Introduction
1. **Histology** - Science that deals with the study of tissues

2. **Tissues**
   a. groups of cells that are similar in structure, function, and embryonic origin
   b. a tissue consists of cells and a matrix (the extracellular material around the cells)

3. **Four Major Types of Tissues** (there are 50 to 75 trillion cells in the body and each cell is organized into one of the four tissue types)
   a. **epithelium** – cover or line all external and internal body surfaces (e.g., epidermis of skin and cells that line intestine)
   b. **connective** – connect and support body parts (e.g., bones, cartilage)
   c. **muscle** – contracts to cause body parts to move (e.g., skeletal muscle moves bones, cardiac muscle in heart pumps blood)
   d. **nervous** – capable of transmitting nerve impulses (e.g., neurons make up the brain and spinal cord)

4. **Body Organization**
   a. tissues are organized into **organs**, such as the heart; organs are made up of 2 or more tissue types
      1. wall of the heart is mostly cardiac muscle
      2. chambers of the heart are lined with epithelial cells
      3. connective tissue forms most of the heart valves
      4. nerves help to regulate the beat of the heart
   b. organs are organized into **organ systems** (e.g., cardiovascular and reproductive systems)

5. **Biopsy** – remove living tissue for microscopic examination to diagnose diseases (pathologies)

**Pathologist** - physician who specializes in the study of tissue cells to help other doctors diagnose problems such as disease. They also perform autopsies.

**Summary of Human Life Cycle**
1. During each menstrual cycle, an ovulated egg leaves the ovary and moves into the oviduct
2. Sexual intercourse results in the ejaculation of sperm-containing semen into the vagina. The flagellated sperm swim out of the vagina and through the uterus and into the oviduct.
3. If sperm and egg meet, then the haploid sperm and the haploid egg fuse at fertilization to form a diploid zygote. Fertilization occurs in the oviduct or fallopian tube.
4. Over the next several days the zygote divides into a growing mass of cells called the embryo. The embryo forms as the zygote divides by mitosis into 2 cells. The cells move down the length of the oviduct as they continue to divide once every 12 to 20 hours. Within 4 days of fertilization, the growing mass of cells (about 300) leaves the oviduct and enters the uterine cavity. Over the next 3 days the developing embryo continues to grow and lives free in the uterus. The embryo eventually transforms into a hollow ball of cells called a blastocyst.
5. Within 6-7 days of ovulation, the early embryo or blastocyst implants into the uterine lining and continues to grow.
   a. It takes about 5 days for the completion of implantation.
   b. 3 germ layers form just after implantation (endoderm, mesoderm, ectoderm)
6. The embryo undergoes **embryogenesis** which is a process that develops the organs and organ systems of the body. Embryogenesis lasts until the end of week 8 (over the first 2 months of pregnancy).
7. When all of the organ systems are formed, the embryo is called a fetus.
8. Fetal development begins at week 9 (after 2\textsuperscript{nd} month) and lasts over the last 7 months of a 9-month pregnancy. Pregnancy lasts about 38 to 40 weeks (approx 266 – 280 days) from the time of fertilization to childbirth.

Sperm/egg (fertilization in oviduct) \(\rightarrow\) 2N zygote \(\rightarrow\) embryo \(\rightarrow\) oviduct (4 days) \(\rightarrow\) uterine cavity (3 days) \(\rightarrow\) implants into wall of uterus around 7 days after fertilization \(\rightarrow\) embryogenesis (2 months) \(\rightarrow\) fetus (7 months of fetal development) \(\rightarrow\) newborn

Embryogenesis – first 8 to 9 weeks of pregnancy when organs and organ systems form (e.g., digestive, skeletomuscular, nervous, urinary, cardiovascular, reproductive, respiratory). At 10 weeks, the embryo is around 1.2” in length (3 cm) and weighs around 8 gms (0.25 ounces, around the same as a quarter)

**Primary Germ Layers**
1. The 3 primary germ layers form in the early embryo: ectoderm, mesoderm, and endoderm. During embryogenesis the germ layers develop into specific organs
2. **ectoderm** – outer layer of cells that go on to form the epidermis and the nervous system (brain and spinal cord); epidermis and glands of skin
3. **mesoderm** – middle layer of cells that differentiate into mesenchymal cells that give rise to muscle, bone, and blood. All connective tissues derive from mesoderm. Dermis of skin and walls of digestive (stomach and intestine) and respiratory tracts (lungs)
4. **endoderm** – inner layer of cells that go on to form the mucous membranes of the digestive and respiratory tracts, as well as the digestive glands
5. endoderm, mesoderm and ectodermal cells can form epithelial cells
Epithelium

1. **Definition** – sheet of tightly packed cells attached to a basement membrane (BM) that cover and line body surfaces and make up most glands

2. **Two types**
   a. **covering and lining** (e.g., form outer layer of skin, line tubes and cavities)
   b. **glandular** – cells that secrete chemicals and solutions (e.g., sweat and oil glands)

3. **Characteristics**
   a. **Cellularity** – tightly packed with minimal matrix between the cells

   b. **Intercellular Junctions**: Special cell-to-cell contacts
      1. **desmosomes** (spot welds) – protein fibers that connect the plasma membranes of adjacent cells at a discrete spot; common between epidermal cells of the skin, cells within organs (e.g., liver)
      2. **tight junctions**
         a. protein fibers that fuse membranes of adjacent cells together; found between cells that line tubes so that fluids cannot leak out between the cells (e.g., between the cells that line the stomach and intestine; cells that line the ureter)
         b. completely encircles an epithelial cell nears its apex and tightly joins it to neighboring cells; similar to the plastic harness or yolk on a six-pack of soda cans
c. **avascular**
   1. no direct blood supply to epithelial tissues; blood vessels are in underlying connective tissue. Chew on inside of mouth or scrape away epidermis and doesn’t bleed
   2. since all living cells need nutrients that come from the blood, nutrients must diffuse into epithelial tissues

d. Some epithelial cells have **microvilli or cilia** on their apical surfaces
   1. **microvilli** (tiny bumps, 1-2 um)
      a. finger-like projections from the apical surface that increase surface area by 15-40x normal as compared to flat (area = length x width).
      b. They do not move or beat. Around 400 microvilli/cell
      c. microvilli are common on the apical surface of epithelial cells that line the intestine. They increase the total surface area for rapid absorption of nutrients
   2. **cilia** (7-10 um)
      a. finger-like projections that are 5-10x longer than microvilli. Around 400-1000 cilia/cell
      b. Cilia wave or beat back and forth and tend to move things past the cell (similar to crowd surfing).
      c. Cilia are organelles of movement and they also increase the total surface area

e. **Basement membrane** (BM, noncellular, non-living); semi-solid, gel-like consistency
   1. sheets of epithelial cells are attached to a basement membrane
   2. formed by secretions from epithelial cells (**basal lamina**) and underlying connective tissue cells (mostly fibroblasts) and is called the **reticular lamina**
   3. the basement membrane anchors epithelium to the underlying areolar connective tissue
   4. **polarity** (opposite ends of epithelial sheet look different)
      a. **apical (top) and basal (bottom) surfaces**
      b. apical surface is towards the **free surface**; one that does not touch another cell; free surface is associated with a sheet of epithelial cells; it doesn’t make direct contact with other epithelial cells
      c. the basal surface is towards the basement membrane
   5. the surface of an epithelium that faces the basement membrane is the **basal surface** and the surface that faces away from the basement membrane is the **apical surface**
f. reproduce readily by mitosis
   1. tend to repair or heal easily when damaged
   2. epithelial cells tend to be replaced rapidly within the body (e.g., cells that line the stomach are replaced every 3 days or so); constant turnover
   3. many cancers originate from epithelial cells (carcinomas): e.g., skin, lung, prostate, cervical

Classification of Epithelium
1. Epithelial tissues are generally referred to by 2 names. They are named based on the number of cell layers and the shape of the cells
2. Number of Cell Layers
   a. simple – single layer of epithelial cells; all contact the BM
   b. stratified – sheet of 2 or more layers of epithelial cells; only the deepest layer attached to BM
   c. pseudostratified – single layer that appears as if there are 2 layers since some cells are longer than others (technically, this is a special type of simple)
3. Shape of Cell (all epithelial cells are roughly hexagonal in cross-section (6-sided), they vary in height)
   a. squamous – flat, scaly, and thin
   b. cuboidal – cube-like, as tall as they are wide (2D – each side is a square or roundish)
   c. columnar (tall and narrow) – taller than they are wide (2D – each side is a rectangular)
Simple Squamous
1. single layer of flat and thin cells
2. found in areas where **diffusion and filtration** must occur rapidly
   a. **diffusion** – movement of chemicals from an area of high to low concentration
   b. **filtration** – water or fluid pressure like blood pressure forces fluids and dissolved chemicals through a membrane, this occurs when blood pressure forces the water and dissolved solutes in plasma through capillary wall
3. **locations**
   a. **air sacs** (alveoli) of the lung where gas exchange (CO$_2$ and O$_2$) occurs by diffusion
   b. **wall of capillaries** nutrients are filtered out of capillaries towards cells

Simple Cuboidal
1. single layer of cube-shaped cells
2. location: **kidney tubules** (tubes in the kidney involved with the production of urine)
3. Function: secretion and absorption
### Simple Columnar Epithelium

**Description:** Single layer of tall cells with round to oval nuclei; some cells bear cilia; layer may contain mucus-secreting unicellular glands (goblet cells).

**Function:** Absorption; secretion of mucus, enzymes, and other substances; ciliated type propels mucus (or reproductive cells) by ciliary action.

**Location:** Nonciliated type lines most of the digestive tract (stomach to anal canal), gallbladder, and excretory ducts of some glands; ciliated variety lines small bronchi, uterine tubes, and some regions of the uterus.

**Photomicrograph:** Simple columnar epithelium of the stomach mucosa (1300x).

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**Simple Columnar**

1. **single layer of column-shaped cells**

2. non-ciliated simple columnar lines the stomach and the intestines all the way to the anal canal
   - secrete digestive enzymes
   - absorb nutrients

3. simple columnar cells that line the small intestine are associated with **microvilli (apical surface)**

4. often associated with **goblet cells** that secrete mucus (goblet cells are glandular epithelial cells)
   - make and secrete a glycoprotein called **mucin** (at least 19 different mucin genes); glycoprotein is a high molecular weight protein with carbohydrate groups attached to it. **Mucin is a gelling agent like the powder called gelatin used to make jello.** There is a mucin called ovomucin that is responsible for the fel-like nature of egg white (clear fluid around yellow yolk)
   - when added to the water outside the cell mucin makes **mucus**
   - mucus is **sticky (slimy) and viscous** (lot of it in spit and snot)
   - function of mucus coating on the cells: **protection and lubrication** (makes tubes slippery)

5. ciliated simple columnar epithelium lines a few portions of the small bronchi of the lungs and the oviducts
Pseudostratified Columnar Epithelium

1. single layer of cells of different sizes that appear stratified; the short cells are relatively unspecialized and give rise to the taller cells
2. often associated with cilia and goblet cells
3. location: lines most of the upper respiratory tract to include the larynx, trachea, and larger bronchi (small bronchioles lined with ciliated simple columnar). Larynx is stratified squamous above vocal cords and pseudostratified ciliated columnar below
4. in the lungs, this tissue is ciliated and contains goblet cells (goblet cells are not ciliated although they may contain some microvilli)
   a. function of mucus and cilia – self-cleansing mechanism called the mucociliary escalator
      1. mucus coats the respiratory tubes
      2. traps dust and lint that enters when one inhales as well as bacteria and fungi, pollen grains
   b. the cilia then beat and move the mucus to the throat where it is swallowed
   c. all debris that comes into the lungs as one inhales is removed from the lungs within 24 hours
5. smoking decreases the ability of the cilia to function properly (smoke paralyzes and kills them over time). Often the lungs of smokers are filled with mucus that they cough up and swallow. Smoker’s often have a smoker’s cough and the mucus in their larynx tends to give them a hoarse and raspy voice.

Smoke: (1) decrease number of cilia per cell, (2) slow movement of cilia, (3) increase number of goblet cells so increase mucus secretion
Stratified Squamous

1. **multiple layers of squamous cells** where only the bottom cells are attached to the BM
2. **upper most cells are squamous-shaped**, whereas the lower cells may be cuboidal to columnar (stratified squamous is named after the shape of the uppermost cells at the apical surface)
3. found in areas of the body that are subjected to **friction**
4. **Regenerate rapidly by the following mechanism**
   a. cells of the deepest or basal layer are undifferentiated stem cells that divide by **mitosis to replace the upper cells that slough off**. Mitosis produces 2 daughter cells: One stays attached to the basement membrane as a basal stem cell and the other becomes a keratinocyte in the upper layers of the epidermis
   b. they push upward towards the outer surface to **replace cells that slough off** due to friction or trauma (injury)
   c. **Exfoliation**: the sloughing off of surface cells is called exfoliation
   d. A Pap Smear is a study of exfoliated cells from the cervix to look for signs of uterine cancer
5. **Locations of Keratinized or Non-Keratinized Stratified Squamous**
   a. **keratinized**
      1. **epidermis** of the skin (outer layer of the skin that can touch with a finger)
      2. **keratinized** – outer cells are dead and filled with a tough protein called keratin
      3. **dry** membrane (no goblet cells)
   b. **nonkeratinized** (lacks the surface layer of dead cells)
      1. **lining of the mouth, pharynx** (throat), esophagus, surface of tongue, vagina, and anal canal
Another Epithelial Classification System – Classify sheets of epithelial cells as epithelial membranes

Epithelial Membranes (Covering and Lining Membranes)

1. Combination of an epithelial layer and underlying connective tissue proper (often areolar); since these membranes consist of 2 tissue types they are simple organs

2. 3 major types of epithelial membranes: mucosa, serosa, endothelium

3. Mucosa (mucous membrane) – Typically contains goblet cells that secrete mucus
   a. epithelial cells covered with a slimy secretion called mucus; the sheets of epithelium that form mucus membranes vary from one location to another (i.e., made of different types of epithelium)
   b. non-keratinized stratified squamous – lines the mouth, pharynx, esophagus, vagina
   c. simple columnar – stomach and intestine
   d. pseudostratified columnar that lines the larynx, trachea and bronchi
   e. mucous membranes line all hollow organs that lead to the outside of the body – respiratory, digestive, and urogenital.

4. Serosa (serous membrane)
   a. single layer of squamous cells on a layer of areolar CT (mesothelium is the simple squamous of serous membranes that line ventral body cavities)
   b. secrete a watery fluid called serous fluid that moistens the surface
   c. lines and covers internal organs in closed ventral cavities (i.e., abdominal and thoracic)
   d. decreases friction as organs slide past each other (they don’t stick together)
   e. Special Names
      1. peritoneum – lines the abdominal cavity and covers organs in it (e.g., intestine)
      2. pericardium – covers the heart
      3. pleura – covers the lungs and lines the thoracic cavity
   f. mesothelium – simple squamous that forms the epithelial layer of serous membranes

5. Endothelium
   a. single layer of simple squamous attached to a BM that is exclusive to the lining of all hollow organs of the cardiovascular and lymphatic organs
   b. endothelium lines the walls of blood and lymph vessels and the chambers of the heart
   c. the wall of a blood capillary is endothelium

6. Cutaneous Membrane – refers to the epidermis of the skin; it is a dry membrane that lacks goblet cells

Glandular Epithelium

1. most glands of the body consist of mostly epithelial cells that produce and secrete chemicals

2. 3 basic types of epithelial glands
   a. Goblet Cell
      1. unicellular gland
      2. usually found among epithelial cells that line the digestive and respiratory tracts
      3. secrete mucin (glycoprotein) that mixes with water outside the cell to form a thick (viscous, consider water versus molasses) solution called mucus
      4. mucus has a protective and lubricant (slimy and slippery) role
   b. Endocrine glands
      1. multicellular glands that are mostly made up of glandular epithelial cells that secrete hormones directly into the bloodstream; some endocrine glands are made of neurons and other type of cells
      2. e.g., thyroid (thyroxin), pituitary (growth hormone, ADH), ovary (estrogen), testis (testosterone), adrenal gland (cortisol)
3. exocrine glands
   1. multicellular glands that secrete chemicals into ducts (a duct is a small tube) that open into a hollow organ or onto the body surface (i.e., open on to the surface of an epithelial sheet)
   2. e.g., sweat gland, oil gland, liver (secretes bile), pancreas (secretes digestive enzymes), salivary, lacrimal or tear glands

Two Types of Glandular Epithelial Cells based on Mode of Secretion

a. merocrine (also called eccrine)
   1. glandular epithelial cells that release their secretions by exocytosis at intervals; exocytosis is a process in which chemicals are secreted from secretory vesicles through the plasma membrane
   2. cells are not destroyed in the process
   3. salivary, sweat, goblet cells and pancreas

b. holocrine
   1. products secreted by the rupture of the gland cell; the entire cell disintegrates, thus the secretion is a mixture of cell fragments and the substance that the cell synthesized prior to death
   2. cells make chemicals that accumulate in the cell. Cell dies and splits open releasing the chemicals. Fragments of the dead cell become part of the secretion. secretions released only after cell death when the plasma membrane ruptures
   3. cells destroyed and are replaced by new cells; stem cells at the base of holocrine glands continually divide to generate new cells
   4. sebaceous or oil glands of the skin
Connective Tissue (CT)

1. Very diverse in function and the most abundant and widespread tissue in the body.

2. Functions of Connective Tissues
   a. Binding
      1. tendons attach muscle to bone
      2. ligaments attach bone to bone
      3. fat holds the kidneys and eyes in place
      4. connective tissues connect the skin to underlying muscle and bone
   b. Support
      1. bones support the body
      2. cartilage supports the ears, nose, trachea, and other organs
   c. Protection
      1. white blood cells attack and kill pathogens
      2. bone protects the brain, heart, and lungs
      3. fat pads protect the kidneys
   d. Movement: bones work with skeletal muscles to allow body movements
   e. Energy storage: fat molecules in adipocytes serve as stored nutrients
   f. Transport: the blood transports gases, nutrients, hormones, wastes, and blood cells

3. connective tissues usually consist of widely spaced cells that rarely touch, but there are exceptions to this (e.g., blood and adipose)

4. all CT cells are derived from embryonic mesenchyme which in turn is derived from mesoderm

5. Characteristics
   a. Matrix (extracellular material)
      1. material between the cells that is secreted by the cells (matrix is a generic term that applies to the extracellular material between cells of any tissue)
      2. consists of ground substance and protein fibers
   b. Ground substance — fills the space between the cells and contains fibers
      1. solution that varies in thickness (thin and watery to thick or viscous); consists of interstitial fluid, cell adhesion proteins, and proteoglycans (e.g., hyaluronic acid, chondroitin sulfate, glucosaminoglycan, keratin sulfate). Proteoglycans are glycoproteins (mostly protein with
small carbohydrate chains attached) that are heavily glycosylated. They have a core of protein with one or more covalently attached glycoaminoglycan (GAG) chain(s). The chains are long carbohydrate polymers. Proteoglycans are common in connective tissues. Proteoglycans are a subclass of glycoproteins that contain extra carbohydrate. Glycoproteins and proteoglycans differ primarily in their protein/carb ratio. Glycoproteins have more protein, less carbs whereas proteoglycans have less protein and more carbs.

2. contains fibers made of protein
3. ground substance composition differs from one CT to another

**Fibers** (3 major types): collagen, elastic, and reticular – fibers made mostly by fibroblasts, type of CT cell that is common to a number of CT’s

1. collagen (white in color and add great strength to CT matrix)
   a. most abundant type of fiber that is made of a protein called collagen (collagen is the most abundant protein and accounts for 20-25% of all the protein in the body)
   b. cells secrete subunits of procollagen by exocytosis that polymerize into collagen strands in the matrix
   c. Vitamin C is necessary for the synthesis of collagen by CT cells (scurvy is a weakening of the CT’s of the body due to a diet low in Vit C)
   d. strong and inelastic
      1. resistant to stretch (high tensile strength like steel fibers)
      2. stronger than steel fibers of the same diameter
      3. once stretched, they tend not to return to their original length (like taffy); collagen fibers can only stretch about 5% of their length without damage (they tear if overstretched)
      4. collagen fibers have extraordinary tensile strength. It takes a load of more than 20 lbs to tear a collagen fiber that is just 1 mm in diameter.
   e. fibers are white in color and often appear like wavy lines under a microscope
   f. found in most, but not all CT’s
   g. sclera of the eye (white part) is a dense regular connective tissue that is rich in glistening white collagen fibers; tendons and ligaments contain a lot of collagen in their matrix

2. elastic (yellow)
   a. distensible fibers made of the protein elastin; they branch and are coiled at rest allowing them to stretch and recoil like a rubber band
   b. if stretched they recoil back to their original length like a rubber band
   c. can be stretched up to 150% of their length without damage (vs 5% for collagen)
   d. fibers often appear coiled under a microscope
   e. abundant in the walls of organs that stretch (e.g., lungs inflate, skin stretches, urinary bladder fills, arteries pulse with blood as heart beats); these organs must expand or stretch to accommodate increasing volume, then elastically recoil back to their original size
   f. Aging: Over time, collagen fibers become increasingly cross-linked and inflexible, and elastins are lost from tissues like the skin. As a result, older people often find that their bones and joints are less flexible and their skin becomes wrinkled and when stretched it returns slowly to its original length.

3. reticular (fine or mesh collagen) – secreted by connective tissue cells called reticular cells
   a. short and thin inelastic fibers made of collagen (variant of the collagen in collagen fibers)
   b. form a meshwork inside glands and other organs (e.g., the spleen and lymph nodes) called a reticulum
c. reticular fibers cross-link to form a meshwork within organs that act as a supporting framework

6. CT’s are generally vascular (i.e., contain blood vessels) to include dense irregular, bone, adipose, and areolar
   a. cartilage is unusual in that it is a CT that is avascular
   b. some dense CT’s associated with tendons and ligaments are poorly vascularized
   c. CT cells are able to divide by mitosis, but the rate at which they do varies depending on their blood supply

d. summary
   1. Cartilage – avascular
   2. Dense regular – poor blood supply
   3. bone, areolar, adipose, dense irregular – good blood supply

<table>
<thead>
<tr>
<th>Connective Tissue Cell lineage</th>
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<tbody>
<tr>
<td><strong>Mesoderm</strong> <em>(found in early embryo just after implantation which occurs about 7 days after fertilization: 3 germ layers are endoderm, mesoderm and ectoderm)</em></td>
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<tr>
<td><strong>Mesenchyme</strong> <em>(embryonic and fetal development)</em></td>
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<tr>
<td><strong>Osteoblast</strong> <em>(osteocytes)</em></td>
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<td><strong>Hemocytoblast</strong></td>
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* all CT’s arise from mesenchyme (an embryonic tissue)

Connective Tissue Proper

1. **Two Broad Categories** *(fibroblasts are the primary type of cell in most of these tissues)*
   a. **Loose**
      1. few fibers in the matrix
      2. areolar, adipose, and reticular
   b. **Dense** *(also called fibrous connective tissues)*
      1. many fibers in the matrix that are densely packed together
      2. dense regular, dense irregular, and dense elastic
      3. elastic is a form of dense connective tissue that contains a lot of elastic fibers in the matrix
   c. **fibroblasts** are the primary type of cell in most of these tissues
      1. fibroblasts are clear cells that don’t show up well on slides (only see the nucleus)
      2. fibroblasts form the matrix of CT proper; continuously secrete ground substance and fibers

2. **Cells of Connective Tissues**
   a. **fibroblasts** – produce protein fibers and ground substance of the matrix
b. **macrophages**
   1. large phagocytic cells that wander through the loose connective tissues where they engulf and destroy bacteria, foreign particles (e.g., pollen and bee venom), and dead or dying cells of our own body
   2. macrophages are derived from a type of white blood cell called a monocyte that crawl through capillary walls and then live in loose connective tissues

c. **neutrophils**
   1. type of white blood cell that crawls through capillary walls and is commonly found in loose connective tissues
   2. neutrophils wander around looking for bacteria to kill

d. **mast cells**
   1. found just outside of blood vessels
   2. secrete histamine in response to allergens and tissue damage to increase blood flow to an area by dilating blood vessels; histamines make the capillaries leaky and result in swelling

e. **adipocytes** (fat cells)
   1. large round cells filled with fat molecules
   2. large concentration of fat cells in adipose connective tissue
Connective Tissue Proper: Loose and Dense

Loose Connective Tissues: Areolar and Adipose

1. three types, but only discuss 2 of them
2. Areolar and adipose (not discuss reticular)

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Areolar (a type of loose CT) — major type of cell is the fibroblast (make the ground substance and secrete collagen and elastic fibers)

1. consists of widely scattered cells (mostly fibroblasts) within a matrix with a loose arrangement of fibers
2. most widespread CT in the body (cobwebby in appearance)
   a. found beneath nearly all sheets of epithelial cells
   b. often surrounds blood vessels
   c. within the interior of many organs and between organs (packaging and binding material)
   d. makes up most of the hypodermis - attaches the skin to underlying bone and muscle
3. may contain fat cells, mast cells, macrophages, fibroblasts, and neutrophils
4. well vascularized

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1 Reticular tissue is a type of loose CT that consists of a mesh of reticular fibers and fibroblasts. It forms the internal framework of a variety of organs to include the spleen, bone marrow, and lymph nodes.
Adipose (fat, type of loose CT)

1. the majority of cells are adipocytes (usually around 80-90%); they are also called lipocytes
2. adipose tissue consists of a dense concentration of adipocytes (fat cells) within an areolar CT framework; adipocytes account for 90% of the mass of adipose – tightly packed cells (exception to the rule for CT’s)
3. locations
   a. beneath the skin in the hypodermis – serves as protection and insulation; location of around 50% of fat deposits in body
   b. around internal organs (heart, spinal cord, intestines, repro organs)
   c. inside shafts of long bones
4. fat cells are big and round with the nucleus pushed against the inside of the plasma membrane (signet ring)

5. fat cells store excess organic nutrients that come into the body with the diet as triglycerides (TG’s, fat molecules, triacylglycerols). 2 biochemical pathways occur in adipocytes: lipogenesis and lipolysis
   a. Lipogenesis (liver and adipocytes) – TG’s consist of glycerol (sugar alcohol) and 3 FA’s
      1. body stores organic nutrients as fat; fatty acids are energy rich compounds that cells use to make ATP by cellular respiration
2. during a meal and while digesting food amino acids, simple sugars like glucose, fatty acids (FA’s) and other molecules are taken up by fat cells and chemically converted to triglycerides (also called neutral fats; consist of 3 fatty acids and glycerol)

b. Lipolysis - between meals the TG’s are broken down to FA’s and glycerol. The FA’s are then released into the bloodstream

c. most cells of the body take up the FA’s and use them to make ATP within mitochondria

d. FA’s are energy-rich molecules that cells use to make ATP. FA’s are broken down by cellular respiration to CO₂ and H₂O as ATP is made. Cells generate around 36 ATP/glucose which is less than the over 100 ATP they form per fatty acid.

e. if one eats too much and doesn’t exercise, then more and more fat gets stored and less and less gets broken down to make ATP – one gets fat.

f. fat storage allows one to go for days without eating and still meet the ATP demands of the cells of the body. If necessary, liver cells can take in fatty acids and convert them to glucose between meals when glucose levels start to fall.

6. well-vascularized – it is not possible to surgically remove body fat by liposuction without breaking a lot of blood vessels (hemorrhage); if remove fat, some fibroblasts in the area will differentiate into fat cells; liposuction or the cosmetic removal of fat deposits results in internal bleeding and bruising

7. Sex differences (overweight individuals are around 20% over their target weight and obese individuals are around 30-50% or more fat)
   a. Males
      1. about 15% body mass made up of fat cells if at target weight
      2. fat tends to accumulate first in abdominal membranes (guys tend to get a “beer belly” as they gain weight)
   b. females
      1. about 22% body mass made of fat if at target weight
      2. accumulate fat first in thighs, butt, hips, and breasts

8. the number of fat cells is relatively the same between lean and obese individuals, although the size of individual cells can vary a lot depending on their fat content

9. adipose cells secrete hormones (e.g., leptin, estrogen, resistin)

10. Functions of Fat Tissue
    a. storage of fat molecules for energy production (make ATP)
    b. insulation to help the body hold heat
    c. protection from fat pads around kidneys, heart, and spinal cord

Dense or Fibrous – poor blood supply

1. 3 types
   a. Dense regular
   b. Dense irregular
   c. Dense elastic

2. Fibroblast – predominate type of cell that makes collagen and elastic fibers and the ground substance (i.e., makes the matrix)
3. **Dense regular**
   a. **dense bundles of collagen fibers** arranged in parallel lines (appear wavy under the microscope so they can stretch a bit before they break); may contain a few elastic fibers
   b. **very strong, but poorly vascularized**
   c. found in **tendons** (connect muscle to bone across a joint) and **ligaments** (connect bone to bone)
   d. **sprain** – damage to a ligament; sprains generally result from overstretching the ligament; they tend to be slow to heal

4. **Dense Irregular**
   a. **irregular arrangement of collagen fibers** (interwoven) – allows tissue to resist tension placed on it from all directions; contains a few elastic fibers
   b. abundant in the dermis of the skin; also found in the articular capsule around joints (e.g., hip, knee, shoulder)
   c. **leather** (cowhide) – dried dermis (very tough for hundreds of years)
   d. Dermis: upper 20% below epidermis is areolar; the lower 80% is dense irregular
5. **Dense Elastic (elastic)**
   a. type of dense CT with a high concentration of elastic fibers
   b. contains more elastic fibers than collagen so can stretch (elastic fibers may appear wavy or coiled under the microscope); elastic fibers are made by fibroblasts and smooth muscle cells
   c. very strong, yet flexible (combine strength with elasticity)
   d. found in walls of organs that need to stretch (aorta, lungs, urinary bladder)
   e. most elastic tissue is found in the walls of arteries

Cartilage
1. cells called chondroblasts secrete the matrix and surround themselves with it until they are trapped in cavities called lacunae. Once enclosed in lacunae the cells are called chondrocytes. Lacunae are found in cartilage and in bone
2. consists of chondrocytes in cavities called lacunae within a gel-like matrix that contains protein fibers
3. the matrix is about 80% water along with a variety of glycoproteins (mostly chondroitin sulfate) that thicken it; the water content of the matrix allows it to have some compressibility and flexibility (it is a semi-solid and rubbery like)
4. Avascular
   a. does not have a direct blood supply, thus if damaged it is slow to heal
   b. nutrients diffuse to chondrocytes from blood vessels in tissues around the cartilage
5. 3 Types of cartilage: hyaline, elastic, and fibrocartilage
6. perichondrium
   a. dense CT that is vascular around elastic and hyaline cartilage (vascular); there is no perichondrium around fibrocartilage
   b. a reserve population of chondroblasts between the perichondrium and the cartilage allows for the growth and repair of cartilage
7. a chicken drumstick (leg) is a place to see articular cartilage; thigh bone is femur; only 1 leg bone in chickens and that is the tibia since the fibula fuses with the tibia to become one bone called the tibia
7. **Hyaline Cartilage**
   a. clear looking matrix that contains thin collagen fibers that are not visible under microscope (collagen is not densely packed); matrix looks like frosted glass
   b. most abundant cartilage in the body; chondrocytes make up 1-10% of its total volume (cartilage is mostly matrix)
   c. pliable, yet strong
   d. locations (cartilage is colored blue on lab models)
      1. articular cartilage (covers the ends of bones where they meet at a joint)
      2. embryonic skeleton (many embryonic bones initially made of hyaline cartilage, then convert to hard bone)
      3. costal cartilage that attaches many of the ribs to the sternum
      4. C-rings in the wall of the trachea (also cartilage plates in the larynx) – strengthen walls of trachea so they don’t collapse when inhale
      5. cartilage at tip of the nose
   e. hyaline cartilage is the “gristle” at the end of chicken legs and pork ribs
8. **Elastic Cartilage**
   a. in addition to collagen fibers in the matrix, there are **elastic** fibers (which are not present in the other types of cartilage) – more **flexible** than other types of cartilage
   b. elastic fibers in elastic cartilages take up a **stain** so that they are visible under the microscope
   c. **Locations** (only 2 in the body)
      1. framework of **pinna** (external ear or auricle); elastic cartilage gives shape to the external ear
      2. **epiglottis**: flap that closes over the glottis when one swallows so that food and drink will not enter into the larynx; the glottis is an opening at the base of the throat that opens into the larynx; the larynx is also called the voicebox because it houses the vocal cords. Air passes through the larynx to the trachea as one inhales and from there to the lungs
9. Fibrocartilage
   a. contains thick bundles of collagen fibers in the matrix; lots of water in matrix
   b. very strong; slightly compressible
   c. Locations
      1. intervertebral disks – shock absorbers that help to prevent the vertebral bones from slamming against one another and fracturing
      2. meniscus (articular disk) – shock-absorbing pad within the knee joint (2 menisci/knee joint)

Blood
1. specialized type of CT in which the cells are in a fluid matrix called plasma
2. RBC’s, WBC’s, and platelets (collectively called formed elements)
3. tightly packed cells
4. blood is a CT without collagen or elastic fibers in the matrix
Bone (also called osseous tissue)
1. consists of osteocytes surrounded by a hard or bony matrix that contains collagen fibers and calcium salts (make the matrix hard like concrete)
2. Two types: compact and spongy
Muscle Tissue
1. Muscles like the biceps brachii are organs and they consist of muscle cells along with CT, blood vessels, and nerves; the primary role of muscle is to exert physical force on other tissues and organs
2. Muscle cells are specialized to contract and when they do they shorten
3. As muscle cells contract, body parts move (muscle is a tissue associated with movement)
4. Special terms
   a. sarcolemma – plasma membrane
   b. sarcoplasm – cytoplasm
5. 3 kinds of muscle tissue: skeletal, smooth, and cardiac
6. Skeletal
   a. attached to bones of the skeleton; when it contracts bones move and move body parts
   b. striated (striped in appearance) and voluntary (contracts only under conscious control with some exceptions)
   c. multinucleate
7. Cardiac
   a. only found in the wall of the heart; contractions of cardiac muscle pump blood through the heart
   b. striated and involuntary (contracts rhythmically without conscious control)
   c. uninucleate or binucleate
   d. branched with intercalated disks joining adjacent cells
   e. cardiac muscle has a limited ability to divide by mitosis. A 20-year old replaces about 1% of heart muscle cells per year. Around 45% or so of the heart muscle cells of a 50-year old were generated after birth.
8. Smooth (visceral)
   a. found within the walls of hollow internal organs of the body (e.g., blood vessels, intestine, urinary bladder)
   b. non-striated and uninucleate
   c. involuntary
Nervous Tissue

1. neurons are specialized to generate and transmit nerve impulses
2. basic neuron structure
   a. cell body or soma (nucleus)
   b. dendrites (L. dendros = tree) – highly branched and short; off the soma
   c. axon with axon terminus (only one axon per neuron)
3. functions
   a. neurons allow all brain functions
   b. stimulate skeletal muscle to contract
   c. regulate the heart beat
SUMMARY OF TISSUES AND THEIR LOCATIONS

EPITHELIUM

Simple Squamous
1. air sacs (alveoli) of the lung where gas exchange occurs by diffusion
2. wall of capillaries nutrients are filtered out of capillaries towards cells

Simple Cuboidal
1. kidney tubules (tubes in the kidney involved with the production of urine)

Simple Columnar
1. nonciliated simple columnar lines the GI tract from stomach to anus;
2. ciliated simple columnar epithelium lines a few portions of the upper respiratory tract and the
   oviducts
3. often associated with mucus-secreting goblet cells

Pseudostratified Columnar Epithelium
1. lines most of the upper respiratory tract to include the larynx, trachea, and bronchi
2. this tissue is ciliated and contains goblet cells (goblet cells are not ciliated although may contain
   some microvilli)

Stratified Squamous
1. keratinized
   a. epidermis of the skin (outer layer of the skin that can touch with a finger)
   b. keratinized – outer cells are dead and filled with a tough protein called keratin
   c. dry cutaneous membrane (no goblet cells)
2. nonkeratinized (lacks the surface layer of dead cells)
   a. lining of the mouth, pharynx (throat), esophagus, tongue, vagina, and anal canal
   b. contains goblet cells and is covered with mucus

Mucosa
1. epithelial cells interspersed with goblet cells and the membrane is covered with mucus (one
   exception is the lining of the urinary tract; it is classified as a mucous membrane but is not covered
   with mucus; it is moist however)
2. non-keratinized stratified squamous – lines the mouth, esophagus, vagina
3. simple columnar – stomach and intestine

Serosa
1. single layer of squamous cells on a layer of areolar CT
2. secrete a watery fluid called serous fluid that moistens the surface
3. lines body cavities and covers internal organs
4. decreases friction as organs slide past each other (they don’t stick together)
5. Special Names for Serous Membranes
   a. peritoneum – lines the abdominal cavity and covers organs in it (e.g., intestine)
   b. pericardium – covers the heart
   c. pleura – covers the lungs
Endothelium
1. single layer of simple squamous attached to a BM that is exclusive to the lining of all hollow organs of the cardiovascular and lymphatic organs
2. endothelium lines the walls of blood and lymph vessels and the chambers of the heart
3. the wall of a blood capillary is endothelium

Cutaneous Membrane – refers to the skin

Glandular Epithelium
Goblet Cell
1. unicellular gland
2. usually found among epithelial cells that line the digestive and respiratory tracts
3. secrete mucin (glycoprotein) that mixes with water outside the cell to form a thick (viscous, consider water versus molasses) solution called mucus

Endocrine glands
1. multicellular glands that secrete hormones directly into the bloodstream
2. e.g., thyroid, pituitary, ovary, testis

Exocrine glands
1. multicellular glands that secrete chemicals into ducts (a duct is a small tube) that open into a hollow organ or onto the body surface
2. e.g., sweat gland, oil gland

Merocrine (also called eccrine)
1. glandular epithelial cells that release their secretions by exocytosis at intervals
2. cells are not destroyed in the process
3. salivary, sweat, and pancreas

Holocrine
1. products secreted by the rupture of the gland cell; the entire cell disintegrates, thus the secretion is a mixture of cell fragments and the substance that the cell synthesized prior to death
2. secretions released only after cell death when the plasma membrane ruptures
3. cells destroyed and are replaced by new cells; stem cells at the base of holocrine glands continually divide to generate new cells
4. sebaceous or oil glands of the skin

CONNECTIVE TISSUE (CT)
Loose Connective Tissues: Areolar and Adipose
1. three types, but only discuss 2 of them
2. Areolar and adipose (not discuss reticular)

Areolar (a type of loose CT)
1. found beneath nearly all epithelia
2. often surrounds blood vessels
3. within the interior of many organs and between organs
4. makes up most of the hypodermis - attaches the skin to underlying bone and muscle

Adipose (fat, type of loose CT)
found in hypodermis and fat deposits elsewhere in the body (e.g., around the heart and spinal cord)

Dense or Fibrous
1. 3 types: Dense regular, Dense irregular, Elastic (special type of dense regular)
2. Dense regular: found in tendons (connect muscle to bone across a joint) and ligaments (connect bone to bone)
3. Dense Irregular: abundant in the dermis of the skin
4. Elastic: found in walls of organs that need to stretch (aorta, dermis of the skin, lungs, urinary bladder)

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