CHAPTER 3

Foundations

Tissues and Early Embryology

Introduction

Histology—or the study of tissues—is entirely a subject unto itself but bridges the fields of cytology and anatomy. Tissues are made of cells. It is important to remember that *all* cells started from a single fertilized egg cell. To produce the diversity of tissues, cells must differentiate and specialize from stem cells. They are referred to as "stem" cells because all other cells stem from them. Individual cells do not have the functional ability to perform all functions carried out by our bodies. But differentiated cells do have a specific set of structural components (anatomy) and functional attributes (physiology). Nearby cells, although considerably different from one another, do function together for a common purpose.

Tissues are the foundation of all organs and systems in the human body. Thus, it is important that the student understand how and why each tissue type appears and functions in the body. Students are often overwhelmed with all the terminology and diversity of different tissue types. Also, they often have great difficulty remembering the details of each tissue because they are not easily seen and visualized. Thus, it is important to stress the reasons for each tissue type, especially the various types of epithelium.

Chapter Learning Outcomes

1. List the functions of epithelial tissues, the criteria used to classify epithelial tissue, the functions of each type of epithelial tissue, and at least one location for each type of epithelial tissue. p. 50
2. List the three categories of connective tissue, their functions, and the cell types that would be found within each category. p. 59
3. Compare and contrast the characteristics of mucous, serous, cutaneous, and synovial membranes. p. 70
4. Summarize how connective tissues establish the framework of the body. p. 73
5. Compare and contrast the three forms of muscle tissue in terms of structure, function, and location. p. 74
6. Differentiate between neurons and neuroglia and discuss the functions of each. p. 76
7. Describe how nutrition and aging affect tissues. p. 76
8. List and explain the key embryological steps in the formation of epithelial and connective tissues. p. 78

Teaching Strategies

1. Lecture Ideas

a. Like Sherlock Holmes solving a mystery, encourage students to hypothesize what type of tissue is needed for various jobs in the body. What shape would work best? What size is best? What type of "equipment" (meaning organelles) is most needed? Try to get students to predict what tissue would be found in each of the organs and systems you study as the term progresses. What makes the most sense?

b. Though tissues are very diverse, there are four primary tissue types: epithelial, connective, muscle, and nervous tissues.

Epithelium: Epithelial tissues are "liners." Emphasize to students that epithelial tissue contains lots of cells and very little extracellular material between them, while connective tissue contains few cells and lots of extracellular-ground substance between them. Remembering this can help students differentiate between epithelium and connective tissue.

c. In addition, remind the students that epithelial tissue is devoid of blood vessels. Once they understand that, they get the picture that epithelial cell thickness is limited by diffusion rates of nutrients, oxygen, etc.

d. The basal surface of an epithelial tissue is attached to a basement membrane. The basement membrane is made up of two parts: the basal lamina (glycoproteins, proteoglycans, and microfilaments that were secreted by the epithelial cells) and the reticular lamina (mainly coarse protein fibers that were produced by the underlying connective tissue).

e. Some terms can be confusing to students. Explain why an endothelium is an epithelium named for its location (inside heart, blood vessels). Also, differentiate between endothelium and mesothelium. Because students get confused with these terms, be sure to emphasize that both endothelia and mesothelial are forms of epithelium.

f. Epithelial tissues consist of continuous sheets, layers, or blocks of cells, and are categorized according to the number of layers and cell shapes. Most students are somewhat familiar with the attributes of skin and have seen peeling skin at one time or another—an example of the continuity of epithelium and its sheet-like structure. Epithelial cells can be loosely or tightly joined together by a variety of structural connections, such as tight junctions and gap junctions. To truly get "inside" a body or organ, a substance must pass through epithelium; otherwise, it is just passing by or skimming the surface. Areas of the body that experience much wear and tear and glands specialized for secretion will often have more than one layer of epithelium (i.e., *stratified*).

Epithelium can come in several shapes:

- **Squamous:** Resemble thin, scale-like plates, look a bit like fried eggs
- **Cuboidal:** Cube-shaped or squarish looking
- **Columnar:** Tall and thin like the columns on a porch

A columnar epithelium can be in a single layer—**simple,** multiple layers—**stratified,** or a single layer of cells, all of which reach the basal lamina, but are of varying heights that give the appearance of multiple layers—**pseudostratified.** Superficially, a pseudostratified epithelium looks like there are multiple layers,

but all cells are actually anchored to the basement membrane. It is an interesting thing for students to combine any of these terms to get varying combinations of epithelium:

- Simple squamous *or* stratified squamous
- Simple cuboidal *or* stratified cuboidal
- Simple columnar, *or* stratified columnar, *or* pseudostratified columnar

But remember, the term *pseudostratified* applies only to columnar epithelia.

When dealing with epithelia, students often get confused when trying to differentiate between microvilli, cilia, and flagella. They understand better when the main function of each is described. For example, microvilli are found lining the lumen of the small intestine. The microvilli serve to greatly increase surface area for more efficient absorption of nutrients. Cilia are found lining much of the upper and lower respiratory tract. A clear description of how cilia move mucus toward the throat gets the point home. Also, the wave of motion of cilia in the uterine tubes is from the fimbriae toward the uterus. They function to slowly move eggs released from the ovary to the uterus. In the human body, a flagellum is a whip-like process only found in sperm cells. It propels the sperm within the female reproductive tract. Relating flagellum to a tadpole helps too.

g. Glands are included with epithelium because they are either derived from or are a part of an epithelium. Students need a description of glands and an explanation of why they are included with epithelium. Students also need a clear description of how glands produce their secretions. This can be done in a fun way: relate secretion to cellular destruction.

- Holocrine secretion: total destruction of the secretory cells
- Apocrine secretion: partial destruction of the cells
- Eccrine (merocrine) secretion: no destruction of cells

h. By drawing the formation of a gland as an invagination of the surface epithelium you can tie it together quite well. Also, express the importance of understanding gland structure (and to some degree, function). We will be seeing glands associated with several systems in the future.

Connective Tissue: Connective tissues "connect" things. Cells, and usually extracellular fibers, are distributed within a fluid called the "ground substance." *Extracellular fibers* plus the *ground substance* equals the *matrix*. In bones, the ground substance begins as an organic deposit with a gel-like consistency that hardens with deposits of calcium salts, such as calcium phosphate, around the collagen fibers. In the hypodermis, just deep to the dermis of the skin, connective tissues consist of multiple extracellular collagen fibers, which provide strength; some elastin fibers, which provide stretchiness; and a more fluid ground substance with white blood cells, adipose cells, and mesenchyme or stem cells.

Connective tissue, like epithelial tissue, can come in a variety of types:

- *Connective Tissue Proper*: This connective tissue really does *connect* structures and/or layers of differing tissues; it is the "glue and strapping tape" that hold things together. There are two basic categories of connective tissue proper: loose connective tissue and dense connective tissue.
    - *Loose Connective Tissue*: Loose connective tissue is softer, and consists of areolar tissue, adipose tissue, and reticular tissue. *Areolar tissue* (same root word as *air* and *aero*) contains mostly ground substances and is like the light attachment between skin and muscle fascia, of organs to epithelial layers, and

so on. This type of connective tissue provides padding and a considerable freedom of movement between the layers it separates (e.g., pinching the skin does not affect the muscle below, nor will muscle contractions distort the skin). *Adipose or fatty tissue* contains mostly adipocytes, providing energy storage, insulation, and cushioning. *Reticular tissue* contains a high number of reticular fibers. These fibers are similar in composition to collagen fibers, but are "formatted" differently, forming a branching, interlinked network of fibers. In organs like the liver, these fibers provide some structural support (the stroma) for the specialized cells within (the parenchyma), which makes organs such as the liver feel a bit more solid.

- *Dense Connective Tissue*: Dense connective tissue has high concentrations of collagen fibers. It includes *dense regular connective tissue*, as in tendons and ligaments; or *dense irregular connective tissue*, as in the deep dermis of the skin (from which leather garments are made) and capsules around many organs. The collagen fibers of regular connective tissues are densely packed parallel to each other. In irregular connective tissues, there is no particular order to the packing of the fibers.

- *Fluid Connective Tissues*: Fluid connective tissues have a number of specialized cells in a fluid ground substance. Obvious examples are blood and lymph.
- *Supporting Connective Tissues*: Supporting connective tissues confer a strong physical frame for the rest of the body, and include cartilage and bone.

There are three categories of cartilage:

1. *Hyaline cartilage* is very common and has less collagen and more matrix (so it's weaker), appearing glassy and translucent. It is found on articular surfaces and in costal cartilages.
2. *Elastic cartilage* is very resilient to being stretched or bent, and has more elastin (like rubber bands) so is quite flexible, such as in the auricle of the ear.
3. *Fibrous cartilage* has very little ground substance and has a lot of collagen to withstand extreme stress and compression, as in vertebral discs and the pubic symphysis.

Muscle Tissue: Muscle will be one of the easiest tissues for students to learn. Each of the three types are quickly seen and understood. The greatest difficulty for students occurs when trying to differentiate between skeletal and cardiac muscle under the microscope. One good approach to making this distinction is to demonstrate that cardiac muscle cells are branched and connect via intercalated discs.

Muscle tissue is the only tissue specialized for contraction. Muscle tissue also has elasticity where, following a contraction, it has the ability to rebound towards its original length. Students will learn about muscle in great detail in upcoming chapters so a simple overview of the three types is enough for now. Muscle comes in three varieties named for its appearance (striated or not), location, or function (voluntary or involuntary):

- **Skeletal** (striated, voluntary) muscle fibers (cells) are put together a bit differently than other cells because of their high degree of specialization for contraction. Although they begin as basic stem cells, these merge together in long skeletal muscle fibers as one long multinucleated cell that has a striated or striped appearance. The cytoplasm is packed with actin and myosin filaments that displace the ER and nuclei to the edges of cells. This also impairs their ability to replicate so muscle cells do not divide. All skeletal muscle is neurogenic.

- **Cardiac** (striated, involuntary) muscle cells of the heart are packed with actin and myosin filaments and appear striated in a manner very similar to that seen in skeletal muscle cells. However, cardiac muscle cells usually have a single, central nucleus, and exhibit more variation in shape and branching. Cardiac muscle cells are also electrically linked by clusters of gap junctions where the branches of one cell are connected to those of another cell. These gap junctions plus desmosomes are located in specialized regions called intercalated discs. All cardiac cells are myogenic. Cardiac muscle will be described in more detail in Chapter 21.
- **Smooth** (nonstriated, involuntary) muscle cells are long, spindle-shaped cells that have a single, central nucleus and do not exhibit any form of striation such as that seen in skeletal muscle and cardiac muscle cells. They contain diffusely arranged (not packed) actin and myosin filaments. Smooth muscle cells retain their ability to divide and can regenerate tissue after injury. There are two types of smooth muscle: one that is neurogenic, and one that is myogenic. Smooth muscle will be described in more depth in Chapter 25.

Nervous Tissue: Along with muscle tissue, nervous tissue is considered "excitable" because it can conduct electrochemical impulses. However, nervous tissue is specialized for rapid communication, measured in milliseconds. There are two types of nervous tissue: neurons (nerve cells) and neuroglia that "tend and serve" neurons. Students will also learn more about nervous tissue in later chapters, so an overview of neurons and neuroglia is sufficient here. Because neurons become highly specialized to conduct impulses, they lose many cellular organelles and capabilities, including the ability to replicate and divide.

2. Lab Ideas

a. A display of fresh tissues, such as a beef or lamb joint with tendons, muscles and ligaments attached, can be quite visual when discussing the diversity of connective tissues. This may be the first time some students have ever seen a fresh joint so it's important to explain what they're seeing.

b. If you have access to a meat market or a butcher shop, try to obtain some *fresh* animal organs to show students. Organs such as lungs, livers, brains, hearts, tongues, intestines, kidneys, and stomachs are all helpful to look at and to feel. In cows, there are several types of stomach. One that some people like to eat is tripe, which is really the reticulum. Ask students where they have heard that term before—endoplasmic reticulum, reticular tissue, and so on. It really does have a mesh-like appearance. Have students notice the different densities of tissues and any coverings such as peritoneum, pleura, or pericardium that are covering the organs. Have students compare and contrast various organs. A good comparison to make is between the liver and the lung. Cut into some of the organs and notice any layers. Setting up stations in the classroom works well; have students visit each station and comment on each organ and the component tissues. Can they find epithelium, muscle, and connective tissues?

3. Analogies

a. Epithelium in all its special forms and locations (e.g., *inside* hollow structures, endothelium) is in essence like the body's shrink wrap or plastic cling wrap.

b. Connective tissue is like Jell-O because Jell-O fills the space within the bowl, like connective tissue fills spaces within the body. Or, in some cases, connective tissue is like gelatin with fruit suspended in it, or like concrete with pebbles and sand and shells distributed through it.

c. Loose areolar connective tissue is like a furnace filter in its appearance and function.

d. Neurons are like the "royalty" that never learn how to work and have to be waited on hand and foot by the neuroglial cells. The neuroglial cells make sure neurons are fed, maintained, and repaired.

e. Cancer is the uncontrolled mitotic division of cells. Think of an assembly line that has been accelerated. Over time, workers can't keep up as the number of abnormal or defective cells increases, and sometimes the abnormal cells aren't eliminated, but instead get shipped off to places they don't belong. This would be like metastasis when the cancer cells spread to other tissues or organs.

4. Demonstrations/Discussions

a. Using simple, everyday items helps students get a feel for the shapes of cells. All students relate to: a fried egg (to represent a squamous cell; even the yolk can be used to demonstrate the position of the nucleus in a section), a straight-sided water glass (to represent columnar cell), a pair of dice (to represent cuboidal cells), and a wine goblet (to show goblet cells), etc.

b. When dealing with intercellular junctions, you can create a mental "visual" for each of them:

- **Tight Junctions**: can be visualized as a bead of caulking around tiles (cells) that prevents water from seeping between them. The bead does not need to extend the entire depth of the tile (cell) to do its job. In the tight junctions of cells, the beads act as seals between the membranes of adjacent cells . . . preventing or slowing down leakage (movement of substances) between cells.
- **Gap Junctions**: can be visualized as pipe fittings (some with valves) between cells. These "pipes" allow for rapid communication between cells that work together to perform a function or functions.
- **Desmosomes**: these are like little "spot welds" between two cells. They are not distributed evenly but hold the cells together while allowing slight movement.

c. Use an inflated balloon to demonstrate the relationship between the two layers of serosa by pushing your fist into the balloon. Also, have students put two wet microscope slides together (lengthwise). Demonstrate how the slides will "slip" against one another easily (almost frictionless movement) but are difficult to pull apart. This is a good visual for describing the "space" between the two layers of serosa. Point out that the pericardium and pleura are good examples of this.

5. Common Student Misconceptions/Problems

a. If any histological work with the four tissues is incorporated into your course it is important to discuss with students how the structure of a cell or tissue may be altered by the plane of section, or by the function of that cell or tissue. Refer students to Figure 1.12 in the text in order to emphasize how plane of section will alter the appearance of a structure. (Slice an orange in a cross section and then in a tangential section and show students how the internal structure of the orange varies in appearance depending upon how it was cut.) In addition, this would be an excellent time to have students think about the correlation between structure and function. Ask students to think about the various functions of an epithelium (protection, absorption, secretion, excretion) and how this function affects the structure of the epithelium (simple versus stratified epithelium; squamous versus columnar) and the polarity of the cells found

within the epithelium (organelle arrangement in a secretory epithelium). Similar discussions may be held dealing with the structure-function relationship seen in the arrangement of cells within skeletal muscle and cardiac muscle and, as a result, help students to understand that cell structure, tissue structure, and organ structure are very closely tied to function.

6. Vocabulary Aids

a. Epi- as a prefix means "upon" or "above" and is used often in anatomy: epigastric region, on the belly; epicondyles on bones; epiglottis; and so on.

b. The term *pseudostratified ciliated columnar epithelium* seems a bit intimidating to students until they perform a dissection on it:

Pseudo: false

Ciliated: covered in cilia

Columnar: tall and thin

Epithelium: a lining or covering

This is a single layer of epithelium because all the cells in the layer are attached at the basal part of their cells, the basal lamina, and are connected to neighboring epithelial cells on all sides; they simply vary somewhat in their heights and shapes, so they don't appear as uniform as many other epithelial cells usually do. Have students look for the goblet cells that look like wine glasses and "pour" out mucus on their exposed surfaces.

c. Proteins of various types are found distributed throughout tissues; indeed, their presence may identify the tissue they are in. Fibrous proteins are produced by cells known as fibrocytes and fibroblasts.

In an epithelium, one might find the following:

- **Keratin:** the fibrous protein in skin, hair, nails, claws, scales, feathers, and horns. It is tough, waterproof, and difficult to dissolve or digest. This is why it is often regurgitated by carnivorous animals and also clogs the sink and shower drains.
- **Melanin:** brown pigment usually found in skin that absorbs ultraviolet light to protect surrounding epithelial cells.
- **Mucin:** primary structural protein in mucus. Mucin plus water = mucus.

In connective tissue, one might find the following:

- **Collagen:** the most abundant structural protein in the body; it provides strength and flexibility to tissues. In multiple strands, it is ropelike with great tensile strength and can be found in tendons, ligaments, bone, and cartilage. In single strands, it may be more branched or mesh-like as in reticular tissue. A reticulum is a mesh or network, previously seen in the endoplasmic reticulum in cells.
- **Elastin:** provides elasticity or the ability to stretch and return to original shape. Aging results in a loss of elastin and collagen, which leads to wrinkles.

In muscles, one finds:

- **Actin and myosin:** contractile fibrous proteins. Actin is also found in the cytoplasm of cells as a major component of the cytoskeleton.

d. Because the organelles in skeletal muscle cells are unique, they have been given more technically correct names. The endoplasmic reticulum is the sarcoplasmic reticulum; the cell membrane is the sarcolemma; the cytoplasm is the sarcoplasm. *Sarco* as a prefix means "flesh."