* **Basics:**
* Basic concepts of anatomy
  + Spatial terminology:
    - Anatomical position:
      * Face, palms, feet are pointed forward
      * Upper and lower limbs are vertical
      * All digits of hand are vertical
    - Body regions:
      * Axial region: everything but the limbs = head, neck, trunk
      * Appendicular (appendages) region: limbs
        + Upper limb: arm (upper part), forearm (middle part), hand (lower part)
        + Lower limb: thigh (upper part), leg (middle part), foot (lower part)
    - Directional terms:
      * Superior: upper
        + In humans (cranial), in four-legged animals (dorsal)
      * Inferior: lower
        + In humans (caudal), in four-legged animals (ventral)
      * Anterior: toward the front
        + In humans (ventral), in four-legged animals (cranial or rostral)
      * Posterior: behind
        + In humans (dorsal), in four-legged animals (caudal)
      * Cranial: toward the head end
      * Caudal: toward the tail end (away from the head)
      * Ventral: toward the belly side
      * Dorsal: toward the back (away from the belly side)
      * Medial: toward the midline, away from left/right
      * Lateral: away from the midline, toward left/right
      * Proximal: part of appendage closer to attachment of trunk
      * Distal: part of appendage farther from attachment with trunk
      * Superficial: toward the surface of the body (outer)
      * Deep: away from the surface of the body (inner)
      * Ipsilateral: on same side (both on left or both on right)
      * Contralateral: on opposite sides (one on left, the other on right)
    - Planes
      * Frontal (coronal) plane: divides the body into anterior/posterior parts
      * Transverse (horizontal) plane: divides body into superior/inferior parts (“cross section”)
      * Sagittal plane: divides body into left/right parts
        + Midsagittal (median) plane = exactly at midline (equal left and right parts)
        + Parasagittal plane = not at midline (unequal parts)
  + Structural hierarchy:
    - 1. All living organisms are made of cells
    - 2. Cells are grouped together into tissues
      * Tissues: groups of cells of similar structure that perform a common function
        + Four basic tissue types:

Epithelium: lining of surfaces

Connective tissue: framework

Muscle: for movement

Nervous: for communication

* + - 3. Different tissues combine to form an organ
      * Every organ is made of 4 basic tissue types
    - 4. Different organs combine to form organ systems
* Cells
  + Size and shape:
    - Around 10 micrometers across
    - \*Limited by reliance on diffusion
    - Can be long and skinny
  + Cell anatomy:
    - Plasma membrane: phospholipid bilayer surrounding rest of cell
      * Proteins in membrane control what enters and exits cell
    - Cytoplasm:
      * Cytosol: semi-liquid material between organelles
      * Organelles:
        + Endoplasmic reticulum (ER): makes products (factory)
        + Vesicle: transports materials (package)
        + Golgi apparatus: packages products from ER and sends them to destination (post office)
        + Lysosome: demolition of materials (trash service)
        + Mitochondria: power generators
        + Cytoskeleton: rod-like proteins in cell providing support and movement

Microtubules: trackway for transport of materials to and from center of cell

Intermediate filaments: prevent cell from being torn apart by tension (pulling) forces

Microfilaments: mainly consists of actin, which interacts with myosin to produce changes in cell shape

* + - Nucleus: the control center of the cell
  + Specialized cell contacts/cell junctions:
    - \*Tight junctions: prevents random diffusion across tissue through extracellular space
    - \*Desmosomes: anchors adjacent cells together
    - \*Gap junctions: passageway from one cell to another (allow communication/coordination)
* **Tissues:**
* Histology: the study of tissues
* NOTE: One tissue cannot be a component (part) of another tissue
* Epithelium
  + Tissue that covers a body surface or lines a body cavity
  + Often forms glands
* General characteristics of ALL epithelia
  + Cellularity: compost almost entirely of cells
  + Specialized cell-to-cell contacts
  + Polarity (the two sides are different)
    - Apical: toward space
    - Basal: toward attachment
    - Ex: goblet cell – secretes mucus
  + Basement membrane: anchors epithelium to the underlying connective tissue
  + Ability to regenerate quickly
  + Avascular: not associated with blood vessels (does not have vessels around it)
  + Innervated: associated with nerve cell processes (does have nerves around it)
* Functions
  + Absorption and secretion:
    - Both are active (cell uses energy)
    - Absorption: active uptake of molecules
    - Secretion: active release of molecules
    - Usually involves micro-villi = extensions to increase surface area
  + Diffusion and filtration:
    - Both are passive (no energy used by cell)
    - Diffusion: molecules move down concentration gradient
    - Filtration: plasma (fluid component of blood) leaks across capillary walls
  + Propulsion: cilia drive fluid along surface of epithelium in coordinated fashion
  + Sliding
  + Protection: has multiple layers for best protection
  + Sensory reception: epithelial cell generates sensory signal
* Classification
  + By layering:
    - Simple: single layer (attached to basement membrane)
    - Stratified: multiple layers
  + By shape:
    - Squamous: squashed/skinny
    - Cuboidal: cube-like (provides more room for organelles)
    - Columnar: rectangular prism-like (provides even more room for organelles)
  + Distribution of epithelium
    - Simple epithelium:
      * Simple squamous: thinnest kind (best for diffusion/passive functions), no surface projections (cilia, microvilli)
        + Lining of air sacs in lungs (alveoli)
        + Glomerular capsule in kidney (where filtration occurs)
        + Endothelium: inner lining of heart/blood vessels (minimal friction facilitates sliding)
        + Mesothelium: lining of closed body cavities (space between organs)
      * Simple cuboidal
        + Most glands
        + Kidney tubules (need room for mitochondria)
      * Simple columnar:
        + Lines most of digestive tract (non-ciliated)
        + Lines small bronchi (air tubes in lungs; ciliated)

Sweeps away debris

* + - * + Lining of uterine tube (ciliated)
        + Goblet cells: secrete mucus (digestive and respiratory tracts)
      * Pseudostratified columnar
        + All cells attached to basement membrane so not truly stratified
        + Undifferentiated (immature) cells don’t reach apical sirface
        + Nuclei occur at different levels so tissue looks “stratified”
        + Lines trachea and upper respiratory tract (ciliated)
* \*Major functions of simple epithelium:

|  |  |  |
| --- | --- | --- |
|  | Simple squamous | Simple cuboidal/columnar/pseudostratified |
| Absorption/secretion | No | Yes |
| Diffusion/filtration | Yes | No |
| Propulsion | No (no cilia) | Yes (if ciliated) |
| Sliding | Yes | No |

* + - Stratified epithelium:
      * Stratified squamous: thickest kind
        + Function: protection
        + Skin (keratinized)
        + Ends of digestive and reproductive tracts (nonkeratinized)
      * Stratified cuboidal:
        + Function: protection/secretion
        + Large ducts of glands
      * Stratified columnar:
        + Function: protection/secretion
        + Urethra
      * Transitional:
        + Function: protection/stretchable
        + Apical cells change shape when tissue stretches
        + Urinary bladder
* Glands
  + Structure whose cells are specialized for secretion
  + Most glands develop from invaginated (folded in on one-self) epithelia
  + Exocrine:
    - \*Secrete products onto body surfaces or into cavities
    - All derived from epithelia
    - Unicellular example: goblet cell
    - Most are multicellular
  + Endocrine:
    - \*Secrete products into the blood
    - Their products are called hormones (have effects on specific target organs)
    - Derived from epithelia OR other tissues (ex: nervous)
* **Connective Tissue:**
* Characteristics
  + Relatively few cells
  + Large amount of extracellular matrix (nonliving material, outside the cells)
    - Ground substance
    - Fibers
  + Vascularized (except cartilage and blood)
* Functions
  + Support and protection
  + Defense (immune cells)
  + Passageway for nerves and vessels
  + Transport and exchange (via blood and interstitial fluid)
  + Insulation and energy storage (fat)
* Structure
  + Cells
    - Derived form mesenchyme (detached cells in embryo)
    - A characteristic type of cell for each kind of CT
    - Cells secrete extracellular matrix
    - May also have other cells (ex: defense cells)
  + Matrix
    - Fibers: three kinds (all protein)
      * Collagen fibers
        + Structure

Collagen molecule (Type 1 is most common)

Collagen fibril: group of collagen molecules bound together

Collagen fiber: group of collagen fibrils bound together

* + - * + Properties

\*Resists tension (pulling)

* + - * Reticular fibers
        + Structure

Each reticular fiber is made of specialized collagen fibrils (made of Type 3 collagen molecules)

Fibers are short, thin, branched

“reticular” means network

* + - * + Properties

\*Forms delicate networks with lots of spaces

Allows smooth gliding/deformation

Used at boundaries of tissue (ex: surrounds capillaries)

Like folding trellis

* + - * Elastic fibers
        + Structure

Main protein is elastin

Coils up at rest

Elastin molecules cross-linked in large groups to form a fiber (no fibrils)

* + - * + Properties

\*Highly elastic: recoils to original shape after being stretched

* + - Ground substance
      * Interstitial fluid (tissue fluid)
      * Additional components (ex: calcium salts in bone)
* Categories of CT
  + Four classes: each has distinctive cell type and resulting matrix
    - Connective tissue
      * Connective tissue proper
        + Relatively unspecialized (classic CT)
        + Cells: fibroblasts (secrete matrix) -> fibrocytes (maintain matrix)

Also other cells

* + - * + Six types, varying in density and types of fibers

Loose CT: lots of ground substance, fewer fibers

Areolar: most widespread, generic CT

\*Gel-like matrix, lots of tissue fluid

\*Adjoins all epithelia

Plays role in exchange

All 3 fiber types

Has defense cells to fight infections

As fat cells to store energy

Adipose:

Matrix as in areolar CT

Mostly fat cells

In hypodermis (superficial fascia/deep to skin)

Also “visceral fat” around internal organs

Energy storage, protection, insulations (fats)

Reticular:

Only has reticular fibers

Exclusively in lymphoid structures (parts of immune system like spleen, lymph nodes, red bone marrow)

Labyrinth used by defense cells

Dense CT: lots of collagen fibers, good at resisting tension (pulling)

Dense regular CT

All collagen fibers run in 1 direction (axis)

Resists tension in 1 direction (axis)

Tendons and ligaments

Fascia (deep fascia)

Dense irregular CT

Collagen fibers oriented in various directions

Resists tension in various directions

In dermis, and fibrous capsules of organs/joints

Elastic CT

Most fibers are elastic fibers (also has collagen fibers)

Able to recoil after stretching

In bronchial tubes in lungs;, artery walls, some intervertebral ligaments

* + - Cartilage
      * Ground substance attracts and holds large amount of water
        + \*Very flexible and resilient
      * Cells
        + Chondroblasts (secrete matrix) -> chondrocytes (maintain matrix, found inside lacunae)
      * Avascular (heals slowly)
      * Not innervated
      * Types differ in matrix composition and physical properties
        + Hyaline: most common type

Has collagen fibrils, but no fibers

Found in many joints, developing and growing bones, respiratory tubes

* + - * + Elastic:

Has collagen fibrils, and elastic fibers (more tolerant of repeated bending than other types)

Found in external ear, epiglottis

* + - * + Fibrocartilage:

Has collagen fibrils, and collagen fibers (more resistant to tension than other types)

Found in intervertebral discs, knee meniscus, pubic symphysis

* + - Bone tissue
      * Only collagen fibers (lots) – resists tension
      * Ground substance: calcium salts (mostly)
        + Like “concrete”
        + Resists compression
      * Not flexible or resilient (can’t put itself back together)
      * Cells: osteoblasts (secrete matrix) -> osteocytes (maintain matrix)
    - Blood
      * Large amount of extracellular matrix: plasma (mainly water)
      * Develops from mesenchyme
      * No fibers
* **Body Cavities and Membranes:**
* Body Cavities
  + Open body cavities
    - Accessible to/continuous outside world (ex: respiratory, digestive, reproductive, urinary tracts)
  + Closed body cavities
    - Not accessible/continuous to outside world
      * Dorsal body cavity:
        + Cranial cavity -> brain
        + Vertebral cavity -> spinal cord
        + Not visceral organs, no serosa, special membranes
      * Ventral body cavity: visceral organs (viscera)
        + Thoracic cavity -> heart, lungs
        + Abdominopelvic cavity -> mainly organs of digestive, urinary, reproductive systems
* Membranes
  + A thin, pliable layer that covers or separates (ex: basement/plasma membranes)
  + We are concerned with multicellular membranes that line the body’s cavities/surfaces
  + Membrane composition: epithelium layer (avascular) + connective tissue layer (vascular)
  + Functions: protection, exchange, sensation, partitioning, sliding, etc.
  + Types:
    - Mucous membrane (mucosa):
      * Produces mucus, enzymes, etc. by secretion (active)
      * Lines lumen (internal space) of open body cavities (ex: respiratory, digestive, reproductive, urinary tracts)
      * \*Tissue layers (deep to superficial):
        + Lumen
        + Epithelium - mucous membrane
        + Lamina propria (CT) - mucous membrane
        + Muscle etc.
    - Serous membrane (serosa):
      * \*Lines the spaces between/around organs in ventral body cavity (closed body cavity)
        + Ventral body cavity (an internal body region) contains:

Visceral organs and serous cavity (a slit-like space)

* + - * Has mesothelium (simple squamous) to allow organs to slide around
      * Produces watery fluid mainly by filtration (passive)
      * Lines outer surface of visceral organs (ex: heart, lungs, stomach, uterus, etc.)
      * Also lines inner surface of body wall
      * \*Tissue layers (deep to superficial):
        + Muscle etc.
        + CT – visceral serosa
        + Mesothelium (epithelium) – visceral serosa
        + Serous cavity
        + Mesothelium (epithelium) – parietal serosa
        + CT – parietal serosa
        + Muscle etc.
      * Organs can have mucous membrane (mouth/nose), serous membrane (heart), both (stomach), or neither (bone, muscle)
    - Cutaneous membrane: the skin
      * Directly exposed to outside world
        + Has glands that secrete (active)
      * Tissue layers (deep to superficial):
        + Muscle etc.
        + Dermis (CT) – cutaneous membrane
        + Epidermis (epithelium) – cutaneous membrane
* \* Be able to label all 12 layers/spaces in target diagram
* **Integumentary System:**
* Skin and its appendages
* Structure of skin
  + Epidermis: outer layer, mostly epithelium (keratinized, stratified squamous)
    - Main cell is keratinocytes
    - Layers of epidermis (deep to superficial):
      * Stratum germinativum (stratum basal)
        + Actively dividing layer
        + Basal surface lies along basement membrane
      * Stratum spinosum
        + Have intermediate filaments called pre-keratin
        + Named for “spiny” appearance after death
        + Held together by desmosomes
      * Stratum granulosum (granules of product)
        + Makes keratin (type of intermediate filament) for mechanical protection
        + Makes glycolipid for waterproofing (prevents water loss)
      * Stratum lucidum
        + Only present in regions of thick skin
        + Translucent appearance
        + Consists of dead cells
      * Stratum corneum
        + Outermost layer
        + Dead cells
        + Highly keratinized (cornified)
* \*Mnemonic for layers (deep to superficial): Good Skin Gets Loving Care
  + - Other cell types:
      * Melanocytes in stratum basale
        + Produce pigment (melanin), deliver to keratinocytes
        + Melanoma: cancer of melanocytes
      * Tactile epithelial cells in stratum basale
        + Senses touch
      * Dendritic cells in stratum spinosum
        + Immune cells
  + Dermis: layer (mainly CT) underlying epidermis
    - Two layers:
      * Papillary layer: superficial
        + Blister: separation of epidermis from dermis by fluid

Fluid comes from dermis (has lots of interstitial fluid)

* + - * Reticular layer: deep
        + Consists of dense irregular CT (pulled in many directions)
    - Structures in dermis
      * Blood vessels, lymph vessels, nerves, sensory receptors, glands and hair follicles
  + Hypodermis: deep to the dermis
    - NOT part of skin (subcutaneous fat – not part of cutaneous membrane)
    - Main tissue is adipose tissue for insulation, cushion, energy storage
* Appendages of the skin
  + Like skin, these are organs of integumentary system
  + Develop by folding of epidermis -> extend into dermis
    - Hair and hair follicle
      * Hair follicle: mainly invaginated epidermis
        + Hair bulb: deepest part of follicle
      * Hair: dead cells produced by follicle
        + Hair root: beneath skin
        + Hair shaft: beyond skin
    - Glands
      * Sebaceous glands:
        + Secrete oil – lubricates skin/hair, antibiotic
        + Associated with hair follicles
      * Sudoriferous (sweat) glands
        + Eccrine glands

Not associated with hair follicles

Over most of skin for thermoregulation

* + - * + Apocrine glands

Associated with hair follicles

Axillary region – produce pheromones

* **Bone Tissue and Bones as Organs:**
* Tissues are made of cells, not other tissues
* Fun facts
  + Largest bone in body: femur
  + Smallest bone in body: stapes (in ear)
  + Number of bones in adults: 206
  + Number of bones in infants: 300
* Functions
  + Support, protection, movement, mineral storage, blood cell formation, energy storage
* Gross structure of long bone
  + Diaphysis: shaft
  + Epiphyses: ends
    - Proximal: toward the body
    - Distal: away from the body
  + \*Epiphyseal line: remnant of bone elongation zone (consists of compact bone where epiphyseal plate used to be)
  + Periosteum:
    - Mainly dense irregular CT
    - Covers most of outer surface
    - Functions:
      * Resists tension
      * Attachments to tendons and ligaments
        + Periosteum secured to rest of the bone by perforating fibers
      * Bone growth and remodeling (contains bone cells)
  + Articular cartilage (hyaline) on epiphyses
  + Medullary cavity in diaphysis
    - Contains (parts of long bone, not tissue):
      * Red bone marrow (at birth)
        + Contains hematopoietic stem cells (immature blood cells)
        + A lymphoid structure (has reticular connective tissue)
      * Yellow bone marrow (in adults)
        + Adipose tissue
  + Endosteum: important for remodeling, similar to periosteum but covers interior surfaces of bone
  + Blood vessels: bone tissue is highly vascularized
  + Compact bone tissue: in out regions of bone
    - Because bending exerts strongest forces in these areas
    - Medullary cavity does not have bone tissue because zero force in center
  + Spongy bone tissue: in inner regions, mainly in or near epiphyses
    - Spongy bone “pillars” (trabeculae) are aligned along stress lines
    - Red bone marrow (even in adults): in spaces between trabeculae
* Histology of bone tissue
  + General
    - Cells:
      * Osteoblasts: bone-building cells
      * Osteoclasts: bone-dissolving cells (larger than other ones)
      * Osteocytes: what osteoblasts turn into when trapped in matrix
    - Matrix:
      * Primarily secreted by osteoblasts
        + Organic: osteoid (primarily collagen) - fibers

Resists tension

Also enzymes, etc.

* + - * + Inorganic: hydroxyapatite = primarily calcium phosphate (calcium salts) – ground substance

Resists compression

* + Compact bone
    - Osteon (haversian system): cylindrical structure, withstands bending/twisting
    - Lamellae: layers of bone tissue
      * Types of lamellae:
        + Concentric lamellae: form an osteon
        + Interstitial lamellae: remnants of old osteon
        + Circumferential lamellae: found close to periosteum
    - Central (haversian) canal at center of each osteon
    - Perforating (volkmann’s) canals connect them
    - These canals lined by endosteum
    - Arteries, veins, nerves run through these canals
    - Osteocytes trapped with lacunae, between lamellae
    - Canaliculi: tiny passageways connecting lacunae
    - Osteocytes connected by gap junctions
  + Spongy bone (trabecular bone)
    - Made of trabeculae (has lamellae but no osteons)
    - Has osteocytes and canaliculi
  + Woven bone
    - Early, disorganized bone tissue
    - Occurs in fetal development, healing fractures
    - Weakest type of bone tissue
    - Eventually remodeled into spongy or compact bone
* Bone formation and growth
  + Intramembranous bone formation: formation of bones from fibrous connective tissue (membrane)
    - Gives rise to “membrane” bones (flat):
      * Most of skull bones
      * Clavicles (collar bones)
    - Steps:
      * 1. Mesenchyme gives rise to osteoblasts
        + Forms an ossification center (bone formation)
      * 2. Osteoblasts secrete osteoid
        + Mineralization occurs
        + Trapped osteoblasts become osteocytes
      * 3. Formation of woven bone and periosteum
        + Woven bone forms from osteoid laid down between blood vessels
        + Periosteum forms on external surface
      * 4. Remodeling into mature bone tissue
        + Compact bone forms under periosteum
        + THe rest becomes spongy bone
  + Endochondral bone formation
    - Formation of bones from hyaline cartilage
    - Gives rise to endochondral bones (most bones)
    - General summary:
      * Chondroblasts, osteoblasts derive from mesenchyme
      * Chondroblasts/cytes do NOT become osteoblasts/cytes
    - Steps:
      * 1. Cartilage model grows a periosteum
        + periosteum produces bone collar
      * 2. Chondrocytes in center of diaphysis cause cartilage matrix to calcify, forming spicules
        + Calcified matrix blocks nutrient diffusion
        + Chondrocytes die -> cavity is produced
      * 3. Periosteal bud (vessels, bone cells) invades diaphysis
        + Woven bone tissue forms over calcified cartilage
        + Resulting bony region is called the primary ossification center
      * 4. Steps 2 and 3 occur in epiphyses as well:
        + Cartilage matrix calcifies
        + Chondrocytes die
        + Bud invades
        + Bone matrix deposited
        + Results in secondary ossification centers
        + Does not happen until around birth
      * 5. Further ossification and remodeling
        + Mature arrangement of compact and spongy bone
        + Cartilage remains in two places: articular cartilage and epiphyseal plate
  + Bone growth
    - Longitudinal bone growth: growing longer
      * Occurs at epiphyseal plate: remaining internal cartilage
      * Childhood to early adulthood
      * Epiphyseal plates “closed” at ages 18 (F) to 21 (M)
        + Becomes epiphyseal line
        + Similar to endochondral bone formation
      * All steps occur simultaneously, in different places:
        + Cartilage grows on epiphyseal side
        + Matrix calcifies
        + Chondrocytes die
        + Osteoblasts deposit bone matrix on diaphyseal side
        + Osteoclasts enlarge medullary cavity to maintain shape of bone
    - Appositional bone growth: growing wider
      * Osteoblasts in periosteum add bone matrix to outer surface
      * Osteoclasts in endosteum remove bone matrix from inner surface
* Bone disorders
  + Achondroplasia
    - Cartilage growth in epiphyseal plate is reduced
    - Closure of epiphyseal plate occurs prematurely
    - The main cause of dwarfism
  + Osteoporosis
    - Osteoclast activity greater than osteoblast activity
      * Bone breakdown is greater than bone formation
    - Bone is porous, breaks easily
  + Osteomalacia
    - Bones not completely mineralized, bends easily
    - Insufficient calcium (ex: due to insufficient vitamin D)
    - Rickets: osteomalacia in children