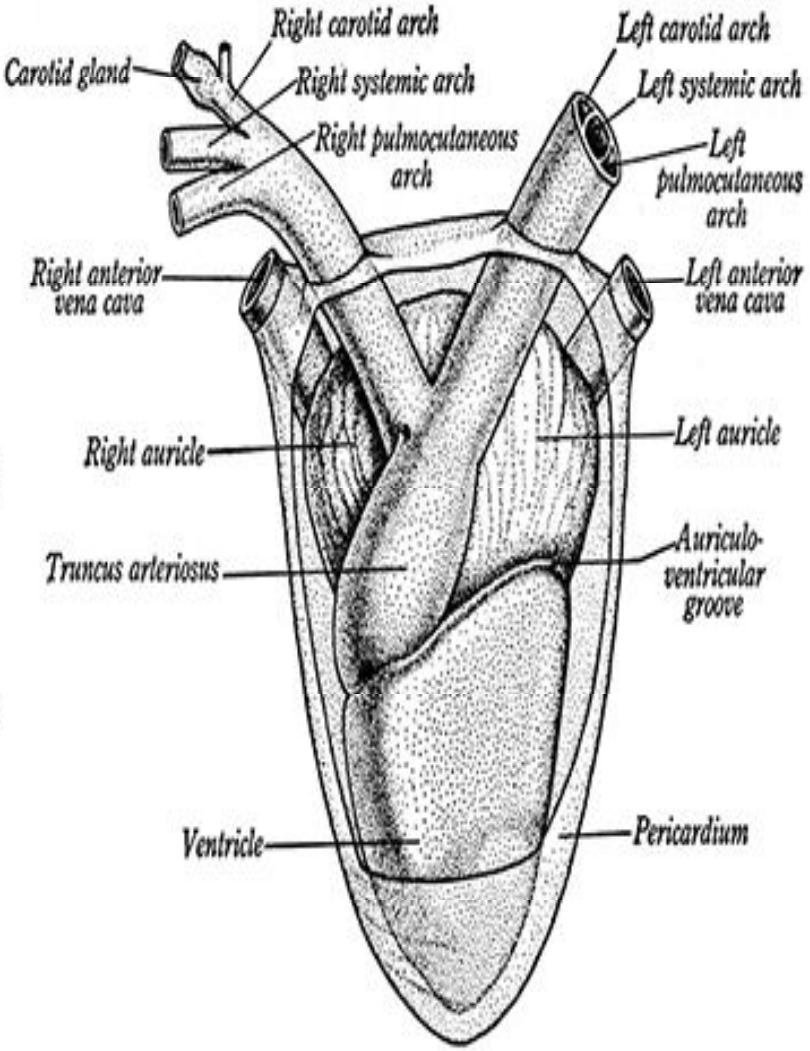
- **The interior layer of mesenschyme cells give rise to a net work of blood vessels surrounding the pigmented retinal layer and are called choroid coat.**
- **The outer layer of mesenchyme form fibrous capsule, the sclerotic coat or sclera around the eye.**
- **The sclera provides protection to eye and the eye muscles. The ectoderm from above and below the original lens placode region grows out as two folds.**
- **These folds grow over conjunctiva and come to touch each other forming a complete layer of ectoderm. At a later stage these folds separate along the line of fusion to form the regular upper and lower eye lids.**

Development of Heart in frog

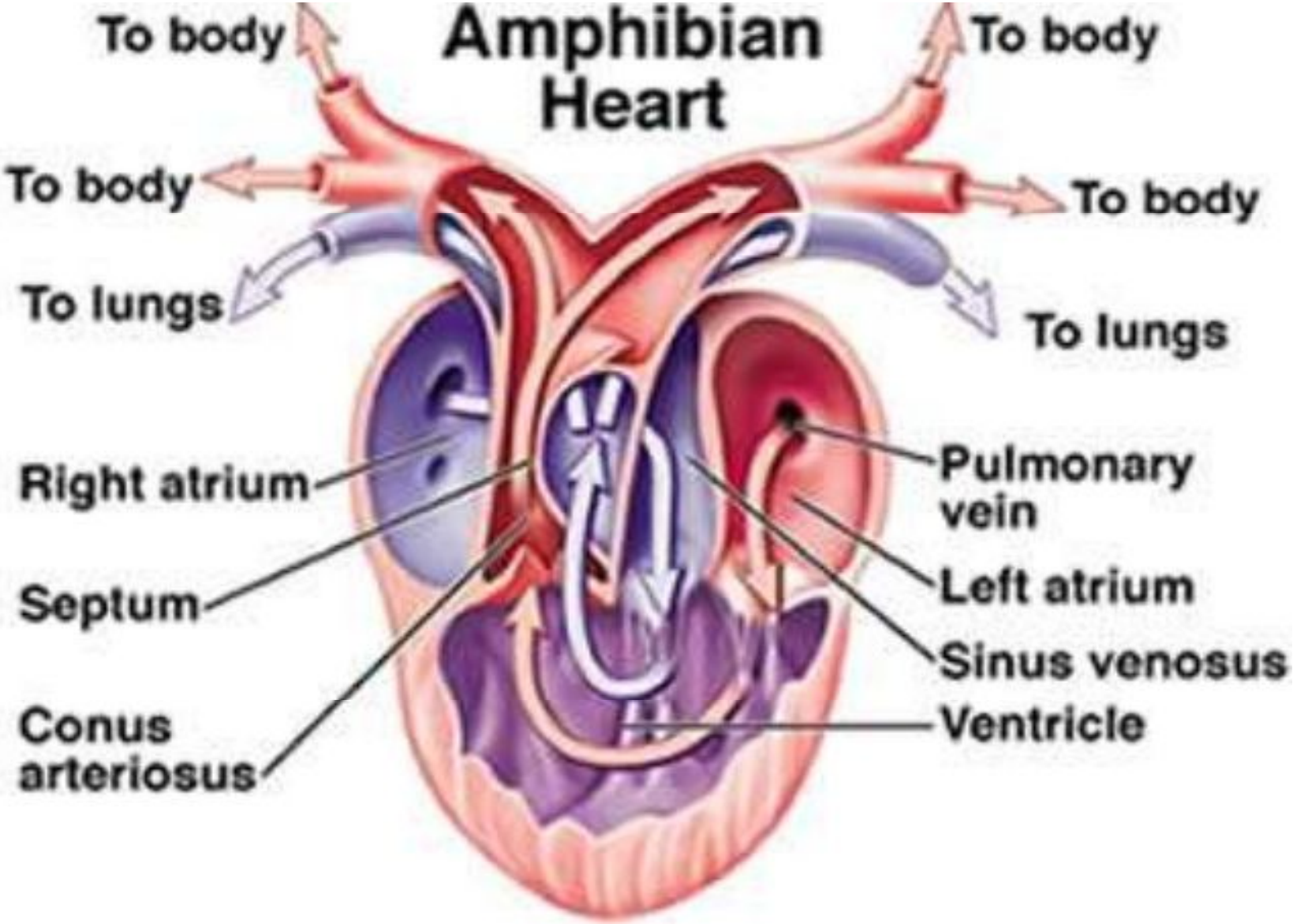

Ventral aorta
Bulbus
Truncus arteriosus
Presumptive ventricle
Presumptive atrium
Sinus venosus
Vitelline vein
A. Right side view
A. Dorsal view
Ventral aorta
Aortic arch
Truncus arteriosus
Left auricle
Anterior cardinal vein
Common cardinal vein
Posterior cardinal vein
Sinus venosus
Left vitelline vein
C. Dorsal view
Ventral aorta
Aortic arch
Truncus arteriosus
Auricle
Bulbus arteriosus
Anterior cardinal vein
Common cardinal vein
Sinus venosus
Posterior cardinal vein
Ventricle
Vitelline vein
C. Right side view
B. Right side view
Truncus arteriosus
Bulbus arteriosus
Ventricle
Atrium
Sinus venosus
Vitelline vein
Truncus arteriosus
Bulbus arteriosus
Ventricle
Atrium
Sinus venosus
Vitelline vein
B. Dorsal view
Ventral aorta
Right auricle
Jugular vein
Truncus arteriosus
Bulbus arteriosus
Subclavian vein
Ventricle
Remnant of posterior cardinal vein
Vitelline vein
D. Ventral view
Truncus arteriosus
Right auricle
Left auricle
Ductus cuvieri
Sinus venosus
Ventricle
Vitelline vein
D. Dorsal view

Dorsal view of Heart of a Frog





Ventral view of heart of frog


Amphibian Heart
To body
To body
To body
To body
To lungs
To lungs
Right atrium
Septum
Conus arteriosus
Pulmonary vein
Left atrium
Sinus venosus
Ventricle

Heart is a derivative of mesoderm and it begins to develop about the tail bud stage. The heart develops under the inductive influence of the archenteric floor.

The splanchnic mesenchymal cells grow ventrally toward the midline below the pharynx and contribute to the formation of heart.

The splanchnic mesoderm at the region of pharynx proliferates and the cells aggregate to form two small masses called endocardial cells.

They become organised into two tubes known as endocardial tubes which fuse together to form a single tube, the rudiment of heart.

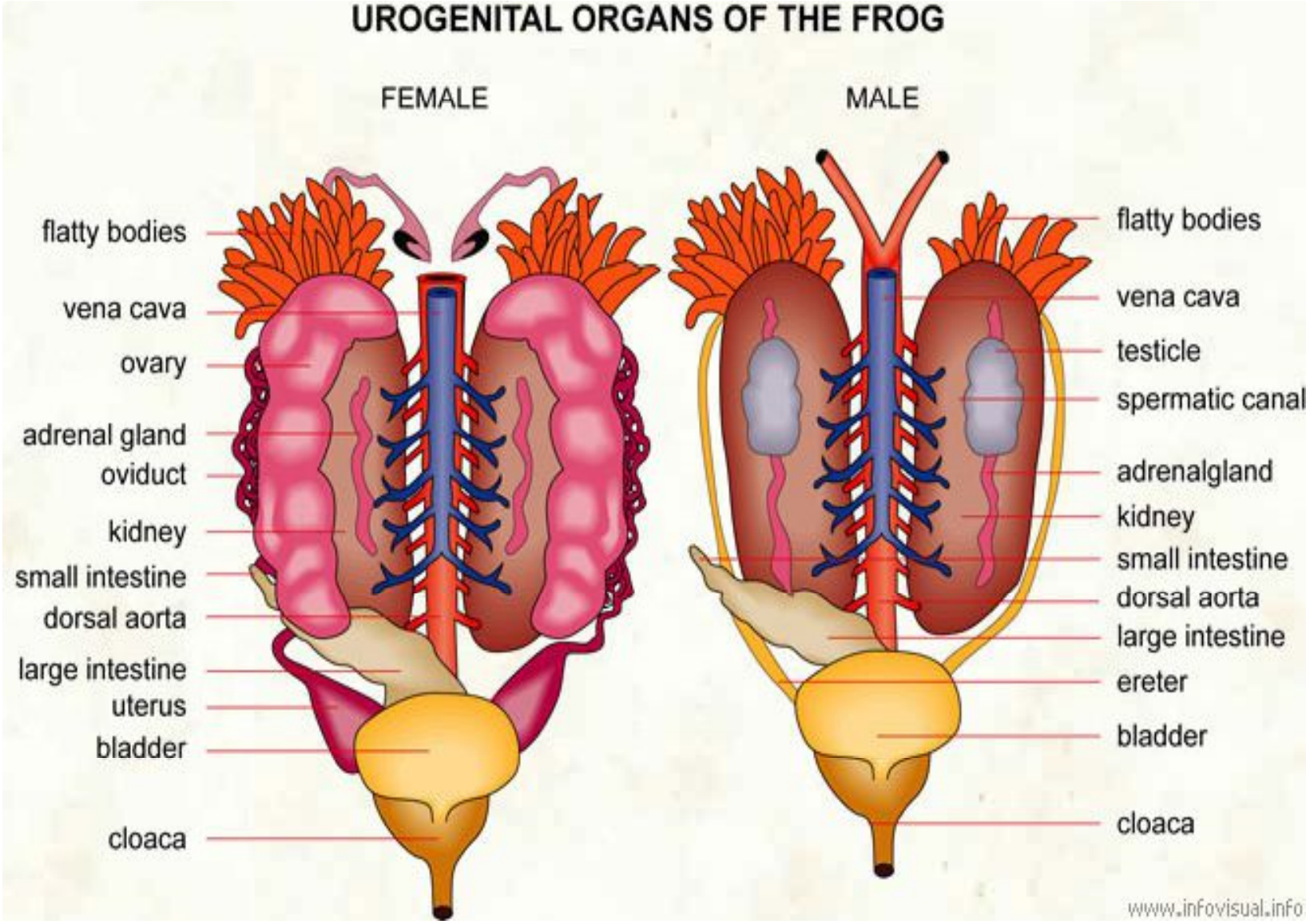
- **Soon the mesoderm converges on either side of the endocardial tube and encloses them. The growing ends of mesoderm meet at first ventrally and fuse below the endocardium.**
- **There appears a ventral mesocardium temporarily.**
- **Soon it disappears. Dorsally, the mesodermal sheets meet just above the endocardium and below the pharynx.**
- **When the fusion of the two mesoderms is complete, the heart is suspended from above by a dorsal mesocardium.**
- **The endocardium is now surrounded by two mesodermal layers - the inner myocardium and the outer pericardium.**

- **The space in between myocardium and pericardium is called pericardial cavity.**
- **The myocardium becomes highly muscular and gives rise to the striated, synsytial and involuntary muscles of the heart.**
- **At the level of heart, the mesocardia disappear both dorsally and ventrally.**
- **This is accomplished in part by the rapid growth and expansion of heart itself.**
- **The rudimentary heart consists of a simple tube which becomes divided into three chambers, two thin walled auricles and one thick - walled ventricle.**
- **Posteriorly, it receives two vitelline veins and anteriorly it loads into truncus arteriosus or ventral aorta.**

- **The development of heart is completed within a limited space provided by the surrounding body tissues and organs.**
- **The developing heart tube undergoes flexion and torsion within the pericardium so that the heart becomes a reversed S-shaped coiled tube .**
- **The posterior part of the original tube becomes folded dorsally and anteriorly.**
- **Then, anterior part of the heart is folded ventrally and posteriorly.**
- **Thu there is a reversal in original antero - posterior relation of heart with respej to embryo.**
- **The ventricular part of heart is brought downward and auricular part upward .**

- **The terminal parts of heart, which are held in position by the dorsal mesocardium are the posterior sinus venosull, and anterior truncus arteriosus.**
- **The point of fusion of the vitelline veins to the heart is called sinus venosus which represents the posterior limit.**
- **Soon there develops a longitudinal sheet of endocardium from the roof of the atrial chamber and that divides auricle into left and right chambers.**
- **The ventricle remains undivided.**
- **The truncus arteriosus becomes partially subdivided by vertical and longitudinal septum and gives rise to the ventral paired aortae which are connected with various aortic arches.**

Development of Kidney


UROGENITAL ORGANS OF THE FROG
FEMALE
MALE
flatty bodies
vena cava
ovary
adrenal gland
oviduct
kidney
small intestine
dorsal aorta
large intestine
uterus
bladder
cloaca
flatty bodies
vena cava
testicle
spermatic canal
adrenalgland
kidney
small intestine
dorsal aorta
large intestine
ereter
bladder
cloaca
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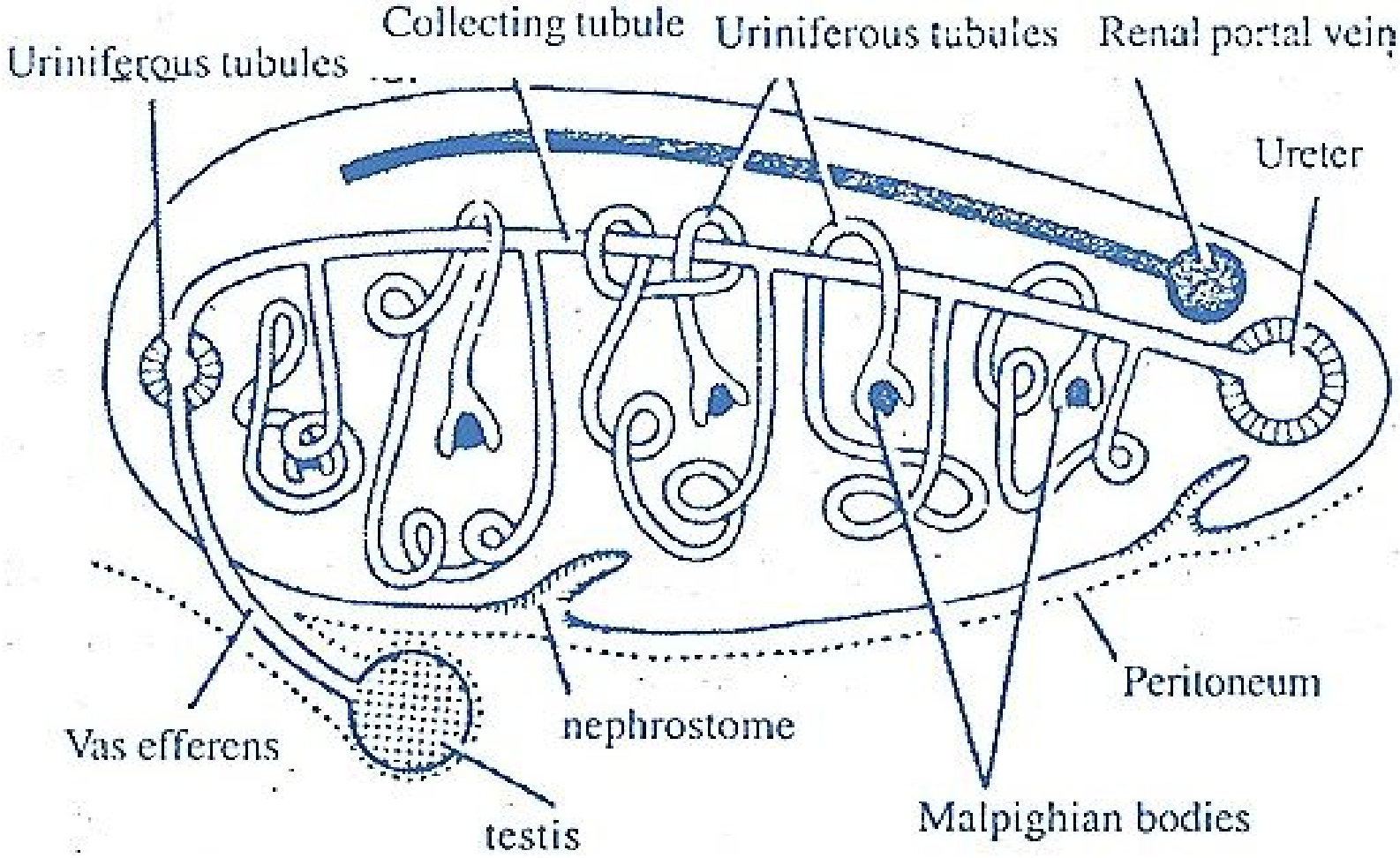
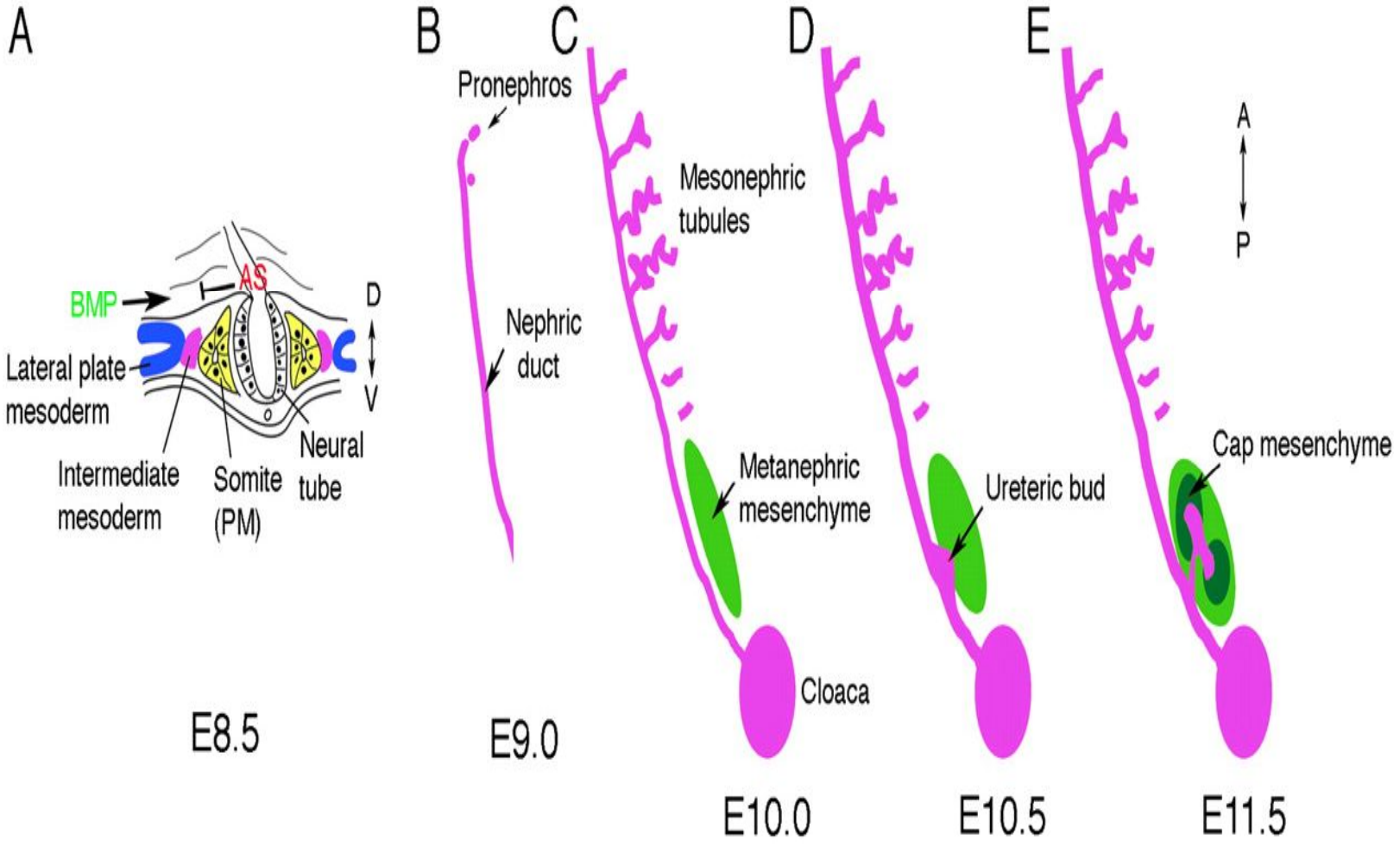
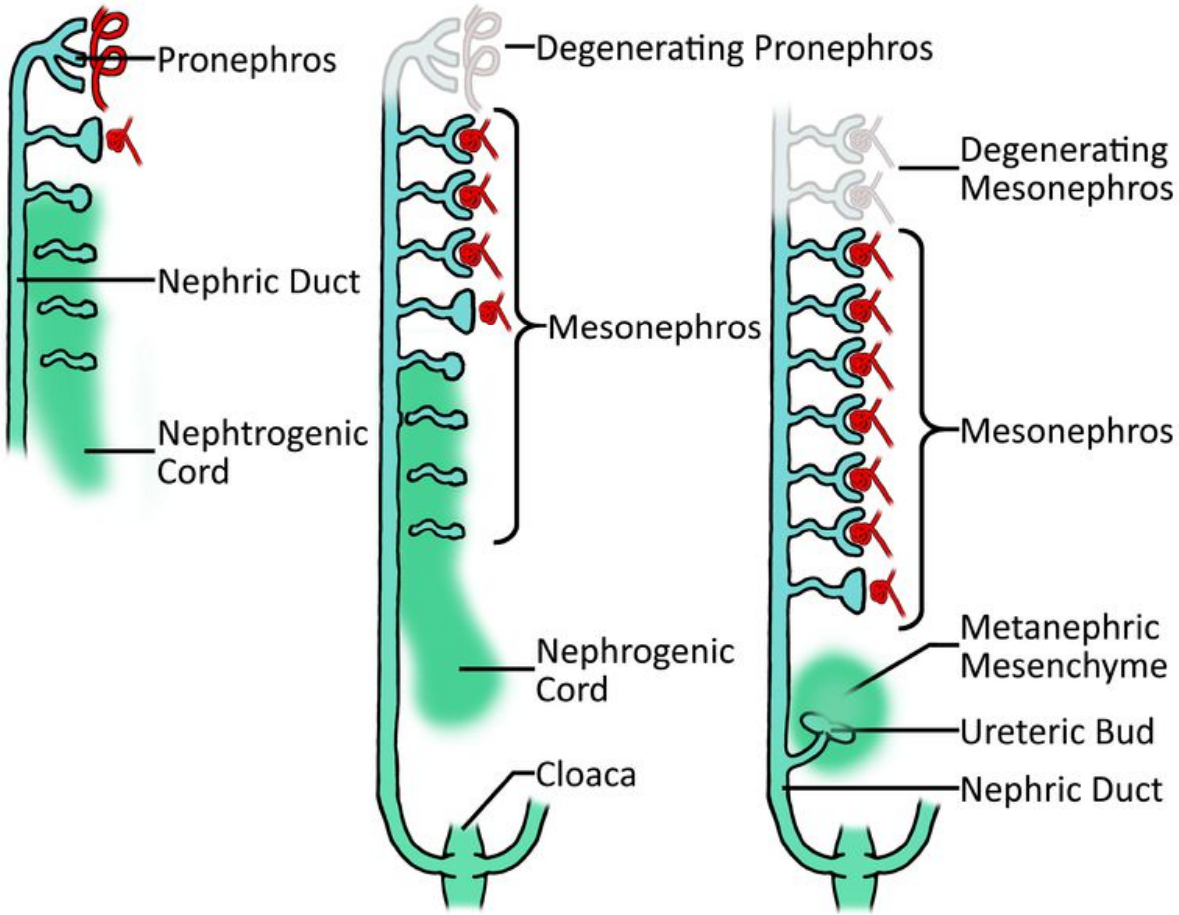


FROG-KIDNEY-TS


A
B
C
D
E
BMP
AS
D
V
Lateral plate mesoderm
Intermediate mesoderm
Somite (PM)
Neural tube
E8.5
Pronephros
Nephric duct
E9.0
Mesonephric tubules
Metanephric mesenchyme
Cloaca
E10.0
Ureteric bud
E10.5
A
P
Cap mesenchyme
E11.5



Sequential development and degeneration of the pronephros and mesonephros, and the induction of the ureteric bud and metanephric mesenchyme during kidney development

- **The pronephros is the most immature form of kidney, while the metanephros is most developed. The metanephros persists as the definitive adult kidney.**
- **The pronephros develops in the cervical region of the embryo.**
- **The paired pronephri appear towards the cranial end of the intermediate mesoderm. In this region, epithelial cells arrange themselves in a series of tubules called nephrotomes and join laterally with the pronephric duct.**
- **This duct is fully contained within the embryo and thus cannot excrete filtered material outside the embryo; therefore the pronephros is considered nonfunctional in mammals.**

Mesonephros

- **The development of the pronephric duct proceeds in a cranial-to-caudal direction. As it elongates caudally, the pronephric duct induces nearby intermediate mesoderm in the thoracolumbar area to become epithelial tubules called mesonephric tubules.**
- **Each mesonephric tubule receives a blood supply from a branch of the aorta, ending in a capillary tuft analogous to the glomerulus of the definitive nephron.**
- **The mesonephric tubule forms a capsule around the capillary tuft, allowing for filtration of blood. This filtrate flows through the mesonephric tubule and is drained into the continuation of the pronephric duct, now called the mesonephric duct or Wolffian duct.**
- **The nephrotomes of the pronephros degenerate while the mesonephric duct extends towards the most caudal end of the embryo, ultimately attaching to the cloaca. The mammalian mesonephros is similar to the kidneys of aquatic amphibians and fishes.**