Chapter 1 Notes

I. Biochemistry

A. Organic compounds are based on carbon atoms that have been combined with hydrogen and oxygen.

1. Nitrogen, sulfur, and phosphorus are frequently found on organic compounds as well.

2. Carbon atoms combine to make a "backbone" that other atoms attach to, giving structure and function.

3. Monomers can be joined together into polymers through dehydration synthesis or broken by hydrolysis.

B. Carbohydrates are composed of carbon, hydrogen, and oxygen in a CH_2O ratio.

1. Monosaccharides (glucose, etc.) are carbo. monomers.

2. Two monosaccharides can be combined to form disaccharides such as sucrose, maltose, or lactose.

3. Several glucose molecules can be combined to form complex carbohydrates (polysaccharides).

a. Starch and glycogen are important energy-storage molecules for plants and animals respectively.

b. Cellulose is a structural molecule in plants used to build cell walls (cotton, wood, etc.).

C. Lipids (fats and oils) are used for long term energy storage and as the structural parts of cell membranes.

1. Lipids are made from C, H, and O, but not in a fixed ratio like carbohydrates.

2. Simple fats (triglycerides) are made from three fatty-acid molecules and one glycerol molecule.

   a. Unsaturated fatty acids can be recognized by C=C and are oily liquids at room temperature.

   b. Saturated fatty acid carbon chains are full of hydrogen and tend to be solids at room temperature.

D. Proteins provide most of the functionality (structure, defense, chemical reactions, etc.) to organisms.

1. Amino acids (the protein monomer) have three main functional groups joined to a central carbon atom.

   a. The amine group (NH_2) and the acid group (COOH) serve to attach one amino acid to another.

   b. The R group can be one of twenty structures that give the A.A. characteristics like polarity.

2. Proteins (polypeptides) are created by joining A.A.'s together with peptide bonds.

3. The sequence of a protein's amino acids is (primary structure) determines its shape and function.

   a. Most proteins fold/twist to form alpha helices and beta sheets – secondary structure.

   b. More complex folding caused by the polarity of R groups creates tertiary structure → function.

   c. Some proteins gain functionality only after 2+ tertiary structures combine into a quaternary structure.

E. Nucleic acids code for the order of amino acids in proteins.

1. The two basic types of nucleic acids are DNA (the genetic code) and RNA.

2. Nucleic acid monomers (nucleotides) are composed of three main parts.

   a. The phosphate group can covalently bond with the sugar group of another nucleotide.

   b. A five carbon sugar is in the middle of the molecule

   c. Attached to the sugar is a nitrogen-containing base.

      i. DNA has four possibilities: adenine (A), guanine (G), thymine (T), and cytosine (C).

      ii. RNA has the same four nitrogenous bases except thymine is replaced by uracil (U).

II. Genetic Coding in Cells

A. A paper proposing the structure of DNA was published by Watson and Crick in 1953 – Nobel Prize.

1. X-ray diffraction data gathered by Rosalind Franklin suggested:

a. DNA is two long chains of nucleotides – each of which is connected by sugar-phosphate bonds running in opposite directions.

b. The two chains are joined because of hydrogen bonding between specific nitrogenous bases: A with T and C with G.

c. The two strands intertwine, forming a double helix (like a twisted ladder).

B. DNA forms genes that code for proteins and are passed on from one generation to the next.

1. DNA nucleotides are arranged to form codons – groups of three "letters."

2. The order of codons in a gene dictates the order of amino acids in the protein the gene codes for.

Unit 2 Notes

I. Energy Flow & Organisms

A. First Law of Thermodynamics: Energy cannot be created or destroyed, but it may change form.

1. Organisms can't make their own energy, but must harvest it from another source (sun, other organisms).

2. After harvesting the energy, it is changed into a storable form, and eventually changed again to make free energy.

B. Second Law of Thermodynamics: Systems tend to change in ways that increase disorder (entropy).

1. To maintain order in a system (organism, building, etc.), free energy must be used.

a. Because energy conversions are not 100% efficient, each time energy changes form to provide free energy, some escapes (usually as heat).

b. To remain ordered, organisms and ecosystems must continually receive new energy to replace the energy that has become unusable (10% rule).

II. Metabolism and Energy Transfer

A. Enzymes are proteins that act as catalysts.

1. Activation energy is normally prevents chemical reactions in living things.

2. By decreasing activation energy, enzymes make rapid chemical reactions possible.

a. One or more reactants (substrates) fit into an enzyme's active site (groove in tertiary structure).

b. Interaction with the substrate(s) causes the enzyme to change shape, putting stress on chemical bonds.

c. The reaction occurs, the product(s) are released, and the enzyme is ready for another reaction.

3. An enzyme works best at a certain temperature, pH, and salinity. (out of range → denature)

B. Metabolism, all the chemical activities that take place in an organism, consists of two basic classes of reactions.

1. Synthesis (anabolic) reactions use free energy to form large, complex molecules from small, less complex ones.

2. Decomposition (catabolic) reactions break large molecules into smaller molecules, releasing free energy (& heat).

3. Synthesis and decomposition reactions are coupled.

C. ATP is a molecule that serves as "energy currency."

1. As various food molecules are decomposed, free energy and heat are released.

2. The free energy is stored by synthesizing ATP from ADP and an inorganic phosphate molecule (P_i).
($ADP + P_i$ + free energy → ATP)

3. The free energy stored in ATP is released when the bond between the second and third phosphate group is broken. (ATP → $ADP + P_i$ + free energy)

4. ATP is formed and consumed rapidly – 10 million molecules are consumed and regenerated per second per cell.

5. ATP is used as an energy carrier in all known living cells.

III. Digestion

A. There are two main categories of digestion (processes that break down food).

1. Physical digestion breaks big pieces of food into smaller pieces of the same food, increasing surface area.

2. Chemical digestion breaks complex food molecules into smaller, more simple ones.

a. Most animals and fungi rely on extracellular digestion.

i. Complex animals use a specialized "external" digestive cavity separated into specialized regions which vary according to the species' diet.

ii. Fungi digest food outside of themselves and then absorb the nutrients.

b. Most plants, bacteria, and protists use intracellular digestion.

B. Human digestion follows a specific series of steps.

1. Food is physically (teeth) and chemically (saliva w/ amylase (carbohydrates → maltose)) digested in the mouth and formed into a bolus.

2. As the bolus is swallowed, the epiglottis covers the trachea to prevent choking.

3. Peristalsis moves the bolus down the esophagus, through the cardiac sphincter, and into the stomach.

4. Food is digested further in the stomach for 2 – 4 hours.

a. Food entering the stomach stimulates the release of the hormone gastrin which causes the secretion of HCl (pH drops → amylase is denatured).

b. The low pH causes inactive pepsinogen to become the active, protein digesting enzyme pepsin.

c. Food is turned into "soupy" chyme and passed through the pyloric sphincter.

5. The chyme is pushed into the small intestine.

    a. The duodenum (1^{st} part of the S.I.) receives pancreatic juice and bile salts.

        i. Bile salts (from the liver / gall bladder) emulsify fat droplets (physical digestion).

        ii. The pancreatic juice raises the pH and supplies trypsin (peptide enzyme), lipase (fat enzyme), and, amylase (carbo. enzyme).

    b. As nutrients pass through the S.I., more proteinases, lipases, and carbohydrases are secreted, eventually digesting food into monomers.

    c. The monomers are small enough to be absorbed into the bloodstream by villi (fingerlike projections rich in capillaries).

6. Undigested material passes to the large intestine.

    a. Water is absorbed (usually…).

    b. Bacteria produce vitamins (B & K) which you absorb.

    c. The remainder (feces) is stored in the rectum and then eliminated through the anus.

Unit 3 Notes

I. Living Systems as Compartments

A. In order to maintain a relatively stable internal environment, living systems are compartmentalized into cells.

1. The membrane surrounding a cell's cytoplasm (interior) must allow a degree of exchange with the environment.

2. Water, food, building materials, gasses and ions must be able to enter the cell.

3. Wastes and cell products must be able to leave.

B. To facilitate both its exchange and environmental separation roles, the cell membrane is selectively permeable.

1. Structurally, the plasma membrane is composed of a phospholipid and protein bilayer.

a. The phospholipids are composed of a polar phosphate group attached to two nonpolar fatty acid chains.

i. The polar (hydrophilic) end faces the watery interior and exterior of the cell.

ii. The nonpolar (hydrophobic) lipid tails face each other (away from water) forming two layers.

b. Proteins, glycoproteins, cholesterol, and glycolipids are sprinkled throughout both sides, sometimes bridging the two layers.

c. The membrane is referred to as a "fluid mosaic model" because individual pieces are free to flow around each other.

2. The size, polarity, and charge of substances affect their ability to pass freely through the membrane.

   a. Small, nonpolar, uncharged molecules pass though with ease (O_2, CO_2, N_2).

   b. Polar molecules can make it across if they are small and uncharged (H_2O, glycerol, ethanol).

   c. Small ions (Na^+, H^+, etc.) and larger, polar molecules (amino acids, glucose, nucleotides) must pass through special transport proteins.

II. How Cells Exchange Materials

A. The random motion of particles in solution cause substances to diffuse from high to low areas of concentration.

1. Concentration gradients are caused by a difference in concentration of molecules across a distance.

   a. Particles naturally move down the concentration gradient, but require energy to move against it.

   b. If particles (H^+, Na^+, etc.) are prevented from moving down the conc. grad. by a membrane, potential energy can be stored like a dam.

2. Osmosis is the diffusion of water across a selectively permeable membrane.

   a. If a cell is in pure water (hypotonic sol'n), water diffuses into the cell from high water conc. outside the cell.

      i. Animal cells will swell and possibly rupture.

      ii. Cell walls in plants and fungi prevent bursting, instead building turgor pressure (crisp veggies).

   b. Cells in concentrated (hypertonic) solutions lose water and shrink.

   c. Isotonic solutions have the same concentration of water as the cell and do not cause diffusion.

3. Diffusion rates depend mainly on two factors.

    a. Steep concentration gradients cause quick diffusion.

    b. Large surface area to volume ratios decreases the distance from the outside of the cell to its center (improves time of diffusion to the center, whatever the rate of diffusion).

B. Many substances must pass through transport proteins rather than directly across plasma membranes by diffusion.

1. Passive transport allows diffusion without input of energy.

    a. Molecules going down their concentration gradient through transport proteins use facilitated diffusion.

    b. The proteins are either open channels or attach to and carry specific molecules across the membrane.

2. In active transport, substances are moved across a membrane against their concentration gradient.

    a. Transport proteins can accomplish this in two ways.

        i. ATP is decomposed into ADP + P_i.

        ii. Movement of one substance against its gradient is coupled to the movement of another substance with its gradient.

    b. Very large molecules (even cells) are moved by the cell membrane forming a pocket around the substance and moving it in (endocytosis) or out (exocytosis) of the cell.

III. Gas Exchange in Multicellular Organisms

A. For aerobic organisms, the basics of gas exchange are fairly universal.

1. O_2 is used by cells during respiration, resulting in low concentrations inside the cell (gradient points in).

2. CO_2 is produced by cells during respiration, resulting in high conc. inside the cell (gradient points out).

3. The gasses must be dissolved in liquid for the exchange.

4. Surface area available for gas exchange is important.

    a. "Simple" organisms with a high surface area to volume ratio can perform direct gas exchange (at the expense of a less controlled internal environment).

    b. Indirect gas exchange requires organs (lungs, gills, etc.) to increase blood-gas surface area and circulation to increase tissue-gas surface area inside the body.

B. Gas exchange in water is done directly or by gills.

1. Gills are made of many thread-like filaments containing a capillary network that is exposed to the water.

2. The huge blood-water surface area uses countercurrent flow to maintain concentration gradients, maximizing gas exchange.

C. Gas exchange with air is done directly or by internal exchange.

1. Air has more O_2 than water, but tends to dehydrate organisms.

    a. Direct exchangers are slimy, leaving them prone to dehydration if they are not under cover (worms, etc.).

    b. Internal exchangers dedicate internal space to gas exchange (lots of surface area), decreasing water loss.

2. Small animals (insects, etc.) have many small, internal tubes (trachea) directly connecting the outside to internal tissues. (Spiracles prevent water loss.)

3. Many land animals use lungs for gas exchange.

    a. Air is warmed, moistened, and cleaned by cilia and mucus as it travels down the nasal passage, trachea, bronchi, and bronchioles.

    b. Fresh air is mixed with some old air in the alveoli (poor concentration gradient, better water retention) where O_2 and CO_2 diffuse in/out of capillaries.

4. Plants allow gasses into their leaves through openings called stomates.

    a. Guard cells govern the size of stomates through osmosis (swelling and opening when full of water).

    b. When closed, water loss (transpiration) is minimized.

IV. Waste Removal

A. Depending on environment and body structure, organisms can demonstrate a variety of strategies to deal with wastes.

1. Simple organisms (large s.a. to v. ratio) can excrete all wastes (H_2O, ammonia, CO_2, etc.) directly through their external surface.

2. More complex animals require special organs and metabolic techniques to deal with wastes.

    a. Salt-water fish have specialized cells in their gills to excrete excess salt; sea-turtles cry a lot; seagulls have salty "snot."

    b. Ammonia (produced from protein and nucleic acid metabolism) is a problem because of its toxicity.

        i. It can be secreted directly if surrounded by water.

        ii. Some animals convert it to urea (less toxic) which is put into solution before excretion.

        iii. Birds and some desert reptiles convert ammonia to uric acid which can be excreted as crystals, requiring little water loss.

B. The human urinary system is composed of the kidneys w/ associated blood vessels (filters blood; forms urine), ureters (connect kidneys w/ bladder), urinary bladder (urine storage), and urethra (allows urine to exit the body).

   1. Each kidney has ~1 million nephrons which clean ~2000 L of blood/day by filtration, reabsorption, and secretion.

      a. Pressure forces blood plasma from the glomerulus into Bowman's capsule.

      b. Glucose and small proteins are actively transported into the blood while in the proximal convoluted tubule.

      c. Water diffuses from the descending loop of Henle to surrounding, hypertonic tissues. (filtrate conc. □)

      d. The ascending limb of the l. o. H. is permeable to salts rather than water – salt diffuses out or is actively transported out of the loop depending on location.

      e. In the distal convoluted tubule, water diffuses out while substances such as ammonia, drug "leftovers", and ions may enter through secretion.

      f. As urine moves through the collecting duct, water diffuses into surrounding hypertonic tissues.

   2. Hormones can be used to help regulate levels of wastes.

      a. Aldosterone decreases K^+ reabsorption and increases K^+ secretion so more is excreted when appropriate.

      b. Antidiuretic hormone increases nephron permeability to H_2O, increasing reabsorption when appropriate.

Unit 4 Notes
Cell Structure and Function

I. The Basic Unit of Life

A. The cell theory was proposed after hundreds of years of microscopy.

1. In 1665 Robert Hook discovered cells by examining thin slices of cork with a crude, compound microscope.

2. Near the end of the 1600's, Anton van Leeuwenhoek observed microorganisms leading to the idea of single celled organisms.

3. In 1831 Robert Brown discovered and named the cell nucleus.

4. In the late 1830's Schleiden and Schwann suggested that plants and animals are made of cells (respectively).

5. After numerous scientists observed cell division, Rudolf Virchow hypothesized: "All cells come from cells."

6. Most simply, the cell theory states:

a. Cells and their products are the units of structure and function in organisms.

b. All cells come from preexisting cells.

B. Advances in technology helped scientists move beyond thinking of cells as tiny blobs of jelly.

1. Improvements in lens grinding microscope construction have lead to compound light microscopes that can magnify images by over 1000x (limited by nature of light).

2. Discoveries in cell staining and slide preparation have made samples easier to see.

3. Electron microscopes (developed in the 1930's) can magnify objects by over 1,000,000x (0.5 nm) – enough to see the structure of molecules such as DNA.

a. Specimens must be dead.

b. Sample preparation can alter the structures observed.

C. There are two basic types of cells.

1. Prokaryotes (bacteria) are very simple, small (~1 – 5 μm across) and extremely adaptable, living in a wide variety of extreme and mild habitats.

2. Eukaryotes (protists, fungi, plants, & animals) are larger (~10 – 50 μm) and more complex.

   a. They have many parts with specific functions, allowing the development of many specialized tissues.

   b. They also contain membrane-bound inner compartments such as chloroplasts, mitochondria, and a nucleus (contains DNA).

II. Cell Structure

A. Prokaryotes have relatively few structures.

1. Cell wall: protection; made of carbohydrates, lipids, and proteins (but no cellulose); composition affects staining.

2. Plasma membrane: sel. perm.; inside cell wall.

3. Nucleoid: location of a single, circular piece of DNA (attached to plasma membrane).

4. Plasmids: much smaller pieces of DNA w/ very few genes.

5. Flagella: whiplike propeller used for swimming.

6. Ribosomes: small body of protein and RNA; assembles amino acids into proteins based on mRNA it reads.

B. Eukaryotes are divided into many small parts (organelles), each with its own structure and function.

1. Cell wall: plants (cellulose); fungi (chitin)

2. Plasma membrane: of course.

3. Nucleus: most noticeable organelle; genetic control center.

   a. A double layered nuclear membrane surrounds the chromosomes (DNA wrapped around histones).

   b. Nucleolus: concentrated drop of RNA which aids in protein synthesis (makes ribosomes).

4. Cytosol: protein rich semi-fluid material; bathes organelles; (cytoplasm is the cytosol <u>and</u> organelles).
5. Cytoskeleton: composed of microtubules, intermediate filaments, and microfilaments; cell shape, organelle organization & movement, cell movement.

6. Ribosomes: slightly different structure than prokaryotic ribo's, but same function.

7. Endoplasmic reticulum (ER): membrane "conveyer belt" for protein transport between organelles; rough kind has ribosomes attached, smooth kind does not.

8. Golgi apparatus: looks like smooth ER; modifies cell products and packages them into membrane bound vesicles for delivery to organelles or outside the cell.

9. Lysosomes (in animals): digestive enzyme containing vesicle; break down old cell parts, digest food, kill bacteria.

10. Vacuoles (in plants): storage container for water, organic acids, digestive enzymes, salts, pigments, etc.; big.

11. Centrioles: paired bundles of microtubules; help organize DNA during cell reproduction.

12. Cilia and flagella: membrane wrapped microtubule bundles (9 x 2); which provide locomotion and substance movement w/ use of ATP.

III. Multicellular Organization

A. Unicellular organisms can cooperate as a colony in ways that give them advantages over isolated organisms.

1. Bacterial colonies can form biofilms to help slow diffusion, stay attached to a surface, and regulate external conditions (pH, food and water conc., etc.).

2. Protists (ex: Volvox) can cluster cells together, forming large colonies that coordinate cell activities (ex: movement) and have a degree of cell specialization (ex: reproduction).

B. Multicellular organisms require many types of cells that carry on basic life activities *and* a special function.

1. A tissue is a group of cells with the same specialization that work together. (muscle, epithelial, nervous, etc.)

2. Various tissues can be arranged to form an organ with a specific function (ex: heart, lung, fruit).

3. A group of organs can be incorporated into a system which performs a set of related functions (ex: digestive).

C. Systems generally deal with problems inherent of organisms composed of billions of cells.

1. Most systems are necessary for the following reasons:

a. Highly specialized cells require a division of labor.

b. Regulation and coordination of large numbers of cells is essential.

c. Most cells are not in direct contact with the outside environment.

2. Some systems have evolved functions that are not directly related to their original function (ex: white blood cells).

Unit 5 Notes

I. Photosynthetic Structures and Pathways

A. Photosynthesis consists of two groups of reactions in two separate regions of the chloroplast.

1. The light reactions occur on the thylakoid membranes – water is consumed and energy rich molecules are produced.

2. The Calvin cycle occurs in the stroma -- the energy rich molecules and CO_2. are consumed to make three carbon sugars.

3. The overall equation for photosynthesis is:

$$3\ CO_2 + 3\ H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_3H_6O_3 + 3\ O_2$$

B. The light reactions generate supplies for the Calvin cycle.

1. Light excites electrons in photosystem II (PSII), causing them to leave for the electron transport chain (e.t.c.).

2. An enzyme near the reaction center of PSII splits water, supplying e^- for the e^- "hole", H^+, and O_2 gas as a waste product ($2\ H_2O \rightarrow 4\ H^+ + 4\ e^- + O_2$).

3. As the excited e^- are passed down the e.t.c., much of their energy is used to actively transport H^+ into the thylakoid interior.

4. The e.t.c. passes the lower energy e^- to PSI where they get an energy boost from the light captured there.

5. These excited e^- are used to reduce $NADP^+$ into NADPH.

6. The other energy rich molecule, ATP, is produced using unequal concentrations of H^+.

   a. The combination of H^+ produced from splitting water, H^+ transported by the e.t.c., and H^+ removed by NADPH builds a H^+ gradient pointing out of the thylakoid.

   b. H^+ diffuses out of the thylakoid membrane through ATP synthetase, providing energy for ATP synthesis.

7. In summary, the light energy captured by PSII and PSI is used to create products (ATP and NADPH) for the Calvin cycle and O_2 gas as a waste product.

C. The Calvin cycle is a series of enzyme catalyzed steps (carried out in the stroma) that use the energy from ATP and NADPH to convert CO_2 into stable, easily transported sugars.

1. 3 CO_2 enter through stomates and are attached (carbon fixation) to 3 5-carbon compound (RuBP) producing 3 unstable, 6-carbon compounds. This step is catalyzed by the enzyme RuBisCO.

2. The 3 6-C compounds immediately split to form 6 3-C molecules of PGA.

3. In two enzymatic steps, 6 ATP and 6 NADPH are used to produce 6 3-C molecules of PGAL.

4. One of these PGAL (3-C) leaves the cycle to be used for maintenance and growth.

5. The remaining 5 3-C molecules of PGAL are converted back into 3 5-C molecules of RuBP (3 ATP are used for this) to begin the cycle again.

D. The 3-C PGAL molecules are used for various purposes.

1. Simple sugars such as sucrose can be made for respiration or transport to other regions of the plant.

2. Starches and lipids can be made for energy storage.

3. With the addition of NH_3, amino acids can be synthesized.

4. With the addition of NH_3 and phosphates, nucleic acids can be synthesized.

II. Photosynthesis and the Environment

A. Light intensity, temperature, O_2, and the availability of water, CO_2, and nutrients all affect the rate of photosynthesis.

1. Increasing light intensity promotes photosynthesis up to the point of photoinhibition (OH^- and H_2O_2 created).

2. The rate of photosyn. increases with temperature until protein shape, gas solubility, and stomate size are affected.

3. Increases in CO_2 conc. and water uptake increase the rate of photosyn. until other limiting factors are fully "taxed."

4. The factor(s) in shortest supply have the greatest effect on the rate of photosynthesis.

B. Photorespiration slows photosynthesis in many plants (C_3), but some have evolved ways around it.

1. In the Calvin cycle, RuBisCO can bind O_2 instead of CO_2 (similar shape) causing the loss of a previously fixed CO_2.

2. Two groups of plants (C_4 & CAM) have evolved ways to reduce photoresp. and aid survival in hot, dry climates.

a. C_4 plants (sugarcane, corn, crabgrass, etc.) fix CO_2 outside of the Calvin cycle, away from rubisco.

i. Mesophyll cells (exposed to gas pockets inside the leaf) use a different enzyme (PEP carboxylase) to fix CO_2. This step creates a 4-C acid.

ii. The 4-C acid delivers the CO_2 to RuBisCO in the bundle sheath cells surrounding leaf veins.

iii. The high conc. of CO_2 around RuBisCO inhibits photoresp., increasing photosyn. by up to 50%.

b. CAM plants (found in hot, arid regions) separate CO_2 fixation with time rather than location (seen in C_4).

i. Stomates are open at night (conserving water) allowing CO_2 to be fixed by organic acids.

ii. During the day, enzymes release the CO_2 from the acids, making it available for the Calvin cycle.

iii. This process is inefficient, causing slow growth.

III. Chemoautotrophy

A. Chemoautotrophs (c.a.t.) are bacteria that oxidize inorganic chemicals to gain energy for carbon fixation.

1. Generally, this does not provide as much energy as photosynthesis or heterotrophy.

2. C.a.t. do not compete well with other organisms for resources, so they must live where others can't.

3. Like photoautotrophs, c.a.t. fix use electron transport to generate ATP and NADPH for the Calvin cycle where CO_2 is fixed.

4. C.a.t. are best off using highly reduced "foods" such as H_2 or S, but will use less reduced ones depending on availability and competition.

B. C.a.t. help shape Earth's environment and may make up the majority of life on the planet.

1. Oxidized products of c.a.t. metabolism form important mineral deposits (S, Fe, Cu, Mn, etc.).

2. Nitrogen-oxidizing bacteria convert ammonium ions (NH_4^+) into nitrites (NO_2^-) and nitrates (NO_3^-) which are important for plants.

3. C.a.t. are the primary producers around deep water volcanic vents and deep underground in the pores of rocks.

Unit 6 Notes: Cellular Respiration

I. An Overview of Cell Respiration

A. Cell respiration is a decomposition pathway that provides energy (ATP) by oxidizing organic foods into CO_2 and H_2O.

1. In aerobic respiration, oxygen is the oxidizing agent that gets e^- from the decomposed food.

a. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + energy

b. One glucose releases more energy than is needed for a single reaction, so many ATP are formed instead.

2. Anaerobic respiration occurs without O_2, using a waste product, a N compound, or a S cmpd. instead.

a. The food is not fully decomposed so it does not release as much energy.

b. Many organisms can store the reduced, energy rich waste products for use later.

B. There are four main stages of aerobic respiration that take place in two parts of the cell.

1. Glycolysis (in cytoplasm) partially oxidizes glucose into two 3-C compounds, releasing a small amount of ATP.

2. The 3-C compounds enter mitochondria, lose a CO_2 (now 2-C) and are bound by coenzyme A.

3. Coenzyme A delivers the 2-C compounds to the Krebs cycle in the matrix of mitochondria.

a. The 2-C compounds are completely oxidized into CO_2.

b. The energy released is used to form some ATP and to reduce NAD^+ into NADH and FAD^+ into $FADH_2$.

4. Still in the mitochondria, NADH & $FADH_2$ drop off e^- and protons at an electron transport chain.

a. High energy e^- are used to actively transport H^+ ions across a membrane (diffusion for lots of ATP).

b. Oxygen accepts the e^- at the end of the e.t.c. and combines with hydrogen to form water.

c. Lack of oxygen as an e^- acceptor backs up (shuts down) both Krebs cycle and the e.t.c.

II. The Reactions of Respiration

A. Glycolysis begins both aerobic and anaerobic respiration.

1. Two enzymatic steps each use an ATP to modify glucose.

2. The 6C molecule now splits into 2 – 3C sugar phosphates. (PGAL may enter here; carbon skeletons available)

3. More enzymatic reactions partially oxidize the two sugar phosphates into two molecules of pyruvate (3C).

a. 2 NADH and 4 ATP are formed.

b. Net yield: 2 NADH and 2 ATP.

4. If sufficient O_2 is present, each pyruvate will go on to a mitochondrion.

5. Insufficient O_2 causes fermentation of pyruvate.

a. NAD^+ is needed for the ATP yielding steps of glycolysis to occur.

b. NADH reduces pyruvate into lactate, alcohol, or acetic acid (vinegar), providing the needed NAD^+.

B. Once inside a mitochondrion, pyruvate must be converted before any carbon is added to the Krebs cycle.

1. Enzymes cause pyruvate to release a molecule of CO_2, forming acetic acid (2C).

2. Acetic acid is oxidized (reducing NAD^+), forming acetate.

3. Coenzyme A binds to acetate (now acetyl-CoA) and delivers it to the Krebs cycle in the matrix.

C. The Krebs cycle completely oxidizes acetate.

1. CoA drops acetate off which is picked up by a 4C compound (oxaloacetate), forming the 6C compound citrate.

2. A series of enzymatic reactions form the following:

a. 2 CO_2

b. 3 NADH and 1 $FADH_2$

c. 1 ATP

3. 2 acetate from each glucose → double products above

4. The end of the Krebs cycle regenerates oxaloacetate.

D. The electron transport chains use NADH and $FADH_2$ to produce ATP.

1. Cytochromes (e^- transport proteins) imbedded in the inner mitochondrial membrane separate H atoms into protons (left in the matrix) and electrons.

2. As e^- are passed down the chain, the energy they release allows enzymes to actively transport protons. ⇑$[H^+]$

3. The H^+ diffuse through ATP synthetase → ATP.

4. Each NADH provides enough energy for 3 ATP while each $FADH_2$ yields 2 ATP.

5. O_2 is the final e- acceptor – if it is not available, the e.t.c. clogs up and will not operate.

E. Various species have varying needs for O_2.

1. Obligate aerobes (us included) can't survive long w/o O_2.

2. Obligate anaerobes use glycolysis and/or fermentation for all their energy needs (O_2 can be poisonous).

3. Facultative aerobes generally prefer to use aerobic resp., but can go for long periods of time w/ anaerobic resp.

III. Respiration and Cellular Activities

A. Fats and proteins may also be used to generate ATP.

1. When lipids are broken down, glycerol enters glycolysis while the fatty acids are converted into acetate.

a. Glycerol can contribute to anaerobic processes.

b. The fatty acids must have O_2 available to become oxidized in the Krebs cycle.

2. Before they are used for energy, proteins must be broken into amino acids and have the amine group removed.

a. NH_3 is formed and is usually converted to urea or uric acid before excretion from the body.

b. The resulting 4C (oxaloacetate) or 5C (ketogluterate) acids can enter the Krebs cycle.

B. Like glycolysis, compounds can be removed from the Krebs cycle to provide carbon skeletons for biosynthesis.

C. Many organisms use respiration for heat production.

1. Warm blooded animals release enough heat to keep their body temperature fairly stable.

2. Alternate respiration pathways in specialized mitochondria release more heat and less ATP than normal.

a. Brown fat (LOTS of mito's) can rapidly raise the temperature of hibernating, small, and/or hairless animals.

b. Some plants have an alternate e.t.c. branch which raises their temp. for producing odors (pollination) or melting snow.

D. The rate of respiration is controlled by supply and demand.

1. When energy demands are low, excess blood glucose is converted to glycogen or fat.

2. When demands are high, glycogen is broken down to supply blood glucose (fats and proteins may also be used, especially when glycogen supply runs low).