

# Tissues & Development

Bio 6A/Sanhita Datta  
Winter 2008

The purpose of this lab is to introduce you to some ideas about how animals are made. You already know the key characteristics that set animals apart from the other kingdoms – complex multicellular bodies, motility, sensory systems, etc. All the characteristics that make an animal an animal come from the ways that animal cells interact to form complex tissues and organs. In this lab, you'll see some microscope slides of the basic tissue types that make up animal bodies, and see how these tissues are derived from events in the early development of the animal.

## Animal Development: A Brief Synopsis

In terms of tissues and organs, animals are more complex than other organisms. Animals simply have more different kinds of cells than do plants or fungi, and those many kinds of cells interact to form complex organs. All the different kinds of cells in an individual animal's body have the same genes, but they use those genes differently.

This complexity of animals begins with early embryonic development. Most multicellular organisms (such as plants, fungi, and algae) develop and grow by adding more cells to particular parts of their bodies. Animal embryos do something not seen in the other kingdoms: they move groups of cells around relative to one another. These tissue movements allow cells to come into contact with new neighbors, and when this happens, information is transmitted from cell to cell, inducing the formation of more complex tissues and organs. In this lab, you'll consider both the basic events of early development and the tissues that are formed by these events.

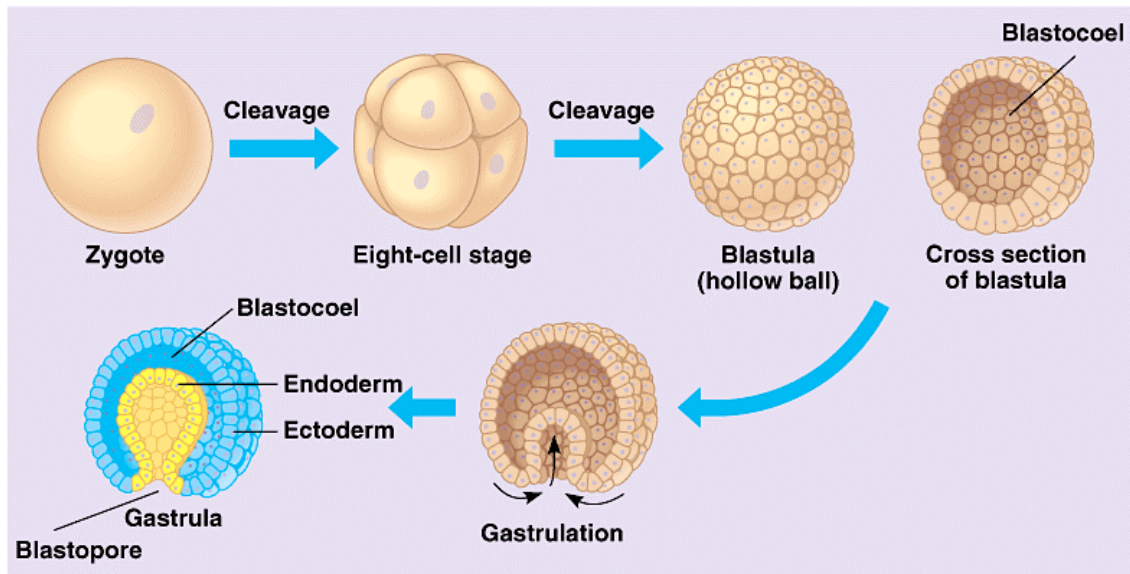
### Some definitions:

---

|                          |  |
|--------------------------|--|
| • <b>Cell</b>            | The basic unit of the body's construction, surrounded by a plasma membrane. All the cells in your body (not counting eggs or sperm) have the same genome. You have about 50 trillion cells.  |
| • <b>Gene</b>            | A segment of DNA that codes for an RNA. In many cases, the RNA encoded by a gene provides instructions for making a specific protein. The protein, in turn, enables the cell to perform specific functions.  |
| • <b>Tissue</b>          | A group of cells with (more or less) the same structure and function. In practice, there are broad categories like epithelial tissue (which lines many surfaces of the body), and more precise categories like ciliated columnar epithelium (which is found only in specific organs). A vertebrate might have 100 or so tissue types.                              |
| • <b>Differentiation</b> | The process by which cells become different from one another. In the early embryo, all the cells look the same; as development proceeds, new tissue types are generated as cells turn on different sets of genes. As a result, each differentiated cell type begins to make a specific set of proteins. The differentiated cells then perform different functions. |
| • <b>Organ</b>           | A multicellular structure in the body, composed of more than one type of tissue, that serves a particular function.  |

---

The basic structure of an animal is generated by the early events of development. After fertilization, the first few rounds of cell division are followed by movements of groups of cells to create a hollow ball of cells that folds in on itself. The diagram below shows the early stages of development (Campbell 7<sup>th</sup> ed., fig. 32.2).



Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

The stages shown here are similar for most kinds of animals. However, the larval forms that occur after the gastrula are very different for different phyla. Regardless of the final body design, three different kinds of events occur to generate the form of the mature animal:

- **Cell proliferation:** production of new cells. Keep in mind that a zygote is one huge cell that then gets divided into a number of smaller cells without any growth occurring. In later development, cell proliferation has to include growth of the cell followed by cell division (otherwise cells would get smaller and smaller).
- **Morphogenesis:** generation of body form. The first steps of animal morphogenesis are the development of the blastula and the gastrula. These events occur by coordinated cell movements. Other morphogenetic movements of cells occur later, until the adult body form is attained.
- **Cell differentiation:** specialization of cells. As morphogenesis happens, cells take on their final identities by turning on specific sets of genes in particular groups of cells. Some of the key signals for this come from cell to cell contacts. As cells begin to differentiate from one another, interactions among different cell types causes even more differentiation to occur. Animals have more differentiation than the other kingdoms, and this is associated with the fact that animal tissues move around in early development.

These processes interact throughout development in all animals. Each of the three processes is dependent on the others, and all three are involved in the formation of the gastrula.

Gastrulation generates the beginning of the intestine (which at this stage is called the archenteron). In echinoderms, as in chordates, the first opening that forms (the blastopore) eventually turns into the anus; the mouth forms later. For this reason, echinoderms and chordates are called **deuterostomes**, which roughly means "after-mouth". Mollusks, annelids, and arthropods are called **protostomes** ("before-mouth") because the blastopore turns into the mouth and the anus forms later (see Campbell, fig. 32.9).

In most animals, gastrulation also generates three embryonic tissue types: **endoderm**, **ectoderm**, and **mesoderm**. Later in development, these three embryonic tissue types interact to generate the many types of tissues found in adult animals.

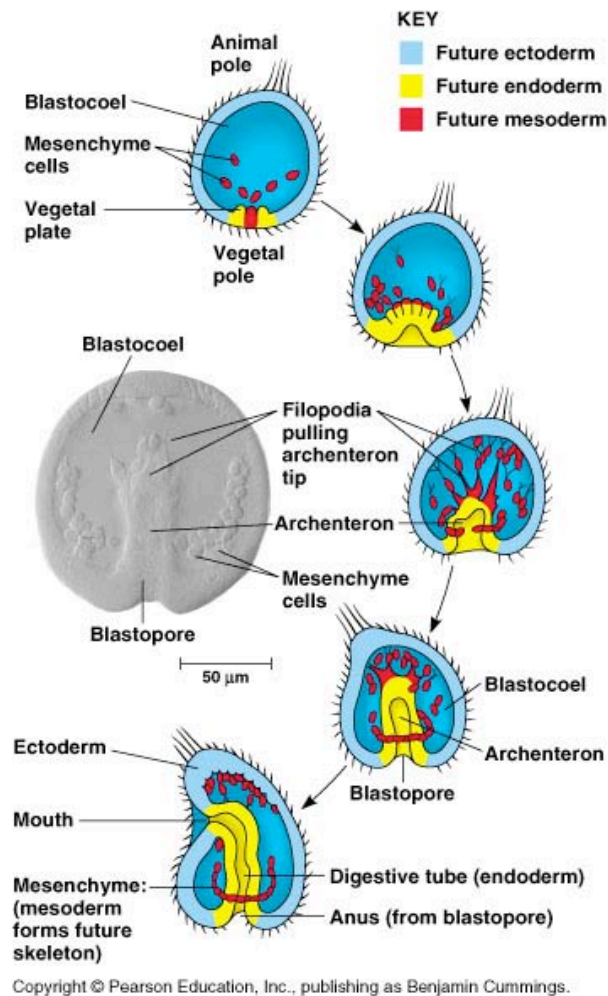
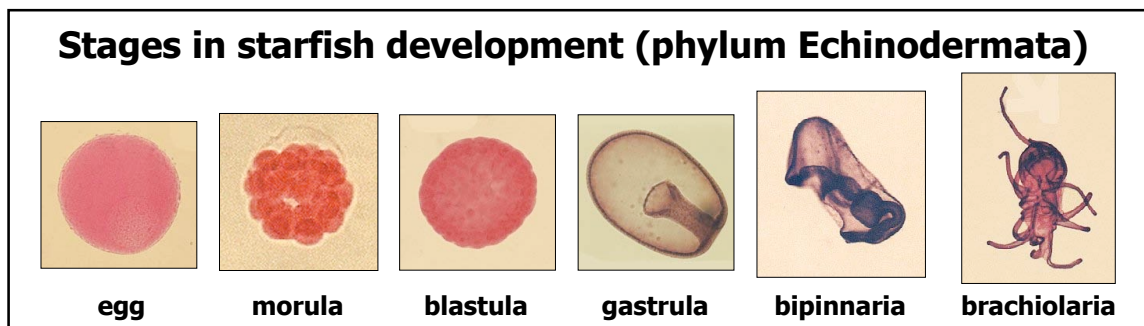


Fig. 47.11 from Campbell, 7<sup>th</sup> ed.

### Starfish Development Slides

Here are some of the stages of development for a starfish:



The bipinnaria and brachiolaria stages are larval stages capable of swimming and feeding. These stages are unique to echinoderms. Eventually the larva undergoes metamorphosis to become a starfish.

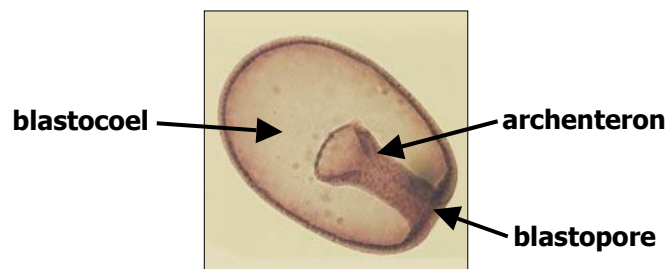
The following stages are found in most animals:

- **Egg:** a single haploid cell, prior to fertilization. You may be able to see the nucleus.
- **Zygote:** (not shown above) a diploid cell resulting from fertilization. The membrane surrounding the nucleus disappears, so you won't see a nucleus.
- **Morula:** is a ball of large cells.
- **Blastula:** a hollow ball of smaller cells.
- **Gastrula:** an indented hollow ball of cells, with the beginning of a gut.

Now a look at the following slides of echinoderm development:

📖 **Starfish early cleavage.** You may see embryos with two, four, eight, or more cells. In these early embryos, you see a bunch of cells that look the same. These cells aren't exactly the same, though. They contain all the same DNA, but they also contain slightly different information telling the cells how to express that DNA. The cells haven't yet begun to differentiate, but they contain some information telling them how to differentiate. (This information consists of proteins and RNAs that regulate gene expression; the mechanisms will be introduced in Bio 6B.)

📖 **Starfish blastula & gastrula.** (Some of these slides are whole mounts; the entire animal is on the slide. Others are sections, or slices through the animal.) The **blastocoel**, visible in both the blastula and the gastrula, is the space occupying most of these hollow embryos. The **archenteron**, visible only in the gastrula, is the folded-in beginning of the intestine. The **blastopore** is the opening into the archenteron.



📖 **Starfish bipinnaria & brachiolaria.** These swimming larvae are far more complex than the gastrula. While the gastrula form is common to nearly all animals, the bipinnaria & brachiolaria larvae are found only in echinoderms. Can you relate any structures in these larvae to structures in the gastrula? Note that these larval forms are bilaterally symmetrical, while the adult forms of echinoderms are not obviously bilateral.

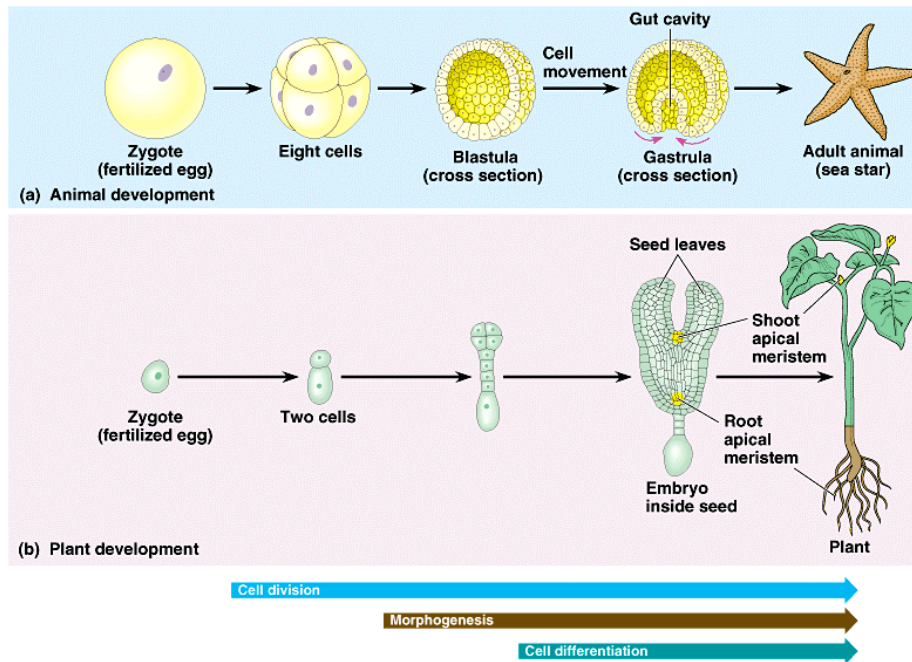
See the Animal Diversity chapter in Campbell for more information on gastrulation and tissue formation. Note that the coelom is not the same as the blastocoel – see Campbell, fig. 32.9 for this.

## Comparing Animal and Plant Development

Plants, like animals, have complex multicellular bodies. However, plants and animals develop in completely different ways. The last common ancestor of plants and animals was probably a

unicellular eukaryote that lived 1.5 billion years ago. Multicellularity evolved independently in of these two groups, and it evolved in different ways.

One key difference is that plants have cell walls and animals don't. Plant tissues often look like a brick wall, with all the cells locked in place in a matrix of semi-rigid cell walls. This means that plant cells don't migrate during development the way animal cells do. This limits the potential tissue complexity of plants.



Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

There are some basic similarities between the developmental processes of animals and plants. They both go through the three basic developmental processes, but in different ways:

- **Cell proliferation** (or cell division). This process is similar for plants and animals, except that the cell walls of plants strongly determine the direction in which the cell can divide, and thus determine in which direction new cells will be added.
- **Morphogenesis.** In animals, morphogenesis occurs by coordinated cell movements. Eventually, the adult body form is attained, and morphogenesis is finished. In plants, since growth is indeterminate, morphogenesis is never finished. Plants tend to keep growing throughout their lives, adding new cells and turning them into structures such as leaves. Animals tend to take their shapes by having cells move to where they are supposed to go, while plants tend to take their shapes by adding new cells in the appropriate places.
- **Cell differentiation.** In both plants and animals, differentiation occurs by turning on specific sets of genes in particular groups of cells. One key difference is that in animals many of the signals that initiate differentiation come from cell contacts, while in plants more of the signals come from hormones that diffuse through the body.

**Observe the prepared slide of *Allium* (onion) root tip.** Study fig. 35.12 in Campbell along with this slide. This is a plant. Note how different the plant tissues are from animal tissues. New cells are added at the apical meristem (zone of cell division). Later, these new cells elongate and differentiate, but they don't move to a new location.

Observe the prepared slide of *Coleus* leaf bud. This slide also shows plant growth at an apical meristem; a single region of cell proliferation produces cells that will later differentiate to become all the tissue types of the leaf and stem.

There is no slide that shows an animal equivalent to the apical meristems of plants. Animals do have cells that specialize in cell proliferation; these are called stem cells. However, in animals, each kind of stem cells produces only one category of new cells.

## Animal Body Cross-Sections

An adult animal's body plan is related to its embryonic development. Take a look at the following animal cross-sections from the point of view of tissue differentiation and development:

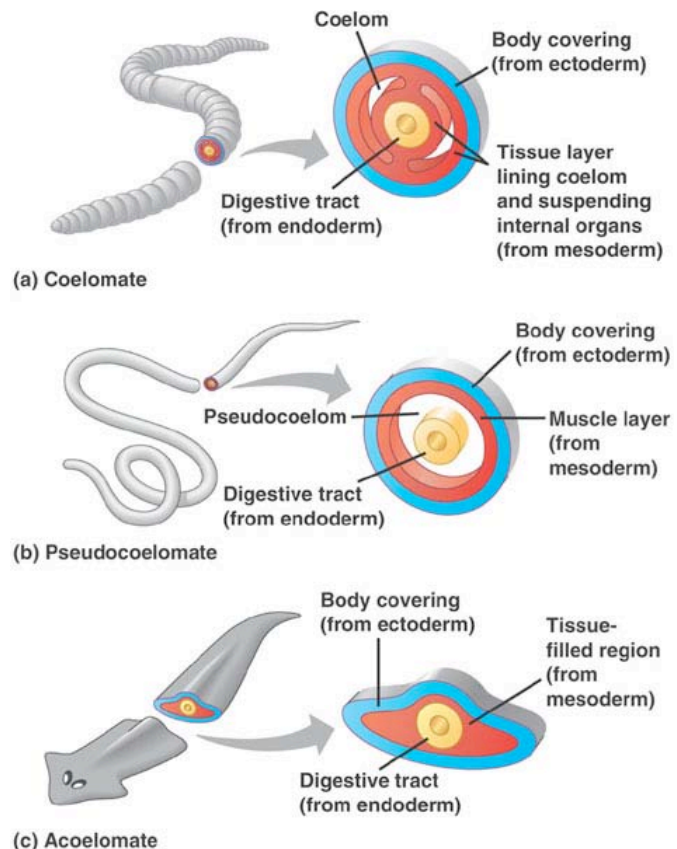
**Sponge (Phylum Porifera): *Scypha* c.s.** This is a cross-section of a small, tube-shaped sponge. You will see a few different types of cells, but you won't see the distinct organs found in more complex animals.

**Cnidarian: *Hydra* c.s.** We have both cross sections and longitudinal sections of *Hydra* polyps. Cnidarians have only two embryonic tissue layers, while most animals have three. In this microscope slide, you should be able to identify two tissue layers. The outer layer is the **epidermis**, and the inner layer (facing the gastrovascular cavity) is the **gastrodermis**. Between these two layers is a thin layer of **mesoglea**, which is jelly-like extracellular material – not a tissue.

**Annelid: Earthworm c.s.** Earthworms have a true coelom, lined with mesodermal tissue on the outer body wall and on the intestine. Note the two distinctive tissue layers of the intestine. The inner lining of the intestine (an epithelium) is derived from endoderm, while the outer layer facing the coelom is derived from mesoderm. The circulatory system is derived from mesoderm.

**Flatworm: *Planaria* c.s.** Flatworms don't have a coelom (they're acoelomate), but they do have three distinct tissue layers. The epidermis is derived from ectoderm, the lining of the gastrovascular cavity is derived from endoderm, and the muscles and other tissues inside are derived from mesoderm. See Campbell, p. 638 for a comparison of three worm phyla.

**Nematode: *Ascaris* c.s.** We haven't looked at this phylum (Nematoda) in lab before. Nematodes are considered pseudocoelomates, because they have a coelom that isn't completely lined by tissue derived from mesoderm. Note that in the cross-section, you see muscles (mesoderm-derived) attached to the outer body wall, but you don't see similar tissues



surrounding the gut. The intestine is essentially one tissue layer. No accessory digestive organs form, because, the intestine does not involve both endoderm and mesoderm coming together. Nematodes have no circulatory systems. Where would it form?

Possible test question: given one of the slides above, you should be able to say whether this animal is acoelomate, pseudocoelomate, or coelomate. Also, you should be able to say whether a particular tissue is derived from embryonic endoderm, mesoderm, or ectoderm.

## Tissue Slides

All the tissue slides are from mammals, but many of the tissues are similar for most of the animal phyla.

As shown above, gastrulation forms the three partly differentiated embryonic tissue types: endoderm, mesoderm, and ectoderm. In the tissue slides, you'll see fully differentiated adult tissues derived from these embryonic tissues.

### Embryonic tissue layers and the adult tissues they give rise to:

|                   |   |
|-------------------|---|
| • <b>Ectoderm</b> | Epithelial tissues such as epidermis of skin; sensory receptors; nervous system.  |
| • <b>Endoderm</b> | Epithelium of digestive tract and lining of respiratory system; liver.  |
| • <b>Mesoderm</b> | Skeleton; muscles; circulatory system; excretory system; much of the reproductive system; dermis of skin; lining of coelom. |

The above table is for vertebrates (phylum Chordata), but other phyla are similar. See Campbell, p. 1007 for a more detailed list. Unfortunately, you can't tell by looking at an adult tissue what embryonic tissue layer it was derived from. The adult tissue types below are classified in term of form and function, not embryonic origin.

### Epithelium

Epithelial tissues form sheets of tightly packed cells that line surfaces on the inside and the outside of the body. Epithelial tissues can be derived from endoderm (the lining of the intestine, for example) or from ectoderm (the outer layer of skin).

☞ **Simple cuboidal epithelium.** These cells are more or less cube-shaped in cross-section. Note that, like most epithelial layers, these cells form a layer that can prevent molecules from passing between the cells. Anything that passes through this epithelium must pass through the cell membranes; the cells determine what gets through and what doesn't. The linings of kidney tubules and collecting ducts are examples of this type of epithelium.

☞ **Simple columnar epithelium.** Column-shaped cells.

☞ **Pseudostratified columnar epithelium.** Note the layer of flattened cells beneath the columnar cells. The columnar cells, like many epithelial cells, are lined with cilia. Such cilia may move mucus or particles within the body.

☞ **Stratified squamous epithelium.** This slide shows distinctly different layers of cells.

You'll see that it is not always easy to say whether an epithelial later is, for example pseudostratified or not. Don't worry; you won't be tested on that. You will be asked to recognize epithelial tissues as distinct from the other general tissue types listed in this handout.

## Connective Tissues

---

Connective tissues typically serve to hold the body together; they often contain sparsely distributed cells with lots of extracellular matrix. Many connective tissues are derived from mesoderm.

**Extracellular matrix** is visible in connective tissues as stringy stuff in between the cells. Extracellular matrix is a mix of proteins and polysaccharides secreted outside the cells, and it often helps form strong tissue.

- ☞ **Areolar tissue.** This is loose connective tissue, with large spaces between the cells. This type of tissue would be found in a variety of locations in the body, including the mesenteries that attach many organs. The empty-looking spaces are filled with ground substance, a watery variation of extracellular matrix. Note the fibers of extracellular matrix (elastic fibers & collagen). The small, scattered cells are mostly fibroblasts. See fig. 1.42 in the Photo Atlas.
- ☞ **Adipose tissue.** The cells appear empty; they're filled with fat.
- ☞ **Hyaline cartilage.** This tissue has a very low density of cells; it's mostly smooth-looking extracellular matrix, with cells scattered around in small openings in the matrix material.
- ☞ **Bone.** This tissue is mostly extracellular matrix – protein and calcium phosphate crystal structures. The cells are relatively sparse, but there are enough cells present to maintain the continual processes of bone destruction and regeneration.
- ☞ **Blood.** Blood is considered connective tissue, too; it has a low density of cells and a lot of extracellular material (plasma).

## Muscle Tissues

---

Muscle tissue is derived from mesoderm.

- ☞ **Skeletal muscle (tongue).** This kind of tissue is filled with contractile protein fibers and mitochondria to generate the ATP to power muscle contractions.
- ☞ **Smooth muscle.** Smooth muscle is not normally under your conscious control; it's found surrounding arteries and the intestine.

## Nervous Tissue

---

Nervous tissue is derived from ectoderm.

- ☞ **Motor end organs.** This slide shows a section of skeletal muscle along with neurons (nerve cells) that activate the muscle. The neurons have long, stringy axons that are attached to the muscle at neuromuscular junctions. These neuromuscular junctions contain numerous mitochondria, which you can see as dark dots.

## Key concepts and vocabulary

By the time you complete this lab, you should be able to explain the terms and concepts listed below.

- Archenteron
- Blastocoel (*and why it's not the coelom*)
- Blastopore
- Blastula
- Cell proliferation (*What's the difference between cell proliferation and cell division?*)
- Coelomate vs. pseudocoelomate (*How is a coelom formed, and how is a pseudocoel formed? Why does it matter?*)
- Connective tissue
- Deuterostome vs. protostome
- Differentiation
- Ectoderm
- Embryo
- Embryonic tissue layers
- Endoderm
- Epithelial tissues
- Extracellular matrix (*Compare & contrast with plant cell walls.*)
- Gastrula & Gastrulation (*Which groups of animals have this? Why does it matter?*)
- Mesoderm
- Morphogenesis
- Muscle tissues
- Nervous tissue (neurons)
- Organ
- Plant development compared to animal development
- Tissue

## Possible test questions on the tissue slides

The point of looking at slides is not for you to memorize the name of each slide. Instead, you should work on trying to recognize the characteristics of the general characteristics listed in the handout. Here's an exam question with some possible answers:

1. What is this?

- |   |  |  |
|---|--|--|
| <ul style="list-style-type: none"><li>• Adipose tissue</li><li>• Animal tissue</li><li>• Bone</li><li>• Cartilage</li><li>• Connective tissue</li></ul> | <ul style="list-style-type: none"><li>• Epithelium</li><li>• Extracellular matrix in cartilage or bone</li><li>• Neuron (Nervous tissue)</li></ul> | <ul style="list-style-type: none"><li>• Plant tissue</li><li>• Skeletal muscle</li><li>• Smooth muscle</li></ul> |
|---|--|--|

As always, you should work on understanding the big concepts before you start memorizing details.