5.2 PROTEIN SYNTHESIS: AN OVERVIEW

Section 5.2 Questions

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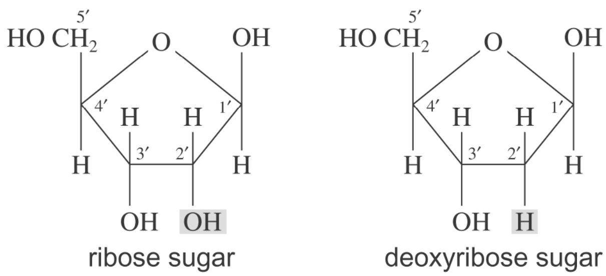
Understanding Concepts

1. Each cell contains one copy of an organism's DNA. Within the DNA, genes are found that encode for the production of all the proteins required for a cell's survival. If the DNA were allowed to exit the nucleus, it would be subjected to possible degradation, damage, or distortion, which would lead to cell death. In addition, the DNA itself could possibly be used by the ribosomes directly for protein synthesis. Direct use of DNA would be inefficient, since only one copy of each gene sequence would be available to be used at any one time, rendering the production of protein very slow. Finally, the DNA would have to reenter the nucleus, requiring that the cell develop a reentry strategy.
2. The central dogma of molecular genetics states that genes found within a DNA sequence are transcribed into messenger RNA. Messenger RNA exits the nucleus and is translated into protein by ribosomes in the cytoplasm.
3.



A deoxyribose sugar differs from a ribose sugar in the 2′ position. The deoxyribose sugar has an H atom attached at the 2′ position, while the ribose sugar has a hydroxyl group on the 2′ position.

4. Messenger RNA (mRNA) represents the product of transcription of a gene. Ribosomes found in the cytoplasm synthesize proteins using mRNA as the template. Transfer RNA (tRNA) delivers amino acids to the ribosome, which are used to build protein during the process of translation. Ribosomal RNA (rRNA) binds with ribosomal proteins to form ribosomes.
5. RNA and DNA are both nucleic acids and polymers. RNA is a single-stranded molecule, while DNA is double stranded. RNA's backbone comprises a phosphate group and a ribose sugar, while DNA's backbone comprises a phosphate group and a deoxyribose sugar. Both molecules contain the nitrogenous bases adenine, guanine, and cytosine. DNA contains thymine, which binds to adenine, while RNA replaces thymine with uracil. DNA is confined to the nucleus while RNA resides both in the nucleus and in the cytoplasm.
6.

	Transcription	**Translation**
Location	Within the nucleus	Within the cytoplasm
Purpose	Copy a DNA sequence representing a gene into a template that can be used by a ribosome to build protein	Uses mRNA as a template in order to build the specified protein
Outcome	mRNA	Protein

7.

	Transcription	**Translation**
Initiation	RNA polymerase binds to the DNA region known as the promoter to start the transcribing process	A ribosome recognizes a specific sequence on mRNA, known as a promoter, and binds to that site
Elongation	RNA polymerase uses DNA as template and synthesizes a complementary mRNA strand using ribonucleotides	The ribosome builds a polypeptide chain using mRNA as the template strand; tRNA delivers appropriate amino acids to the ribosome; the ribosome reads the mRNA strand in triplets known as codons, beginning with the start codon
Termination	RNA polymerase ceases the transcription process when it encounters the termination sequence on the DNA template strand	The synthesis of the polypeptide chain ceases when the ribosome encounters a stop signal, which causes the ribosome to fall off of the mRNA strand

8. The reading of code in pairs of nucleotides is insufficient since only 16 different combinations (4^2) of the four nitrogenous bases can be made. Given that there are 20 amino acids, 16 different combinations would not suffice.
9. The start codon (AUG) signals to the ribosome that translation should commence at this point, while the stop codons (UAA, UAG, UGA) act as signals to the ribosomes to cease translation.
10. CCUAGUCCAGGUCCGUUAAAUCGUACGGGGUU
11. DNA sequence divided into codons
    5'–GGC-AUG-GGA-CAU-UAU-UUU-GCC-CGU-UGU-GGU-GGG-GCG-UGA–3'
    The start codon is the second codon, AUG; therefore, translation into protein commences with the amino acid methionine.
    Translation results in the following protein:
    Met-Gly-His-Tyr-Phe-Ala-Arg-Cys-Gly-Gly-Ala
    The last codon, UGA, is a stop codon.

Applying Inquiry Skills

12. $4^4 = 256$, therefore the codons must comprise a minimum four ribonucleotides each. A total of 254 different amino acids could be coded for, assuming that there is one start codon and one stop codon.

13.(a) Since there are five amino acids found in this polypeptide, there must be at least five codons. Since each codon consists of three nucleotides, 15 (5×3) nucleotides would be required to code for this peptide sequence.

Making Connections

14. Student answers will vary. Some points that could be made are as follows. A strong piece of evidence that supports the theory of evolution is the relationship that different organisms share with respect to their DNA. The more closely related two species are, the less variation there is between their DNA. Since the same code is used by all life, it indicates that all species at some point started off more or less from one origin. If a different code were used for each species to build proteins, this would indicate that many origins of life existed, negating the theory of evolution. The biotechnology industry would also be affected if a different code were used by each species. During the process of genetic engineering, if a gene that coded for a specific protein were excised and placed into foreign DNA, it would now code for a different protein. The different protein would not act in the same manner in the new organism as it did in the parent organism.

5.3 TRANSCRIPTION

Case Study: Human Immunodeficiency Virus

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Understanding Concepts

1. No, HIV cannot attach itself to a muscle or a skin cell. HIV's antigens are not complementary to the binding sites (receptors) of skin cells and muscle cells (Figure 6, p. 245 in the Student Text).
2. You cannot obtain AIDS through shaking hands, because for the AIDS virus to be transmitted, there must be contact between two individuals via body fluids. This type of contact includes sexual contact, blood transfusions, or from mother to child during pregnancy. There is no exchange of bodily fluids through shaking hands; hence, AIDS cannot be transmitted in this manner. The antigens on HIV are not complementary to the receptor sites on skin cells; therefore, HIV cannot bind to skin cells.
3. Reverse transcriptase uses RNA as a template and builds a complementary DNA strand, thereby transcribing RNA into DNA. Reverse transcriptase is an appropriate name for the enzyme, given that conventional transcription of genetic material is in the direction of DNA to RNA. In this case, RNA is transcribed into DNA, meriting it the label of reverse transcription.
4. If a helper T cell divides and viral DNA has been incorporated into the cell's genome, it will also be replicated and be present in both of the daughter cells.
5. HIV can stay dormant for many years before symptoms are exhibited in its carrier, therefore, an individual can be infected with HIV but not necessarily show any symptoms.
6. People who are infected with HIV usually die of another infection because HIV attacks helper T cells, which are part of a human's immune system. Helper T cells act as guards against invading pathogens. Since HIV destroys helper T cells, the body cannot launch an immune response to secondary infections such as pneumonia. Therefore, a person infected with HIV is susceptible to infection.
7. Severe combined immunodeficiency (SCID) is a genetic disease. SCID has three major causes: (1) the helper T cells are absent or functioning poorly, (2) the thymus gland is absent or functions poorly, or (3) the bone marrow stem cells from which the mature T cells develop are defective or absent. In the absence of T cells, the immune system cannot function normally. The thymus gland is the organ in which immature cells from the bone marrow mature and "learn" how to become helper T cells, suppressor T cells, or killer T cells. If the thymus is not working properly, no mature T cells are