University of Cyprus Biomedical Imaging and Applied Optics



### ECE 370 Introduction to Biomedical Engineering

### **Anatomy and Physiology**

### Introduction

- The basic organizational structure of the human body is the cell.
- There are 50-100 trillion cells in the human body.
- **Differentiation is when cells** specialize.
- As a result of differentiation, cells vary in size and shape due to their unique function.



(a)

(b)



## A Composite Cell

- Major parts include:
  - Nucleus
    - contains DNA
  - Cytoplasm
    - cellular contents
    - between plasma membrane & nucleus
  - Cell membrane
    - selective barrier





### Cell Membrane (aka Plasma Membrane)

- Outer limit of the cell
- Controls what moves in and out of the cell
- Selectively permeable
- Phospholipid bilayer
  - Water-soluble "heads" form surfaces (hydrophilic)
  - Water-insoluble "tails" form interior (hydrophobic)
  - Permeable to lipid-soluble substances
- Cholesterol stabilizes the membrane
- Proteins:
  - Receptors
  - Pores, channels and carriers
  - Enzymes
  - CAMS
  - Self-markers



### **Cell Membrane Electrochemical Gradient**

- Due to selective permeability
- Difference in concentration of chemicals across membrane
- Difference in distribution of charges across the membrane
  - → difference is the membrane potential



### **Cell Adhesion Molecules (CAMs)**

- Guide cells on the move
- Selectin allows white blood cells to "anchor"
- Integrin guides white blood cells through capillary walls
- Important for growth of embryonic tissue
- Important for growth of nerve cells





### Cytoplasm

- Cytosol = water
- Organelles = solids
- Cytoplasm is really like a Jello fruit salad
  - The Jello is the cytosol and the fruits (oranges, grapes, bananas, maybe walnuts, etc.) are the organelles.





#### • Endoplasmic Reticulum (ER)

- Connected, membrane-bound sacs, canals, and vesicles
- Transport system
- Rough ER
  - Studded with ribosomes
- Smooth ER
  - Lipid synthesis
    - Added to proteins arriving from rough ER
  - Break down of drugs

#### Ribosomes

- Free floating or connected to ER
- Provide structural support and enzyme activity to amino acids to form protein (protein synthesis)
- Golgi apparatus
  - Stack of flattened, membranous sacs
  - Modifies, packages and delivers proteins







#### Mitochondria

- Membranous sacs with inner partitions
- Produce 90 % of the cells energy
- Few 100s to several 1000s depending on the cell's energy needs.
- Approximately the size of a bacterium
- Have their own DNA
  - → Reminants of endocytosed bacteria?



#### Lysosomes

- Enzyme-containing sacs
- Digest worn out cell parts or unwanted substances

#### Peroxisomes

- Enzyme-containing sacs
- Break down organic molecules

#### Centrosome

- Two rod-like centrioles
- Used to produce cilia and flagella
- Distributes chromosomes during cell division





- Cilia
  - Short hair-like projections
  - Propel substances on cell surface
- Flagellum
  - Long tail-like projection
  - Provides motility to sperm







#### Microfilaments and microtubules

- Thin rods and tubules
- Support cytoplasm
- Allows for movement of
- organelles

#### Inclusions

 Temporary nutrients and pigments







### **Cell Nucleus**



- Is the control center of the cell
- Nuclear envelope
  - Porous double membrane
  - Separates nucleoplasm from cytoplasm
- Nucleolus
  - Dense collection of RNA and proteins
  - Site of ribosome production
- Chromatin
  - Fibers of DNA and proteins
  - Stores information for synthesis of proteins
- More on the DNA in the genetics lecture



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## **Movements Into and Out of the Cell**

#### Passive (Physical) Processes

- Require no cellular energy and include:
  - Simple diffusion
  - Facilitated diffusion
  - Osmosis
  - Filtration

# Active (Physiological) Processes

- Require cellular energy and include:
  - Active transport
  - Endocytosis
  - Exocytosis
  - Transcytosis



### Diffusion

#### Simple Diffusion

- Movement of substances from regions of higher concentration to regions of lower concentration
  - Oxygen, carbon dioxide and lipid-soluble substances

#### Facilitated Diffusion

- Diffusion across a membrane with the help of a channel or carrier molecule
  - Glucose and amino acids



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#### Permeable Solute molecule Water molecule membrane (1) (2) (3) Time **Region of higher** concentration Transported substance **Region of lower** concentration **Protein carrier**

molecule

membrane



### Osmosis



- Movement of water through a selectively permeable membrane from regions of higher concentration to regions of lower concentration
  - Water moves toward a higher concentration of solutes
- Osmotic Pressure ability of osmosis to generate enough pressure to move a volume of water
  - Osmotic pressure increases as the concentration of nonpermeable solutes increases
- Isotonic same osmotic pressure
- Hypertonic higher osmotic pressure (water loss)
- Hypotonic lower osmotic pressure (water gain)









### **Active Transport**

- Carrier molecules transport substances across a membrane from regions of lower concentration to regions of higher concentration
  - Sugars, amino acids, sodium ions, potassium ions, etc.
- Energy is expended





### **Endocytosis**



- Cell engulfs a substance by forming a vesicle around the substance
- Three types:
  - Pinocytosis substance is mostly water
  - Phagocytosis substance is a solid
  - Receptor-mediated endocytosis requires the substance to bind to a membrane-bound receptor



### **Exocytosis**



- Reverse of endocytosis
- Substances in a vesicle fuse with cell membrane
- Contents released outside the cell
  - E.g. release of neurotransmitters from nerve cells



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### The Cell Cycle

- Series of changes a cell undergoes from the time it forms until the time it divide
- Stages:
  - Interphase
  - Mitosis

#### Interphase

- Very active period
- Cell grows
- Cell maintains routine functions
- Cell replicates genetic material to prepare for nuclear division
- Cell synthesizes new organelles to prepare for cytoplasmic division
- Phases:
  - G phases cell grows and synthesizes structures other than DNA
  - S phase cell replicates DNA





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# The Cell Cycle

#### Mitosis

- Produces two daughter cells from an original somatic cell
- Nucleus divides karyokinesis
- Cytoplasm divides cytokinesis
- Phases of nuclear division:
  - Prophase chromosomes form; nuclear envelope disappears
  - Metaphase chromosomes align midway between centrioles
  - Anaphase chromosomes separate and move to centrioles
  - Telophase chromatin forms; nuclear envelope forms





### **Stem and Progenitor Cells**

- Stem cell:
  - Can divide to form two new stem cells
    - Self-renewal
  - Can divide to form a stem cell and a progenitor cell
  - Totipotent can give rise to every cell type
  - Pluripotent can give rise to a restricted number of cell types

#### Progenitor cell:

- Committed cell
- Can divide to become any of a restricted number of cells
- Pluripotent





### **Cell Death**

- Necrosis
  - Because of trauma
  - Cell dies and disintegrates

#### Apoptosis

- Programmed cell death
- Acts as a protective mechanism
- Is a continuous process
- More on cell growth and death in the cancer biology lecture





### **Anatomy and Physiology**

#### Anatomy – study of structure

- (Greek "a cutting up")
- Physiology study of function
  - (Greek "relationship to nature")
- "Structure dictates function."





### **Levels of Organization**



## **Levels of Organization**

#### Tissue

- Group of cells working together to perform a function
- 4 basic types
  - epithelial (epi)
  - connective tissue (ct)
  - muscle (mm)
  - nerve (n)





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## Levels of Organization

#### Systems

- Related organs with a common function
- 11 systems





### Integumentary system

#### Components

- skin
- hair
- glands

- protection
- regulates body temperature
- eliminates waste
- vitamin D
- sensations





### **Skeletal system**

#### Components

- Bones
- Joints
- Cartilage

- Support
- Protection
- Body movement
- Produces blood cells
- Stores minerals & fats





### **Muscular system**

- Components
  - skeletal muscles

- body movement
- posture
- generates heat





### Nervous system

#### Components

- brain
- spinal cord
- nerves
- special sense organs

- action potentials (nerve impulses)
- detects, interprets, and responds to changes in environment





### **Endocrine system**

#### Components

 hormone-producing glands and cells

#### Functions

regulates body activities





### **Cardiovascular system**

#### Components

- blood
- heart
- blood vessels

- pumps blood
- carries O2 and nutrients to cells and wastes away
- regulates temperature, acidbase balance, and H2O





### Lymphatic system

#### Components

- lymph fluid & vessels
- spleen
- thymus
- lymph nodes
- tonsils

- transports dietary lipids
- protection





### **Respiratory system**

#### Components

- lungs
- pharynx
- larynx
- trachea
- bronchial tree

- exchange of gases
- acid-base balance
- sound production





### **Digestive system**

#### Components

- mouth
- pharynx
- esophagus
- stomach
- small intestines
- large intestines
- salivary glands
- liver
- gallbladder
- pancreas

- breakdown of food
- absorption of food
- eliminates wastes





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### **Urinary system**

#### Components

- kidneys
- ureters
- urinary bladder
- urethra

- eliminates waste
- regulates blood composition & volume
- acid-base balance





### **Reproductive system**

#### Components

- ovaries
- testes
- associated structures

- produce gametes
- hormone regulation of reproduction





### **Characteristics of Life (10)**



- Movement change in position; motion
- Responsiveness reaction to a change
- Growth increase in body size; no change in shape
- Reproduction production of new organisms and new cells
- Respiration obtaining oxygen; removing carbon dioxide; releasing energy from foods
- Circulation movement of substances in body fluids
- **Digestion** breakdown of food substances into simpler forms
- Absorption passage of substances through membranes and into body fluids
- Assimilation changing of absorbed substances into chemically different forms
- Excretion removal of wastes produced by metabolic reactions
- Differentiation unspecialized to specialized

### **Maintenance of Life**

- Life depends on five (5) environmental factors:
  - Water
    - most abundant substance in body
    - required for metabolic processes
    - required for transport of substances
    - regulates body temperature
  - Food
    - provides necessary nutrients
    - supplies energy
    - supplies raw materials
  - Oxygen
    - one-fifth of air
    - used to release energy from nutrients
  - Heat
    - form of energy
    - partly controls rate of metabolic reactions
  - Pressure
    - application of force on an object
    - atmospheric pressure important for breathing
    - hydrostatic pressure keeps blood flowing





### **Maintenance of Life**

#### Homeostasis

- Maintaining of a stable internal environment
- "physiological normal"
- dynamic
- involves maintaining the volume and composition of body fluids
  - intracellular (ICF)
  - extracellular (ECF)
- More on homeostasis during the Analysis of Living systems lecture





## **Organization of the Human Body**

Body cavities



### **Anatomical Position**

 Anatomical Position – standing erect, facing forward, upper limbs at the sides, palms facing forward and thumbs out





### **Body Sections or Planes (3)**



- Sagittal or Median divides body into left and right portions
  - Mid-sagittal divides body into equal left and right portions
- Transverse or Horizontal divides body into superior and inferior portions
- Coronal or Frontal divides body into anterior and posterior portions



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