* **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