Biology 340
Comparative Embryology
Lecture 7
Dr. Stuart Sumida

Introduction to Tetrapoda; Vertebrata

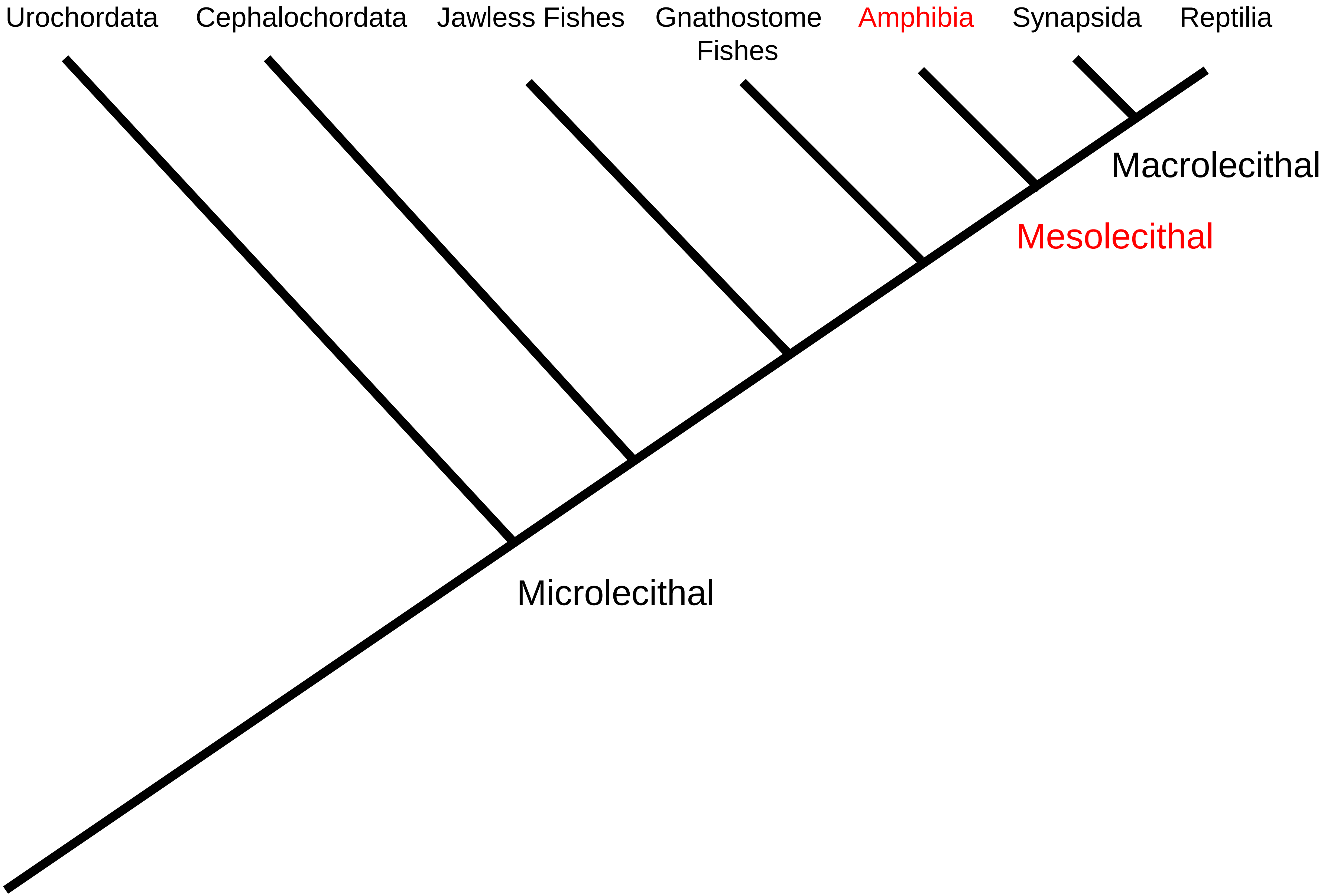
Extant Amphibia – (Frogs)

PHYLOGENETIC CONTEXT:

We will now begin our examination of early development in vertebrates. Recall the three different types of eggs based on yolk type, micro-, meso- and macrolecithal eggs.

In our rough "morphological series" (a series of extant taxa used to demonstrate our best estimate of actual phylogenetic progression), we now examine:

Microlecithal – Amphioxus
Mesolecithal – Amphibian (frog)
Macrolecithal – Bird (as model of basal reptile)
(Back to) Microlecithal – Therian mammal.


Urochordata
Cephalochordata
Jawless Fishes
Gnathostome Fishes
Amphibia
Synapsida
Reptilia
Macrolecithal
Mesolecithal
Microlecithal

Many of the differences in the early development of amphioxus and the early development of frogs may be ascribed to two major things: (1) the difference in the amount of yolk present; and (2) presence of neural crest.

The ovum (egg) of the frog is MESOLECITHAL, containing a moderate amount of yolk. However, it is still very much less than the macrolecithal yolk of basal amniotes such as monotremes, reptiles and birds.

THE FROG EGG

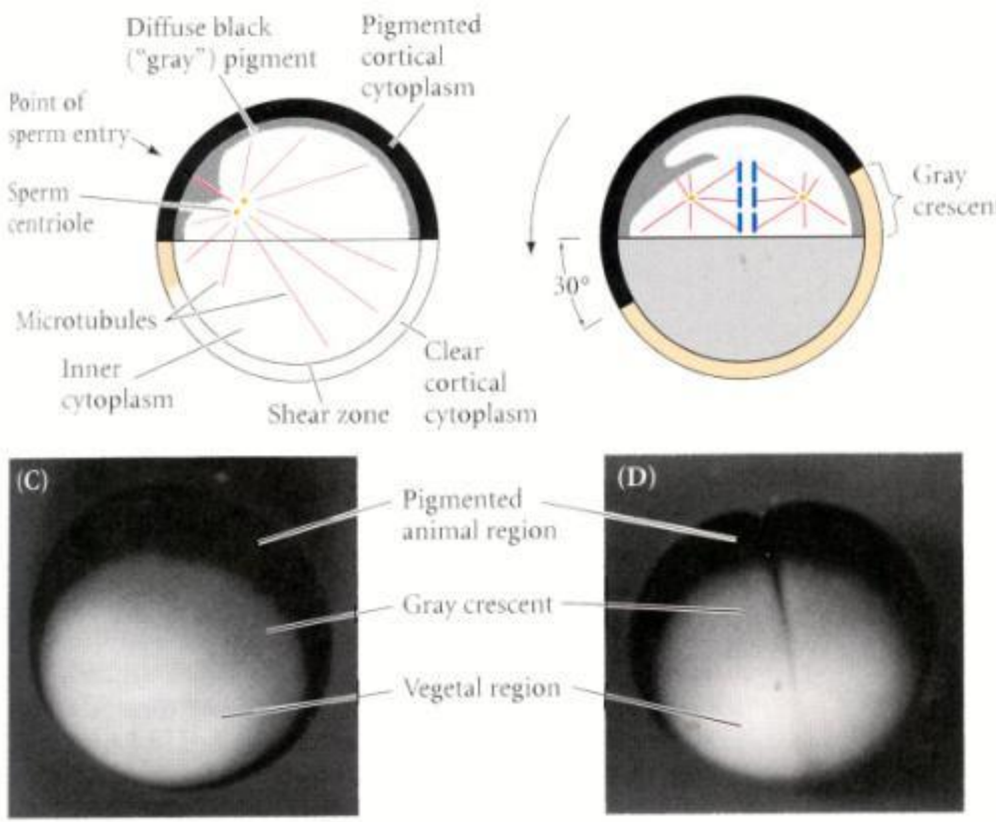
The egg is coated with a fine membrane, the VITTILINE MEMBRANE.

More superficially there are a number of jelly-like membranes that swell when the eggs hit the water in which they will develop. These are the JELLY MEMBRANES.

Fertilization in (most) frogs is external, so all of the processes we will describe here take place outside of the female.

Immediately following fertilization, the vitteline membrane lifts away from the eggs slightly, and the egg rotates to that the heavier, more yolk laden vegetal pole comes to lie more downward.

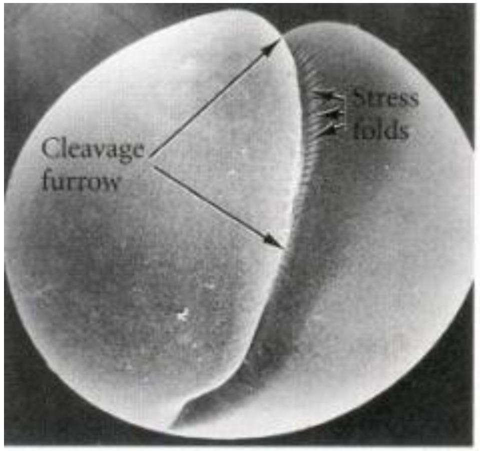
Then, there is a differential migration of pigments that allows the distinction of an area called the GREY CRESCENT. The materials of the grey crescent will give rise to the notochord. (Note, that with the formation of the grey crescent, bilateral symmetry is already confirmed on the embryo.)

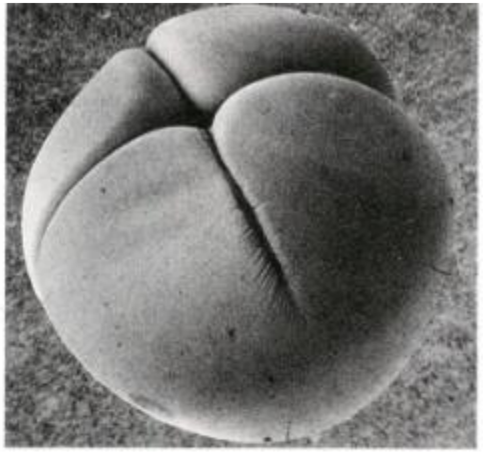


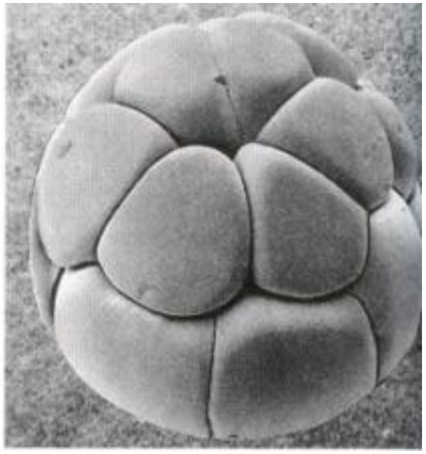
The first plane of cleavage comes very close to the plane of bilateral symmetry. Note, as vertebrates, and thus deuterostomes, cleavage is radial. That is, the first plane of cleavage is meridional and essentially bisects the grey crescent.

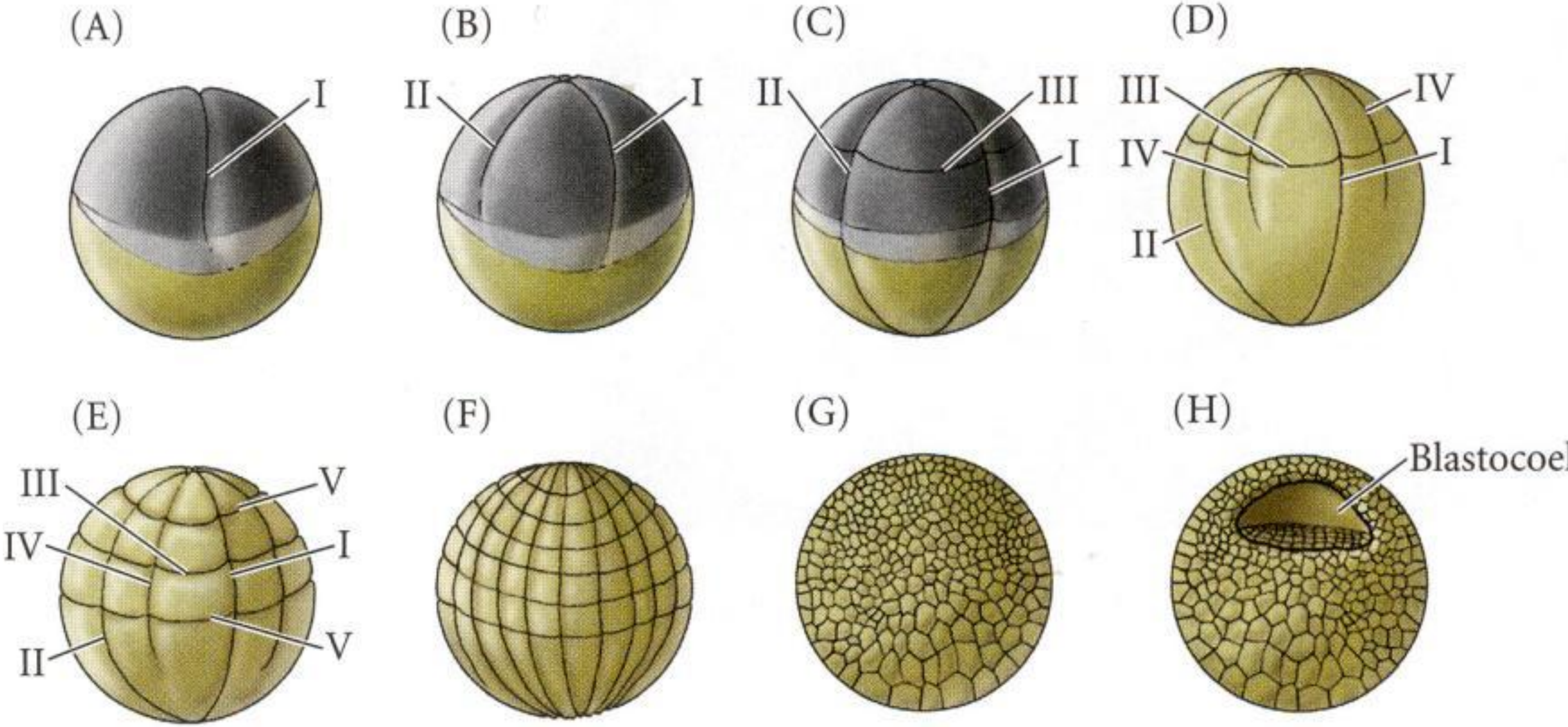
The second plane of cleavage is also meridional and is at a right angle to the first. Although there is a moderate amount of yolk, cleavages is holoblastic. Thus, cleavage is RADIAL and HOLOBLASTIC.

Although cleavage is holoblastic, the larger amount of yolk makes its presence felt. Cleavages take place more slowly, and with lesser frequency in the vegetal hemisphere than in the animal hemisphere.





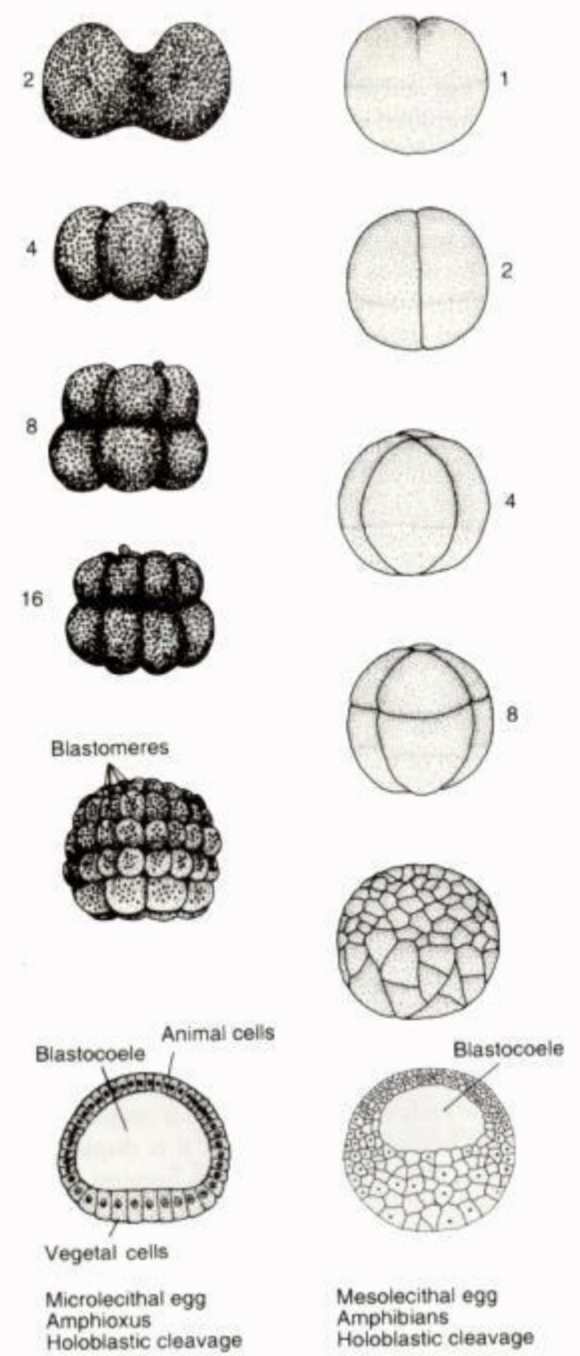


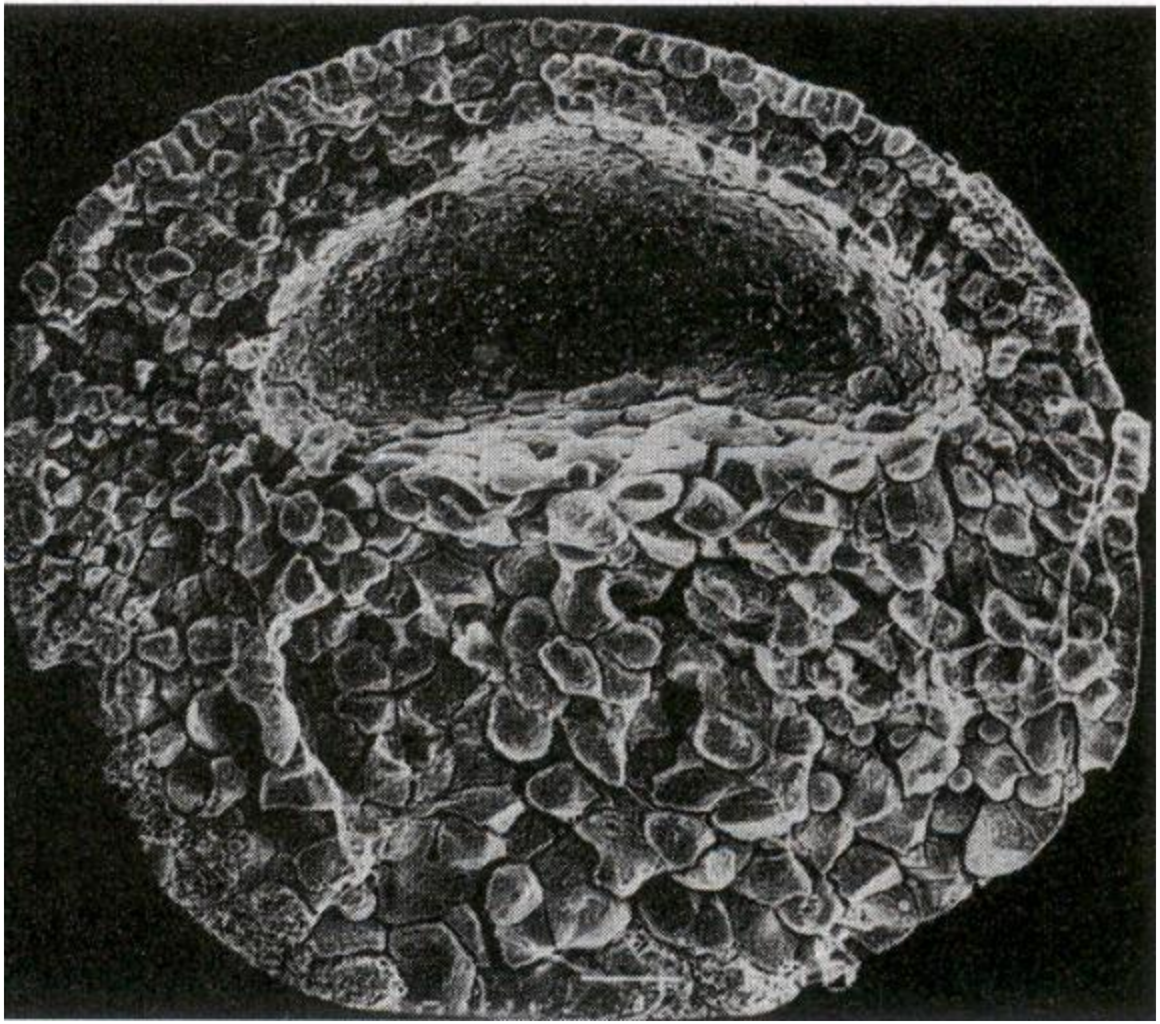


(A)
I
(B)
II
I
(C)
II
III
I
(D)
III
IV
IV
I
II
(E)
III
V
IV
I
II
V
(F)
(G)
(H)
Blastocoel

Because of this, by the time we reach the blastula stage, the yolky cells of the vegetal hemisphere are considerably larger than those of the animal hemisphere.

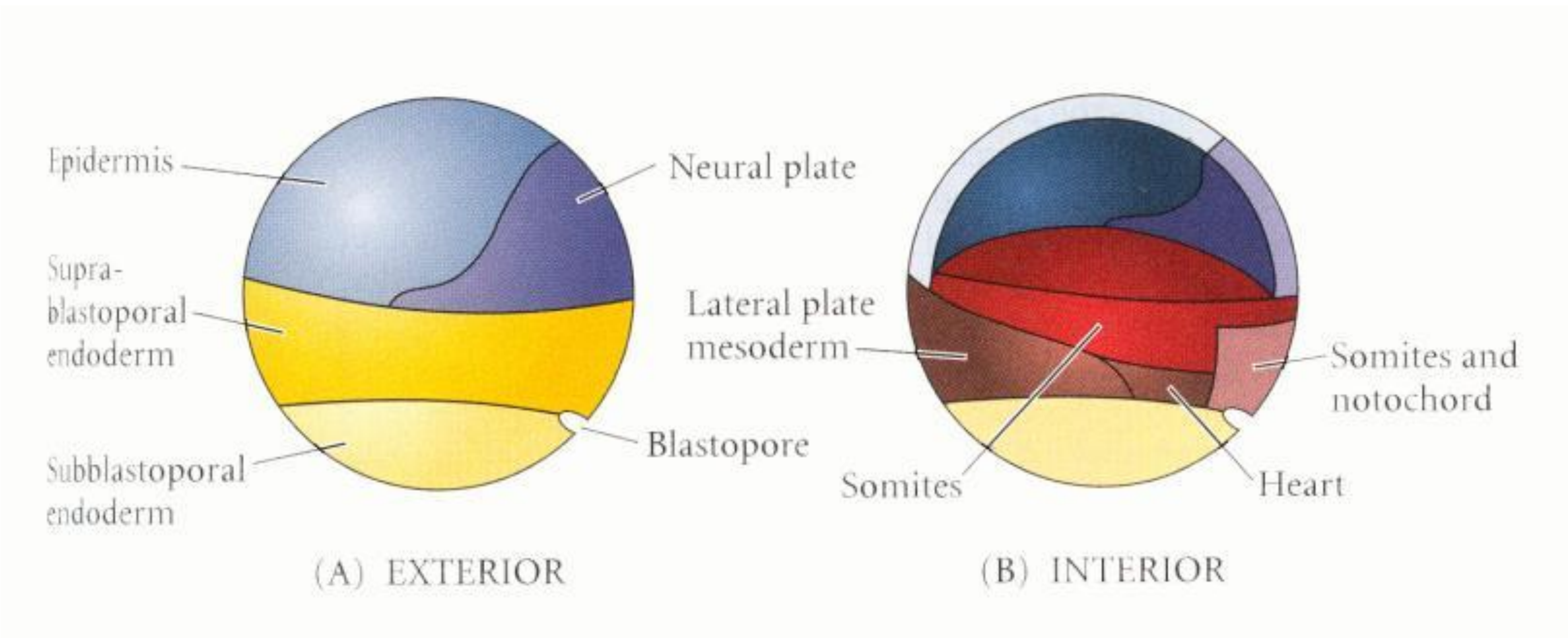
Unlike the condition in sea urchins and amphioxus where the blastula is surrounded by a single layer of cells, the walls of the amphibian blastula are multicellular and the blastocoele is eccentrically placed.

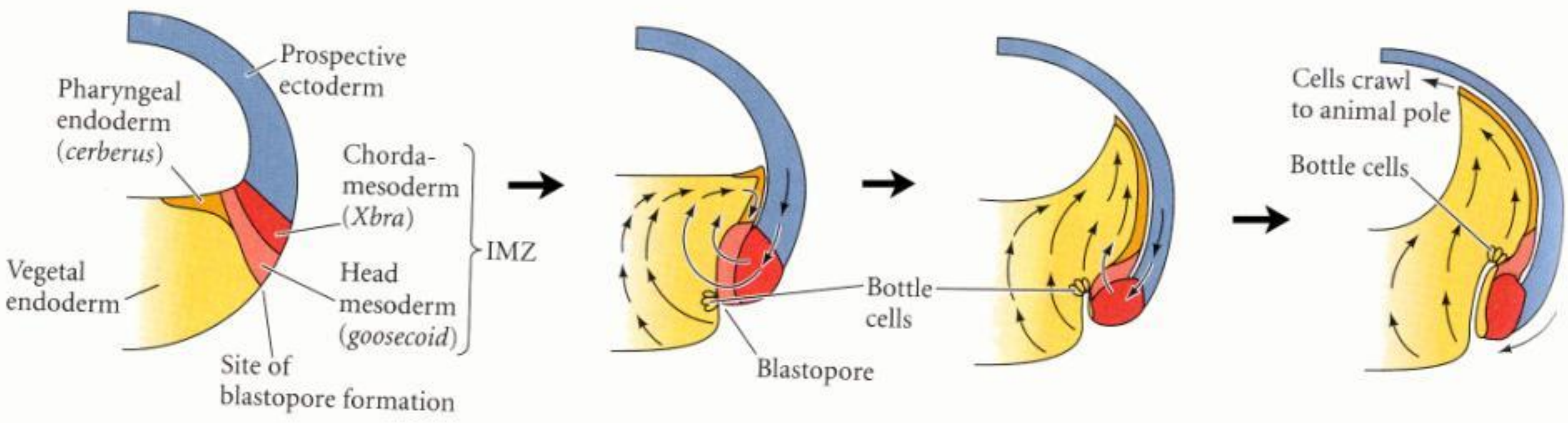




Draw a diagram of the amphibian blastula here:

After this begins the process of GASTRULATION, and at this point we may construct a fate map showing the derivation of particular adult materials:





Detail on fate map.

Draw a diagram of the amphibian gastrula fate map here:

Recall of course that there is no actual, physical difference in the appearance of the cells of these various regions. All this diagram does is show the prospective distribution of cells derived from these areas.

The distribution of presumptive adult materials at the beginning of gastrulation in frogs is essentially very similar to that which we saw in amphioxus with a few minor differences.

GASTRULATION

The large yolky cells of the prospective endoderm prevent the large-scale invagination that we saw in sea urchins and amphioxus. Instead, the blastopore of the frog makes its first appearance as a shallow indentation.

However, as in amphioxus, the blastopore does appear in the region of the prospective endoderm.

Note the materials that lie on the surface of the blastula that are destined to move inwards through the blastopore: prechordal mesoderm (which will give rise to parts of the braincase), notochordal mesoderm, lateral mesoderm, and endoderm. Epidermal ectoderm will remain outside to give rise to skin structures.

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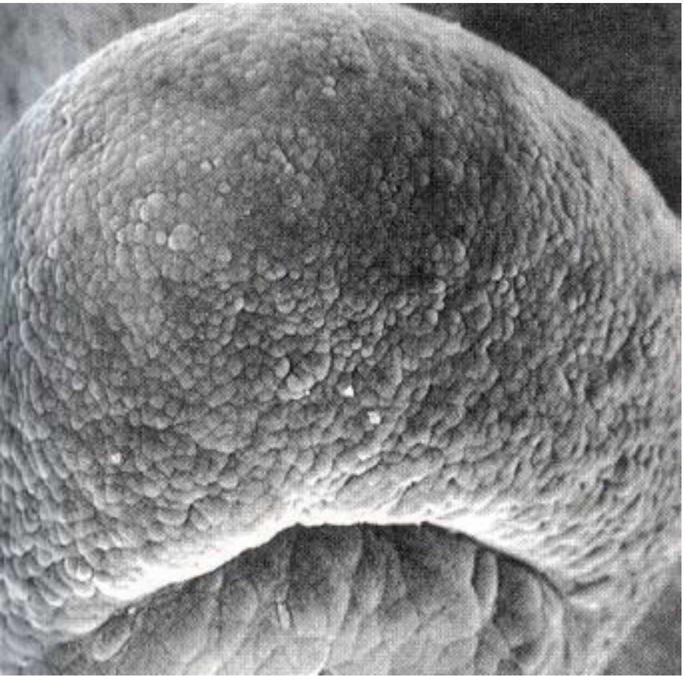
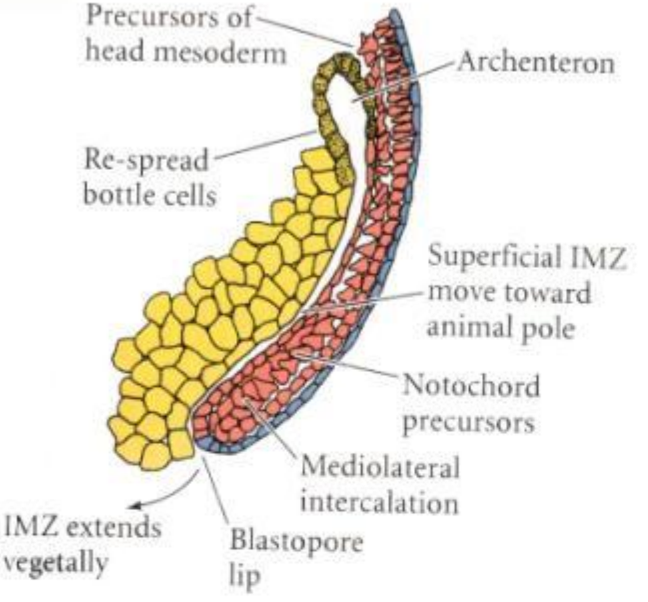
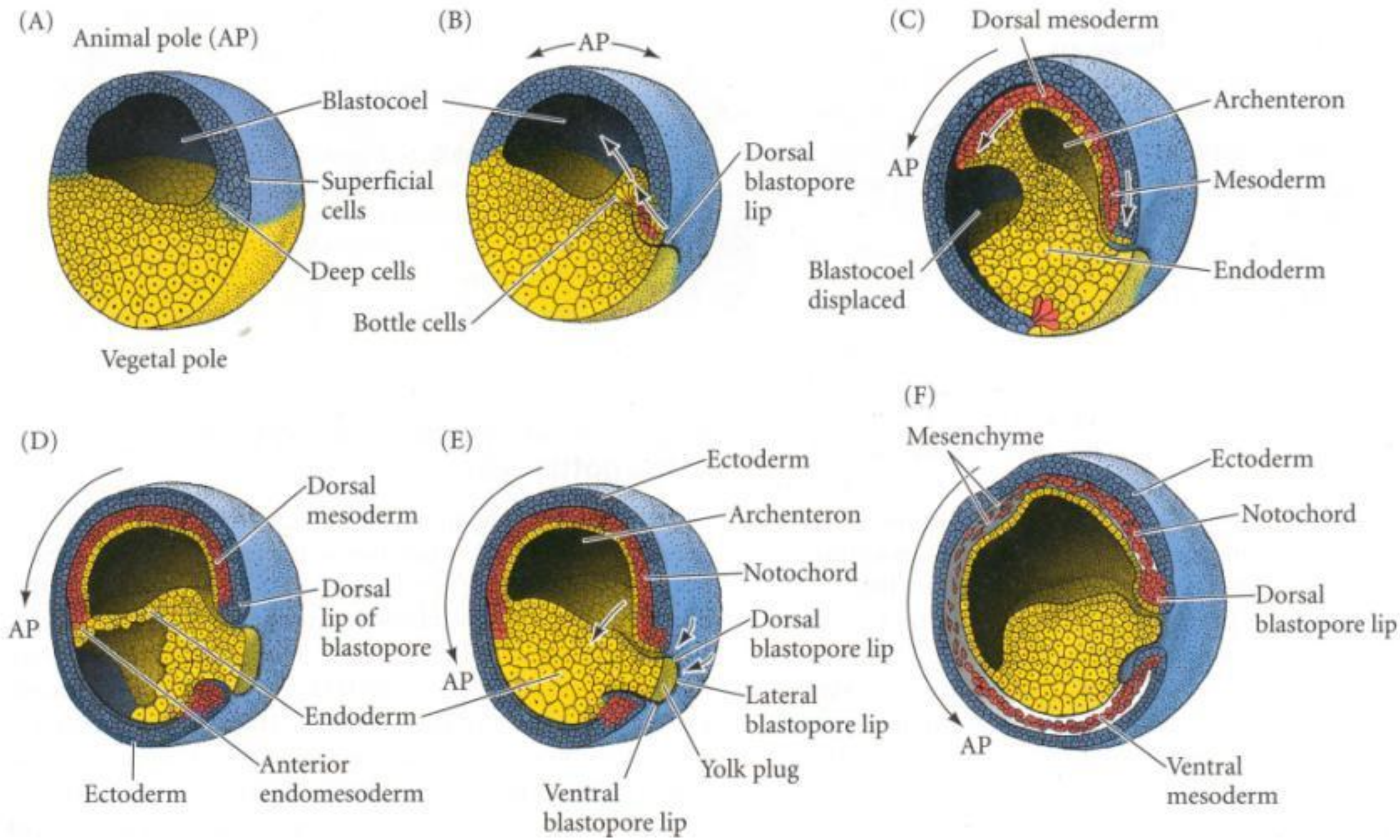
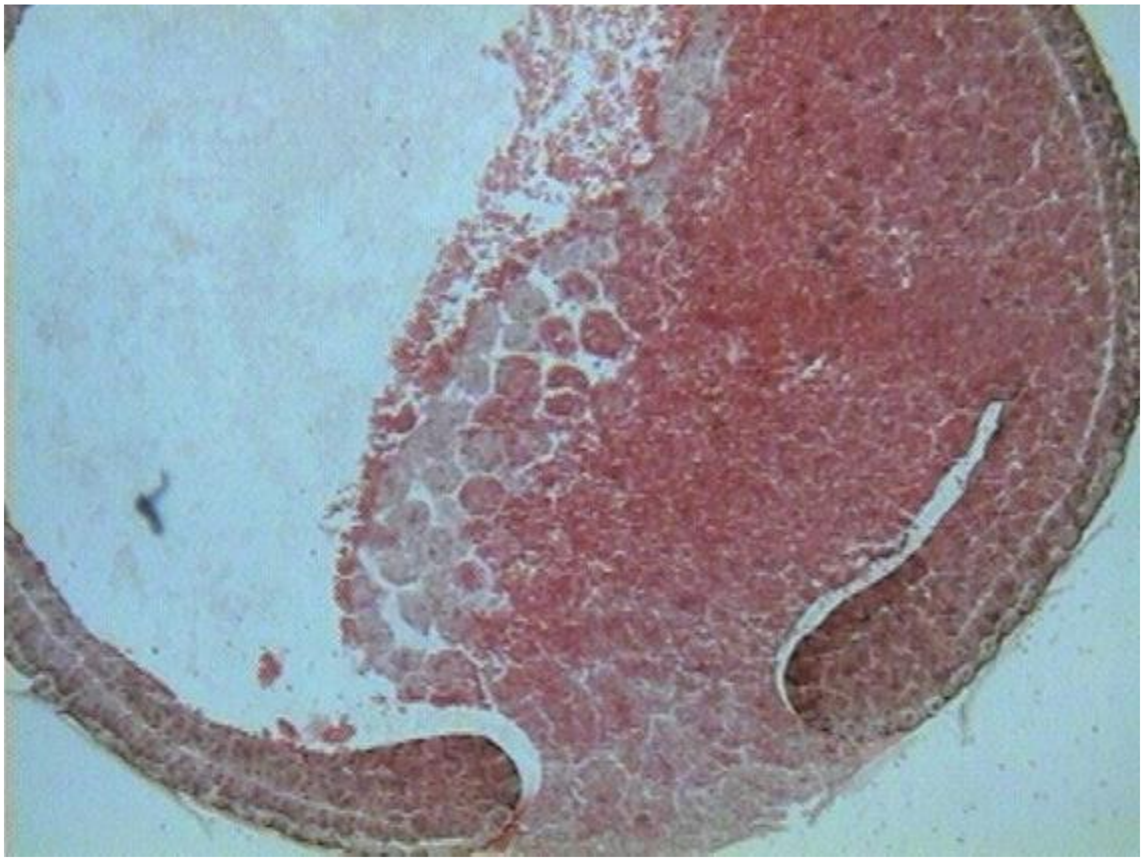






It is important to remember that throughout this process, although cell multiplication is taking place, the total amount of protoplasm remains fairly constant. Although the embryo is developing, it is NOT growing at this time. (This is quite different from what we will see in more derived vertebrates later on…)

A bit farther on, the distribution of endoderm viewed in sagittal section reveals a large YOLK PLUG. Mesodermal materials are moving in at the DORSAL LIP of the blastopore, and the VENTRAL LIP of the blastopore.



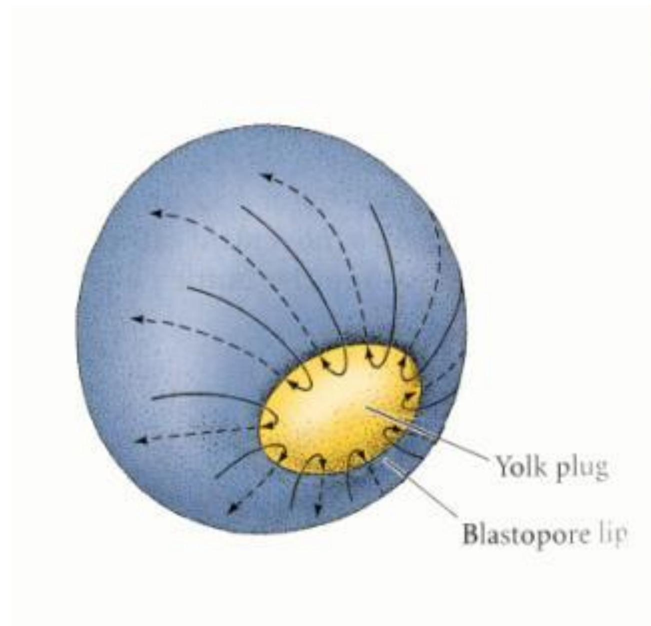


Diagram stage with yolk plug here.

As in amphioxus, the embryo undergoes rotation.

Note that as the GASTROCOELE (ARCHENTERON) expands, the blastocoele necessarily becomes reduced in volume – ultimately becoming obliterated.

Again, note, that although the processes look superficially different from those in amphioxus due to the large amount of yolk, they retain an essential similarity.

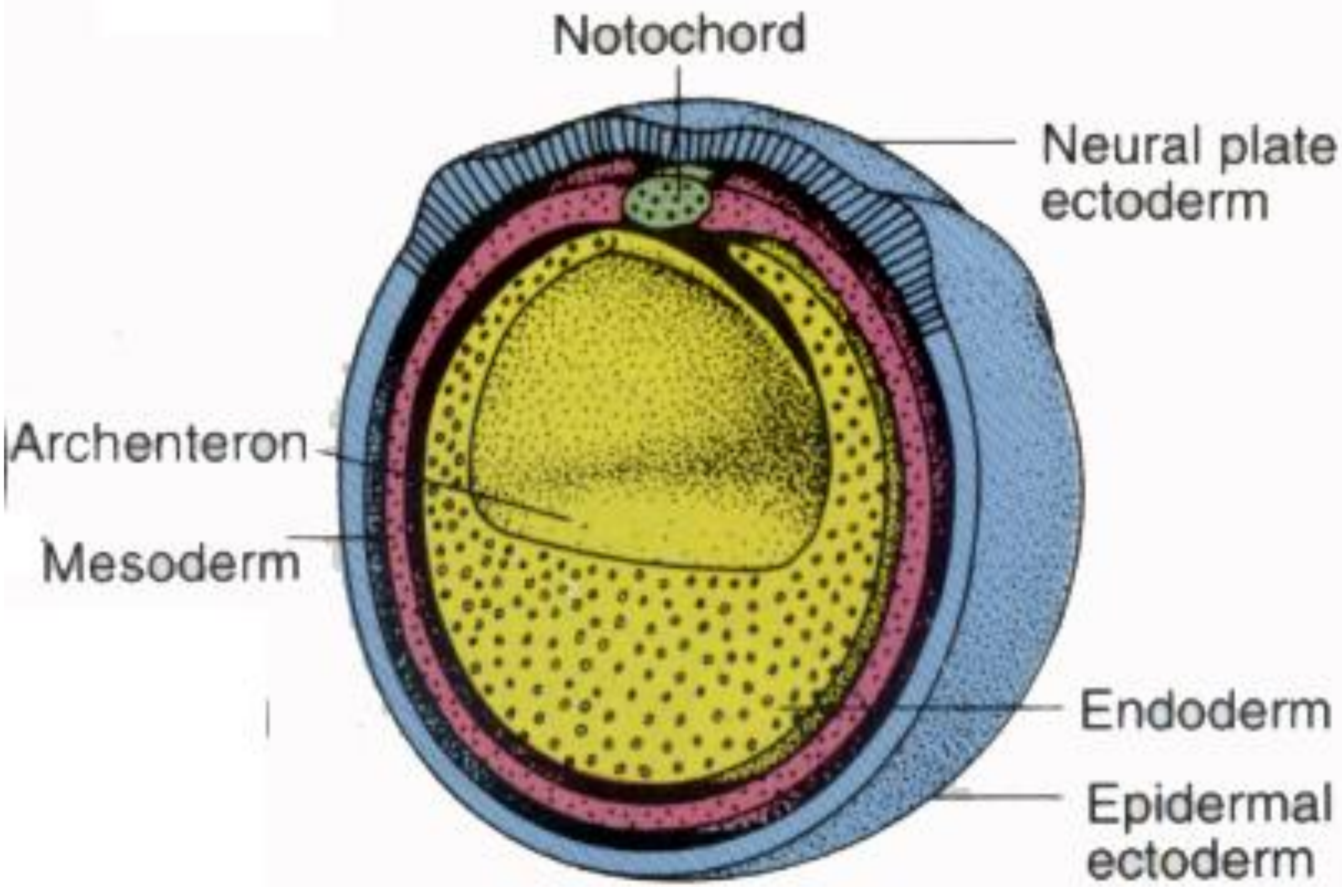
Diagram that here:

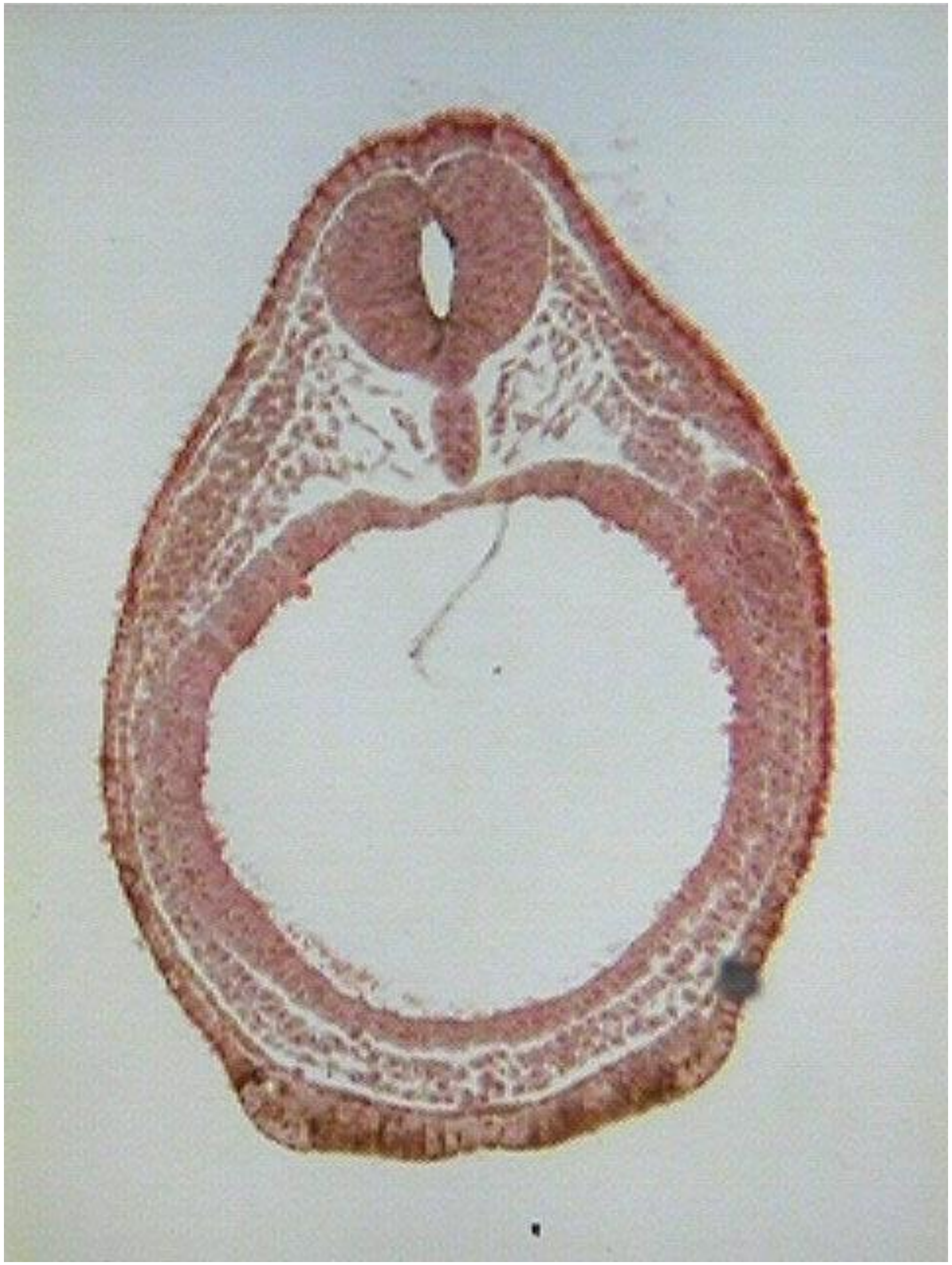
FURTHER MESODERMAL MOVEMENT

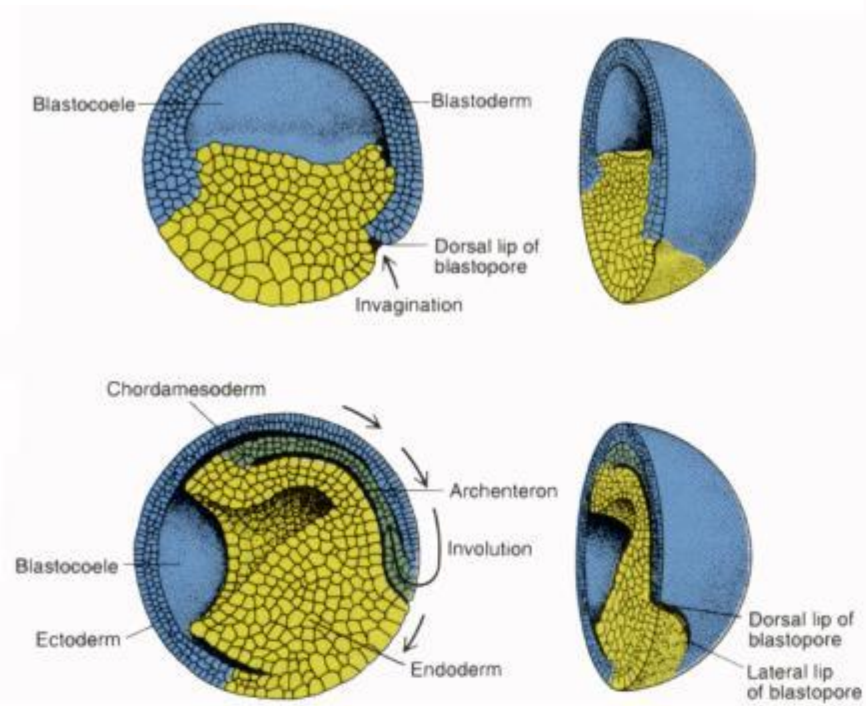
Sagittal sections do not adequately show what is happening to the mesoderm. In addition to turning in at the ventral lip, it has been turning in at the lateral lips of the blastopore as well.
It has also been streaming in at the lateral lips as well. It has been moving upwards and forwards, COMING TO LIE ALONGSIDE THE NOTODHORDAL MATERIALS.

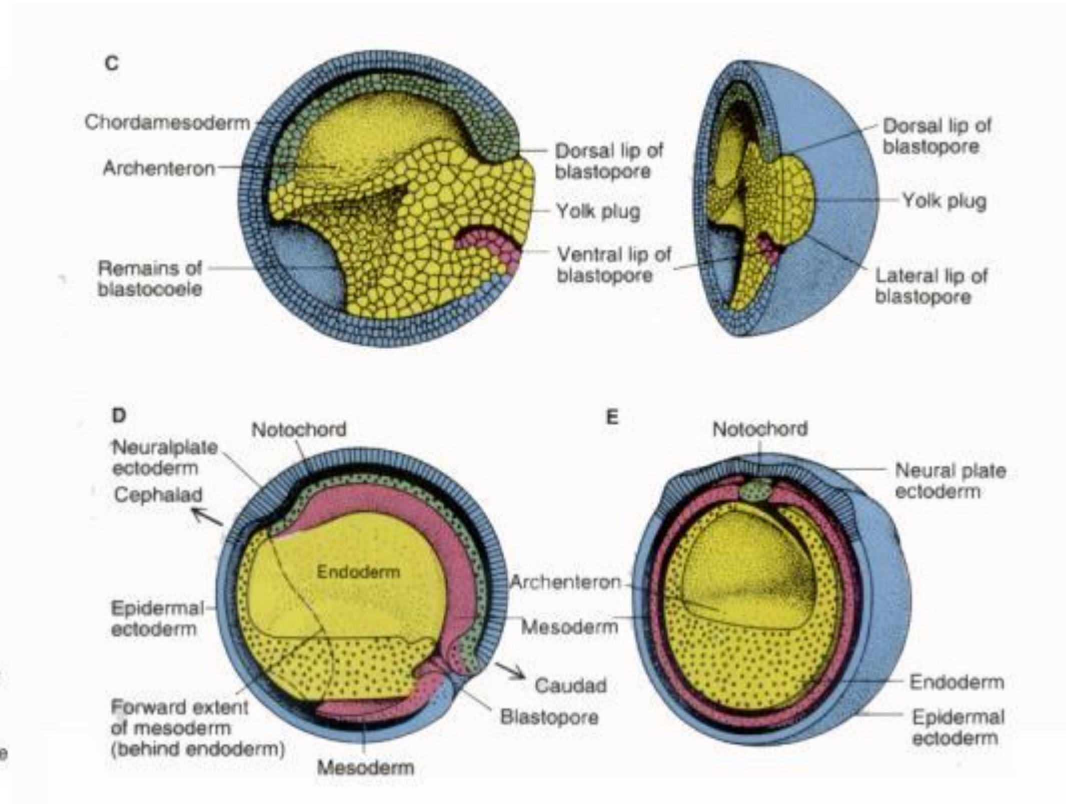
For this reason, a TRANSVERSE section is in order:

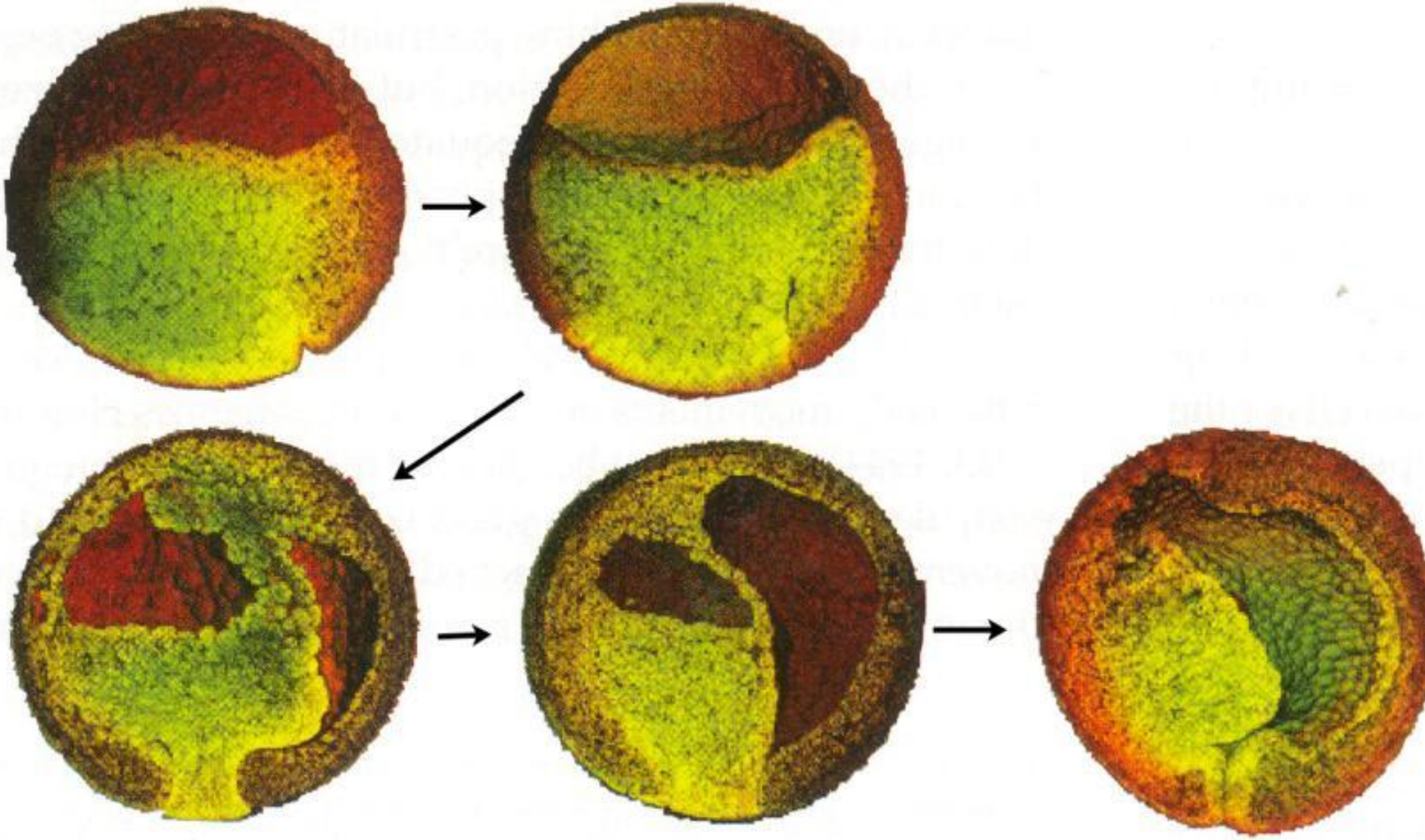
Diagram stage with well-developed neural plate here.


Notochord
Neural plate ectoderm
Archenteron
Mesoderm
Endoderm
Epidermal ectoderm




Blastocoele
Blastoderm
Dorsal lip of blastopore
Invagination
Chordamesoderm
Archenteron
Involution
Blastocoele
Ectoderm
Endoderm
Dorsal lip of blastopore
Lateral lip of blastopore


C
Chordamesoderm
Archenteron
Remains of blastocoele
Dorsal lip of blastopore
Yolk plug
Ventral lip of blastopore
Dorsal lip of blastopore
Yolk plug
Lateral lip of blastopore
D
Notochord
Neuralplate ectoderm
Cephalad
Endoderm
Epidermal ectoderm
Forward extent of mesoderm (behind endoderm)
Mesoderm
Archenteron
Mesoderm
Caudad
Blastopore
E
Notochord
Neural plate ectoderm
Endoderm
Epidermal ectoderm



Note that the essential “tube within a tube” structure has been attained, even though the lower portion of the inner tube is pretty thick with yolk-laden cells.

However, we cannot yet talk of a somatopleure and a splanchnopleure. Recall that those are necessarily derived from two germ layers, one of which will be mesoderm.

Draw…

With further development:

1. The neural plate thickens. It will eventually fold upon itself, for form a rolled up neural tube as in amphioxus. The folds are made of neural ectoderm. However, the neural plate does not break away and sink as in amphioxus.

2. NEURAL CREST material will appear at the junction of the neural ectoderm and the epidermal ectoderm.

3. The notochord had formed.

4. Beneath the arms of the notochord, the arms of the endoderm and extended and come together (zipped up) to form the lining of the gut cavity.

5. The mesoderm spreads ventrally. It pushes between the ectoderm and the endoderm. As it does so, it splits on either side, forming the COELOM. Note that this is not an enterocoelous coelom formation as in amphioxus. In the vertebrates, coelom formation has returned to a SCHOTIZOCOELOUS condition.

Draw a cross-section of an amphibian embryo. Be sure to include: epidermal ectoderm, dorsal hollow nerve cord, notochord, gut tube, somite, coelom, somatopleure, splanchnopleure.