THE CHEMICAL BUILDING BLOCKS OF LIFE…….. THE GRAND SCHEME

1. **PROTEINS**

Define what a protein is and/or of what it is made. *(Being in favor of young people is not a valid answer)*

Protein: A protein is a 3D polymer constructed from a set of 20 different monomeric units called amino acids. Proteins consist of one or more polypeptide chains folded into a unique three-dimensional shape or conformation. Each polypeptide chain consists of a particular unique sequence of amino acids. This sequence is referred to as the protein's primary structure, and it determines the chemical properties and further structures of the protein. The pleated folding or helical coiling of the chain is called the secondary structure of the protein. The tertiary structure refers to the complex, three-dimensional globular structure assumed by some proteins as their polypeptide chains bend and ball up. Finally, a protein is said to have a quaternary structure if it has more than one polypeptide chain; quaternary structure refers to how these chains are shaped and associated with each other. The structure of a protein is responsible for the way it functions.

Define all the different functions that a protein may have.

Enzymes - catalytic activity, carry out biological chemical reactions and functions A ---> B
Transport Proteins - bind & carry molecules from one point to another
Storage Proteins - store amino acids (C, H, O, & N) for later use
Ex: ovalbumin (egg white), ferretin iron protein of bacteria), casein (a milk protein)
Contractile - can contract, change shape, responsible for movement (actin and myosin in muscle) make up the elements of cytoskeleton & muscles
Structural - Support... collagen of tendons; elastin of ligaments; keratin of hair & feathers; fibroin of silk & spider webs.
Defensive - protect: make up antibodies (IgG, etc…), fibrinogen & thrombin (coagulation protein of blood), snake venom's (phosphodiesterases enzymes digest nucleic acids)
Regulatory - regulate many metabolic processes, i.e., hormones and internal physiological control, transcription factors & enhancers, which help DNA genes make other proteins

NUCLEIC ACIDS

Define what a nucleic acid is and/or of what it is made. How many different kinds of nucleic acids can you name? Which Came First, DNA or RNA and why?

Nucleic acids store and transmit hereditary information. Genes are the units of inheritance, which determine the primary structure of proteins. **Nucleic acids** are macromolecules that carry and translate this code. **DNA, deoxyribonucleic acid,** is the genetic material that is inherited from one generation to the next and is reproduced, cell division (mitosis and meiosis) in each cell of an organism. **RNA, ribonucleic acid,** reads the instructions coded in DNA and directs the synthesis of proteins, the ultimate enactors of the genetic program. In a eukaryotic cell, DNA resides in the nucleus and messenger RNA carries the instructions for protein synthesis to ribosomes located in the cytoplasm.

DNA molecules consist of two chains of nucleotides spiraling around an imaginary axis in a **double helix.** In 1953, Watson and Crick first proposed this double helix arrangement, which consists of two sugar-phosphate backbones on the outside of the helix with their nitrogenous bases pairing and hydrogen-bonding together on the inside. Adenine always pairs with only thymine; guanine always pairs with cytosine. Thus, the sequences of nitrogenous bases on the two strands of DNA are complementary to each other. Because of this specific base-pairing property, DNA can replicate itself and precisely copy the genes of inheritance.

There are at least 6 different types of nucleic acids: 1) **DNA**, the genetic material of most cells, 2) ribosomal RNA (**rRNA**) which makes up the ribosome, the site of protein synthesis in cells, 3) transfer RNA (**tRNA**) which carries an amino acid to the ribosome for protein synthesis, 4) messenger RNA (**mRNA**) is a complementary copy of the DNA genes, which codes for the amino acid sequence in a newly made protein, 5) heterogeneous nuclear RNA (**hnRNA**) which is the primary copy of the DNA into an RNA product and is the precursor of mRNA, 6) small nuclear ribonuclear particles (**snRNP**) which is a particle like a ribosome that specifically cuts hnRNA into smaller pieces of mRNA.

Most nucleic acid biochemists, today, believe that RNA came before DNA. The main evidence to support this premise is: 1) the ability of some RNA's of today to replicate themselves, 2) the fact that some small RNA pieces, called introns, have catalytic activity and can cut other RNA molecules, and 3) the idea of complimentary templating, where a randomly assembled RNA can makes its own compliment, which can then make back the original RNA sequence. Remember, most of these observations are speculative and border on the realm of ironic science in that they are not fully experimentally testable hypotheses.

2. Some **KEY TERMS** in the Chemistry of Life. Define each of the terms given below:

macromolecule

a very large molecule, usually composed of a polymer of monomeric units linked together via condensation reactions into a long chain molecule. Examples include polysaccharides, proteins, and nucleic acids.

polymer

a chemical compound or mixture of compounds formed by polymerization and consisting essentially of repeating individual structural units (monomers)

enzyme

word derived from the Greek "*en- + zyme"* leaven (1881)**:** any of numerous complex proteins that are produced by living cells and catalyze specific biochemical reactions at body temperatures

active site

The active site is an enzyme's catalytic center: *a closer look….* The substrate is held in the active site by hydrogen or ionic bonds, creating an enzyme-substrate complex. The side chains (R groups) of some of the surrounding amino acids in the active site facilitate the conversion of substrate to product. The product then leaves the active site, and the enzyme can bind with another substrate molecule.

Enzymes can catalyze reactions involving the joining of two reactants by providing active sites in which the substrates are bound closely together and properly oriented. An induced fit can stretch or bend critical bonds in the substrate molecule and make them easier to break. An active site provides a microenvironment, such as a lower pH, that is necessary for a particular reaction. Enzymes may also actually participate in a reaction by forming brief covalent bonds with the substrate.

The rate at which an enzyme molecule works partly depends on the concentration of its substrate. The speed of a reaction will increase with increasing substrate concentration up to the point at which all enzyme molecules are saturated with substrate molecules and working at full speed.

Peptide

A term commonly used by biochemists and biologists to describe very short proteins; any of various polymers that are made from two or more amino acids linked by a combination of the amino group of one acid with the carboxyl group of another; a byproduct obtained by partial hydrolysis of whole proteins.

Polypeptide

A linear chain of many amino acids; more than a peptide, but less than a protein? a term often used as analogous to the word 'protein'.

cofactor

Cofactors are small molecules that bind with enzymes and are necessary for enzyme catalytic function. They may be inorganic, such as -various metal atoms [Fe, Mn, Co, Zn, Mg], or large organic molecules called **coenzymes.** Most vitamins are coenzymes or precursors of coenzymes.

amino acid

Most **amino acids** are composed of an asymmetric carbon bonded to a hydrogen, a carbonyl group, an amino group, and a variable side chain called the R group. The R group confers the unique physical and chemical properties of each amino acid. Side chains may be either non-polar and hydrophobic, or polar or charged and thus hydrophilic. Acidic side chains contain carboxyl groups and are usually negatively charged; basic side chains contain an amino group and are usually, positively charged.

peptide bond

A **peptide bond** links the amino group of one amino acid with the carboxyl group of another, yielding a polymer of amino acids called a **polypeptide.** The polypeptide chain has a free carboxyl group at one end and a free amino group at the other end. Polypeptides vary in length, from a few amino acids to a thousand or more amino acids.

conformation

A protein's function depends on its specific **conformation,** which is any of the spatial arrangements of a molecule that can be obtained by rotation of the atoms about a single bond. Proteins have unique three-dimensional shapes created by the twisting or folding of one or more polypeptide chains. The unique conformation of a protein, which results from its sequence of amino acids, enables it to recognize and bind to other molecules.

primary structure, secondary structure, tertiary structure, quaternary structure.

Four Levels of Protein **Structure** There are three structural levels in the conformation, of a protein. A fourth level may be present when a protein consists of more than one polypeptide chain.
Primary structure is the unique, genetically coded sequence of amino acids within a protein. i.e., a slight deviation from the sequence of amino acids can severely affect a protein's function by altering the protein's conformation. In the early 1950s, Fred Sanger determined the primary structure of insulin through the laborious process of hydrolyzing the protein into small peptide chains, using chromatography to separate the small pieces, determining their amino acid sequences, and then overlapping the sequences of small fragments, created with different agents, to reconstruct the whole polypeptide. Most of these steps are now automated and can be done in an afternoon.

Secondary structure involves the coiling or folding of the polypeptide backbone, stabilized by hydrogen bonds between, the electronegative oxygen of one peptide bond and the weakly positive hydrogen attached to a nitrogen of another bond. An **alpha helix** is a delicate coil produced by hydrogen bonding between every fourth peptide bond. A **pleated sheet is** also held by repeated hydrogen bonds along the protein's backbone. This secondary structure forms when the polypeptide chain folds back and forth or when regions of the chain lie parallel to each other.

Interactions between the various side chains of the constituent amino acids produce a protein's **tertiary structure. Hydrophobic interactions** between non-polar side groups in the center of the molecule, hydrogen bonds, and ionic bonds between negatively and positively charged side chains produce the stable and unique shape of the protein. Strong covalent bonds, called **disulfide bridges,** may occur between the sulfhydryl side groups of cysteine monomers that have been brought close together by the folding of the polypeptide.

Quaternary structure occurs in proteins that are composed of more than one polypeptide chain. The individual polypeptide subunits are held together in a precise structural arrangement.

disulfide bridges

a covalent linkage between two sulfhydryl (SH) groups on the amino acids cysteine. Commonly joins or links two proteins or two different parts of the same protein together. ----S-----S----

enzyme inhibitors

Enzyme Inhibitors. Enzyme inhibitors selectively disrupt the action of enzymes, either by reversibly binding with the enzyme via weak electrostatic bonds or by irreversibly attaching often via covalent bonds. **Competitive inhibitors** compete with the substrate for the active site of the enzyme. Increasing the concentration of substrate molecules may overcome this type of inhibition. **Non-competitive inhibitors** bind to a part of the enzyme separate from the active site and change the conformational shape of the enzyme, thus impeding enzyme action. Many pesticides and antibiotics are inhibitors of key enzymes and act as metabolic poisons.

chaperone proteins (heat shock proteins)

Chaperone proteins help the intracellular folding of proteins. The amino acid sequences of hundreds of proteins have been determined. Using the technique of X-ray crystallography, coupled with computer modeling and graphics, biochemists have established the 3D shape of many of protein molecules. Researchers have developed methods for following a protein through its intermediate conformational states on the way to its final form and have discovered **chaperone proteins** which assist the folding of other proteins. Originally called heat shock protein, these molecules protect other proteins by changing their shapes and conformations. As protein folding becomes better understood, scientists are learning to produce amino acid sequences for proteins that will be able to perform predetermined functions.

globular proteins

any protein with an approximately rounded 3D shape. Most enzymes are globular shaped.

allosteric regulation

Allosteric Regulation (inhibition) regulation of enzyme activity by the binding of a regulator molecule to an **allosteric site,** a receptor site separate from the active site. Complex enzymes made of two or more polypeptide chains, each with its own active site may have allosteric sites located where subunits join. The entire unit may oscillate between two conformational states, and the binding of an activator (or inhibitor) stabilizes the catalytically active (or inactive) conformation. Allosteric enzymes are often critical regulators of metabolic pathways.

fibrous proteins

a protein with an elongated shape; typically one such as collagen or an intermediate filament protein, which are able to associate into long filamentous structures.

nucleotides

Nucleotides are the building block units of nucleic acids. Each nucleotide consists of a five-carbon sugar (ribose or deoxy-ribose), a phosphate group, and a nitrogenous base (A,U,G,C, and T). Nucleotides are also components of other biologically important compounds such as ATP and the coenzyme NAD^+.

phosphodiester bond

Nucleotides are linked together into a DNA polymer by **phosphodiester** covalent bonds, which join the phosphate of one nucleotide with the sugar of the next. The nitrogenous bases extend from this repeating sugar-phosphate backbone. The unique sequence of bases in a gene codes for the specific amino acid sequence of a protein.

purines

one of the two categories (pyrimidines being the other) of nitrogen-containing hetero-cyclic ring (2 rings) compounds found in DNA and RNA. Examples include adenine and guanine.

Pyrimidines

one of the two categories (purines being the other) of nitrogen-containing cyclic ring (1 ring) compounds found in DNA and RNA. Examples include cytosine, thymine, and uracil.

adenine (A), guanine (G), cytosine (C), thymine (T), uracil (U),

double helix

the typical conformation of a DNA molecule in which two strands are would around each other with hydrogen bonding base-pairing between the two strands

3. Match the following numbers with an appropriate statement. A number may be used more than once

Numbers: **0, 1, 2, 3, 4, 5, 6, 12, 20**

Statements:

a. the number __**5**___ of different nitrogenous bases in DNA
b. the number __**3**__ of different chemical classes of amino acids
c. the number __**2**__ of chains of nucleotides in a DNA molecule
d. the number __**4**__ of different nitrogenous bases in RNA
e. the number __**20**_ of different amino acids found in proteins
f. the number __**1**__ of chains of nucleotides in most RNA molecules

LEARNING CHECKLIST

1. What is the building block unit of proteins? How do these building blocks differ from each other?

The building blocks are amino acids, which are organic molecules that contain both an amino groups at one end and an acid group (carboxyl) at the other end. Alpha amino acids are those in which the amino group and the carboxyl group are linked to the same carbon atom. The amino acids differ from each other in the composition of a 'side group', which is a variable chemical group or chain called the R group. The R group confers the unique physical and chemical properties of each amino acid. Side chains may be either non-polar and hydrophobic, or polar or charged and thus hydrophilic. Acidic side chains contain carboxyl groups and are usually negatively charged; basic side chains contain an amino group and are usually, positively charged.

2. List three structural differences and one functional difference between DNA and RNA.

There are 3 structural differences between DNA and RNA; 1) DNA contains the sugar 2'-deoxy-ribose, while RNA contains the sugar 2'-ribose, which means at the number 2 carbon on the pentose sugar there is an OH group. Deoxy means there is no OH group at that position. 2) in RNA the nucleotide uracil commonly replace the nucleotide thymine found in DNA. The difference between Uracil and thymine is that uracil has no methyl group attached to the pyrimidine ring, while thymine does have the methyl group, and 3) RNA is usually single stranded, not double stranded.

PROVIDE THE APPROPRIATE TERM TO COMPLETE EACH STATEMENT.

1. The most abundant protein in your body is collagen which is a type of __**fibrous** _ protein.
2. __**aromatic**__ amino acids have side groups that contain an organic ring structure.
3. __**denaturation**__ refers to a protein losing its three dimensional structure.
4. Hereditary information is stored in macromolecules called __ **DNA and RNA**___?

BRIEFLY ANSWER EACH OF THE FOLLOWING QUESTIONS.

1. The double helix structure of DNA has been compared to a spiral staircase. What makes up the sides of the staircase and what the steps? What holds these parts together?
   The sides of the staircase are the sugar phosphate backbone of the individual nucleotides linked together through 3' to 5' phosphodiester covalent bonds. These backbone links are formed by a condensation reaction that eliminates water. Protruding from each sugar phosphate is the nitrogenous base molecules of the nucleotides (adenine, guanine, cytosine, or thymine). The two chains of the staircase are held together by hydrogen bonding between the nitrogenous bases.
2. What Determines Protein Conformation?
   Protein conformation is dependent upon the interactions among the amino acids making up the polypeptide chain and usually arises spontaneously as soon as the protein is synthesized in the cell. These weak molecular interactions can be disrupted by changes n pH, salt concentration, temperature, or other aspects of the environment, and the protein may **denature,** losing its native conformation and thus its function.
3. Can we use DNA and Proteins to monitor the progress of evolution? If so, How?
   We can use DNA and proteins as tape measure of evolution. Genes form the hereditary link between generations. Closely related members of the same species share many common DNA sequences and proteins. More closely related species have a larger proportion of their DNA and proteins in common. This "molecular genealogy" provides evidence of evolutionary relationships.
4. How does a cell's chemical and physical environment affect enzyme activity?
   Effects of Temperature and pH. The velocity (rate) of an enzyme-catalyzed reaction may increase with rising temperature up to the point at which increased thermal agitation begins to disrupt the hydrogen and ionic bonds and other interactions that stabilize a protein's conformation. A change in pH may denature an enzyme by disrupting the hydrogen bonding of the molecule. Each enzyme has a temperature and pH optimum at which it is most active.
5. Why would a change in pH cause a protein to denature?
   A change in pH will cause the weak electrostatic forces holding the protein in its specific conformation to change. Hydrogen bonds, ionic bridges, van der Waal's forces, hydrophilic, and hydrophobic interactions may changes thereby causing the loss of some 3D structure. When a native stable conformation is lost, the biological activity of the protein may be lost and it is said to be denatured.
6. A denatured protein may reform to its original functional shape when returned to its normal environment. What does that indicate about a protein's conformation?
   The 3D native conformation that a protein assumes under "its normal environment" is a very stables and non-energy-expending shape. While all the forces are weak molecular electrostatic forces, they do assume a "native conformation" at which the proteins is most energetically stable, thus there must be an optimal conformation at a given environment which is "best" for a protein. Remember, what is best in one specific environment may not be best at some later time.
7. Why would transfer to an organic solvent (such as alcohol) cause denaturation?
   Organic solvents, such as alcohols, compete for the available water of solvation, which is the water that helps solubilize molecules in an aqueous environment. As one increase the concentration of the alcohol, less and less water is available to solvate the protein, so it begins to precipitate. As a matter of fact, the use of organics solvents is a typical way of isolating and purifying proteins form a solution of soluble proteins.