Topic 1: CONCEPTS AND THEMES OF PHYSIOLOGY

I What is human physiology?

A. Physiology = the study how living things function; HUMAN physiology = the study of the function of the human body

B. "Universal" functions of living things

1 Self-reproducing

2 Self-ordering

3 Self-regulating

II Levels of organization in the body

A Cells: basic unit of life; smallest unit capable of carrying out the processes associated with life

1 Basic Cell functions

2 Specialized Cell functions

B Tissues: composed of cells of few types + extracellular material

C Organs

1 Composed of two or more primary tissues organized to perform a specific function

2 Example: Stomach

E Body Systems

1 Collection of organs that perform related functions and interact to accomplish a common activity essential to survival of body.

2 Example: Digestive system composed of: mouth, pharynx, esophagus,

stomach, small & large intestines, salivary glands, pancreas, liver, and gallbladder.

III Homeostasis

A Definition & Concepts:

1 Keeping the internal environment constant = regulated constancy.

2 Environment of the cell is extracellular fluid

a blood plasma

b interstitial fluid

B Factors that must be homeostatically maintained

C Regulation of Homeostasis

1 negative feedback regulation: room temperature

a sensor = thermometer

b set point = 72° F

c integrator = thermostat

d effector = furnace

2 negative feedback regulation: body temperature

a. Summary: an external change triggers an internal change that restores the normal state

2. one-way vs. two way (room temp vs. body temp)

3. direct vs. indirect (indirect involves behavior – common homeostatic mechanism, esp. in humans)

4. imperfect/failed regulation – time lag in neg. feedback; results in overshoots and undershoots (e.g. overheating during exercise; overcooling

following exercise)

IV Regulated changes

A. development/growth
B. temporary changes for emergencies
C. cycles
D. permanent changes
E. mechanisms of regulated changes:
    1. reset the set point
    2. positive feedback

V Law of Mass Balance
A. If the amount of any substance in the body is to remain constant, then
B. Input = Output
C. Example: temperature
    1. Heat gain from environment and metabolic activity = heat loss to environment
    2. A mismatch results in overheating

D. Example: body weight
    1. Intake of food = output of metabolic and other activities
    2. A mismatch results in gain or loss of body mass

VI Homeostasis is essential for the survival of each cell, and each cell contributes as part of a body system to homeostasis.

Topic 2: CHEMISTRY FOR PHYSIOLOGISTS

I Atoms , Molecules & Compounds

A Atoms
1 Proton: heavy, positive charge, in nucleus
2 Neutron: heavy, no charge, in nucleus
3 Electron: light, negative charge, orbits nucleus
4 # protons = # electrons, atom has no charge

B Compounds
1 Pure substance that contains more than one type of atom (eg, water)

C Molecule is smallest unit of pure substance that has properties of that substance and is stable.
1 e.g. water H_2O oxygen O_2

D Weights and measures
1 Mole: 6.02×10^{23} *particles* (amount of pure substance that has a mass equal to the substance's molecular weight
2 Molecular Weight: number of grams/mole for a substance
a eg, mol weight of H_2O is 18.02 g
b all molecular weights are relative to the defined molecular weight of hydrogen (1.0)

II Chemical Bonds and Ions

A Shells
1 Grouping of electrons
2 Energetically favorable for e- to belong to lowest shell possible
3 A filled shell is electrically favored
4 Atoms tend to undergo processes that result in filled shells
5 There are a variety of ways to fill shells

B Charged atoms (ones that have donated or accepted an electron) are called ions.

C Ionic Bonds
1 Ions of opposite charge attract

D Covalent Bonds
1 electron sharing
2 examples: H_2O, H_2

E Polar Molecules
1 Electrons not distributed uniformly in molecule
2 Example: water

F Hydrogen bond
1 hydrogen in polar molecule is positive & is attracted to negative end of another molecule
2 this is a relatively weak interaction
3 very important interaction; makes complex biological structures possible, and is the basis of many biological reactions

III Chemical Reactions

A Reactants make products
1 $A + B \rightarrow C + D$
2 energy is needed to start the reaction = activation energy

B Irreversible
1 Burn methane to make water and CO_2
a $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
b activation energy to go the other way is too high

C Reversible
1 carbon dioxide reacts with water to make carbonic acid
a $CO_2 + H_2O$ _ H_2CO_3

D Catalysts: speed up reactions
  1 Heat: Provides activation energy
  2 Enzymes: Speed up reactions by
    a. Lowering the activation energy
    b. Pushing reactions through unstable intermediates (making those intermediates more stable)

IV Solutions

A Homogeneous mixtures with large amount of solvent and small amount of solute.
B In body, water is the usual solvent
C Ionic solutes dissolved in water, solution conducts electricity=electrolyte
  1 salt water does (breaks into Na+ and Cl-)
  2 sugar water does not (nonelectrolyte)
D Concentrations: (important ones for course underlined but you will encounter the others!)
  1 <u>Molarity (M) = number of moles of solute in one liter of SOLUTION.</u>
  2 Molality (m) = number of moles of solute in 1 kg of solvent
  3 Normality (N) = number of equivalents of solute in 1 liter of solution.
    a equivalent = number of moles of positive charges
    b NaCl: get one positive charge/molecule, so 1 M of NaCl is 1 N
    c $CaCl_2$: get two positive charges/ molecule, so 1 M of $CaCl_2$ is 2 N
    d works only for electrolytes
  4 <u>Osmolarity (osm) = total number of solute particles in one liter of solution.</u>
    a Glucose does not dissociate in water, so 1 M = 1 osm
    b NaCl dissociates into Na and Cl so 1 M = 2 osm

V Acids, Bases, and Salts
A Acid: Any substance donates a hydrogen ion (proton) to another substance.
B Base: Any substance that accepts a hydrogen ion
C $HCl + H_2O \_ H_3O^+ + Cl^-$ (HCl is acid, water is base)
D Salt: contain positive ion of a base and a negative ion of an acid:
  1 $NaOH + Hcl \rightarrow NaCl + H_2O$ (so NaCl is the salt)

VI Organic Molecules of Importance to Course

A Carbohydrates
- 1 contain carbon, hydrogen and oxygen in ratio of CH_2O
- 2 monosaccharide is simplest: (glucose, fructose, galactose) - contain 5 or 6 carbons
- 3 disaccharide: two monosaccharides together (sucrose, lactose)
- 4 polysaccharide: many monosaccharides together in a chain
  - a glucose based ones are: glycogen, starch, cellulose
  - b glycogen is most branched, cellulose is least branched

B Lipids
- 1 classification: insoluble in water, but soluble in non-polar solvents
- 2 Are waxy or greasy
- 3 Repel water = hydrophobic
- 4 Simple biological lipids = fatty acids, glycerol
- 5 Complex
  - a contain glycerol and fatty acids
  - b Phosopholipids contain glycerol, 2 fatty acids, and phosphate; this is the major constituent of plasma membranes
- 6 Other
  - a steroids – flat, ringed multiple carbon structures; cholesterol is the basic structure
  - b misc. hydrophobic biological molecules: vitamin A, vitamin D, eicosanoids (signaling molecules)

C Proteins
- 1 Composed of chains of amino acids
  - a Amino acids held together by peptide bonds
- 2 Function
  - a enzymes are proteins
  - b structural proteins

D Nucleic Acids

1 consist of base (nucleoside - 4 types) + 5-carbon sugar + phosphate

a adenine (A)

b guanine (G)

c thymine (T)

d cytosine (C)

2 Make up DNA (sugar = deoxyribose); double-stranded

3 Make up RNA (sugar = ribose); single-stranded (Uracil instead of Thymine)

4 Central Dogma of Biology: DNA ➔ RNA ➔ protein

a sequence of bases is the information that determines:

i DNA (when cell replicates DNA before dividing)

ii RNA (when gene is expressed)

b RNA involved in translating the DNA sequence into a protein sequence

E High Energy Molecules

1 Molecules that store energy in phosphate bonds

2 Most common is ATP (adenine triphosphate)

3 ATP $\rightarrow$ ADP + PO_4 yields energy (ADP = adenine diphosphate)

Topic 3: INTRODUCTION TO CELL PHYSIOLOGY

I General Structure of the Cell

A Major parts
1 plasma or cell membrane
2 nucleus
3 cytoplasm

B Cell membrane (will discuss extensively in another lecture)
1 Thin structure that encloses each cell
2 Mechanical barrier & selectively permeable
3 Intracellular fluid (ICF) fluid inside cell
4 Extracellular fluid (ECF) fluid outside cells

C Nucleus
1 distinct sphere in center surrounded by a double membrane
2 contains DNA which is packaged into chromosomes

D Cytoplasm
1 That part of cell that is not nucleus.
2 Contains organelles dispersed in a gel like mass called cytosol
3 Organelles are separate compartments specialized for particular functions
4 Cytosol is semiliquid mass laced with elaborate protein network called cytoskeleton.

II Organelles

A Advantages to compartmentalization
1 Maintain environment specialized for a particular function
2 Reactions facilitated
3 Same reasons why different bodily functions are sequestered in specialized organs

B Endoplasmic reticulum

1 One continuous fluid-filled membrane organelle in each cell, continuous with the nuclear membrane

2 Function of RER (rough ER)

a is rough because of attached ribosomes

b ribosomes “read” RNA message and make proteins

c RER involved in synthesis of proteins & their release into ER lumen (space with ER membrane)

d these are proteins destined for

i the ER

ii other membrane-bound organelles

iii the cell surface

iv extracellular release

d Lots of RER found in cells specialized for protein synthesis

3 Function of SER (smooth ER)

a Most cells: central packaging & discharge site for molecules to be transported out of ER (usually destined for Golgi complex)

b Piece of SER pinches off with molecule inside = transport vesicle

c some cells: SER specializes in lipid synthesis & transport

d in liver cells, SER detoxes harmful chemicals

e muscles: modify ER into sarcoplasmic reticulum

B Golgi complex

1 Flat, slightly curved membrane enclosed sacs, closely associated with ER

2 Function

a Destination point for ER transport vesicle

b Sort & direct finished products to final destination

C Lysosomes

1 Membrane enclosed vesicle containing digestive enzymes at a low (acidic) pH

2 Function

a Digest cellular debris & foreign material

b Can digest aged or damaged organelles

D Peroxisomes
- 1 membrane enclosed vesicle (smaller than lysosomes) containing oxidative enzymes
- 2 Function
  - a Peroxisomes contain oxidative enzymes (peroxidase) that catalyze the following reaction: $RH_2 + O_2 \rightarrow R' + H_2O_2$ to strip hydrogen ions from various molecules
  - b Catalase removes peroxide ($2H_2O_2 \rightarrow H_2O + O_2$), which itself is highly toxic to cells

E Mitochondria
- 1 Structure
  - a Bacteria-sized organelle (long rod shape or oval)
  - b Outer membrane surrounds mito
  - c Inner membrane that forms infoldings called cristae
  - d Has its own DNA
  - e Divides independently of nucleus
- 2 Function – in greater detail as its own topic
  - a "Powerhouse of cell"
  - b Produce high energy molecules (ATP)

III Cytosol
- A Semiliquid, highly organized gelatinous mass (55% of cell volume)
- B Function
  - 1 Intermediary metabolism
    - a metabolism of small organic molecules
    - b glycolysis
  - 2 Protein synthesis via cytosolic ribosomes
    - a proteins needed in cytosol itself (eg glycolytic enzymes, cytoskeletal proteins)
  - 3 Storage of fat and glycogen

IV Cytoskeleton

A "Bone and muscle" of cell (cells must either maintain shape or move, and the cytoskeleton permits this)

B Microtubules

1 Structure
- a Largest of cytoskeletal elements
- b Slender, long hollow straight tubes
- c Composed of small globular protein called tubulin

2 Function
- a Helps maintain asymmetrical cell shape (eg axons)
- b Secretory vesicles transported down microtubules by motor proteins
- c Dominant components of cilia & flagella which are used to move materials across cell surface or to propel cell
- d Forms mitotic spindle which organizes chromosomes during mitosis

3 Associated molecular motors: ATP-requiring
- a dynein – moves microtubules past each other in cilia
- b kinesin – moves vesicles along microtubules (away from nucleus)
- c cytoplasmic dynein – moves vesicles along microtubules (toward nucleus)

4 Microtubules can assemble and disassemble depending on the concentration of other specific proteins and cofactors, but are generally stable

C Microfilaments

1 Structure
- a Smallest of cytoskeletal elements
- b composed of small globular protein called actin
- c two strands of actin twisted together

2 Function: contractile and structural systems within cell
- a cell locomotion
- b split cell during mitosis
- c mechanical stiffeners
- d form microvilli-projections from gut epithelium and elsewhere

3 Associated molecular motors
- a myosin I – one type specific to muscles
- b myosin II – another type for other cells

4 Actin filaments can assemble and disassemble depending on the concentration of other specific proteins and cofactors – this process drives the growth of nerve axons and the “pseudopodia” movement of other motile cells
- a gelation = assembly of actin into filaments
- b solation = disassembly into individual globular proteins

D Intermediate filaments

1 Structure
- a Intermediate in size
- b irregular, threadlike molecules
- c form tough fibers

2 Function
- a Strengthen & stabilize other components of cytoskeleton

b Do not spontaneously assemble/disassemble