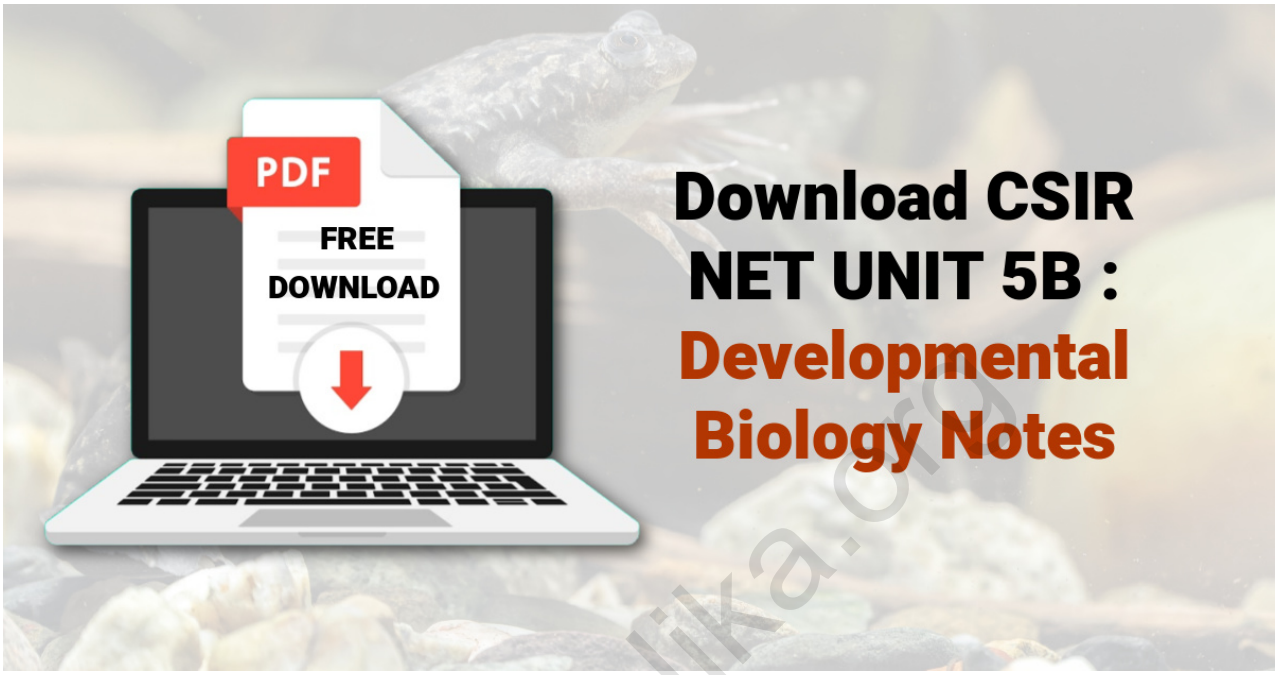
Download CSIR NET UNIT 5B : Developmental Biology Notes – Gastrulation, Early Development In Amphibians



CSIR NET Developmental Biology Notes

CSIR NET UNIT 5 Developmental Biology – a very important unit as per the CSIR NET exam with a good weightage. Nearly 30+ marks of questions are asked from this UNIT every year. So one must not skip studying this unit at all. Some students find it a little difficult to understand the concepts. Thus it is suggested to prepare this unit beforehand and avoid last-minute study. Atleast the important topics from this unit must not be skipped.

Check the Important Topics List from CSIR NET Unit 5 here

Important REFERENCE BOOKS For CSIR NET Life Science UNIT 5

- Developmental Biology by Scott F. Gilbert
- Principles of Development by Lewis Wolpert, Cheryll Tickle

In this notes Topics related to Gastrulation / Early Development In Amphibians have been covered. **CSIR NET Developmental Biology Notes**

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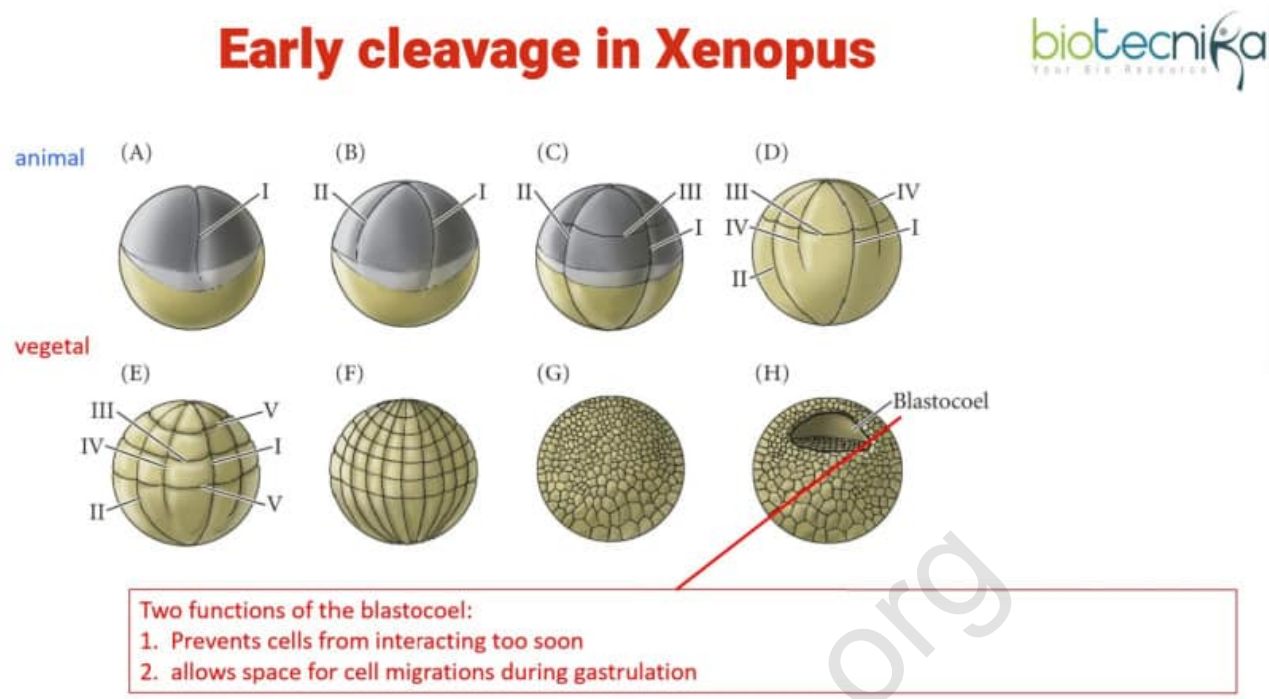
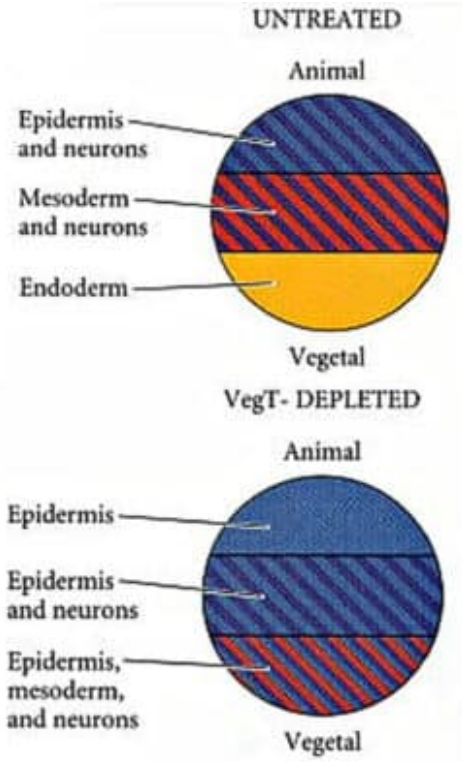


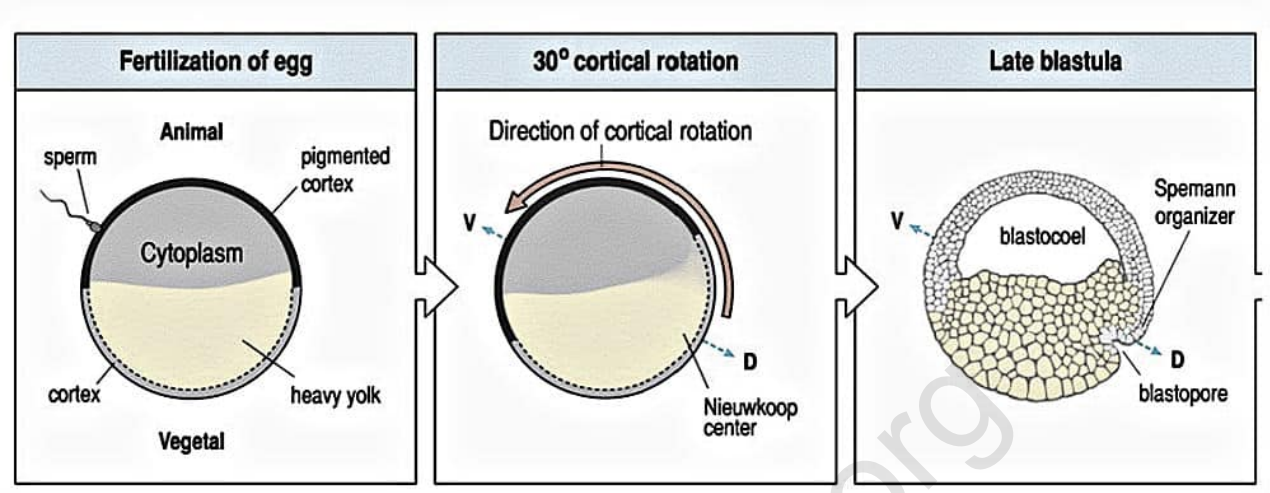
FATE MAP

- The surface of the animal hemisphere will become the cells of the ectoderm (skin and nerves),
- the vegetal hemisphere surface will form the cells of the gut and associated organs (endoderm), and the mesodermal cells will form from the internal cytoplasm around the equator.
- This general fate map is thought to be imposed upon the egg by the transcription factor VegT and the paracrine factor Vg1.
- The animal third of the embryo produced only ventral epidermis, while the marginal cells (which normally produced mesoderm) generated epidermal and neural tissue.
- The vegetal third (which usually produces endoderm) produced a mixture of ectoderm and mesoderm.
- Joseph and Melton (1998) demonstrated that embryos that lacked functional Vg1 lacked endoderm and dorsal mesoderm.



Cortical Rotation

- During cortical rotation, the plasma membrane and cortex (the cytoplasmic region just below the plasma membrane) rotate relative to the inner cytoplasm.
- The pigmentation of frog eggs makes it possible to observe this process visually and results in a gray area, called the gray crescent
- Rearrangement is mediated by the ATPase Kinesin
- Rearrangement of cytoplasm helps in the determination of dorsal & ventral axis



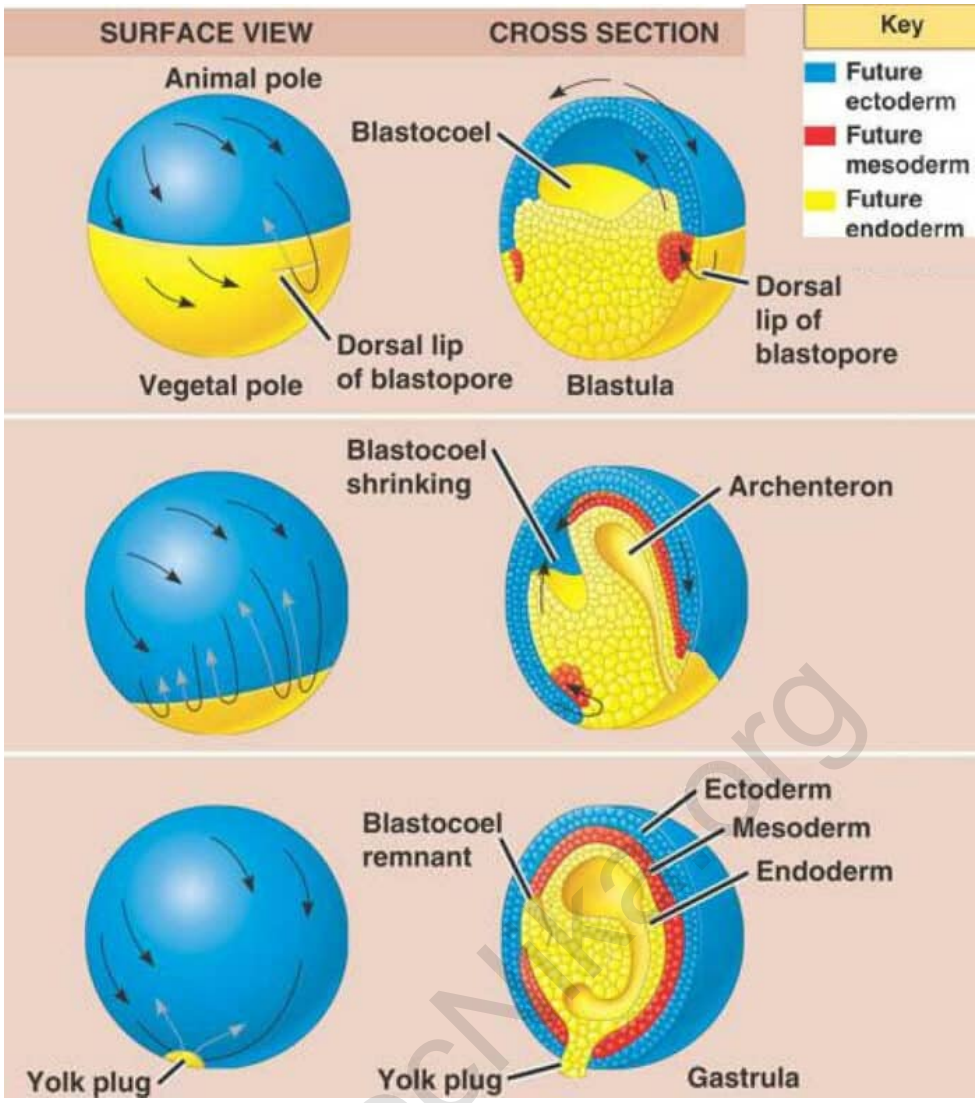
Certain Experiments Related to Cortical Rotation

1. If cortical rotation occurred at about 90° of the sperm entry instead of 30°, then the dorsal lip of the blastopore will be formed as the same region where sperm entered
2. If the egg is activated without sperm, then cortical rotation occurs but the direction cannot be predicted
3. If sperm entry does not induce cortical rotation then a Grey crescent will not form and embryonic development will not take place.

EARLY-GASTRULATION

Blastopore Formation

- The bottle cells of the margin move inward to form the dorsal lip of the blastopore.
- The mesodermal precursors involute under the roof of the blastocoel
- Animal pole will change as gastrulation continues.



Involution of Marginal zone cells

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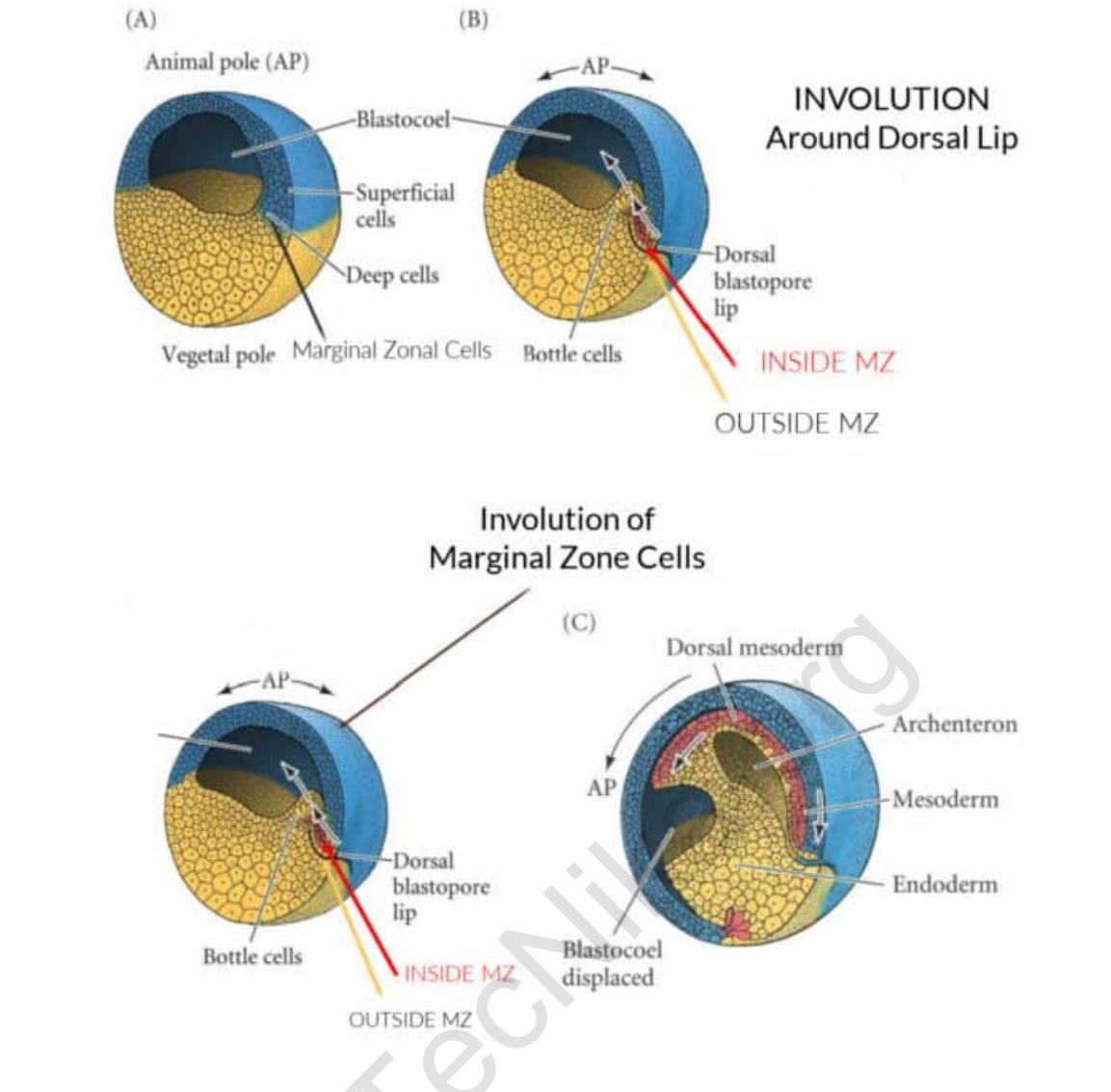
- movement of inside MZ cells dependent on ectoderm cells of blastocoel roof secreting fibronectin
- Fibronectin is essential for mesodermal cell involution during gastrulation



MID-GASTRULATION

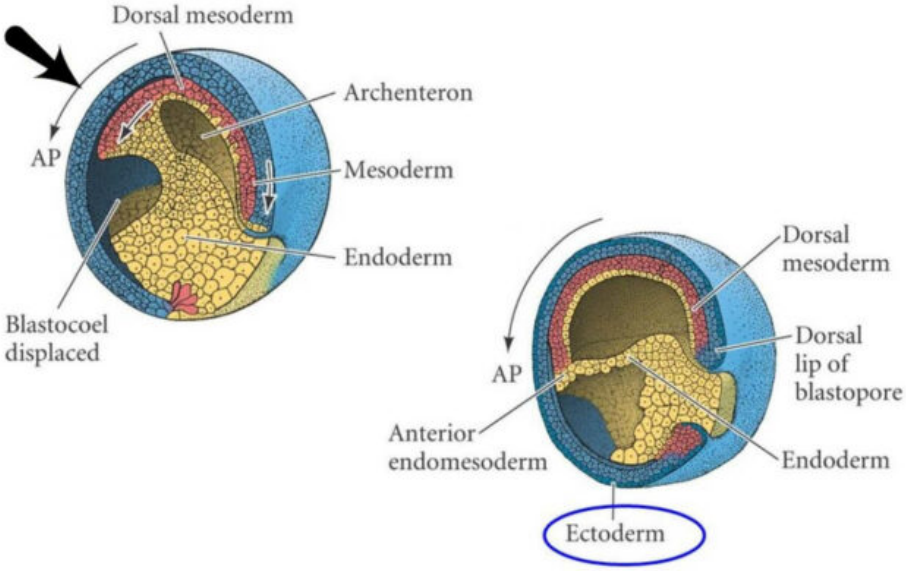
Formation of the Archenteron = Convergent Extension of the Dorsal Mesoderm

- The archenteron forms and displaces the blastocoel Cells to migrate from the lateral and ventral lips of the blastopore into the embryo.
- The cells of the animal hemisphere migrate down toward the vegetal region, moving the blastopore to the region near the vegetal pole.

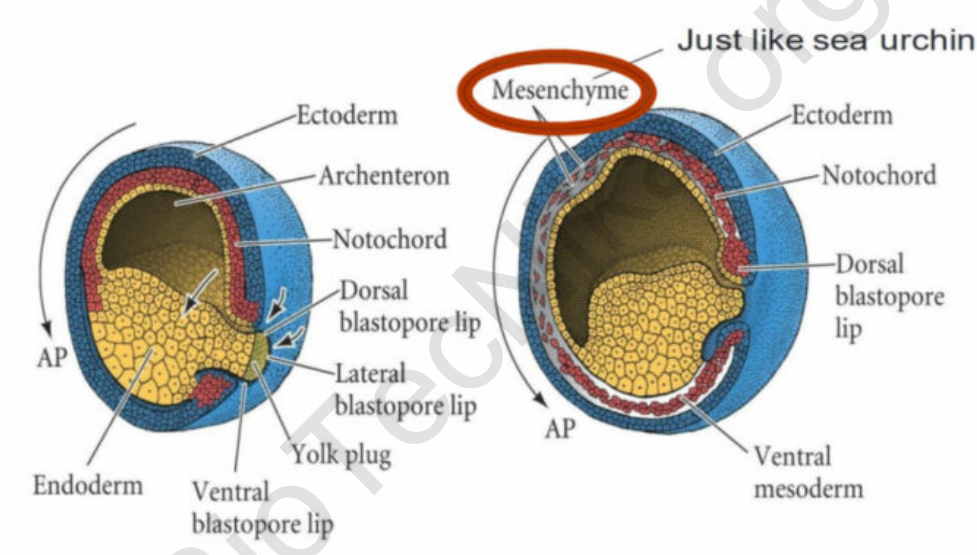
Toward the end of gastrulation

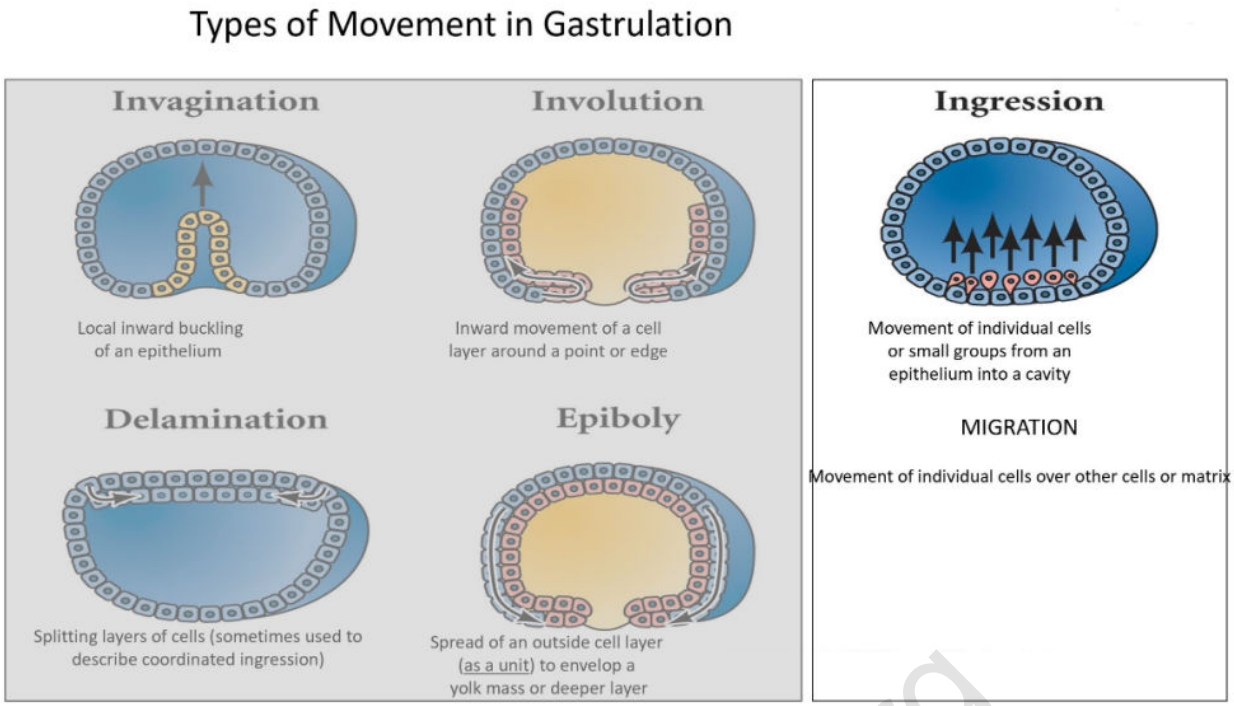
• The blastocoel is obliterated
• The embryo becomes surrounded by ectoderm.
• The endoderm has been internalized
• The mesodermal cells have been positioned between the ectoderm and endoderm.

Epiboly of the Ectoderm

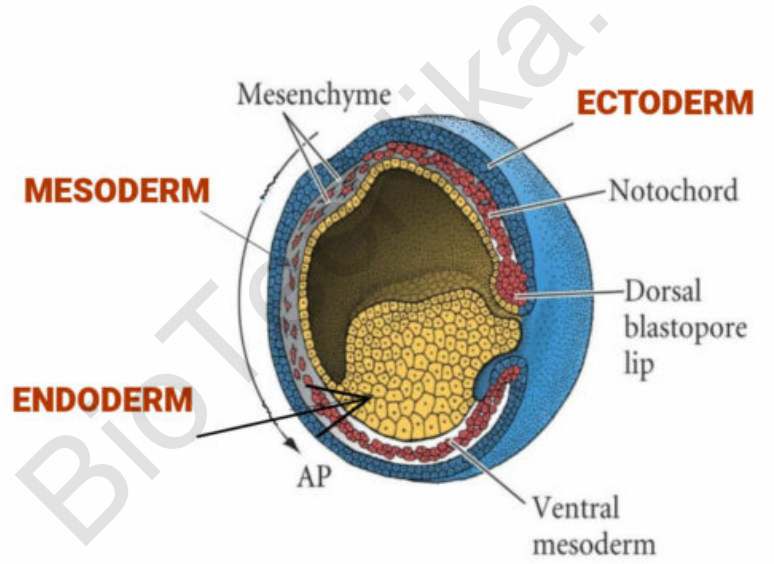


Mesenchyme Migration





Gastrulation: Mission Accomplished



ECTODERM

- Ectoderm (outer layer) will produce skin & the central nervous system (brain, spinal cord) through later invagination of the neural tube.
- In vertebrates, migrating neural crest cells form the peripheral nervous system & many other structures, including some bone, cartilage, and connective tissue in the head.

MESODERM

- MESODERM (middle layer) will produce muscles, connective tissue, blood and blood vessels.
- In vertebrates also the notochord (progenitor of vertebrae), bones & cartilage, and circulatory and urogenital systems (kidneys, gonads).

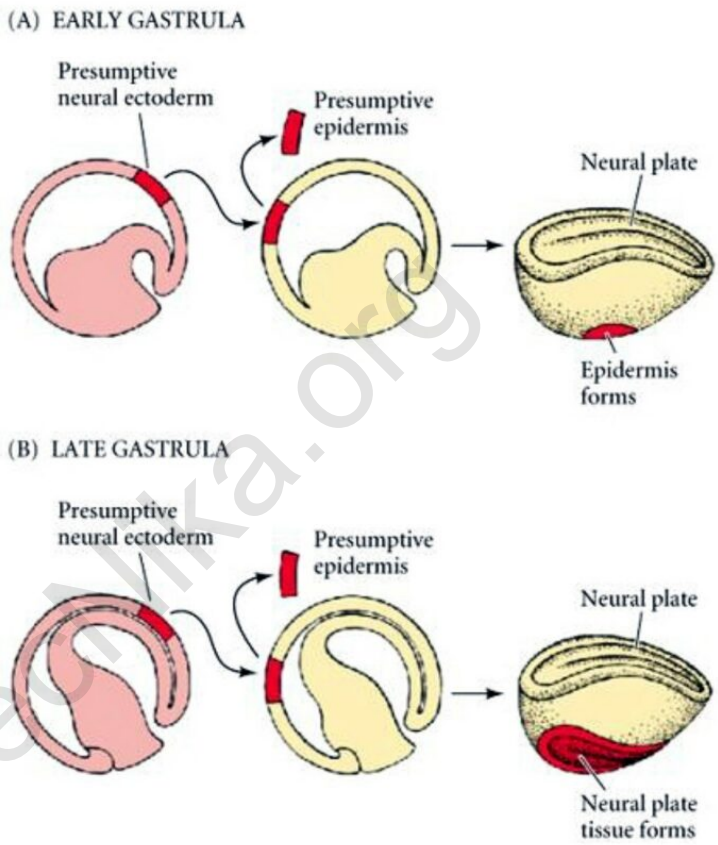
ENDODERM

ENDODERM (inner layer) will produce the gut (entire digestive system) and other internal organs that arise as out pocketing of the gut in- vertebrates such as the liver, lungs, pancreas, and salivary glands.

Axis formation in amphibians

Amphibian axis formation is an example of regulative development wherein

1) an isolated blastomere has a potency greater than its normal embryonic fate
2) a cell's fate is determined by interactions between neighboring cells. Such interactions are called inductions



- The first cleavage plane normally split the gray crescent equally into the two blastomeres.
- If these cells are then separated, two complete larvae develop.
- However, should this cleavage plane be aberrant (either in the rare natural event or in an experiment), the gray crescent material passes into only one of the two blastomeres.
- Spemann found that when these two blastomeres are separated, only the blastomere containing the gray crescent develops normally.
- The most important clue came from the fate map of this area of the egg, for it showed that the gray crescent region gives rise to the cells that initiate gastrulation.
- These cells form the dorsal lip of the blastopore.
- The cells of the dorsal lip are committed to invaginate into the blastula, thus initiating
  gastrulation and the formation of the notochord.
- Because all future amphibian development depends on the interaction of cells rearranged during gastrulation, Spemann speculated that the importance of the gray crescent material lies in its ability to initiate gastrulation and that crucial developmental changes occur during gastrulation.
- The process by which one embryonic region interacts with a second region to influence that second region's differentiation or behavior is called induction

- Because there are numerous inductions during embryonic development, this key induction wherein the progeny of dorsal lip cells induce the dorsal axis and the neural tube is traditionally called primary embryonic induction.

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Organizer Concept

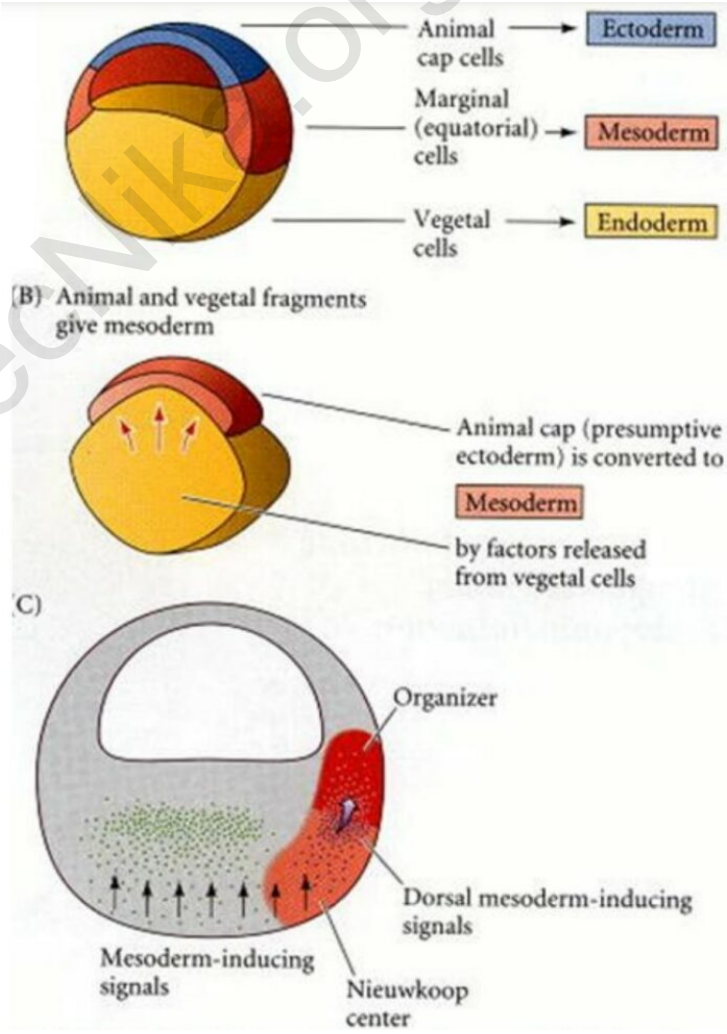
Spemann (1938) referred to the dorsal lip cells and their derivatives (notochord, prechordal mesoderm) as the organizer because:

1. They induced the host's ventral tissues to change their fates to form a neural tube and dorsal mesodermal tissue (such as somites).

2. They organized host and donor tissues into a secondary embryo with clear anterior-posterior and dorsal-ventral axes.

The Mechanisms of Axis formation in Amphibians

The experiments of Spemann and Mangold showed that the dorsal lip of
the blastopore, and the notochord that forms from it, constituted an "organizer"
that could instruct the formation of new embryonic
axes.



THE ORIGIN OF THE NIEUWKOOP CENTER

- The dorsal most vegetal cells of the blastula, which are capable of
inducing the organizer, have been called the Nieuwkoop center
- The Nieuwkoop center is created by the cytoplasmic rotation that
occurs during fertilization.
- When this rotation is inhibited by UV light, the resulting embryo will not form dorsal-anterior structures such as the head or neural tube

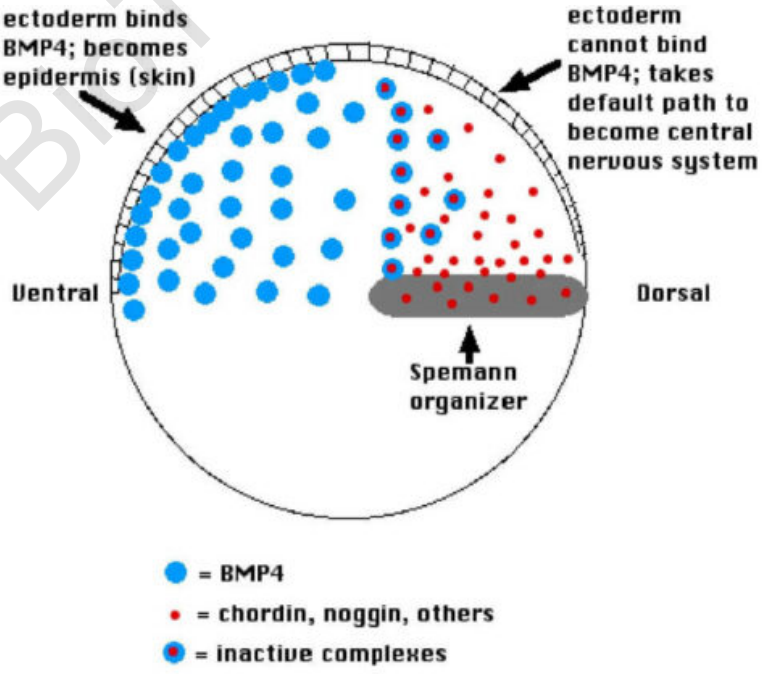
- The polarity of this induction (whether the animal cells formed dorsal mesoderm or ventral mesoderm) depended on the dorsal ventral polarity of the endodermal (vegetal) fragment.
- While the ventral and lateral vegetal cells (those closer to the side of sperm entry) induced ventral (mesenchyme, blood) and intermediate (muscle, kidney) mesoderm, the dorsal most vegetal cells specified dorsal mesoderm components (somites, notochord), including those having the properties of the organizer.

Functions of the Organizer

1. The ability to become dorsal mesoderm (prechordal plate, chordamesoderm, etc.)
2. The ability to dorsalize the surrounding mesoderm into lateral mesoderm (when it would otherwise form ventral mesoderm)
3. The ability to dorsalize the ectoderm into neural ectoderm
4. The ability to initiate the movements of gastrulation
5. The ability to cause the neural plate (the induced neural ectoderm) to become the neural tube

BMP inhibitors

- The ectoderm is actually induced to become an epiderm.
- The agents of this induction are bone morphogenetic proteins (BMPs)1. the “default fate” of the ectoderm is to become neural
  2. Certain parts of the embryo induce the ectoderm to become epidermal tissue
  3. The organizer tissues act by secreting molecules that block this induction, thereby allowing the ectoderm “protected” by these factors to become neural.
- Ectodermal cells are induced to form neuroectoderm from a variety of



signals.

- Ectoderm sends and receives signals of bone morphogenetic protein 4 (BMP4) and cells that receive BMP4 signals develop into the epidermis.
- The inhibitory signals chordin, noggin, and follistatin are needed to form a neural plate.
- These inhibitory signals are created and emitted by Spemann's organizer.
- Cells that do not receive BMP4 signaling due to the effects of the inhibitory signals will develop into the anterior neuroectoderm cells of the neural plate.
- Cells that receive fibroblast growth factor (FGF) in addition to the inhibitory signals from posterior neural plate cells.

Noggin: Induces dorsal ectoderm to form neural tissue, and it dorsalized mesoderm cells that would otherwise contribute to the ventral mesoderm.

• Noggin binds to BMP4 and BMP2 and inhibits their binding to receptors
• Chordin and Follistatin bind directly to BMP4 and BMP2 and prevent their complexing with their receptors
• Nodal-related-3 (Xnr-3) is synthesized by the superficial cells of the organizer and is also able to block BMP4
• In the mesoderm, BMP4 activates genes such as Xvent1, which give the mesoderm, a ventral phenotype.

Formation of head

1. The most anterior regions of the head and brain are underlain not by the notochord, but by pharyngeal endoderm and head (prechordal) mesoderm.
2. Cerebrus: Induces dorsal ectoderm to become an anterior-most region of the head like the eye, olfactory lobes
3. Frz-b: Responsible for the development of the head region
4. Dickkopf: Responsible for forebrain
5. Neurogenin: Responsible for induction of dorsal ectoderm cells to form nerve cells

Concept Review Questions:

Q1. Dorsal lip of amphibians is equivalent to chicks

a. Hensen node
b. Primitive grove
c. Animal pole
d. Vegetal pole

Q2. Which protein secreted by the amphibian organizer induces neural tissue formation by inhibiting Bone Morphogenetic Protein?

a. β-catenin. b. Noggin.

c. Dickkopf. d. Dishevelled.

Q3.The blastopore region of amphibian embryo that secretes BMP inhibitors and dorsalizes the surrounding tissue is known

a. Brachet's cleft b. Nieuwkoop center

c. Spemann's organizer d. Hensen's node

Q4. The dorsal-most vegetal cells of the amphibian embryo that is capable of inducing the organizer are called as Nieuwkoop center and is marked by the presence of

a. Chordin
b. β-catenin
c. Goosecoid
d. Nanos

Q5. The grafting of the dorsal lip of the blastopore from an early Xenopus gastrula onto the ectopic ventral side of an early embryo will result in two complete embryos. Thus dorsal can be designated

a. Primary organizer
b. Cytoplasmic determinant
c. Morphogen
d. Primitive

Q6. The presence of β-catenin in the nuclei of blastomeres in the dorsal portion of the amphibian embryo is one of the determinants for laying down the dorso-ventral axis. What will be the outcome of expressing a dominant-negative form of GSK3 in the ventral cells of the early embryos?

a. The dorsal cells will be ventralized
b. A secondary axis will be formed
c. The primary organizer will not be formed
d. The embryo will develop normally

Answers:

Q1- a Hensen's Node
Q2- b- Noggin
Q3- c Speeman's organizer
Q4- b- Beta-catenin
Q5- a- Primary organizer
Q6- b – A secondary axis will be formed

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