Name: _____

3.0 Histology

While the cell is the fundamental structural and functional building block of the human body (and in fact of all living things), it is the complex combination of cells that defines human anatomic structure. Cells with similar structural and functional characteristics combine to form tissues. In turn different tissues combine to form organs, organs that work together form organ systems, and organ systems collectively make up the whole human organism. In this course we will explore all levels in the structural hierarchy. In this section we will focus on the tissues as structural and functional building blocks of the organs and systems that they are part of. The study of the tissues is called "Histology". Different techniques are used in the study of anatomy depending on which level in this hierarchy of structure one is studying. To study the tissues we will need the help of the microscope.

I. HISTOLOGY

The Primitive Germ Layers

We all start as a single cell, called the zygote. This cell undergoes mitotic cell division eventually creating a collection of 50 to 100 trillion cells making up the adult body. Each cell is genetically identical to any other and yet each seems to be structurally and functionally distinct. This differentiation first occurs early in development (at about day 12) during a stage of development called gastrulation. During gastrulation different cellular groups are exposed to slightly different surroundings. It is believed that cell structure is altered due to the environment to which the cells are exposed. Cells in common areas are exposed to the same environment and differentiate following similar patterns while cells in other areas differentiate differently. Consequently cells of similar structure (similar developmental lineages) are grouped together forming the tissues. Gastrulation results in the formation of the three primitive germ layers, the first tissues. This initial differentiation between cells continues throughout development until all of the structures of the body are formed.

A. Ectoderm - principally differentiates into epithelial tissue & nervous tissue
(i.e. epidermis of skin, mucous membranes, nervous system, eyes, ears...)

B. Mesoderm - principally differentiates into epithelial tissue, connective tissue & muscle tissue
(i.e. lining of body cavities, muscles, bones, cardiovascular system, kidneys...)

C. Endoderm - principally differentiates into epithelial tissue
(i.e. digestive tract, liver, pancreas, respiratory tract & lungs, bladder...)

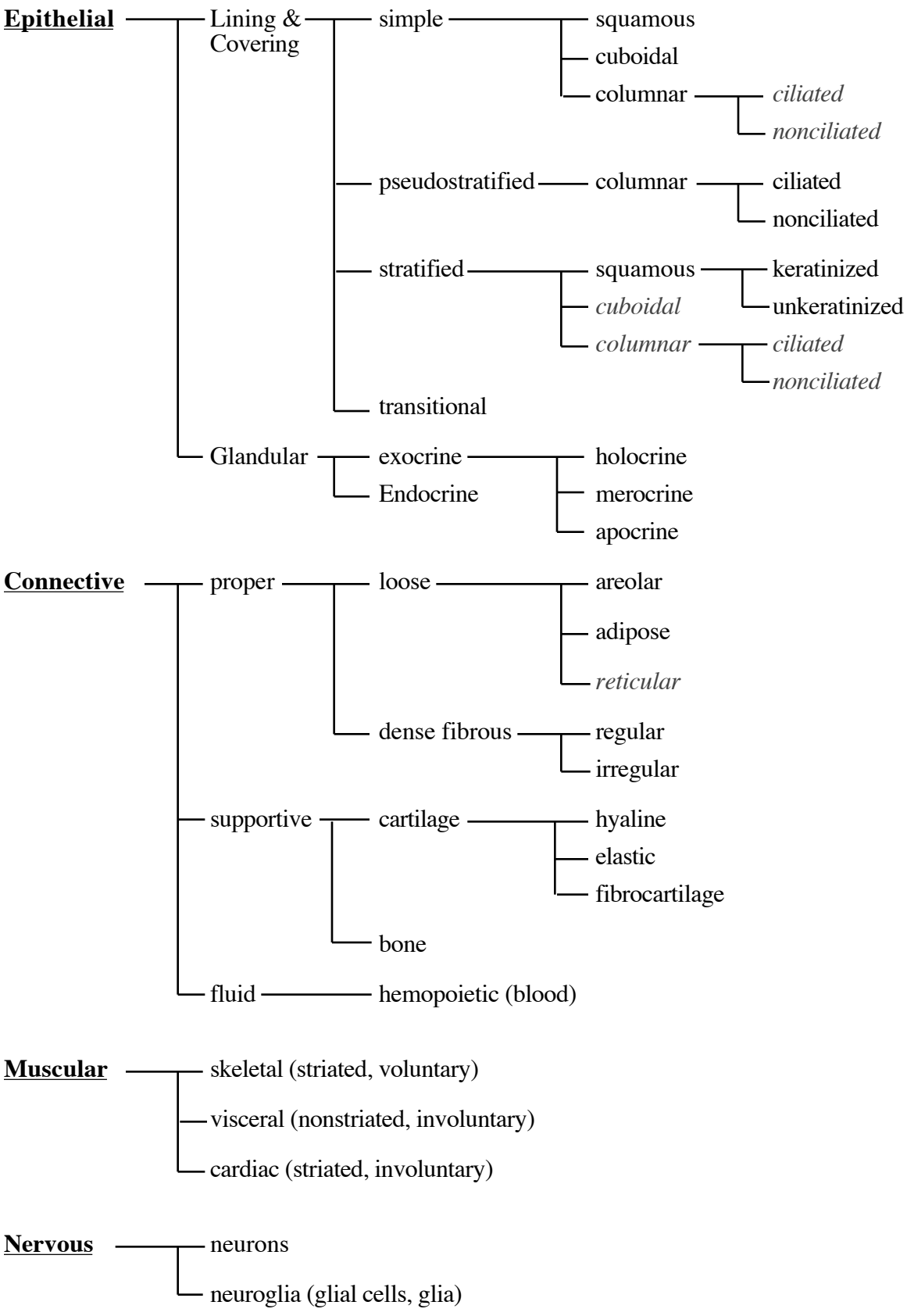
The Four Adult Tissue Types

These primitive tissues continue to differentiate eventually forming the four adult tissues. The cells that form a tissue have a common structure and function, thus the tissue typically has a single function. All tissues are composed of two key components:

1) Cells - cells are the basic building block of all tissues and are the smallest structural and functional unit of all living things.
2) Extracellular Space - the space internal to the body but not within the cells. This is subdivided into several subdivisions (several are listed below):
   - Interstitial Space (aka internal environment) - fluid space between and surrounding the cells. Composed primarily of water, dissolved solutes and occasionally protein fibers and/or mineral salts.
   - Plasma - fluid space in the blood
   - Other - fluid space within body cavities and other internal spaces

There are four basic tissue types: epithelial, connective, muscle, and nervous tissue.

A Morphological Classification of the Tissues



A. Epithelial Tissue - (derived from ectoderm, mesoderm, & endoderm)

Epithelial tissues are characterized by:

1) *cellularity* - epithelial tissues are highly cellular, cells are *tightly bound* together with little extracellular space, typically forming sheets of cells.
2) *polarity* - one surface of the sheet of cells is affixed to an underlying extracellular matrix (the *basement membrane*) while the opposite surface is exposed (apical surface). This characteristic is unique to epithelial tissues.
3) *regeneration* - epithelial cells are replaced rapidly by ongoing cell division.
4) *vascularity* - epithelial tissues are avascular, blood vessels are not found in epithelial tissues.

Different epithelial tissues are distinguished by the arrangement and shape of the cells that make them up, and by their function.

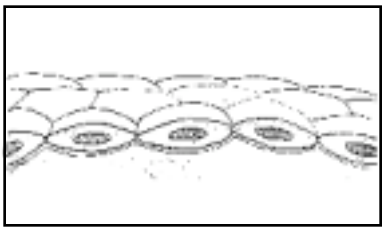
1. Organization - epithelial tissues primarily make up protective coverings and linings, however, they also make up glands
   a. Covering & Lining - sheets of epithelial cells overlying connective tissue (i.e. membranes) - classified by cell arrangement and shape
   b. Glandular - singular or clusters of epithelial cells that secrete a product
      i. Classification by Type
         Endocrine - "ductless" glands that secrete their products (hormones) into the interstitial spaces then to the blood
         Exocrine - glands that secrete their products into a duct
            Structure of Ducts - single cell (in wall of tube, i.e. mucus cells in intestine)
            - tubular (may be simple or compound)
            - alveolar aka acinar (may be simple or compound)
      ii. Classification by Cellular Mode of Secretion
         Holocrine - entire cell filled with secretory products is shed (i.e. sebaceous glands)
         Apocrine - secretion filled vesicles pinch off of apical end of cell (i.e. axillary sweat glands, mammary glands, ceruminous glands)
         Merocrine / Eccrine - secretory product released by exocytosis (i.e. majority of sweat glands, salivary glands)

2. Cell Arrangement - epithelial tissues may be distinguished by the number of layers
   a. Simple - single layer
   b. Pseudostratified - single layer of columnar cells that appears multilayered due to staggered arrangement of the nuclei of adjacent cells.
   c. Stratified - multilayered
   d. Transitional - appearance changes from the relaxed to the stretched state

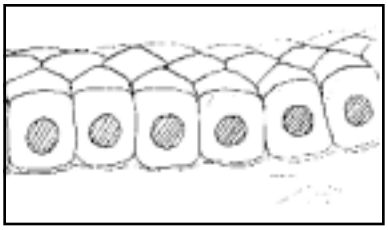
3. Cell Shape - epithelial tissues may be distinguished by the shape of the cell (in multilayered epithelia the cell at the free surface is the defining cell shape)
   a. Squamous - flattened cells
   b. Cuboidal - cube shaped cells (in section)
   c. Columnar - elongated column shaped cells (in section)

4. Specific Examples of Epithelial Tissues

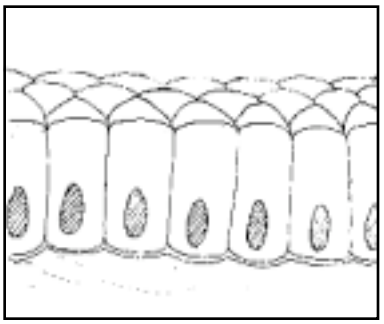
a. Simple Squamous - a single layer of flattened cells laid side by side like floor tiles. The nucleus, like the cell, is flattened. *Found lining blood vessels (endothelium), forming alveoli, and Bowman's capsule in the kidney.*



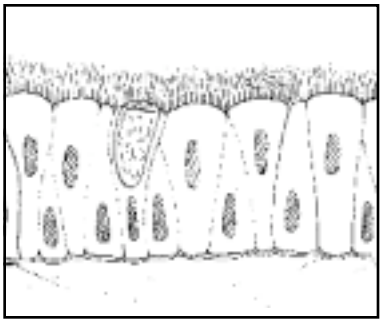
b. Simple Cuboidal - a single layer of cube shaped cells with round centrally located nuclei. *Found in glandular tissues (secretory cells), in portions of kidney tubules, and liver cells (hepatocytes).*



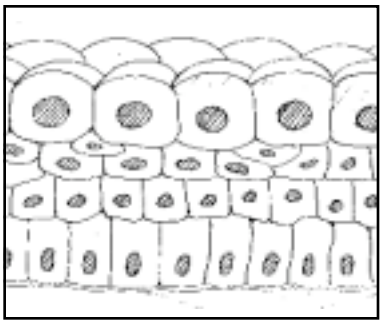
c. Simple Columnar - a single layer of rectangular shaped cells. Ovoid nuclei are predominantly located near the bound (basal) end of the cell. Cells may be ciliated or have microvilli. *Found lining the digestive tract from stomach to anus, within uterine tubes and uterus.*



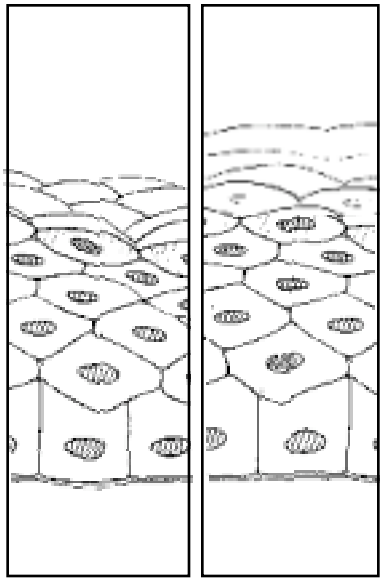
d. Pseudostratified Columnar - similar in appearance to simple columnar epithelium except not all cells appear to reach the free surface. Nuclei often appear to be distributed in two rows, and may be irregular in shape. Free (apical) surface is often, but not always ciliated. *Found in large respiratory airways (i.e. trachea, nasal cavity) and vas deferens.*



e. Transitional - multilayered loosely connected cells (permits stretching). Columnar cells are present at the bound surface, cell shape at the free (apical) surface is variable with the amount of stretch (note: most stratified epithelia have columnar cells at the bound surface, they are named for the cell type at the free surface). In the unstretched state apical (surface) cells appear dome shaped and flatten with stretching. *Found lining the ureter, urethra, and bladder.*



f. Stratified Squamous - multilayered with columnar cells at the bound surface and squamous at the free (apical) surface. Divided into two subgroups based on presence of keratin in apical cells.



i. Keratinized Stratified Squamous - also known as cornified epithelium. The apical (surface) layer of dead keratin filled squamous cells form a protective layer against abrasion. Basal cells divide rapidly replacing cells that have sloughed off. *Found as the epidermis of the skin.*

ii. Unkeratinized Stratified Squamous - like above but lacking the layer of dead keratinized cells at the free (apical) surface. *Found lining the mouth, esophagus, anus, and vagina.*

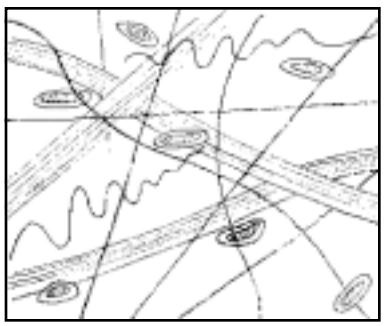
B. Connective Tissue - (derived from mesoderm)

Connective tissues are characterized by:

- *sparce cells* - cells (aka fibroblasts) are *loosely bound* together, often separated by large amounts of extracelular space. The extracellular space is composed of *ground substance* (water and dissolved proteoglycans & glycoproteins, i.e. hyaluronic acid) with embedded protein filaments (collagen fibers "white", elastic fibers "yellow", and reticular fibers). The protein filaments in the extracellular matrix are produced by fixed connective tissue cells called fibroblasts. Fibroblasts as well as other "mature" connective tissue cell types are derived from mesenchymal stem cells (some connective tissue fibroblasts may be incompletely differentiated). The *extracellular matrix* forms the "glue" holding the cells together.cells are *tightly bound* together with little extracellular space, typically forming sheets of cells.
- *polarity* - connective tissues are non-polar, found everywhere in the body and play a supportive role by "connecting" different tissues together. Connective tissues are effectively never exposed to the outside. They are commonly found deep to epithelial tissues, filling spaces and surrounding muscle and nerve cells.
- *regeneration* - connective tissues exhibit varying degrees of cell division. Many include cells that are actively dividing throughout life (although not as rapidly as epithelial tissues).
- *vascularity* - connective tissues usually contain abundant blood vessels and nerves although this can vary dramatically.

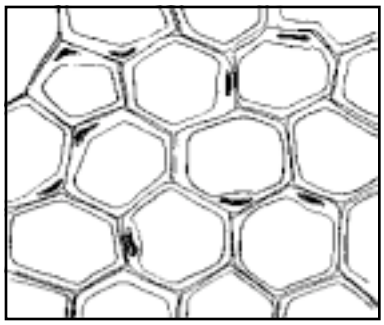
1. Connective Tissue Proper

a. Loose connective tissue - extracellular protein fibers are sparse forming a flexible tissue (found filling spaces between organs, providing pathways for blood vessels and nerves, forming the delicate framework of organs, storing fat)



i. Areolar - this "space filling" connective tissue consists of sparce cells (fibroblasts) and often only the nuclei are visible. Cells are surrounded by a semifluid ground substance with white collagenonus fibers (broad pink) and elastic fibers (thin dark). *Found throughout the body (example: under epithelial tissues and surrounding muscle cells).*

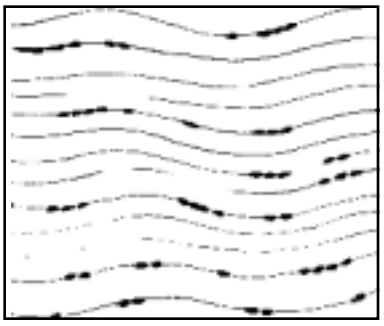
ii. Adipose - extracellular space is obscured by highly expanded cells, thus adipose is a "cellular" connective tissue. Adipose cells appear hollow due to a large fat containing vacuole that pushes the nucleus to the side (producing a "signet ring" appearance). Adipose can be deposited anywhere but is most conspicuous subcutaneously.



iii. Reticular - consists of many small interwoven fibers with few cells. Provides a framework holding many soft tissues together such as the liver, bone marrow, and spleen.

b. Dense Fibrous Connective Tissue - extracellular protein fibers are prominent forming a tough often inflexible tissue (such as tendons and ligaments). Fibers may be regularly or irregularly arranged.

i. Regular - this connective tissue may contain dense collagenous (aka "white") fibers and/or elastic (aka "yellow") fibers with few cells and little extracellular matrix. Cells are pushed aside and tend to appear organized into rows between the fibers. The regular arrangement of the fibers provides tremendous strength along a single axis. Collagen containing regular CT is very resistant to stretch and is commonly found in tendons. Elastic fibers are found in somewhat more elastic ligaments.

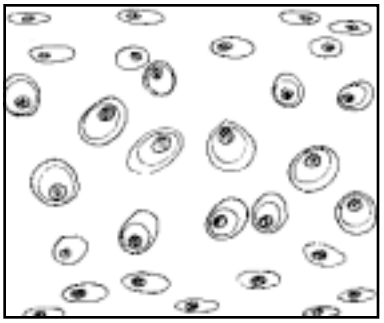


ii. Irregular - the fibers of dense irregular CT are woven together into a mesh of fibers in many orientations. This fiber arrangement provides strength in many directions. The sheath that encloses bones (periosteum) and the dermis of the skin are examples of dense irregular CT.

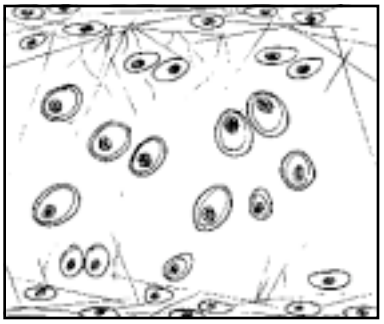
2. Supportive Connective Tissue

a. Cartilage - The extracellular matrix in cartilage is rich in proteoglycans forming a gel like consistency strengthened by extracellular proteins. Cartilage is often found forming supportive frameworks and protective cushions. The cells, called chondrocytes, enclosed in cavities called lacunae, have a poor blood supply. The different types of cartilage are named based on the predominant fiber in the extracellular matrix.

i. Hyaline Cartilage - fibers are not visible but the large chondrocytes in their lacunae give them a distinct appearance that can look like an eye. *Found at the ends of bones (articular cartilage), nose, trachea, larynx, bronchi, and costal cartilage's.*



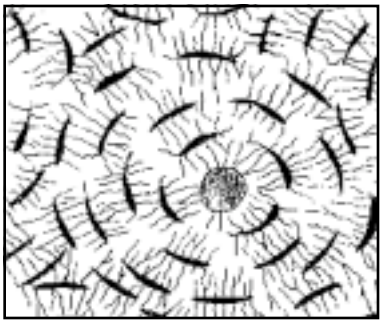
ii. Elastic Cartilage - similar in appearance to hyaline cartilage but fine interwoven elastic fibers are visible. *Found in the ear, and forming the epiglottis.*



iii. Fibrocartilage - many collagenous fibers (stain red depending on stain) around small chondrocytes in lacunae (stain purple). *Found as joint pads between vertebrae, pubic bones (pubic symphysis), and in the knee (meniscus).*

b. Bone - bone is structurally similar to cartilage with the addition of mineral salts (hydroxyapatite - primarily calcium phosphate plus calcium hydroxide) to the extracellular matrix which hardens the extracellular matrix. The matrix is laid down in layers called lamellae. The cells, called osteocytes, are found in lacunae and are interconnected by fine processes passing through canaliculi. Depending on the pattern of extracellular matrix deposition two types of bone can be recognized.

i. Compact Bone - essentially all of the extracellular space is calcified, the extracellular matrix is calcified in very regular rings of bone (lamellae) surrounding a central blood vessel containing canal (variously called the Haversian canal, central canal or osteonic canal).

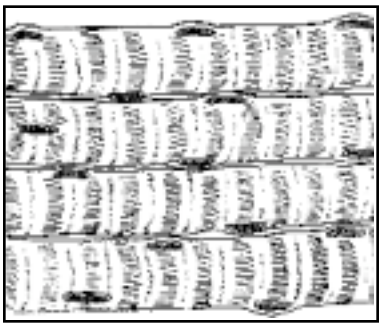


ii. Cancellous ("spongy") Bone - calcification is incomplete forming an irregular "honeycomb" pattern of calcification. Bone marrow with blood vessels and nerves fills the spaces between the struts of bone (trabeculae).

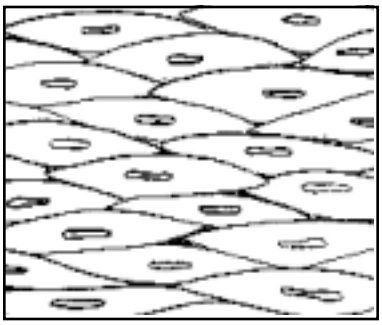
4. Hemopoietic Tissue (blood) - blood consists of cells suspended in a fluid matrix (plasma) similar to that of typical connective tissues hence it is classified as a connective tissue. Unlike other connective tissues the extracellular fibers in the plasma are normally soluble resulting in a freely fluid tissue. Another key difference is that the extracellular proteins are not produced by the cells in the blood but by the liver. In addition, the cellular component consists predominantly of red and white blood cells produced in bone marrow.

C. Muscle Tissue - (derived from mesoderm) composed of cells close together with little interstitial material and surrounded by connective tissue richly invested with blood vessels and nerves. Cells are unique in their ability to contract due to the overlap and relative sliding of intracellular protein filaments (actin and myosin). Three muscle tissue types are recognized.

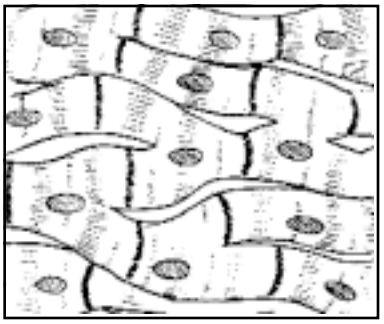
1. Skeletal (striated, voluntary) - made up of large rope shaped, multinucleated cells. These cells have a distinct pattern of stripes, called striations. Bundled together by connective tissues they form the skeletal muscles which are attached to bones by tendons and are responsible for movement of the skeleton.



2. Visceral (smooth, involuntary) - often called smooth muscle, this muscle is composed of relatively smaller spindle shaped cells with a central nucleus. Visceral muscle is predominantly found in sheets surrounding tubes (i.e. intestines, blood vessels...).



3. Cardiac (striated, involuntary) - cells are branched with a single centrally located nucleus. Striations are visible but less distinct than in skeletal muscle. Junctions between cells, called intercalated discs, are visible as dark bands. These intercalated disks characterize cardiac muscle.



D. Neural Tissue - (derived from ectoderm) The tissue making up the nervous system is composed primarily of two cell types:

1. Neurons - the functional cell of the nervous system (capable of relaying signals). The three key parts of a neuron are the cell body (soma), dendrites, and a single axon.

2. Neuroglial (aka glial) Cells - these protect the fragile neurons and enhance their function .

Name: _____

Questions / Review Lab 3.0

In addition to identifying all of the tissues and features underlined in your handout you should be able to answer the following types of questions. These questions are designed to help you focus your studies, how you use them and answer them will determine how much you get from them.

1. Define each of the following:
   a. extracellular space
   b. interstitial space

2. What are the distinguishing characteristics of epithelial tissues (i.e. what distinguishes epithelial tissues from all other tissues)?

3. Name and draw a picture of each of the cell shapes characteristic of epithelial tissues. What are some of the distinguishing characteristics of each cell shape?

4. Name and draw a picture of each of the cell arrangements characteristic of epithelial tissues. What are some of the distinguishing characteristics of each arrangement?

5. Epithelial tissues are named based on cell shape and cell arrangement. In multilayered epithelial tissues the shape of the cells is not constant from one layer to the next. How are these epithelial tissues named?

6. Epithelial tissues are often divided into two different functional epithelial tissue types. What does this mean? What are the two functional epithelial tissue types?

7. What are the distinguishing characteristics of connective tissues?

8. What are the two key structural components of connective tissues?

9. What is the extracellular matrix of connective tissue composed of?

10. What tissue type would you expect to find lining body cavities? Explain.

11. Injections are often given into muscle or connective tissues. Why do you think these are good sites for injections (note: the patients comfort is not part of the answer)?

12. What three characteristics are used to distinguish between the three different types of muscle? Describe each.