SAT Biology Review: Biochemistry & Cellular Biology

I. Biology is the study of living things. Living things have the following characteristics (though this list varies):

1- **The Cell Theory**: all life made up of one or more cells; cells are the smallest unit of structure and function; cells can only arise from other cells. Understand how viruses are different.

2- Reproduce: organisms pass on their characteristic to a new generation.

3- Grow and repair: all organisms can repair injuries, replace worn out proteins and other molecules, and increase the size of their cells or multicellular organisms.

4- Nutrition: all cells must take in material (heterotrophy) or create material (autotrophy) for use as building blocks for growth and repair, and for burning (respiring) for energy.

5- Movement: every life form moves, be it as obvious as an animal running to the invisible movement of ions across a membrane.

6- Response to stimuli: every life form can sense the outside environment and react to those conditions.

7- Homeostasis: every life form can keep its internal conditions (ion concentrations, temperature, water levels) at a stable level no matter how the outside environment fluctuates.

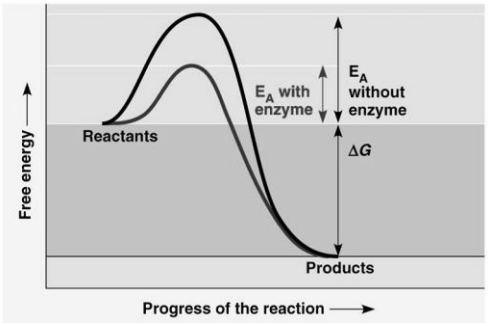
II. Simple biochemistry

Biomolecule	**Monomers**	**Polymers**	**Function**
Carbohydrates	Simple Sugars end in *-ose* (*e.g.*, glucose, lactose maltose)	Starch (plants) or glycogen (animals) Cellulose Chitin	Energy Storage Cell wall of plants Cell wall of fungi, Exoskeleton of arthropods
Proteins	Amino Acids (20 different types) proteins end in *-in* (*e.g.*, keratin) enzymes end in *-ase* (*e.g.*, peptidase)	Proteins (also called polypeptides)	Primary structural component of cells Enzymes: speed up rate of chemical reactions by lowering activation energy. Are not used up in the reaction others....
Lipids	Fatty acids and glycerol	Lipids	Long term energy storage Steroid Hormones Membranes
Nucleic Acids	Nucleotides	DNA RNA also ribozymes	Long term coding of information Short term coding of information RNA catalysts

III. Protein chemistry and enzymology

Proteins are long polymers (chains) of amino acids. The shape of proteins can be described at four levels: Primary (1°) structure is the order of the individual amino acids in the chain. Secondary (2°) structure is usually described by two forms that the amino acids fold into: α-helixes (coils) and β-pleated sheets (regular folds). Tertiary (3°) structure is the overall 3-D shape of the protein. Quaternary (4°) structure is not present in all proteins, and occurs when multiple protein subunits work together to form a large structure.

Enzymes are proteins that act as catalysts: they can lower the activation energy ($\mathbf{E_A}$) of a chemical reaction (though **ribozymes**—RNA that act as catalysts—are becoming more and more important). They orient their **substrate** (the reactant) in such a way that covalent bonds can be easily broken or formed. The substrate binds in the **active site**, a specially shaped pocket that the substrate fits in. The shape of the active site is so precise, only one substrate out of millions of different chemicals can fit inside—thus enzymes are very specific. A problem with this precise fit in the active site is that enzymes are especially sensitive to **denaturing** by heat and pH changes.



Enzymes can be regulated by control molecules. These **regulators** can activate enzymes (turn them on) or shut them down through **competitive inhibition** (the regulator competes with the substrate to plug the active site) or **noncompetitive inhibition** (the regulator binds to its own special site, and shuts down the enzyme).

IV. Cell Biology.

All life is composed of one or more cells. This is a basic biological law, called the **Cell Theory**. A cell is the basic unit of structure and function for an organism. Anything smaller than a cell cannot carry out all of the functions of life, and therefore are not considered "alive." A final point of the cell theory is that all cells must come from preexisting cells (**biogenesis**).

The SAT test emphasizes three primary types of cells (though there are more): prokaryotic, animal, and plant. The differences between these three are very important, and should be memorized.

All cells are simply huge collections of biological molecules suspended in water, locked away in a protective fat layer. The fat layer is the outer boundary of the cell, called the **cell membrane**. It is composed of a bilayer of **phospholipids**, fat molecules with a phosphate group attached. With the lipids at one end of the molecule and the phosphate group at the other end, the molecules have both a **hydrophobic** and **hydrophilic** end (amphoteric), which gives the membrane its unique chemical characteristics. Cell membranes are **selectively permeable**, which means they let some molecules pass through, and restrict others. Membranes are studded with proteins that serve as transporters, serving either as tunnels through the membrane for molecules to pass through, or as pumps that grab molecules and pull them through the membrane (these last ones are powered by ATP). Only active transport pumps can move material against its concentration gradient.

Some cells, like those of bacteria, plants, fungi, and some protists, also have a protective **cell wall**. This wall gives the cell shape, serves as a barrier from debris, and most especially stops osmotic swelling. However, from a molecular standpoint, the cell wall is built like a chain-link fence, with large openings that allow almost all molecules to pass with ease. As a result, it is completely permeable. Bacterial cell walls are made of sugar-protein chains (peptidoglycan), plant cell walls are made of cellulose (chains of glucose), protistal cell walls vary and can be made of such things as cellulose and glass, and fungi cell walls are made of chitin (chains of glucose with different linkages than cellulose).

The interior of the cell is called the **cytoplasm**. The cytoplasm is very thick, like oatmeal. It consists of all the enzymes, proteins, organelles, and molecules that make up a cell packed very closely together. The little spaces between the molecules are packed with water.

Within the cytoplasm are the large molecules like the **ribosomes** (protein and RNA complexes that make proteins) and DNA.

Eukaryotes also have these specialized structures:

-**Nucleus**: a membrane bound sack that encloses the DNA. These often have dark patches called the **nucleolus**, the area in the nucleus where DNA encoding the parts of ribosomes are found. Bacteria do not have nuclei: their DNA floats free inside the cell. Cells with nuclei are Eukaryotic. Those without are prokaryotes. The only prokaryotes are bacteria.

-**Endoplasmic Reticulum** (ER): a series of tubes made up of phospholipids that extend throughout the entire cell. They serve as transport tubes for new proteins. Rough ER contains ribosomes, smooth ER does not.

-**Golgi bodies**: a set of stacked membranes (they look like stacks of plates or pancakes) that receive proteins from the ER and package them into sacks called vesicles. Vesicles packed with digestive enzymes are called lysosomes.

-**Mitochondria**: found in all eukaryotic cells, these structures are the site of energy production. Here, glucose ($C_6H_{12}O_6$) is broken down into CO_2, and the energy released from the breaking of the bonds stored in the all-purpose energy molecule adenosine triphosphate (ATP).

$$C_6H_{12}O_6 + 6O_2 + 38ADP + 38P_i \rightarrow CO_2 + H_2O + \sim 38ATP$$

-**Chloroplasts**: only in plants, these structures are the site of photosynthesis, or the use of light energy to fix inorganic CO_2 into organic sugar for the cell's use. The light reactions produce ATP and electrons, and occur in the **thylakoid** membranes. The Calvin cycle, or dark reactions, occur in the **stroma**, and fix carbon dioxide into glucose.

$$6CO_2 + 6H_2O + ATP \rightarrow C_6H_{12}O_6 + ADP + P_i + 6O_2 + 6H_2O$$

It takes about 55 ATP equivalents to make one molecule of glucose (remember that cells get only 38 ATPs from a molecule of glucose when it is respired in the mitochondria). The plant's energy expense is enormous. The only way it can afford to invest the energy to make its own sugar is by using the energy of the sun.

-**Centrioles**: only in animals, these paired cylinders are used to pull the chromosomes to opposite ends of the cell in mitosis and meiosis.

Summary:

Prokaryote	Eukaryotic Plant	Eukaryotic Animal
Cell Membrane Ribosomes	Cell Membrane Ribosomes Vesicles	Cell Membrane Ribosomes Vesicles
Cell Wall	Cell Wall	
	Nucleus ER Golgi Bodies Mitochondria	Nucleus ER Golgi Bodies Mitochondria
Some have chlorophyll and photosynthesize, but no chloroplasts	Chloroplasts	Centrioles (for reproduction)
	Tend to have a large vacuole in center of cell	