**Making Proteins and Biotechnology Learning Objectives**

1. **DNA, and in some cases RNA, is the primary source of heritable information.**
   1. DNA and RNA molecules have structural similarities and differences that define function.
      1. Both have three components — sugar, phosphate and a nitrogenous base — which form nucleotide units that are connected by covalent bonds to form a linear molecule with 3' and 5' ends, with the nitrogenous bases perpendicular to the sugar-phosphate backbone.
      2. The basic structural differences include:
         1. DNA contains deoxyribose (RNA contains ribose).
         2. RNA contains uracil in lieu of thymine in DNA.
         3. DNA is usually double stranded, RNA is usually single stranded.
         4. The two DNA strands in double-stranded DNA are antiparallel in directionality.
   2. Both DNA and RNA exhibit specific nucleotide base pairing that is conserved through evolution: adenine pairs with thymine or uracil (A-T or A-U) and cytosine pairs with guanine (C-G).
      1. Purines (G and A) have a double ring structure.
      2. Pyrimidines (C, T and U) have a single ring structure.
   3. The sequence of the RNA bases, together with the structure of the RNA molecule, determines RNA function.
      1. mRNA carries information from the DNA to the ribosome.
      2. tRNA molecules bind specific amino acids and allow information in the mRNA to be translated to a linear peptide sequence.
      3. rRNA molecules are functional building blocks of ribosomes.
      4. The role of RNAi includes regulation of gene expression at the level of mRNA transcription.
   4. Genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a protein.
      1. The enzyme RNA-polymerase reads the DNA molecule in the 3' to 5' direction and synthesizes complementary mRNA molecules that determine the order of amino acids in the polypeptide.
      2. In eukaryotic cells the mRNA transcript undergoes a series of enzyme regulated modifications.*For example:*
         1. Addition of a poly-A tail
         2. Addition of a GTP cap
         3. Excision of introns
      3. Translation of the mRNA occurs in the cytoplasm on the ribosome.
      4. In prokaryotic organisms, transcription is coupled to translation of the message.
      5. Translation involves energy and many steps, including initiation, elongation and termination.
         1. ***X The details and names of the enzymes and factors involved in each of these steps are beyond the scope of the course and the AP Exam.***
         2. ***The important features include:***
            1. The mRNA interacts with the rRNA of the ribosome to initiate translation at the (start) codon.
            2. The sequence of nucleotides on the mRNA is read in triplets called codons.
            3. Each codon encodes a specific amino acid, which can be deduced by using a genetic code chart. Many amino acids have more than one codon.
            4. ***X Memorization of the genetic code is beyond the scope of the course and the AP Exam.***
            5. tRNA brings the correct amino acid to the correct place on the mRNA.
            6. The amino acid is transferred to the growing peptide chain.
            7. The process continues along the mRNA until a “stop” codon is reached.
            8. The process terminates by release of the newly synthesized peptide/protein.
   5. Phenotypes are determined through protein activities.*For example:*
      1. Enzymatic reactions
      2. Transport by proteins
      3. Synthesis
      4. Degradation
   6. Genetic engineering techniques can manipulate the heritable information of DNA and, in special cases, RNA.*For example:*
      1. Electrophoresis
      2. Plasmid-based transformation
      3. Restriction enzyme analysis of DNA
      4. Polymerase Chain Reaction (PCR)
   7. Illustrative examples of products of genetic engineering include:
      1. Genetically modified foods
      2. Transgenic animals
      3. Cloned animals
      4. Pharmaceuticals, such as human insulin or factor X
2. **Changes in genotype can result in changes in phenotype.**
   1. Alterations in a DNA sequence can lead to changes in the type or amount of the protein produced and the consequent phenotype.
      1. DNA mutations can be positive, negative or neutral based on the effect or the lack of effect they have on the resulting nucleic acid or protein and the phenotypes that are conferred by the protein.
3. **The subcomponents of biological molecules and their sequence determine the properties of that molecule.**
   1. In proteins, the specific order of amino acids in a polypeptide (primary structure) interacts with the environment to determine the overall shape of the protein, which also involves secondary tertiary and quaternary structure and, thus, its function. The R group of an amino acid can be categorized by chemical properties (hydrophobic, hydrophilic and ionic), and the interactions of these R groups determine structure and function of that region of the protein.
      1. ***X The molecular structure of specific amino acids is beyond the scope of the course and the AP Exam.***
   2. Proteins have an amino (NH2) end and a carboxyl (COOH) end, and consist of a linear sequence of amino acids connected by the formation of peptide bonds by dehydration synthesis between the amino and carboxyl groups of adjacent monomers.
4. **The structure and function of subcellular components, and their interactions, provide essential cellular processes.**
   1. Ribosomes are small, universal structures comprised of two interacting parts: ribosomal RNA and protein. In a sequential manner, these cellular components interact to become the site of protein synthesis where the translation of the genetic instructions yields specific polypeptides.
   2. Endoplasmic reticulum (ER) occurs in two forms: smooth and rough.
      1. Rough endoplasmic reticulum functions to compartmentalize the cell, serves as mechanical support, provides site-specific protein synthesis with membrane-bound ribosomes and plays a role in intracellular transport.