5.4 TRANSLATION

Section 5.4 Questions

(Page 254)

Understanding Concepts

1. (a) The A and P sites are found in a ribosome that is translating an mRNA sequence into protein. The A (acceptor) site is where tRNA molecules bring in the appropriate amino acid. The P (peptide) site is where peptide bonds are formed between adjoining amino acids on a growing polypeptide chain.
   (b) A codon is a triplet of ribonucleotides on mRNA that encodes a single amino acid. An anticodon is a triplet of ribonucleotides on tRNA that recognizes and pairs with a codon on the mRNA.
   (c) The start codon signals to the ribosome to start synthesizing the polypeptide chain. The start codon is always AUG and codes for methionine. The stop codon signals to the ribosome to stop the process of translation. The stop codons are UGA, UAG, and UAA.
   (d) A charged tRNA carries a corresponding amino acid. The tRNA is charged by the enzyme aminoacyl-tRNA-synthetase. An uncharged tRNA lacks its corresponding amino acid.
2. The three types of RNA are mRNA, tRNA, and rRNA. Messenger RNA (mRNA) represents the product of transcription of a gene. It encodes the sequence of triplet codons that will be read by the ribosomes to build proteins. It also encodes the start and stop codons that ribosomes use to initiate and terminate translation. Transfer RNA (tRNA) delivers amino acids to the ribosome, which are used to build proteins during the process of translation. Each amino acid has a corresponding tRNA. Ribosomal RNA (rRNA) binds with ribosomal proteins to form ribosomes. The two subunits of the ribosome would not be able to bind without rRNA and translation would not take place.
3. The possible codons are obtained from the genetic code (Figure 7, Section 5.2, p. 240 of the Student Text). The anticodons comprise complementary RNA.

Amino Acid	Possible Codon	Corresponding Possible Anticodon
Threonine	ACU ACC ACA ACG	UGA UGG UGU UGC
Alanine	GCU GCC GCA GCG	CGA CGG CGU CGC
Proline	CCU CCC CCA CCG	GGA GGG GGU GGC

4. An error in the third base of a codon in mRNA may not necessarily result in an error during the process of translation because more than one codon encodes a particular amino acid. The codons differ by the third nucleotide. For example, proline can be encoded by the codons CCU, CCC, CCA, and CCG. If a mistake is made in the third nucleotide of the codon, it is negligible. It does not matter what the third nucleotide is—the two first nucleotides, CC, will always code for proline. The possibility of flexibility in the third nucleotide of a codon is termed the wobble hypothesis.
5. The genetic code (Figure 7, Section 5.2, p. 240 of the Student Text) comprises 64 codons. Three of those codons do not code for an amino acid. These are the stop codons. Therefore, $64 - 3 = 61$ codons require a tRNA to bring in a corresponding amino acid. Codons that do not differ in their first two nucleotides but code for one amino acid (e.g. proline: CCU, CCC, CCA, and CCG) are counted as one tRNA requirement. Codons that do not differ in their first two nucleotides but code for more than one amino acid (e.g. phenylalanine: UUU and UUC, and leucine: UUA and UUG) are counted as four tRNA requirements, since the nucleotide is critical in distinguishing between the leucine or phenylalanine being brought in. The total minimum number of tRNAs required is 40.
6. The genetic code (Figure 7, Section 5.2, p. 240 of the Student Text) must be used. AUG is always the start codon and encodes for the amino acid methionine:
   5'–GGC-CCA-UAG-AUG-CCA-CCG-GGA-AAA-GAC-UGA-GCC-CCG–3'
   Met–Pro–Pro–Gly–Lys–Asp–Stop

7. The only amino acid that does not need to enter the A site before entering the P site on a ribosome during the process of translation is methionine. Methionine is coded for by AUG, the start codon, and therefore it is always the first amino acid in a newly synthesized polypeptide. Since it is the first amino acid, there will be no amino acid before it to form a peptide bond with and hence it need not enter the A site. It automatically enters the P site to form a peptide bond with the amino acid that comes in after it.
8. Before translation can be initiated, a ribosome must bind to the mRNA transcript. The two ribosome units (60S and 40S) recognize the 5' cap on the mRNA. The intact ribosome moves along the mRNA until it encounters the start codon, AUG. Translation is initiated when methionine, the amino acid encoded by the start codon, is brought into the P site of the ribosome by its corresponding tRNA. The tRNA and mRNA interact via complementary base pairing. The methionine tRNA possesses the nucleotide sequence UAC on its base, which is complementary to AUG. UAC is the anticodon.
   The polypeptide is elongated from this point on. The second codon after the start codon is found in the A site of the ribosome. Its corresponding tRNA will bring in the appropriate amino acid to the site. At this point a peptide bond is formed between methionine (P site) and the amino acid in the A site. The ribosome now shifts over one codon. Methionine exits the P site, the second amino acid and it's corresponding tRNA enters the P site, and the A site is vacant. The corresponding amino acid to the third codon is now brought in to the A site and a peptide bond is formed between the second amino acid and the third.
   The process of elongation continues until a stop codon is reached signalling termination. Once a stop codon (UAG, UGA, or UAA) is reached, the ribosome stalls. A protein, known as the release factor, recognizes that the ribosome has stalled and causes the ribosome to dismantle and fall off the mRNA. The newly formed polypeptide chain is also released.
9. Translation is the process of expressing to another medium. Typically, translation means to express in another language. Translation during protein synthesis lends itself to the same concept. During protein synthesis, mRNA, which consists of ribonucleotides, is translated into protein, which consists of amino acids, using the genetic code. The process of translation has been appropriately named in protein synthesis.

Making Connections

10. Student answers will vary depending on research. Tetracycline, streptomycin, and chloramphenicol arrest bacterial growth by blocking various steps in proteins synthesis.
   (a) Tetracycline inhibits the binding of the tRNA to the small subunit of the ribosome. Therefore, the tRNA cannot deliver the appropriate amino acid.
   (b) Streptomycin induces mRNA misreading and inhibits the initiation of the process of translation. Streptomycin accomplishes the inhibition by binding to the small subunit of the ribosome. If misreading occurs, then dysfunctional proteins are built.
   (c) Chloramphenicol inhibits the enzyme peptidyl transferase. Peptidyl transferase is the enzyme that forms the peptide bond between the two amino acids found in the P site and A site.

5.5 CONTROL MECHANISMS

SECTION QUESTIONS

(Page 258)

Understanding Concepts

1. operon: a cluster of genes under the control of one promoter and one operator in prokaryotic cells; acts as a simple regulatory loop
   operator: regulatory sequences of DNA to which a repressor protein binds
   corepressor: a molecule (usually the product of an operon) that binds to a repressor to activate it
   housekeeping gene: a gene that is switched on all the time because it is needed for life functions vital to an organism
   signal molecule: a molecule that activates an activator protein or represses a repressor protein
2. It is to a cell's advantage to have some of its genes under regulation because not all proteins are required at all times, nor are all diminished quickly. It would be a waste of the cell's resources (energy and materials) if all genes were transcribed and translated at all times. By having some genes under regulation, the cell can manage the inventory (protein product) as it is needed.
3. If the level of lactose is low, then the enzymes β-galactosidase, β-galactosidase permease, and transacetylase are not required by the cell. These enzymes are involved in the metabolism of lactose, and their expression is under the regulation of the *lac* operon. Under low lactose levels, RNA polymerase is blocked from transcribing the genes for the lactose metabolizing enzymes. LacI, a repressor protein, is bound to the operator, which follows the promoter. When RNA polymerase binds to the promoter, it cannot get past the LacI repressor protein, and transcription is blocked. If lactose is introduced to the system, the enzymes must be transcribed. On introduction of lactose, lactose binds to the LacI repressor, changing LacI's shape and making it fall off the operator. Now that LacI has been removed from the operator, RNA