

## Lesson 5

### ◇ Lesson Outline:

- ◆ Developmental Origins of the Chordate Body Plan
  - Craniate Eggs
  - Cleavage and the Blastula
  - Gastrulation
  - Coelom Formation
  - Division of the Coelom
  - Neurulation
  - Organogenesis
    - ◆ Differentiation of the Mesoderm

### ◇ Objectives:

At the end of this lesson you should be able to:

- ◆ Describe the different types of eggs in craniates
- ◆ Describe gastrulation and neurulation
- ◆ Describe how the chordate coelom is formed.
- ◆ Describe the different divisions of the coelom in different vertebrate groups.
- ◆ Roughly distinguish which vertebrate organs arise from which germ layers.
- ◆ Describe differentiation of mesoderm in chordates.

### ◇ References:

- ◆ Chapter 5: 86-104

### ◇ Reading for Next Lesson:

- ◆ Chapter 6: 105-132

## **Craniate Eggs**

### ***Egg Types***

All craniates begin as a single fertilized egg cell and develop into a multicellular organism. In the initial stages, some animals survive from nourishment in the form of yolk, alone. Some receive supplemental nourishment in other ways.

little yolk = microlecithal  
(the yolk in these cells tends to be uniformly distributed throughout the cytoplasm = isolecithal)

moderate yolk = mesolecithal  
large yolk = macrolecithal  
(the yolk tends to be concentrated at one end of the egg cell (telolecithal), and as cell division progresses, cells at one end of the cell mass have very little yolk while those at the other end are mostly yolk)

### ***Oviparity and Viviparity***

Animals that lay eggs are oviparous

They must contain sufficient yolk to nourish the developing embryo until it is free living and can take food orally.

If the egg is macrolecithal, the young may hatch essentially fully formed. If there is less yolk, they will hatch in a larval form

Animals that give birth to free-living young are viviparous

*Euviviparous* refers to cases where the mother continuously provides the developing embryo with protection, nourishment and oxygen and removes waste products (such as in placental mammals) until it is born.

*Ovoviviparous* refers to cases where the embryo forms as an egg (with or without a soft shell) with yolk for nourishment but depends on the mother for oxygen and protection. The embryo may develop in the ovary or uterus and a wide variety of unique surfaces may be used to exchange oxygen and carbon dioxide (pericardial sac, gut or some other surface)

### ***Internal and External Fertilization***

Animals that are viviparous require internal fertilization. Animals that lay eggs with impermeable shells also require internal fertilization.

Animals that extrude eggs with permeable coverings can be fertilized externally.

## Early Development - Amphioxus

The processes we are about to describe take place by slightly different means in different chordate groups (as a function of the amount of yolk and the design of the egg). For our purposes, the details are not as important as the general trends. For illustrative purposes we will focus on the processes in amphioxus, the lancelet, only. This is an organism with very little yolk to obstruct the pattern of development.

### *Cleavage and the Blastula*

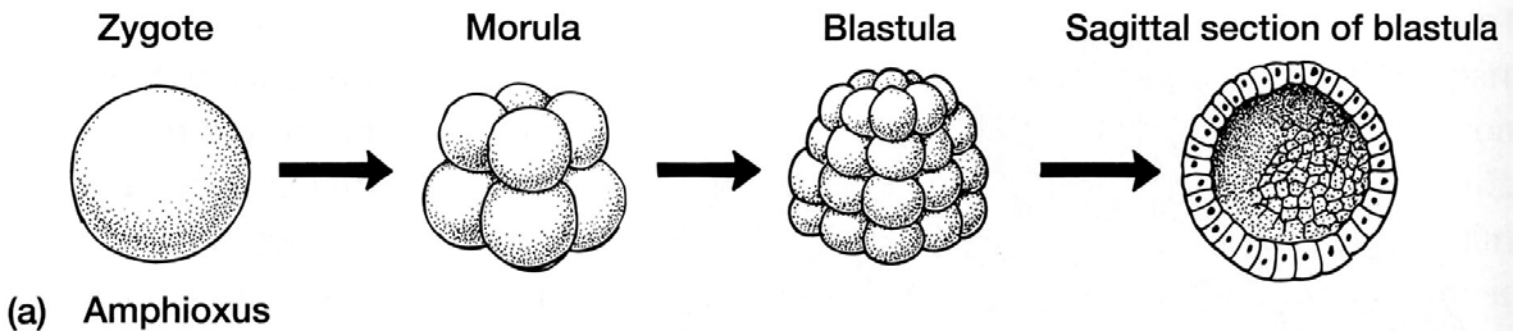
Fertilization initiates cell division

The zygote becomes subdivided into smaller and smaller cells. This solid ball of cells is the morula.

The dividing cell mass ultimately forms a hollow sphere.

This hollow ball of cells is the blastula, Each cell of a blastula is a blastomere. The cavity is the blastocoel.

During this stage of development, specific areas begin to differentiate into cells that will give rise to three distinctive germ layers.



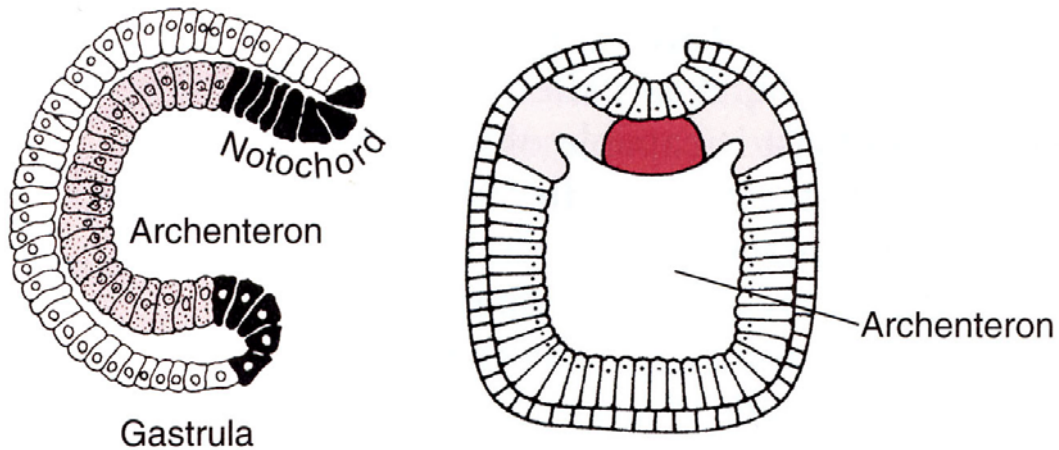
***Gastrulation: Formation of the Germ Layers and Coelom*** (Gastrulation = gut formation)

Gastrulation is the process by which part of the hollow sphere invaginates into the blastocoel. In the process:

A new cavity is formed. This is the archenteron, which becomes the gut

The opening to this cavity is the blastopore.

The cells that involute into the archenteron become endoderm. Those that form the outer surface become ectoderm.



**a) Formation of the Germ Layers**

A small group of cells at the rim of the blastopore become mesoderm. These migrate in along the roof of the archenteron. Those cells in the midline will become the notochord. Those lateral and parallel to the developing notochord will become the remainder of the mesoderm.

Another small group of ectodermal cells in the midline near the rim of the blastopore (neural ectoderm) will develop into the neural plate

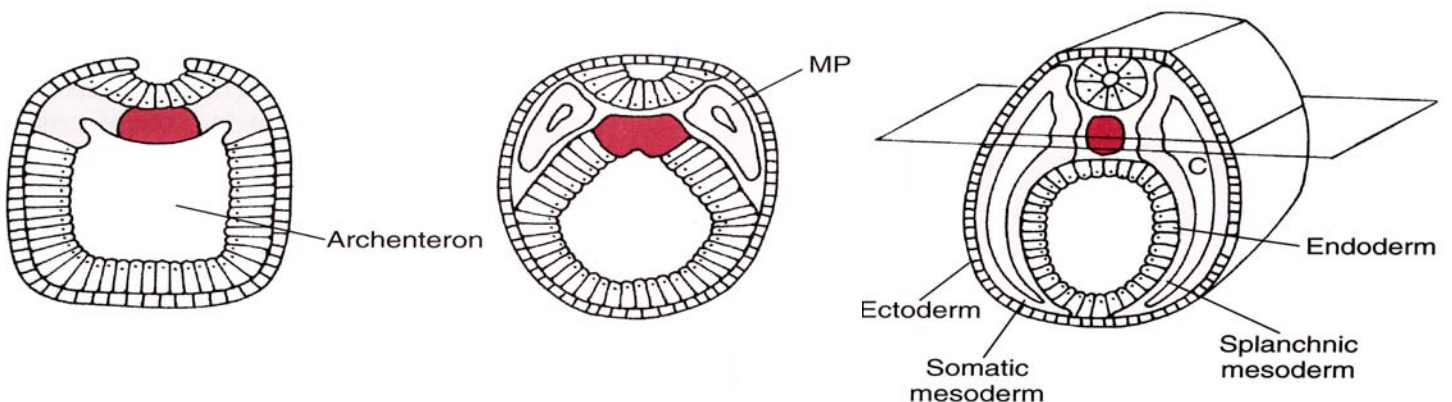
**b) Formation of the Coelom**

The mesoderm in the dorsolateral roof of the archenteron folds upward, separates from the endoderm and forms a series of hollow coelomic pouches.

The larva continues to grow and elongates (no longer a sphere). The notochord and mesodermal bands elongate and additional coelomic pouches form

The coelomic pouches grow ventrad, pushing between the ectoderm and endoderm. By this point the blastocoel no longer exists. The mesoderm of the two pouches ultimately meets underneath the gut.

Ultimately, the coelomic cavities within successive pouches become confluent and the right and left cavities become confluent beneath the gut - forming one contiguous coelom.



### ***Division of the Coelom***

1) In all vertebrates, the coelom becomes divided by a fibrous transverse septum into the:

pericardial cavity (containing the heart)  
pleuroperitoneal cavity (containing the viscera)  
(and the lungs in air breathing vertebrates)

2) In mammals, a coelomic fold grows behind the lung and connects to the transverse septum.

This: - becomes invested with muscle and becomes the diaphragm  
- separates the pleuroperitoneal cavity into the  
pleural cavity (contains the lungs)  
peritoneal cavity (contains the rest of the viscera)

### ***Neurulation***

Neurulation = nerve formation

Neural ectoderm, overlying the notochord, thickens to form the neural plate. The neural plate sinks while the lateral borders of the neural plate become elevated to form neural folds and a neural groove.

The neural folds grow towards one another and fuse in the midline, converting the neural groove into a neural tube.

Thus, the central nervous system is ectodermal, dorsal and hollow. The cavity is the neurocoel which becomes the ventricles of the brain and the central canal of the spinal cord.

Note: The neural crest is formed beside the neural tube from ectodermal cells left behind as the neural folds move up and fuse. These cells are future sensory cells and will be described later.

### **Induction of Differentiation: Morphogens**

The process by which different cells are induced to differentiate into different tissues is regulated by proteins called morphogens. These in turn are under tight control by a series of specific genes. Remember that all cells originated from one original fertilized egg cell. Thus, all cells have the genetic make up to become any tissue in the body. Which cell type they become is a function of which genes are turned on or off and the processes involved here are fascinating but beyond the scope of this course.

*Mesenchyme* is an unorganized accumulation of undifferentiated embryonic cells. Mesenchyme can be transformed into different organs or tissues. Most mesenchyme arises from mesoderm but it can also be ectodermal in origin. While most mesenchyme is

embryonic, some mesenchyme formation continues in adults. These are reserve cells used to replace worn or damaged tissue.

## Organogenesis - Fates of the Ectoderm, Endoderm and Mesoderm

The three primary germ layers become established during gastrulation and neurulation. Thereafter they become differentiated into the various structures of the body. The embryonic origin of each organ or parts of an organ can be traced back to these specific germ layers

In general,

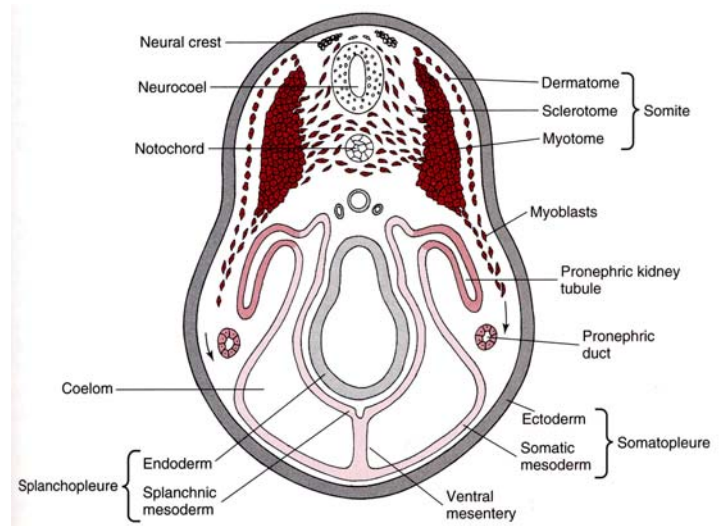
Ectoderm produces the skin and many glands contained within the dermis and epidermis, as well as the nervous system and many sensory organs

Endoderm produces the digestive tract and its visceral derivatives (liver, pancreas, gall bladder, glands, lungs, swim bladders, urinary bladder, etc.)

Mesoderm produces skeleton, muscle and the circulatory system

The mesoderm grows down between the endoderm and ectoderm and differentiates into three regions - the dorsal Epimere, the intermediate Mesomere and the ventral Hypomere.

The Hypomere surrounds the coelom and consists of splanchnic and somatic mesoderm. The splanchnic hypomere gives rise to smooth muscle and connective tissue of the digestive tract and its derivatives which include viscera, heart and blood vessels. The somatic hypomere gives rise to the skeleton of the body wall, limbs and girdles.



The Mesomere gives rise to the kidneys and the ducts of the urogenital system.

The Epimere gives rise to three subdivisions, the sclerotome (that gives rise to the vertebral column and ribs) the dermatome (which gives rise to the dermis and skin musculature) and the myotome (which forms the skeletal muscles of the body).

Note: the epimere also differentiates along the longitudinal axis of the body such that it becomes segmented. Each segment is a somite.