MODULE 1: HISTOLOGY I

An Introduction to Histology; Begin Epithelial Tissue and Connective Tissue

Histology is the study of the microscopic anatomy of the cells and extracellular matrix that make up the tissues of the body. Using the physical appearance of cells and the matrix that surrounds them, the 10-100 trillion cells of the human body can be grouped into just four major tissue types: epithelial, connective, muscle and nervous tissues. In the Histology Modules of this course, you will learn to identify each of these tissue types as well as their subclasses and important structures.

Chemical fixatives are used to preserve tissues when they are harvested. These fixatives are important to preserve the tissue from degradation. These chemicals also destroy the biological function of the cells, so all of the cells in any micrograph images that you see are dead.

Biological tissue has little inherent color. In fact, in reality, the tissues that you study would look transparent or have various shades of gray for the most part. However, scientists use staining techniques to help highlight particular features of a tissue. As a student of histology, you should avoid the temptation to memorize tissues based on color. Since it is possible to stain the same tissue with a variety of different colors, you could be easily fooled if you trained yourself to recognize color as the major feature of tissues that you study. The wiser approach would be to carefully learn the shapes and physical characteristics other than color when studying histology. Students who memorize color as the main characteristic to trigger their memory will be disappointed when the exam does not maintain color schemes.
Why would anyone want to study tissues through a microscope? Well, it turns out that histology is an important tool in medicine. Accurate diagnosis of many diseases, including cancer, usually requires someone trained in histology. Physicians who are trained in this often work as “pathologists” and their skills are critical in the efforts to determine an appropriate treatment plan. Anyone working in the lab to discover the effects of almost any type of medical treatment will also need to be trained in histology so that they can assess the effects of their efforts on biological tissue at the cellular level.

In this course, we will provide a basic view of the four major tissues and their subcategories. Upon mastery of this module, you should have the basic skills required to go on to more advanced courses such as BIO 380 – Histology. You will also have the basic skill necessary to understand many histological characteristics of diseases that affect humans across a lifespan.

Epithelial Tissue

General Characteristics of Epithelial tissues

- Composed almost entirely of close-packed cells with very little extracellular material
- Usually form a barrier, therefore, the cells are arranged in a dense and closely packed fashion
- Have a free surface (apical surface) which is exposed to the body exterior (skin) or the cavity of an internal organ (body cavities, blood vessels, heart, digestive and respiratory system passageways, covering of internal organs, etc.)
- Have a basement membrane (composed of glycoprotein material plus collagen fibers) – The basement membrane anchors basal surface of epithelium to the underlying connective tissue
- Do not have blood vessels (avascular): the blood supply is in the underlying loose connective tissue
- Cells are held together by specialized contacts including tight junctions and desmosomes

General Functions of Epithelial tissues

- Protect underlying structures
- Act as a barrier to prevent movement of substances through the epithelial layer
- Permit movement of some substances through the epithelial layer such as oxygen and carbon dioxide
- Secretion of substances such as mucous, sweat, and digestive enzymes
- Absorption of substances such as nutrients in the digestive system

Simple Epithelium - single layer

A. Simple squamous epithelium: This tissue is composed of a single layer of flattened cells with nuclei that resemble flattened ovals. The cells are very thin and the nuclei are often thicker than the rest of the cell and bulge into the free space giving the tissue the appearance of a fried egg. This tissue forms the walls of capillaries in the cardiovascular system and alveoli in the lungs. It lines all blood vessels, lymphatic vessels and the chambers of the heart, and forms Bowman's capsule in the kidneys. Additionally, the serous membranes you learned about in lecture in chapter 1 are composed of simple squamous epithelium.

B. Simple cuboidal epithelium: This tissue is composed of a single layer of cells that have roughly the same height as width. The most distinguishing characteristic of simple cuboidal epithelium is their large round nuclei that are typically located near the center of the cell. This tissue often forms ducts or tubes. When viewed in cross-section, the round nuclei are lined up in a single row around the circumference of the tube while in longitudinal section the nuclei resemble a string of beads. Simple cuboidal epithelium is found forming the tubules of the kidneys, forming exocrine glands and their ducts, forming the choroid plexus of the brain and on the surfaces of the ovaries.

C. Simple columnar epithelium: Simple columnar epithelium is composed of a single layer of cells that are taller than they are wide. As a result, the nuclei reflect this shape by becoming elongated ovals that run perpendicular to the surface of the tissue. Typically the

nuclei are located closer to the basal surface than the apical surface, typically in the lower ½ of the cell. Another common feature of simple columnar epithelium is the presence of specialized, mucous-secreting cells known as **goblet cells**. These are easily identified as they frequently break the otherwise continuous arrangement of columnar nuclei and are much lighter in color. Under higher magnification, you will be able to see the presence of **microvilli (brush border)** on the apical surface of the columnar cells. Microvilli are finger-like projections of the plasma membrane that greatly increase the surface area of the apical surface. In addition, some simple columnar epithelium possess another cell surface modification on their apical surface known as **cilia**. Cilia are thread-like projections capable of wave-like motion and assist in propelling substances over the surface of the cells. Simple columnar epithelium is found throughout the digestive system, lining the chambers of the stomach, small intestines and large intestines. In addition, it is found lining the chambers of the uterus, uterine tubes, gall bladder and bile ducts.

D. Pseudostratified columnar epithelium: Although it looks like it is multi-layered, pseudostratified columnar epithelium is actually a single layer of cells. Each cell is connected to the basement membrane; however, not all cells project all the way to the free surface. The "shorter," basal cells are wedge shaped, with their nuclei near the basement membrane, while the nuclei of the "taller," apical cells are located higher in the tissue. The overall effect is that of several layers of nuclei giving it a stratified appearance. Like simple columnar epithelium, pseudostratified columnar epithelium typically contains **goblet cells** and **cilia**. This tissue is found lining the nasal cavity, the nasal sinuses, the auditory tubes, the trachea and the bronchi of the lungs.

Stratified Epithelium - multiple layers

A. Keratinized stratified squamous epithelium: As the name implies, this tissue is composed of squamous-type cells that are piled into a multi-layered tissue. However, stratified epithelia are named based on the shape of the cells on the apical surface. As you examine this tissue, you will see that at the basal surface the cells are actually columnar shaped and then transition as they move toward the surface to cuboidal and finally to squamous shaped cells. Keratinized stratified squamous epithelium is characterized by the presence of a keratinized layer at the apical surface composed of dead, squamous shaped cells that are filled with the tough protein keratin. Another distinct characteristic of stratified squamous is its wavy basement membrane. This formed by projections of the underlying dermis called papillae that protrude into the epithelium of the epidermis. Keratinized stratified squamous is found on the skin.

B. Non-keratinized stratified squamous epithelium: This tissue looks very much like the keratinized stratified squamous with the exception that it lacks the keratinized layer. One key feature of all stratified squamous epithelium is that the lowest layer of cells stains dark purple. Cells that are more superior become gradually lighter toward the apical surface. This tissue is found lining the mouth, the throat, the esophagus, the vagina, the anus and the cornea

C. Transitional epithelium: Although this is a stratified epithelium, we do not include the term stratified in the name. Transitional epithelium is found in the urinary bladder and some of the other structures of the urinary system. It can have two different appearances depending on the state of the organ so it is named transitional epithelium. For example, when the urinary bladder is in its empty or relaxed state, the epithelium will appear like stratified cuboidal epithelium. When it is filled or stretched, it will appear more like stratified squamous. All of the images you will see are of the tissue in the relaxed state.

In addition to stratification also look for the characteristic brick cells on the free surface that will cover 2-3 of the cells below them and often bulge into the lumen organ. Transitional epithelium is found lining the urinary bladder, the ureters and the superior urethra.

List of Terms

Spend as much time as you need reviewing Epithelial Tissues and structures. The most important thing will be for you to practice identifying all of the structures listed in the table below. Use your online resources, open lab, and any other tool that you have to become confident in your identification skills. Your exam will ask you to identify and then write in (Fill in the Blank) the correct term for your identification. The table below is a comprehensive list of all the terms from this section that we would consider asking you to identify on an exam.

List of Terms for Epithelial Tissue	
Simple squamous epithelium	**Apical (free) surface**
Simple cuboidal epithelium	**Basal surface**
Simple columnar epithelium	**Goblet cell**
Pseudostratified columnar epithelium	**Cilia**
Keratinized stratified squamous epithelium	**Microvilli (brush border)**
Non-keratinized stratified squamous epithelium	**Basement membrane**
Transitional epithelium	

Connective Tissue

General Characteristics of Connective Tissues

- Very few cells compared to other tissues
- Large amounts of extracellular (intercellular) substance called matrix (matrix = ground substance plus fibers)
- Contains various fibers
- Vascular, meaning blood vessels are present (exceptions are cartilage and dense connective tissue)

General Functions of Connective Tissues

- Connect and bind other tissues together
- Support and give structure to the body

- Protect and cushion organs
- Defense against disease (inflammation and immunity)
- Storage of energy and minerals
- Repair of damaged tissue
- Transportation of nutrients, gases and wastes

Loose Connective Tissues

A. Loose fibrous connective tissue (areolar connective tissue): This tissue is often lacy in appearance and is found in numerous fluid-filled spaces. It constitutes the loose packing material in many organs. Loose fibrous connective tissue connects the skin to underlying structures and is composed of **collagen fibers**, **elastic fibers** and a variety of cells including **fibroblasts** and **mast cells**. It can be found directly under all epithelial tissue where its appearance can be quite variable.

B. Adipose tissue*:* Adipose tissue is widely distributed throughout the body and has very typical characteristics. Unlike the other connective tissues, adipose tissue has very little extracellular matrix. This tissue is characterized by large, round, open spaces separated by very thin plasma membranes. Adipose cells (adipocytes) contain a large lipid droplet inside that is dissolved away during preparation of the slides making them appear clear and open. The lipid droplet pushes the nucleus and other organelles of the cell up against the plasma membrane. The nucleus is small, flattened, and is usually visible in most of the cells. These nuclei resemble the nuclei of simple squamous epithelium. This tissue is one of the easier tissues to identify in that it looks much like a hair net. Most of our adipose tissue is found in the subcutaneous areas. It can also be found in the mesenteries, renal pelvis, mammary glands, around the kidneys and attached to the surface of the colon.

Dense Connective Tissues

A. Dense regularly arranged fibrous connective tissue: This tissue is composed primarily of very large **collagen fibers** that are tightly packed in parallel bundles. Scattered among the parallel collagen fibers are the elongate, sliver-like nuclei of the **fibroblasts** that run parallel to the direction of the fibers. This tissue has a very poor blood supply; consequently, when it is damaged, it takes a long time to heal. Dense regularly arranged fibrous connective tissue is found forming tendons and ligaments.

B. Dense irregularly arranged fibrous connective tissue: Like regularly arranged connective tissue, irregularly arranged connective tissue is also composed of large **collagen fibers**. In this tissue, however, the fibers are not all parallel, but run in several different directions. In addition, nuclei of the **fibroblasts** are more oval shaped. This tissue is located in the dermis of the skin, the outer coverings of body tubes, and the fibrous capsules of organs and joints.

Cartilage

Although there are three distinct types of cartilage, all have similar characteristics. Among these characteristics are the presence of small open spaces **(lacunae)** within the matrix of the
cartilage and cartilage cells **(chondrocytes)** occupying these openings. Like denser regularly arranged fibrous connective tissue, cartilage has a poor blood supply and thus

heals slowly when damaged. We will learn to identify two of the three types, **hyaline** and **elastic cartilage**; we will not, however, ask you to identify **fibrocartilage**.

A. Hyaline cartilage*:* The matrix contains roughly equal amounts of collagen fibers and ground substance. Since the collagen fibers are evenly distributed throughout the matrix, it generally appears as a homogenous pink or blue material. **Lacunae**, small open spaces, are present throughout the cartilage matrix. **Chondrocytes** can be found within the lacunae. Notice the **perichondrium** along the edge of this tissue. This tissue will contain immature chondrocytes known as **chondroblasts** and is composed mainly of dense regularly arranged connective tissue. Once the chondroblasts become surrounded by matrix, they are called chondrocytes. Hyaline cartilage is found in the growth plates of growing long bones, the rings of the trachea and bronchi, the nose, articulating surfaces of joints and the embryonic skeleton.

B. ***Elastic cartilage****:* This tissue looks much like to the hyaline cartilage. The major identifying feature is that the matrix contains large amounts of elastic fibers which appear dark purple in the micrographs. Elastic cartilage is found in the ears and the epiglottis.

Solid Connective Tissue

Bone is classified as a connective tissue. Like all connective tissue, it has more matrix than cellular component. In this case, the matrix is a calcified solid material surrounding collagen fibers. Under the microscope, you will see many structures and openings within the solid matrix of the bone that are essential to allow the bone tissue to live.

A. Compact bone: Compact bone is composed of small units called **osteons or Haversian systems**. Under the microscope these systems have the appearance of targets with a large bull's eye in the center. The bull's eye is formed by the **central or Haversian canal**. In living bone, blood vessels pass through these canals. Surrounding the central canal are a series of concentric rings of matrix called **concentric lamellae** (*lamella*, singular). At the borders between the lamellae are **lacuanae** (*lacuna*, singular), and within the lacunae are the cells that maintain the matrix, the **osteocytes**. If you look closely under high magnification, you can observe small, crack-like structures radiating out from the lacunae and interconnecting the lacunae of the different lamellae. These small tubes, called **canaliculi**, allow nutrients and wastes to pass between the osteocytes and the blood. If the bone is cut just right, you can see structures that connect one Haversian canal to another; these are the **Volkmann canals**. Compact bone is found in all bones of the body.

Fluid Connective Tissue

A. Blood: Blood cells are found in a fluid matrix called plasma. Blood is a bit unusual among the connective tissues because it does flow and the matrix is a liquid. Cells in other connective tissues are more or less stationary and do not move around much. Cells in blood however move freely and rapidly. Many blood cells freely move in and out of the blood vessels.

List of Terms

Spend as much time as you need reviewing Connective Tissues and structures. The most important thing will be for you to practice identifying all of the structures listed in the table below. Use your online resources, open lab, and any other tool that you have to become confident in your identification skills. Your exam will ask you to identify and then write in (Fill in the Blank) the correct term for your identification. The table below is a comprehensive list of all the terms from this section we would consider asking about on an exam.

List of Terms for Connective Tissue	
Loose fibrous (areolar) connective tissue • **Fibroblasts** • **Mast cells**	**Bone (compact)** • **Periosteum** • **Endosteum** • **Osteon (Haversion system)** • **Haversian (central) canal**
Dense regularly arranged connective tissue • **Fibroblasts**	**Osteocyte** • **Lacuna** • **Canaliculi** • **Volkmann's canal** • **Concentric lamella** • **Interstitial lamella**
Dense irregularly arranged connective tissue • **Fibroblasts**	**Blood**
Adipose connective tissue	
Hyaline cartilage • **Chondrocyte** • **Lacuna** • **Perichondrium**	
Elastic cartilage • **Elastic fibers** • **Chondrocyte** • **Lacuna**	