Biology 340
Comparative Embryology
Lecture 6
Dr. Stuart Sumida

Introduction to Embryology of Chordata

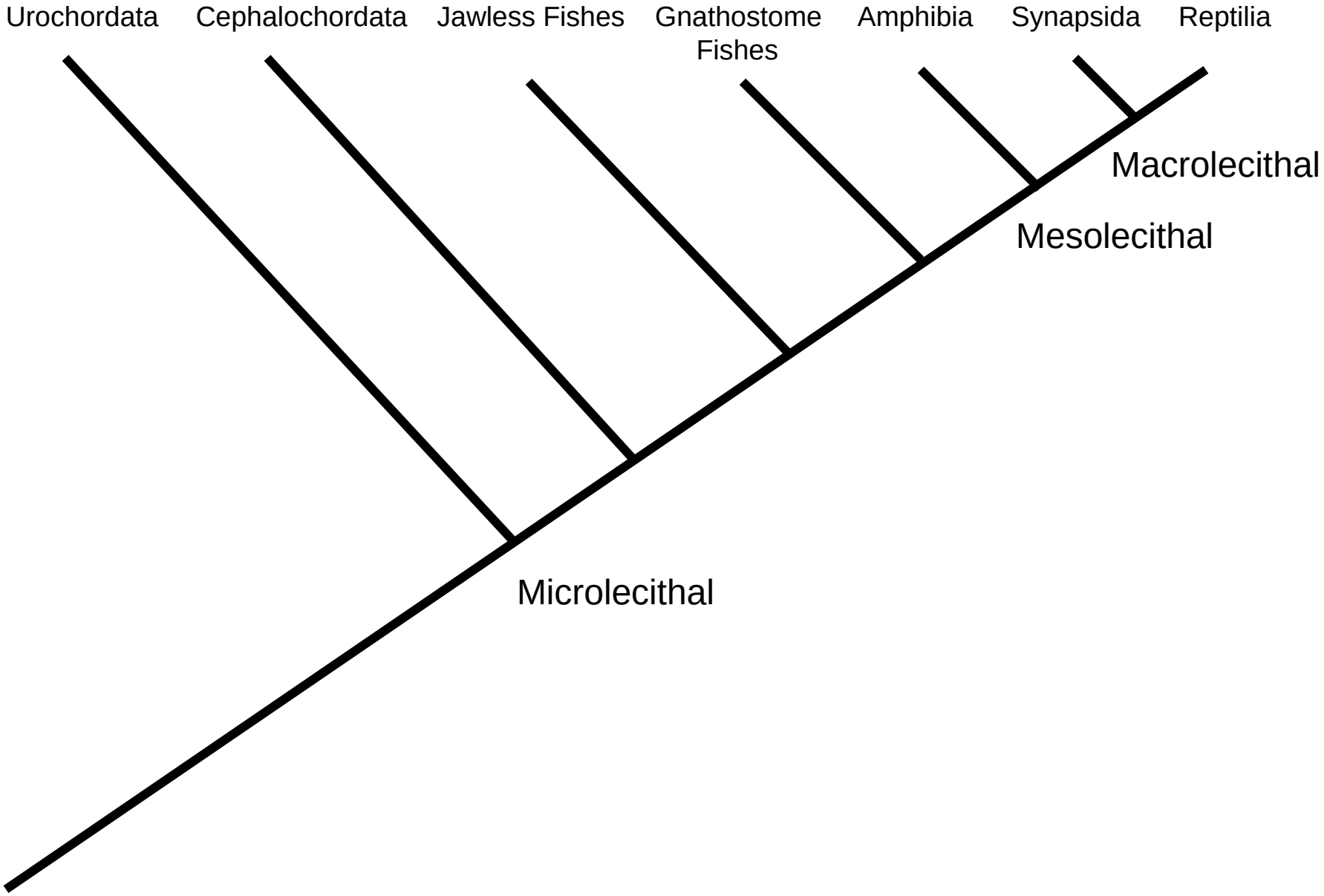
Cephalochordata – Amphioxus

PHYLOGENETIC CONTEXT:

We will now begin our examination of early development in chordates. Recalling the three different types of eggs based on yolk type, we will examine taxa with micro-, meso- and macrolecithal eggs.

We will model a rough “morphological series” (a series of extant taxa used to demonstrate our best estimate of actual phylogenetic progression). As most members of the Chordata are extinct, what we do will necessarily be incomplete, but we will do our best:

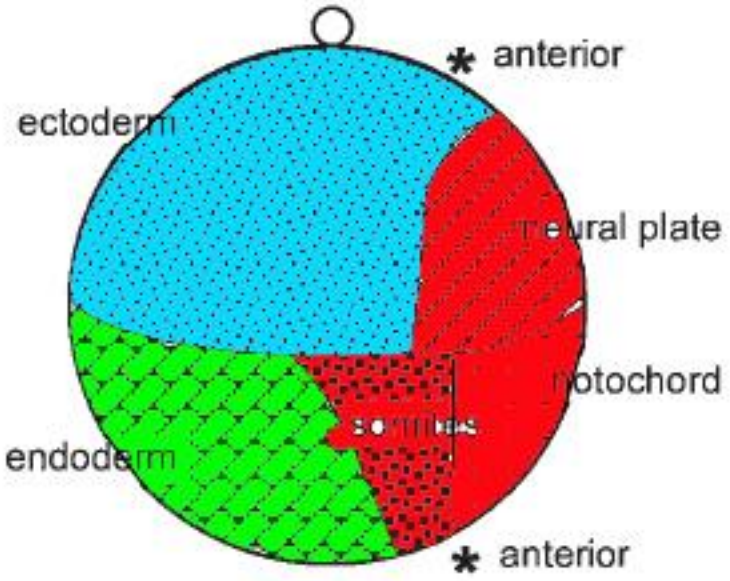
Microlecithal – Amphioxus
Mesolecithal – Amphibian (frog)
Macrolecithal – Bird (as model of basal reptile)
(Back to) Microlecithal – Therian mammal.


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

AMPHIOXUS – A CEPHALOCHORDATE

Amphioxus, more properly referred to as *Branchiostoma*, begins our survey of chordates. While not a vertebrate, it can give us an idea of the more basal chordate condition.

Staining studies have indicated that different parts of the fertilized egg are destined to give rise to certain specific materials of the adult animal in the course of normal development. Thus, we can construct a fate map. Recently…just this past year…a new fate map was published for Amphioxus.



Draw this for yourself:

Note that because of the distribution of the presumptive materials, bilateral symmetry is already evident – or, radial symmetry is already lost.

Determination comes fairly quickly in Amphioxus. Recall that as a deuterostome, cleavage is radial and initially indeterminate. Determination does come fairly quickly however. In urochordates it can be as early as the 8-cell stage.

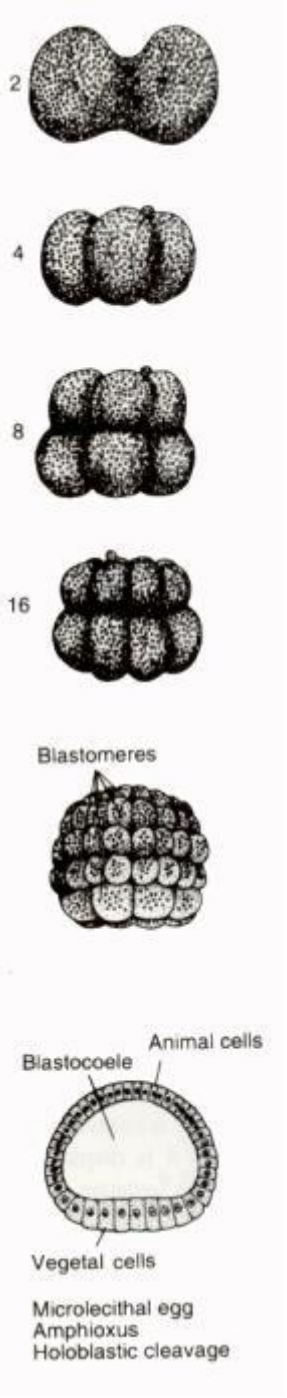
Endoderm lies near the bottom of the egg, which is heavier because although there is little yolk, there is SOME. And, that yolk (which is heavier) comes to lie near the vegetal pole.

(The fact that the disposition of materials may be followed to particular elements of the adult by no means implies preformation at this early stage. Experiments wherein one of the two cells of the first cleavage is removed still results in a viable embryo. This has been shown for many deuterostomes: sea urchins, urochordates, amphioxus, frogs, salamanders, others. [However, here we're focusing on normal development.])

EARLY CLEAVAGE IN AMPHIOXUS

During the earliest cleavages, growth does not occur. In fact, as nutritive materials are used to power the earliest proeses, the embryo may actually decrease in size.

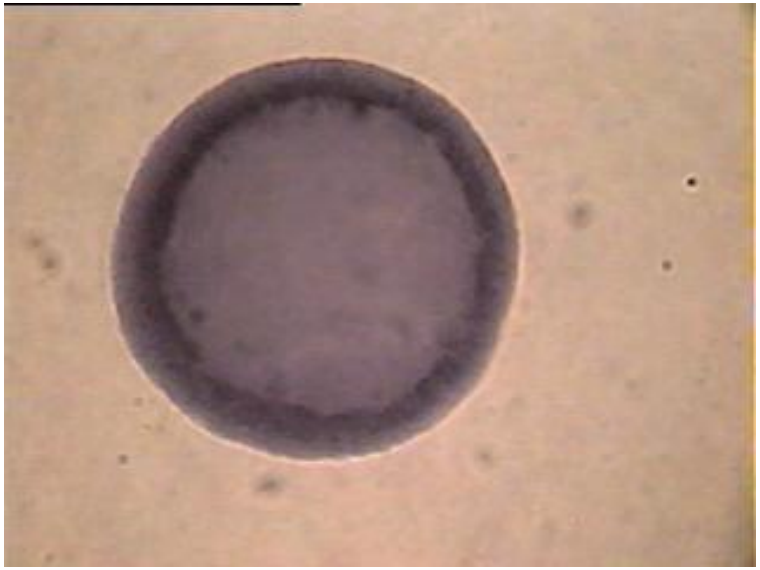
Cleavage planes pass entirely through the egg. They are holoblstic. The first two are meridional, giving the four-cell stage. The third is equatorial. The third cleavage is not exactly perfectly distributed. Lower, yolkier cells are somewhat larger.



THE BLASTULA

Eventually after a number of cleavages, the divisions are no longer synchronous. Before long, a single layer of cells defines a hollow ball – the BLASTULA has been formed.

The cavity of the blastula, the BLASTOCOELE, is filled with liquid. Note that at this stage, the cells of the vegetal hemisphere are slightly larger than those of the animal hemisphere. These are cells of the prospective endoderm. They are somewhat richer in the yolky material than the other cells.



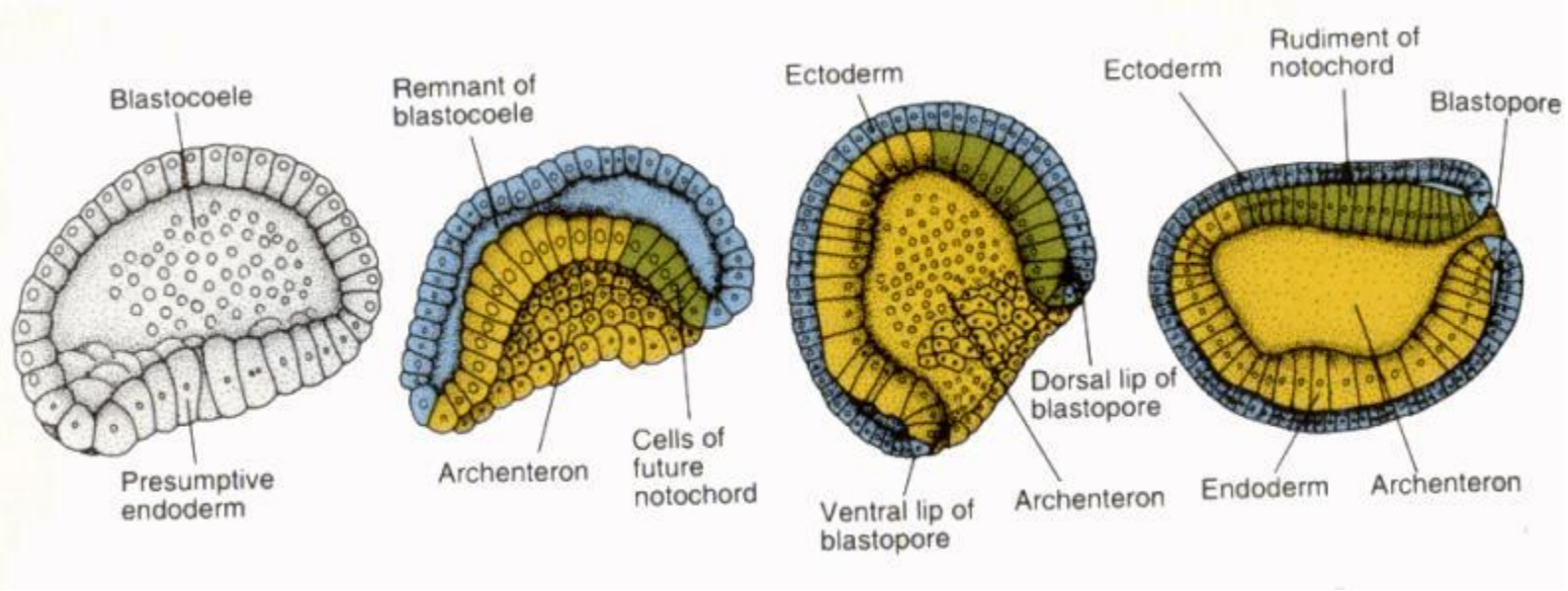
Draw Amphioxus Blastula Fate map:

GASTRULATION

Due to faster growth of cells at the position of the prospective blastopore, the surface of the region increases. This causes a dimpling in, or INVAGINATION.

In addition to invagination, we also have INVOLUTION, a movement of cells inward s fast as they are produced. This multiplication and involution takes place most rapidly at the dorsal lip of the blastopore.

The dorsal lip of the blastopore is an important organizing region for the embryo. In the following two-dimensional drawing, realize that the blastopore is representing a circular opening.



Draw Amphioxus Gastrula here.

The original blastocoele is decreasing in size as the process of involution continues. This stage is now called the GASTRULA, as the primitive gut tube, or ARCHENTERON has been formed. We now have an animal that is a tube within a tube.

The blostocoele becomes progressively more obliterated, and the blastopore becomes somewhat constricted. Eventually, you get a sort of a sausage shaped embryo.

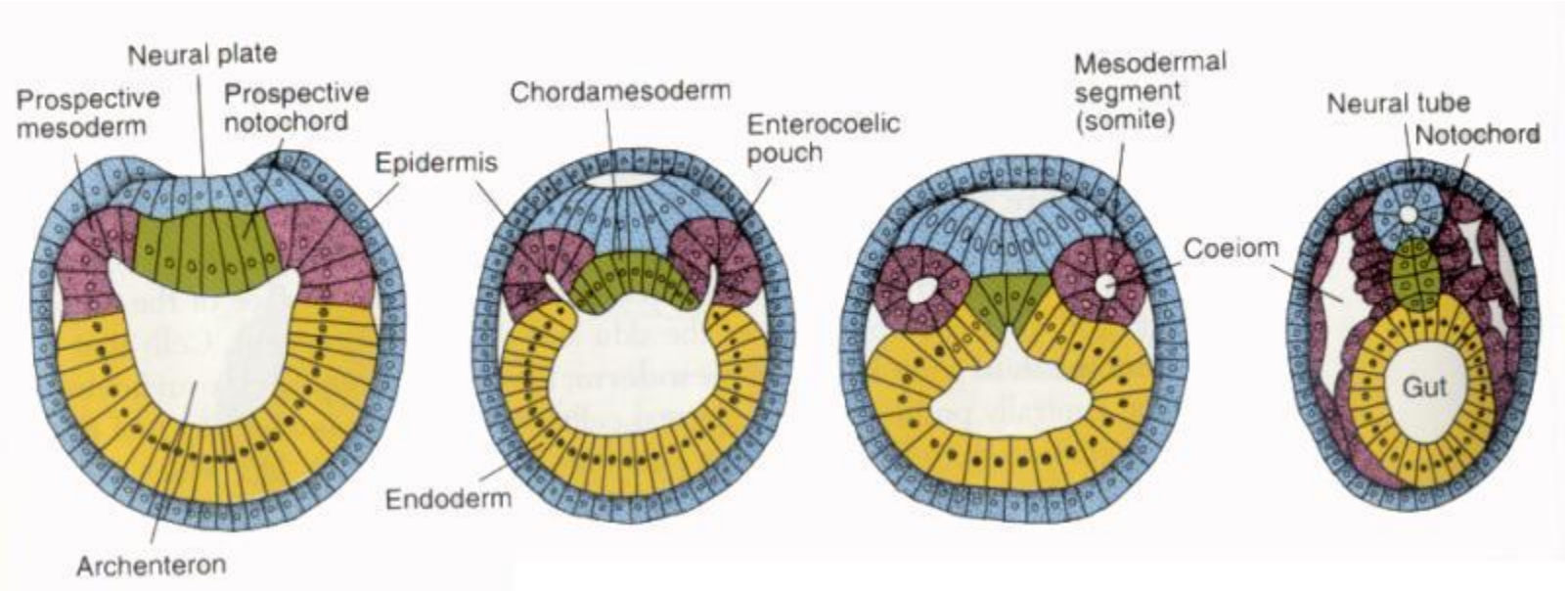
Draw diagram of an Amphioxus gastrula in saggital section. (ca. 1 hour development)

NEURULATION

After gastrulation, we enter the stages of neurulation, where a number of processes occur simultaneously. It is impossible to follow all of them at once, so we will try to break them down. First in transverse section we will follow the process of formation of the neural tube and somites.

As endoderm thickens, it *breaks away from the epidermal ectoderm* and comes to sink in as the NEURAL PLATE. (This is different from what we will see in vertebrates where the neural ectoderm rolls up on itself.)

Neural plate formation is induced by the notochord tissue.



Draw beginning of neurulation in Amphioxus here.

ENTEROCOELY

Note that while the neural plate was thickening, the mesoderm is beginning to pouch away from the lining of the archenteron.

Eventually, the neural ectoderm rolls upon on itself to form the neural tube.

The notochord separates from the rest of the archenteron as well as the rest of the mesoderm.

The remaining mesodermal pouches close off on themselves. The endoderm closes off on itself dorsally, and the inner lining of the gut is formed.

Draw ending of neurulation and enterocoely in Amphioxus here.

Because the mesodermal pouches budded off of the original archenteron to form pouches – the COELOM(!), coelom formation in amphioxus is known as ENTEROCOELOUS COELOM FORMATION.

(Notably, this is the pattern for the cranial/anterior end of the animal. More posteriorly, they form by cavitation.)

Recall that echinoderms are enterocoelous. Urochordates are as well.

Later we will see that vertebrates go their own way in coelom formation, doing it in a schitzocoelous fashion.

OTHER FEATURES OF BEING A DEUTEROSTOME

As chordates are deuterostomes, the anus develops near (not necessarily from) the blastopore. Some interesting changes take place near the region of the blastopore.
In dorsal view, realize we would see a “neural trough” before the dorsal hollow nerve cord closed off.

As the neural fold zips up, the blastopore eventually comes to be covered up. (We can think of the neural trough as being “zipped over”.

Now remember, the blastopore opened into the archenteron. So, as it gets zipped over, it actually winds up connecting with the neural canal. Thus, for a time, there is a connection between the neural tube and the gut. This is the NEURENTERIC CANAL.

Draw series of dorsal views of neural trough in Amphioxus here.

Draw 2-hour lateral view of Amphioxus here.

Note also the position of the somites. They have become separated into a segmental series. This is the ontogenetic beginning of somatic segmentation.

PARTIAL SUMMARY

Note that we have seen at least two of the four major chordate features develop.

Development of the gill slits was not discussed, as it is extremely complex, and initially asymmetrical.

INTRODUCTION TO EARLY DEVELOPMENT IN VERTEBRATES: A jawless fish – the Lamprey.