Instructor's Answer Key

Chapter 3: Cell Structure and Genetic Control

Answers to Test Your Understanding of Concepts and Principles

1. The phospholipid component of the plasma membrane allows the lateral movement of molecules within it, hence the descriptive term "fluid mosaic" used to describe the membrane. New molecules are constantly added to the membrane (by fusion of vesicles derived from the Golgi complex or apparatus) and are frequently removed from the membrane (as occurs in the formation of endocytotic vesicles). Additionally, the membrane as a whole is capable of movement in some cells, particularly in those that are phagocytic and those that can move by amoeboid motion. [Note: This question is also answered in the Student Study Guide.]

2. The nucleosome is comprised of histone proteins core around which two turns (146 base pairs) of the DNA molecule are wrapped or spooled. The positive charge of the histones allows for the interaction with the negatively charged DNA molecule. The nucleosomes are essential for the packaging of the DNA in the nucleus and for the regulation of gene expression. Regulation of gene expression at the level of the nucleosome is believed to involve chemical changes in the histones.

3. The genetic code is the sequence of bases in DNA that specifies the construction of particular RNA molecules. The code consists of base triplets; each base triplet, transcribed into a complementary base triplet in mRNA, is translated into the placement of a specific amino acid in a specific position in a particular protein. The genetic code thus determines the structure of proteins, and activity of different genes determines the protein content of cells. Since enzymes are proteins, and enzymes determine the structure and function of the body through the reactions they catalyze, the genes can indirectly regulate the structure and function of the body.

4. The codons in mRNA bond by complementary base pairing to the anticodons in tRNA. In this way, specific tRNA molecules, carrying specific amino acids, are brought into position so that their amino acids can be added to the growing polypeptide chain. The tRNA molecules, therefore, provide the means of translating the code of nucleotide bases into the "language" of protein structure.

5. Cellular proteins are produced in free polyribosomes, whereas proteins that will be secreted by a cell are produced in ribosomes that are attached to a rough endoplasmic reticulum. Proteins produced by the rough endoplasmic reticulum are passed to the cisternae of first the endoplasmic reticulum, and then the Golgi apparatus. Secretory proteins are further modified, such as by the attachment of carbohydrates, and are packaged within secretory vesicles that fuse with the plasma membrane during exocytosis.

6. The term *genome* can refer to all genes in a particular individual or all of the genes in a particular species. Each gene is a region of DNA that codes (through RNA) for the synthesis of polypeptide chains (proteins). The newer term *proteome* refers to all of the proteins produced by the genome. For any specific cell only a small portion of the genome (select few genes) are actively producing proteins so that the proteome of one cell type can be very different from that of another cell type and yet the genome of all cells in the body is the same. These terms are further complicated because a gene may produce more than one protein so that the number of proteins produced by a cell can greatly exceed the number of active genes.

7. Proteins produced for secretion are made within the rough endoplasmic reticulum and then are transferred to the Golgi complex or apparatus for further modifications, such as:
    a. Addition of carbohydrates to form glycoproteins.
    b. Separation of different types of protein according to their function and destination.

    After modifications, newly made proteins for export are packaged in vesicles created by the Golgi apparatus. These vesicles may become lysosomes, storage granules of secretory products, or additions to the plasma membrane.

8. A centriole is a short cylindrical array of microtubules. A pair of centrioles is found at the center of a centrosome in animal cells. Cell centrioles are duplicated during interphase, but as mitosis begins, the pairs separate and become part of an aster that helps to form the poles of the mitotic spindle, required in the separation of chromosomes.

9. The phases of the cell cycle are interphase (G_1, S, G_2), and mitosis phases (prophase, metaphase, anaphase, and telophase). Interphase is that part of a cell's life when it is not dividing whereas mitosis refers to the phases of cell division. Gap phase 1 (G1) is the first period of growth in an active cell during which new proteins are made from mRNA. Synthesis or S phase is when new DNA is made or replicated. In gap phase 2 (G2) the chromatin condenses in preparation for mitosis. A group of proteins known as cyclins promote different phases of the cell cycle. An increase in cyclin D proteins hastens the G_1 phase of the cell cycle by activating otherwise inactive enzymes known as cyclin-dependent kinases.

10. Oncogenes are mutated forms of normal genes (called proto-oncogenes) that now promote the formation of cancer. Tumor suppressor genes inhibit the formation of cancer. An example of an oncogene is the gene for cyclin D. Since cyclin D hastens cell division, cyclin D could influence cancer. An example of a tumor suppressor gene is the gene for p53, a protein that interferes with cell division. Chimera mice or mice whose p53 genes were "knocked out" using embryonic stem cells all developed tumors. The p53 gene, interestingly, is needed for normal apoptosis to occur when a cell's DNA has been damaged.

11. Apoptosis, or programmed cell death, is a pattern of cell shrinkage in which the plasma membrane remains intact but becomes bubbled and the nuclei condense as lysosomes release their digestive enzymes. For example, apoptosis occurs normally as a part of programmed cell death that accompanies embryonic development. The mechanism of cell death may be set in motion by extracellular regulatory molecules that interact with receptors on the plasma membrane. This leads to activation of enzymes called caspases, the "executioners" of the cell. Other sequences that can lead to apoptosis come in response to intracellular signals – such as oxidative stress action on mitochondria. Apoptosis is physiologically significant because programmed cell death is a means for specialization of many tissues. In embryonic growth, for example, early structures such as gill pouches are remodeled or replaced as the embryo matures. Apoptosis has also been implicated in many disease processes.

Answers to Test Your Ability to Analyze and Apply Your Knowledge

1. The protein content of chromatin is made up of a type known as histones. As previously mentioned in the answer to question #2, histone proteins are positively charged and organized to form three-dimensional spools, about which the negatively charged strands of DNA are wound. The chromatin that is active in genetic transcription (RNA synthesis) is in a relatively extended form known as *euchromatin*. By contrast, heterochromatin is highly condensed with genes that are permanently inactivated in that cell. Chemical changes to the euchromatin such as the acetylation of the histone proteins, opens the configuration of the chromatin in specific locations, allowing the DNA to be "read" by transcription factors that promote RNA synthesis. Removal of the two-carbon-long acetyl group (deacetylation) stops transcription of the gene. Specific regulatory molecules, such as hormones, act as *transcription factors* by binding to the promoter region of a particular gene and thereby activating the gene. The activated genes then transcribe mRNA molecules that eventually migrate to ribosomes in the cytoplasm for the assembly of many copies of one particular polypeptide chain (protein).

2. The normal p53 gene protects against cancer by indirectly blocking the ability of cyclin proteins to stimulate different phases of the cell cycle, including cell division. In part, p53 does this by inducing the expression of another gene, called p21, which produces a protein that binds to and inactivates the cyclin-dependent kinase enzymes. The p21 protein thus inhibits cell division as it promotes cell differentiation (specialization). Cancer is likely to develop if the p53 gene becomes mutated and therefore ineffective as a tumor suppressor gene. In this case, cells with damaged DNA, following ultraviolet light exposure for example, may not undergo normal p53-directed programmed death or apoptosis but rather may continue to divide producing mutated daughter cells that perhaps develop into cancer. Gene therapy in which healthy p53 genes are inserted into cancerous cells or drug interventions that manipulate the cyclin-dependent kinase enzymes and therefore cell division are possible treatments for patients with growing tumors or cancer.

3. Lysosomes are membrane-bound organelles containing powerful hydrolytic enzymes that can digest foreign molecules and worn and damaged organelles. Lysosomes also fuse with food vacuoles during the normal process of endocytosis, releasing enzymes that digest the vacuole particles for the cell's use. Lysosomes also destroy worn-out organelles so that they can be continuously replaced (autophagy). Finally, lysosomes have been called "suicide bags" because a break in their membranes would release enzymes that would destroy the cell. This happens normally in apoptosis or programmed cell death particularly in embryonic growth and the early differentiation of tissue. A drug that destroys all lysosomes would eliminate all of these important vital functions.

4. If a hormone's effects on a tissue were blocked immediately by puromycin, *genetic translation* (assembly of proteins) must be the notable mechanism of action for the hormone. The hormone action in this case appears to involve stimulating the synthesis of new polypeptides in the target tissues. Puromycin thus interferes with the hormone effects by interrupting the assembly of protein molecules under the direction of mRNA at the ribosomes and thereby blocking the synthesis of the hormone-directed new polypeptides. The hormone does not seem to affect genetic transcription (synthesis of mRNA) in the nucleus since actinomycin D had no effect.