

## Topic 1: Structural Organization of the Human Body

### 1.1 Levels of Structural Organization

- from simplest to most complex form:

chemical (atom, molecule), cellular (organelle, cell), tissue, organ, organ system, organismal

*In depth...*

#### **atom:**

- the smallest particle of an element with all the properties of that element
- tiny building blocks of matter
- proton, neutron, electron

#### **molecule:**

- the smallest amount of a substance that can exist alone = a combination of **atoms**

#### **organelle:**

- molecules associated in specific ways to form organelles = basic components of living **cells**
- ex. mitochondria, centriole, lysosome, E.R., ribosomes

#### **cell:**

- fundamental structural & functional unit of a living thing; cells vary widely in size and shape, reflecting unique functions in the body

#### **tissue:**

- groups of similar cells that have a common function
- the four basic types of tissues in the body are: epithelium, muscle, connective tissue, and nervous tissue

#### **organ:**

- structure composed of at least two (but usually 4) tissue types that performs a specific function for the body
- ex. liver, brain, stomach, heart
- at this level extremely complex functions become possible

#### **organ system:**

- organs that work closely with one another to accomplish a common purpose
- the systems of the body include: respiratory, cardiovascular, lymphatic, integumentary, skeletal, muscular, nervous, endocrine, digestive, urinary, and reproductive system
- ex. the heart and blood vessels of the cardiovascular system circulate blood continuously in order to deliver oxygen and nutrients to the cells of the body

#### **organismal:**

- represents the sum total of all structural levels working together to keep us alive

### 1.2 The Cellular Basis of Life

*the smallest living unit..*

Three main parts:

- **Plasma Membrane:** the outer boundary of the cell
- **Cytoplasm:** the intracellular fluid which contains the organelles
- **Nucleus:** an organelle that controls cellular activities

Structures in the cell:

#### **Mitochondria:**

- the power house of cell; major supply of ATP in the cell
- two membranes: *outer and inner membrane*
- folds called *cristae* protrude into the matrix of the organelle

#### **Ribosomes:**

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- small dark-staining granules composed of proteins and a variety of RNAs called *ribosomal RNAs*
- each ribosomes has two subunits
- the site of protein synthesis
- ribosomes are either attached to the E.R. which is then called the **rough E.R.** or they are free floating

### **Endoplasmic Reticulum (E.R.) :**

- network of interconnected tubes and parallel membranes

#### *Rough:*

- studded with ribosomes which manufacture all proteins secreted from cells
- proteins travel through the fluid-filled interior called cisterns

#### *Smooth:*

- enzymes play no role in protein synthesis
- the enzymes:
  - Metabolize lipids, synthesize cholesterol, and synthesize the lipid components of lipoproteins (in liver cells)
  - Synthesize steroid-based hormones such as sex hormones (testosterone-synthesizing cells of the testes are full of smooth ER)
  - Absorb, synthesize, and transport fats (in intestinal cells)
  - Detoxify drugs, certain pesticides, and cancer-causing chemicals (in liver and kidneys)
  - Break down stored glycogen to form free glucose (in liver cells especially)
- skeletal and cardiac muscles have elaborate smooth ER called sarcoplasmic reticulum which aids in storage and release of calcium ions when contracting muscles

### **Golgi Apparatus:**

- stacked, flattened membranous sacs accompanied by tiny vesicles
- "traffic director" for cellular proteins
- modifies, concentrates and packages protein, made from the rough ER, for delivery

### **Lysosomes:**

- spherical organelles containing active digestive enzymes
- large and abundant in phagocytes (cells which dispose of invading bacteria and debris)
- called acid hydrolases since they work best under acidic conditions
- the membrane contains H<sup>+</sup> "pumps" which works to maintain the acidity

### **Peroxisomes:**

- spherical sacs containing powerful enzymes, including; oxidase (uses O<sub>2</sub> to detoxify harmful substances and neutralize free radicals) and catalase (converts hydrogen peroxide made by oxidase, to water)

### **Microtubules:**

- hollow tubes made from spherical protein subunits called tubulins
- constantly growing from the centrosomes
- determine the overall shape of the cell and the distribution of organelles
- motor proteins constantly move and reposition the organelles hanging from the microtubules

### **Microfilaments:**

- thinnest elements of the cytoskeleton
- semi-flexible strands of the protein actin
- each cell has a unique, dense entanglement of strands called the terminal web

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- most are involved with cell movement and changes in shape

### **Intermediate Filaments:**

- tough, insoluble proteins (resemble ropes)
- most stable and permanent
- attach to desmosomes and mainly resist pulling forces on the cell

### **Centrioles and Centrosome:**

- centrosomes are the place of microtubule organization
- organizes mitotic spindle
- centrioles form the bases of cilia and flagella

### **Cilia:**

- whiplike and motile cell extensions that occur typically in large numbers
- ciliary action moves substances in one direction across cell surfaces

### **Flagella:**

- subsequently longer than cilia
- only sperm has a flagellum
- propels the cell itself rather than other substances in order to move

### **Microvilli:**

- fingerlike projections that increase the surface area of the plasma membrane
- most commonly found on absorptive cells

### **Nucleus:**

- control center
- contains all genetic information

### **Nuclear Membrane:**

- Separates the nucleoplasm from the cytoplasm and regulates passage of substances to and from the nucleus.

### **Nucleoli:**

- the dark staining spherical bodies found within the nucleus where ribosomal subunits are assembled

### **Chromatin:**

- threadlike material found in the nucleus containing:
  - 30% DNA
  - 60% globular histone protein (package and regulate DNA)
  - 10% RNA chains

## **1.3 Tissues**

*a group of structurally similar cells that perform common/related functions*

### **Four Primary Tissues**

#### **Epithelial Tissue**

- sheet of cells that covers a body surface or lines a body cavity

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- forms boundaries between different environments in the body
- protection, absorption, secretion, excretion, filtration, and sensory reception
- eg. skin

### **Connective Tissue**

- supports, protects, and binds other tissues together
- eg. bones, tendons

### **Nerve Tissue**

- internal communication in the body
- eg. brain, nerves

### **Muscle Tissue**

- contracts to cause movement
- eg. muscles attached to bones

### **Epithelial Tissue**

- sheet of cells that covers a body surface or lines a body cavity
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### *Seven Special Structural Characteristics...*

- 1) Cellularity: high cell density
- 2) Specialized Contacts: tight junctions to perform proper functions, hard to break, tightly attached to one another
- 3) Polarity: apical (top) and basal (attached to basal lamina) surfaces, microvilli or cilia
- 4) Basal Lamina: non-cellular, underlying supportive sheet of glycoproteins. Giving somewhere for cells to attach to, protection, cross link fibres of glycoproteins to be selectively permeable
- 5) Supported by Connective Tissue: basement membrane = basal lamina and underlying reticular connective tissue(fine meshwork)
- 6) Avascular: no direct blood supply, nourished by diffusion and concentration gradient, constantly being damaged and replaced (disposable) e.g. acid destroys the GI tract
- 7) Regenerative: high regenerative capacity due to the need for replacement and high damage rate

### Types of Epithelial Cells

*simple (single layer)*

*stratified (multiple layers)*

- 1) Simple Squamous Epithelium: thin and permeable, filtration, diffusion (smallest, thinnest possible cell) e.g. kidney, lungs

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- 2) Simple Cuboidal Epithelium: secretion and absorption, but allows movement, fair amount of movement, but cells must have the organelles to perform functions
- 3) Simple Columnar Epithelium: digestion and secretion (digestive tract) Contain all organelles
- 4) Pseudostratified Columnar Epithelium: a single layer, cilia and mucus secretion are local specializations (respiratory tract)
- 5) Transitional Epithelia: (not simple) lines the bladder (must stretch and fill) The basal layers are columnar - cuboidal, apical layers become increasingly flattened/squamous as filling occurs
- 6) Structured Stratified Squamous Epithelium: undergo mitosis to keep generating layers
- 7) Glandular Epithelia: one or more cells that make and secrete a particular product

### *Glands*

endocrine: produce hormones, do not have ducts (ductless)

exocrine: produce a variety of things (i.e. enzymes), use ducts to transport

### *Exocrine Glands*

**Unicellular:** goblet cells -- produce mucus (digestive and respiratory system), single celled and therefore ductless

**Multicellular:** epithelium-derived duct and secretory cells, surrounded by supportive CT, brings blood vessels and nerves

### Secretory Method

*merocrine:* exocytosis (most common type) pancreas, salivary glands, sweat

*holocrine:* cell rupture, ONLY sebaceous glands

*apocrine:* cell apex pinches off with secretory product

### **Connective Tissue**

- supports, protects, and binds other tissues together
- eg. bones, tendons

5 major types: mesenchyme, CT proper, cartilage, bone and blood

### *Main functions:*

- 1) binding support (e.g. cartilage)
- 2) protection (e.g. bones, skin has the dermis)
- 3) insulation (e.g. adipose)
- 4) transportation (e.g. blood)

### Structural Elements of CT

- a) Ground Substance: interstitial fluid and cell adhesion proteins and proteoglycans (molecular sleeve)
  - fibronectin, laminin (attach CT elements -- cells)
  - proteoglycans: large molecules with gel-like properties, fluid reserve, attach water

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### b) Fibres

- collagen fibres: high tensile strength
- elastic fibres: elastin has coiled structure to allow stretch and recoil
- reticular fibres: thin collagen protein; fine network to support blood vessels, soft tissues

### c) Cells: immature ("blast") vs mature ("cyte")

- "blasts" are actively dividing/synthesizing cells during growth and repair
- "cytes" primarily provide a level of maintenance

## Types of CT

### 1) **Mesenchyme**: source of all other CT's

### 2) **CT Proper**: 2 subclasses

#### A) **Loose CT** (areolar, adipose, reticular)

- **Areolar CT**: gel-like matrix with all 3 fibre types; cells = fibroblasts, macrophages, mast cells, and some WBCs
  - description: loose arrangement of fibres, reservoir of water and salts, prime site of edema (during inflammatory reaction)
  - location: widely distributed under epithelia of body
  - function: cushioning of organs, immunity (macrophages) and inflammation; fluid reservoir
- **Adipose Tissue**: areolar CT modified to store nutrients (adipocytes)
  - description: fat-filled adipocytes with displaced nuclei; do not reproduce; scanty matrix
  - location: under skin, around kidneys and eyeballs, in bones and within abdomen, in breasts, 18% of average weight (22% in ♀, 15% in ♂)
  - function: fuel reservoir, insulation, supports and protects organs
- **Reticular CT**: like areolar CT, but only reticular fibres
  - location: lymphoid organs (lymph nodes, bone marrow, spleen)
  - function: fibres form soft internal skeleton that supports free blood cells

#### B) **Dense CT** (dense regular, dense irregular, elastic)

##### - **Dense Regular CT**

- bundles of collagen fibres running parallel to direction of pull -- white, flexible tissue with great resistance to tension
- location: tendons (bones to muscle), ligaments (bones to bones), also aponeuroses
- function: attachment with strength

##### - **Dense Irregular CT**:

- same as regular but collagen bundles are thicker and arranged irregularly
- location: dermis, submucosa of digestive tract, fibrous capsules of organs and joints
- function: withstand tension exerted in many directions; strength

##### - **Elastic CT**:

- like dense regular CT, but a very high content of elastic fibres; found in some very elastic ligaments

### 3) **Cartilage**

- features between dense CT and bone -- tough but flexible
- avascular, devoid of nerve fibres

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- ground substance contains lots of the GAGs chondroitin sulfate and hyaluronic acid - also chondronectin (adhesive protein)
- collagen fibres (can have some elastic fibres)
- up to 80% H<sub>2</sub>O

### 4) **Bone**

- calcium salts give hardness and strength for support/protection of softer tissues; cavities for fat storage and synthesis of blood cells
- osteoblasts -- immature, new bone lay down
- osteocytes -- maintaining cells
- osteoclasts -- breakdown bone, turnover

### 5) **Blood**

- classified as CT because it consists of cells (RBCs, WBCs) surrounded by a nonliving fluid matrix, blood plasma
- "fibre" components are soluble protein molecules - only visible during clotting