AP® Biology
2001 Sample Student Responses

These materials were produced by Educational Testing Service (ETS), which develops and administers the examinations of the Advanced Placement Program for the College Board. The College Board and Educational Testing Service (ETS) are dedicated to the principle of equal opportunity, and their programs, services, and employment policies are guided by that principle.

The College Board is a national nonprofit membership association dedicated to preparing, inspiring, and connecting students to college and opportunity. Founded in 1900, the association is composed of more than 3,900 schools, colleges, universities, and other educational organizations. Each year, the College Board serves over three million students and their parents, 22,000 high schools, and 3,500 colleges, through major programs and services in college admission, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT™, the Advanced Placement Program® (AP®), and Pacesetter®. The College Board is committed to the principles of equity and excellence, and that commitment is embodied in all of its programs, services, activities, and concerns.

4. Proteins–large complex molecules–are major building blocks of all living organisms. Discuss the following in relation to proteins.

(a) The chemical composition and levels of structure of proteins

(b) The roles of DNA and RNA in protein synthesis

(c) The roles of proteins in membrane structure and transport of molecules across the membrane

a) Proteins are polymers made of amino acid monomers. An amino acid is a molecule containing an amine group ($-NH_2$), and a carboxyl group ($-COOH$) bonded to a central carbon atom that can be bonded to another unit (the R group), as small as an H atom or much larger. There are twenty amino acids which differ because of their R groups. These amino acids are arranged in specific orders to form polypeptides. A polypeptide is the primary structure of a protein. The secondary structure of a protein involves the coiling or folding of a polypeptide. Polypeptides can coil into alpha helixes or fold into pleated sheets. These structures are determined by attractions, such as hydrogen bonds, between the R groups of the polypeptide's amino acid components. The tertiary structure of a protein involves the relationships among the components of the secondary structure. Two pleated sheets at opposite ends of a polypeptide may be attracted to each other, bring those parts of the polypeptide, for example. Disulfide bridges forming between R groups containing sulfhydryls often help establish a protein's tertiary structure. In general, the tertiary structure is the overall shape of one polypeptide resulting from hydrogen bonds and disulfide bridges. The quaternary structure is only seen in proteins consisting of multiple polypeptides; it is the overall structure formed when multiple polypeptides bond with each other. The primary, secondary, tertiary, and quaternary structures of a protein contribute to its overall conformation which makes its function possible.

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

b) DNA is the genetic material that dictates how a protein will be made, ~~by dictating~~ by dictating the order of the protein's ~~protein~~ amino acids. But DNA cannot make proteins. DNA passes its genetic information to mRNA through the process of transcription. mRNA can then be translated into the amino acid sequence of a protein's polypeptides. Two other types of RNA aid in this process: tRNA and rRNA. tRNA has an area called the anticodon that binds to units of 3 nucleotides in mRNA. The other side of tRNA binds to a specific amino acid, which it adds to the polypeptide being formed during translation. Thus each set of 3 nucleotides in mRNA dictates the next amino acid in the polypeptide sequence. rRNA is a component of ribosomes, which hold mRNA and tRNA together during translation and allow the tRNA to add a new amino acid to the polypeptide being held by another tRNA, which moves to the ribosome's exit site when the polypeptide is passed to the tRNA bearing the new amino acid.

c) Proteins serve six basic functions when they are part of plasma membranes: transport, signal-receiving, cell-cell recognition, enzymatic activity, connection to the extra-cellular matrix and cytoskeleton, and connection to other cells. Transport proteins sometimes simply provide channels through which ions or molecules too large or polar to pass through

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

the plasma membrane can diffuse down their concentration gradients in a form of passive transport called facilitated diffusion — the protein facilitates the diffusion of molecules. In other cases, transport proteins function in active transport, a process that requires energy, usually in the form of ATP, to transport molecules against electrochemical gradients. Transport proteins are integral proteins that traverse the plasma membrane, while peripheral proteins do not. Peripheral proteins, on the membrane's exterior, are often involved in cell-cell recognition, but only if they are glycoproteins having carbohydrates attached. These carbohydrates identify the cells they belong to so that other cells can recognize them.

4. Proteins–large complex molecules–are major building blocks of all living organisms. Discuss the following in relation to proteins.

   (a) The chemical composition and levels of structure of proteins

   (b) The roles of DNA and RNA in protein synthesis

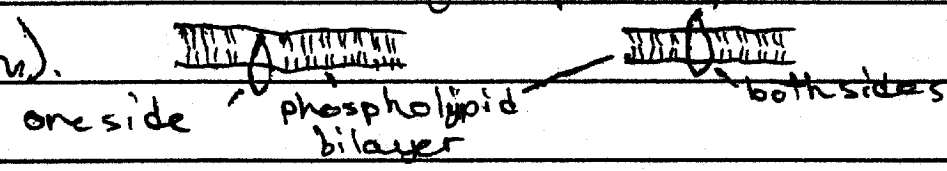
   (c) The roles of proteins in membrane structure and transport of molecules across the membrane

(a) Proteins are made up of long chains of amino acids, and are organized into four levels of structure. Primary structure is the order and number of the amino acids. The secondary structure is the way sections of these amino acids 'structuralize' themselves, causing structures such as the β-pleated sheet. The tertiary structure is the overall structure of the protein, and it is largely affected by hydrogen or sulfide bonds between various amino acids. Finally, the quaternary structure is the structure these proteins are in relation to each other. All of these have effects on the way the protein works, especially enzymes, in which if the active site (tertiary structure) is not 'correct' the enzyme will not work.

(b) DNA has a sequence of bases which determines in what order and what type amino acids are made, which determines what the protein is. mRNA transcribes the DNA sequence, and this mRNA is translated by tRNA, in which groups of three base pairs each code for a certain amino acid. This then goes to rRNA, which assembles the amino acids, and these are turned into the finished product: a protein.

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

(c) The main role of proteins in a membrane is to provide support for the membrane. Types of ~~proteins~~ only have one side that is hydrophilic, while others have both (see diagram).



Proteins help transport molecules across membranes in many different ways. One is facilitated diffusion, where a protein will help substances diffuse across the membrane that could not otherwise diffuse across the membrane for a variety of reasons (polarity, size, etc). They also allow 'trades' to occur, in which one molecule will bind to the protein on one side of the membrane, and another molecule will bind on the other side and they will trade places.

Perhaps the most important protein in a membrane is ATP synthase. Protons diffuse through ATP synthase from the outside of a membrane to the inside, and this ATP synthase turns this diffusion and an ADP molecule into ATP. This is known as oxidative phosphorylation, and is a crucial component of both respiration and photosynthesis.

4. Proteins–large complex molecules–are major building blocks of all living organisms. Discuss the following in relation to proteins.

(a) The chemical composition and levels of structure of proteins

(b) The roles of DNA and RNA in protein synthesis

(c) The roles of proteins in membrane structure and transport of molecules across the membrane

a.) The chemical composition of proteins is rather unique compared to other complex molecules. Proteins are composed of an amine group H_2N and a carboxyl group $C(=O)OH$

The major delineation of proteins from other structures is the nitrogen found in the amine group. Aside from the chemical composition of proteins, there are also various levels of structure. The primary structure, secondary structure, tertiary structure, and quaternary structure are the major components. In each structure there are key characteristics. After the primary structure begins to change shape, the secondary phase consists of alpha helices and beta-pleated sheets. These terms merely describe the twisting and contouring of the protein. From there, the protein takes a globular structure in the tertiary phase and is connected by sulfur-cross-bonds in the quaternary stage. All of these changes in structure dictate overall function.

b.) DNA and RNA have a pivotal role in protein synthesis. The double helix DNA is hacked apart by helicase. From there, it is separated into its leading and lagging strand. Ligase links decoded fragments to the lagging strand and DNA polymerase pastes nucleotides, adding length. Once that has been completed, RNA is produced and made

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

into its various forms, mRNA, tRNA, rRNA ~~and~~ through transcription. Afterwards, ~~forming~~ base pairs of RNA link up to complimentary bases of DNA on one helix. As the RNA codes for each nucleotide triplet, it eventually promotes the addition of a polypeptide, which is a series of proteins. It is here, ~~that~~ the addition of those proteins aids in protein synthesis for the cell is now ready to be divided.

c) Proteins act as the "taxi-cabs" of the cells, carrying numerous molecules from each membrane and transporting them across the membranes. They also aid in the membrane structure by providing it with support. They are usually situated between the phospholipid-bilayer and are ~~also~~ stationed in the middle of the hydrophilic and hydrophobic areas. They function as transport molecules because they are primary components of nucleotides. In forming RNA, proteins are parts of the nucleotides and act in tRNA and mRNA. When RNA transfers codons and anti-codons down the sequence of nucleotides, the proteins are attached to it, aiding in the RNA's progression along the chain.