Test 1 Study Guide

Chapter 1 – Introduction

A. Definition
   a. Microbiology – study of organisms too small to see with naked eye.
   b. Why do we care?
      i. Disease, environment, positive human interactions
      ii. Research and commercial application
B. Types of Microbes
   a. Nomenclature – *Genus species*.
   b. Major Groups (Fig. 1.1)
      i. Viruses – smallest. Noncellular, obligate parasite
      ii. Bacteria – single-celled. Very diverse.
         1. Eubacteria – more common and may cause human disease
         2. Archaea – live in harsh environments
      iii. Protists – complex single-celled.
         1. Protozoa – animal-like
         2. Algae – plant-like
         3. Slime molds – fungal-like
      iv. Fungi – multicellular, complex. Absorbs food, nonmotile.
      v. Animals – multicellular, complex. Eats food, motile.
C. History of Microbiology
   a. Ancient times – Indigenous peoples use in food/medicine is unclear. Egyptians describe beer/wine making. Greeks describe transmissible diseases.
   b. The Cell
      i. 1665 – Robert Hooke – organisms are composed of cells
      ii. 1673-1723 – Antoni van Leeuwenhoek – saw microbes w/ microscope. (Fig. 1.2)
      iii. 1839 – Matthias Schleiden and Theodor Schwann – Cell Theory: cells are the fundamental units of life.
   c. Refute Spontaneous Generation
      i. 1668 – Rancesco Redi. Meat in mesh does not produce maggots.
      ii. 1861 – Louis Pasteur. Microbes did not grow in heated/sealed (or curve necked) vessels. Later discovers fermentation, invents pasteurization, and helps explain immunity. (Fig. 1.3)
   d. Germ Theory
      i. 1796 –Edward Jenner – Vaccination – immunity to smallpox could come from cowpox.
      ii. 1876 - Robert Koch - Koch's Postulates: specific microbes cause specific disease.
      iii. 1928– Alexander Fleming – Antibiotics, discovers penicillin. (Fig. 1.5) Clodomiro (Clorito) Picado Twight might have discovered it earlier.
   e. DNA Technology
      i. 1953 – Watson and Crick – DNA structure –solved structure of DNA
      ii. 1972 – Boyer and Cohen – Recombinant DNA Technology –used first restriction enzyme to cut and paste DNA.
      iii. 2001 – US Government and Craig Venter – Genomics: using DNA sequence

Chapter 2 – Biological Molecules

A. The atom (Fig. 2.1)
   a. Nucleus in center – made from protons (+) and neutrons (=). Both have an atomic weight of 1
   b. Shell on outside. Made up of electrons (-) with close to zero weight. Electrons orbit the nucleus. (Fig. 2.1)
   c. Common elements (Tab. 2.1)
   d. Isotopes are atoms with a different number of neutrons. E.g. radioisotopes.
B. Bonds
   a. Atoms form bonds with each other mostly because of electron stability. Atoms are happiest when outer shells have 2 or 8 electrons. If not, they try to share or give them to achieve this. (Tab. 2.2)
   b. Compound is a molecule made up of different types of atoms.
   c. Bonds
      i. Ionic – when electron is transferred. This results in charged atoms called ions. (Fig. 2.2 and Audesirk movie)
      ii. Covalent – when electron is shared. This is how a molecule is formed. (Fig. 2.3 and movie)
         1. Polar – asymmetrical, slight charge
         2. Non-polar – symmetrical, no charge.
      iii. Hydrogen – polar molecules form bonds from slight – and + charges. (Fig. 2.4)
   d. Chemical reactions
      i. Reactants → Products, reversable
      ii. Exergonic releases energy while endergonic requires energy
      iii. Synthesis is a building reaction (anabolism) while decomposition is breaking down (catabolism). Exchange reactions involve both.
C. Water – polarity and size give it unique properties (Fig. 2.4)
   a. Liquid vs. ice
   b. Cohesive and adhesive: surface tension.
   c. Solvent – solutes dissolve in it. (Fig. 2.5) (Audesirk 2.2 movie)
   d. Heat sink – resists temperature change. Calorie is defined as energy required to raise 1 ml or g of water 1 ^{o}C. Heat is given off by evaporation, e.g. sweating.
   e. Acids and bases. Water dissociates into equal numbers of *hydrogen* ions and *hydroxide* ions. $H_2O \rightarrow H^+ + OH^-$ (Fig. 2.6, 2.7)
      i. pH Scale. Defined as negative logarithm of the hydrogen ion concentration; pH = - log [H^+]. Neutral water dissociates into 10^{-7} moles/liter of hydrogen ions.
      ii. Log is a ten-fold scale.
D. Organic molecules contain carbon and hydrogen.
   a. Overview
      i. Functional groups give organic molecules different characteristics (Tab. 2.3)
      ii. Macromolecules are made from monomers and polymers.
      iii. Dehydration synthesis to link monomers and hydrolysis to separate.
   b. Carbohydrates
      i. Chemical formula is usually $(CH_2O)_n$
      ii. Monosaccharide. Making disaccharide, polysaccharide (Fig. 2.8)
      iii. Examples
         1. Starch – a storage polysaccharide in plants
         2. Glycogen – storage in animals
         3. Cellulose – cell wall structure
   c. Lipids – fats
      i. Hydrophobic – "water fearing". Long hydrocarbon chains.

ii. Triacylglycerol (triglyceride) contains 3 fatty acid and 1 glycerol. Saturated vs. unsaturated fats. Unsaturated has double bonds and is not saturated with hydrogen. (Fig. 2.9)
iii. Phospholipids have a polar head with a phosphate group and a non-polar tail. (Fig. 2.10)
iv. Steroids – four ring groups. E.g. cholesterol (precursor to other steroids and membrane component), estradiol, testosterone (Fig. 2.11)

d. Proteins
   i. Monomers are amino acids. Monomers are linked by peptide bonds. (Fig. 2.12, 2.14)
   ii. 20 different R groups. (Tab. 2.4)
   iii. Function related to final structure. Temperature, pH and salt can affect final shape. Denaturation like boiled eggs. (Draw pacman)
   iv. Levels of structure (Fig. 2.15)
      1. Primary – basic sequence
      2. Secondary – 3D motif, e.g. helix, sheet
      3. Tertiary – whole protein structure
      4. Quaternary – more than 1 peptide

e. Nucleic Acids (Fig. 2.16)
   i. Monomer is nucleotide (phosphate-sugar-base)
   ii. DNA is string of deoxynucleotides. Has four bases ATGC. Genetic material.
   iii. RNA is less stable. Has AUGC. Genetic messenger. (Fig. 2.17)
   iv. ATP is a unit of energy. High energy phosphate bond. (Fig. 2.18)

Chapter 4 – Cell Structure

A. Overview – differences between prokaryotes and eukaryotes
   a. Prokaryotes ("before nucleus")
      i. No membrane bound organelles
      ii. Free DNA, association with some proteins.
      iii. Always have cell walls with complex structure
      iv. Usually divide by binary fission
   b. Eukaryotes ("true nucleus")
      i. Have organelles
      ii. Enclosed DNA, high association with proteins (histones)
      iii. If cell wall is present it is simple in structure
      iv. Divide by mitosis.

B. Prokaryotes
   a. Shape and Arrangement (Fig. 4.1, 4.2)
      i. Monomorphic (only one shape) vs. pleomorphic (more than one shape)
      ii. Coccus – small spheres
         1. Diplo (2), tetra (4), sarcina (8)
         2. Strepto – chains
         3. Staphylo – large clusters
      iii. Bacillus – rods
         1. Coccobacillus are very short rods
      iv. Spirals (Fig. 4.4)
         1. Vibrio – short curve
         2. Spirillum – helical. Use flagella to move
         3. Spirochete – twists to move (no flagella)

- v. Others (Fig. 4.5)

b. External structures
   - i. Glycocalyx (sugar coat)
     1. Capsules and slime layers (loose)
     2. Functions: attachment, protection
   - ii. Flagella (4.8)
     1. Structure: filament, hook, basal body
        - a. Filament – made of protein called flagellin wrapped like a hollow rope.
        - b. Hook – attached to filament and rotates
        - c. Basal body – anchors to cell wall/membrane
     2. Movements – taxis is movement towards a stimulus (e.g. phototaxis, chemotaxis) (Fig. 4.9)
     3. Axial filaments are bundles that wrap around cell. Spirochetes use these for movement (Fig. 4.10)
   - iii. Pili
     1. Contain pilin. Used for attachement/invasion
     2. Frimbriae – very short and numerous, for attachment
     3. Sex Pili – longer and fewer. Forms bridge to transfer DNA. (Fig. 4.11)
   - iv. Cell wall (Fig. 4.13)
     1. Functions: protection, maintain shape. Site of some antibiotics (because animals don't have them)
     2. Peptidoglycan (Fig. 4.12)
        - a. Backbone – NAG-NAM chain (N-acetylglucosamine and N-acetylmuramate)
        - b. Linked by polypeptides
     3. Gram+
        - a. Have many layers of peptidoglycan
        - b. Teichoic acid links layers. May regulate ion movement. Provides antigenic specificity.
     4. Gram-
        - a. Have one or few layers of peptidoglycan (weaker)
        - b. Have outer membrane
          - i. Protective, binds hosts, and regulates crossing of molecules.
          - ii. Have lipopolysaccharides (LPS). Provides antigenic specificity. Can serve as an endotoxin.
     5. Acid fast
        - a. Have very little peptidoglycan
        - b. Mycolic acids and waxes prevent drying out and very resistant environment, including stains and antibiotics

c. Internal structures
   - i. Membrane
     1. Structure – Fluid Mosaic Model (Fig. 4.14)
        - a. Phospholipid bilayer
          - i. Phospholipids have polar head and nonpolar tail
          - ii. Tails inside, heads face out.
        - b. Proteins
          - i. Peripheral – on outside of bilayer. Can be involved in signaling, support, enzymes.

- ii. Integral – embedded in membrane. Can be involved in transport across membrane and signaling.
- 2. Transport Across Membrane
  - a. Passive transport – diffusion (Fig. 4.16)
    - i. Down a concentration gradient (high → low) (movie)
    - ii. Osmosis – diffusion of water across a membrane (Fig. 4.18)
    - iii. Tonicity – relation of solute concentrations across a membrane
      - 1. Isotonic: =
      - 2. Hypotonic <
      - 3. Hypertonic >
    - iv. Facilitated diffusion – uses a protein (Fig. 4.17)
  - b. Active transport
    - i. Against concentration gradient
    - ii. Requires energy
    - iii. Example: Na-K pump – a bi-directional pump that uses ATP. (movie)
  - c. Endocytosis – membrane envaginates to form a vesicle. Phagocytosis is when large particles are taken in.
  - d. Exocytosis – opposite of endocytosis.
- ii. Cytoplasm – stuff inside cell membrane (80% water)
- iii. Nucleoid – holds DNA in the bacterial chromosome.
- iv. Ribosomes – makes proteins. Large and small subunit is made from many protein and RNA molecules. (Fig. 4.19)
- v. Inclusions – storage deposits. Can be called granules or end in "some". E.g. lipid granules, magnetosome (holds iron) (4.20)
- vi. Endospores – a dormant cell. E.g. anthrax. Hard to kill.
  - 1. Dehydrated cell with thick walls, additional layers. Highly protective. Spores have been germinated after millions of years.
  - 2. Sporulation – spore formation is triggered by bad conditions (low nutrients, water) (Fig. 4.21)
  - 3. Germination – return to vegetative state.

C. Eukaryotic Organelles

- a. Differences between plants and animals – plants have a cell wall, plastids, central vacuole. Animals have centrioles.
- b. Cilia and Flagella – movement and water movement.
  - i. Cilia "eyelash" are small and numerous. Flagella "whip" are large and few. (Fig. 4.23)
  - ii. Uses microtubules that slide pass each other.
- c. Cell wall, membranes, cytoplasm, ribosome are similar so skip
- d. Nucleus – "control center" (Fig. 4.24)
  - i. Holds DNA in form of chromatin (DNA + protein). Chromosomes are the DNA part.
  - ii. Nucleolus is center for ribosome assembly.
  - iii. Nuclear envelope is a double membrane. Nuc. pores allow RNA to exit.
- e. Endoplasmic Reticulum – "manufacturing center"
  - i. Membranes form flattened tubes called cisterns. Lumen is on inside.
  - ii. Rough ER has ribosomes. Proteins made and translocated into the lumen. (Fig. 4.25)

iii. Smooth ER has no ribosomes. Used for lipid and carbohydrate metabolism and detoxification.
iv. Buds vesicles to Golgi.

f. Golgi Complex – "post office" (Fig. 4.26)
    i. Sorts incoming proteins and lipids
    ii. "Tags" or modifies some for destination
    iii. Packages them for final destination in vesicles.
g. Vacuole – "storage and recycling plant"
    i. Like a large vesicle.
    ii. Store water, food, salts, pigments, and wastes.
h. Lysosomes – "digestive system"
    i. Contains hydrolytic enzymes at low pH. Digests all classes of macromolecules.
    ii. Tay-Sach's disease is genetic and is caused by missing digestive enzyme. The enzyme digests lipids. Lipids build up and kill cell. Death occurs in children
i. Mitochondria – "powerhouse"
    i. Produce ATP from glucose
    ii. Structure: double membrane, cristae (folds), matrix all have enzymes. (Fig. 4.27)
j. Chloroplasts – "solar power plant" (Fig. 4.28)
    i. Family of plastids that produce and store food.
    ii. Makes glucose using chlorophyll and carotenoids
    iii. Has three membranes. Inner most makes up thylakoid. Grana are stacks of thylakoids. Stroma is inside space.
k. Peroxisomes – "detox center". Metabolize small organic compounds. E.g. Hydrogen peroxide and ethanol.

D. Endosymbiosis (movie)
    a. Organelles evolved from prokaryotes.
    b. Larger heterotrophic bacteria engulfs a smaller one and cannot digest it. They enter a symbiotic relationship. Larger one gets energy, smaller one gets shelter.
    c. Evidence
        i. Unique DNA and proteins
        ii. Similar size and structure to bacteria
        iii. Symbionts (e.g. paramecium w/ algae in it)

Chapter 5 – Metabolism

A. Metabolism Overview
    a. Metabolism – sum of all chemical reactions
        i. Catabolism – break down organic molecules
        ii. Anabolism – build up organic molecules
    b. Redox reaction– reduction (gain e-) coupled with oxidation (lose e-)
        i. NAD is a common electron carrier. $NAD^+ + H_2 \rightarrow NADH + H^+$ (Fig. 5.9, 5.10)
        ii. Also $FAD + H_2 \rightarrow FADH_2$
    c. ATP is used to couple reactions (provide energy for endothermic rxns) (Fig. 5.1)
    d. Ways to obtain energy (5.28)
        i. Autotrophs – make their own organic compounds from CO_2
            1. Photoautotrophs – use light energy
            2. Chemoautotrophs – use inorganic compounds for energy
        ii. Heterotrophs – eat their organic compounds
            1. Photoheterotrophs – use light energy to use organic compounds
            2. Chemoheterotrophs – use energy from organic compounds directly

iii. Energy mechanisms use photosynthesis and respiration
    1. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + energy

e. Uses of energy
    i. Biosynthesis – production of chemicals through a series of reactions
    ii. Movement – cell movement, internal movement, membrane transport
    iii. Bioluminescence - glowing

B. Enzymes
  a. Enzymes are catalysts that speed up reactions by lowering activation energy (Fig. 5.2)
    i. Reactions must be spontaneous
    ii. Enzymes binds to substrate specifically
    iii. Enzymes are reused
  b. Enzyme function – E + S → ES → EP → E + P (Fig. 5.4)
    i. Active site binds substrates (reactants).
    ii. Reaction occurs on enzyme
    iii. Release of products
  c. Enzyme regulation
    i. Environment (Fig. 5.5)
      1. Enzymes function at optimal pH, temperature, salt concentration
      2. Substrate concentration gives different curve.
    ii. Activation
      1. Coenzymes – organic. e.g. vitamins
      2. Cofactors – inorganic. e.g. minerals
    iii. Inhibition
      1. Competitive inhibition – binds active site (Fig. 5.7)
      2. Noncompetitive regulation – binds elsewhere
      3. Feedback inhibition – product inhibits its maker (Fig. 5.8)

C. Respiration
  a. $C_6H_{12}O_6 + 6\ O_2 + 38\ ADP \rightarrow 6\ CO_2 + 6\ H_2O + 38\ ATP$
  b. Two important coenzymes: NAD and FAD. These pick up electrons and transfer them later to make ATP. NAD makes 3 ATP, FAD makes 2 ATP.
  c. Occurs in 4 sets of reactions: Glycolysis → Acetyl-CoA Formation → Kreb's Cycle → Electron Transport System (Fig. 5.11)
  d. Glycolysis (Fig. 5.12)
    i. Glucose → Pyruvate
    ii. Yields 2 ATP and 2 NADH
    iii. Glucose activation steps
      1. 2 ATPs used in 3 steps.
      2. $C_6 \rightarrow 2C_3$ (G3P) in 1½ steps.
    iv. Energy harvesting steps
      1. 4 ATPs and 2 NADHs produced in 5 steps. Remember, these totals reflect doubling of reactions because of 2C3 molecules.
      2. These ATPs are made by substrate level phosphorylation (direct transfer of phosphate by intermediate).
  e. Acetyl-CoA formation (Fig. 5.13)
    i. Yields 2 NADH (1 per pyruvate)
    ii. Pyruvate + CoA → CO_2 + Acetyl-CoA
  f. Kreb's Cycle (Fig. 5.13)
    i. Yields 2 ATP, 6 NADH, and 2 $FADH_2$ (2 turns for 2 acetyl-CoA)
    ii. C_4 (oxaloacetate) + Acetyl-CoA → citrate (C_6) + CoA
    iii. $C_6 \rightarrow C_5 \rightarrow C_4$ yielding 2 CO_2 + energy.
  g. Electron Transport and Chemiosmosis (Fig. 5.14)

i. Occurs on a membrane. (Fig. 5.15)
ii. Converts energy carried by NADH and $FADH_2$ to ATP (3/NAD, 2/FAD) (Fig. 5.16)
iii. Chemiosmosis – production of ATP by a proton (H^+) gradient.
1. Protons have been pumped into inter/outer-membrane space. High concentration drives movement of protons back across membrane.
2. ATP synthase: force of proton movement turns powers ATP synthesis.
3. Electrons accepted by various molecules (Fig. 5.27)

h. Balance sheet: 38 ATP (34 from 10 NAD and 2 FAD) (Fig. 5.17))

D. Fermentation – a "shortcut" respiration process. It just regenerates NAD^+ to run glycolysis. This produces ATP by substrate level phosphorylation only. Inefficient but very fast and no oxygen required. (Fig. 5.18)
a. Alcohol fermentation – done by yeast. Ethanol and CO_2 produced. (Fig. 5.19)
b. Lactic acid fermentation – done by humans, strep. Lactic acid produced.

E. Lipid and Protein Catabolism
a. Fats and proteins enter in different places of respiration (Fig. 5.21)
b. Triacylglycerol is broken down to fatty acid and glycerol (Fig. 5.20)
c. Proteins are broken down to amino acids and deaminated.

F. Photosynthesis overview

$$6\ CO_2 + 6\ H_20 + \text{energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

a. *Light dependent reactions* make ATP and NADPH using light. (Fig. 5.25)

$$12\ H_20 + 12\ NADP^+ + 18\ ADP + \text{light} \rightarrow 6\ O_2 + 12\ NADPH + 18\ ATP$$

i. Cyclic photophosphorylation makes only ATP and recycles electron.
ii. Noncyclic makes both ATP and NADPH. Electron goes to NADPH.

b. *Light independent reactions* (dark reactions) fix CO_2 into carbohydrates. (Fig. 5.26)

$$6\ CO_2 + 12\ NADPH + 18\ ATP \rightarrow C_6H_{12}O_6 + 12\ NADP^+ + 18\ ADP + 6\ H_2O$$

i. Calvin cycle – 3 CO_2 in, 1 C_3 out per turn. 9ATP used.