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

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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

polymerase can proceed with transcription as normal. The three enzymes involved in the metabolism of lactose are transcribed and expressed.

4. (a) The LacI protein will be dysfunctional, if it functions at all. It will not be able to bind either to the *lac* operon operator or to lactose. Therefore, transcription of the three genes of the *lac* operon will take place continuously, irrespective the level of lactose in the cell.
   (b) If a mutation is found in the second gene of the *lac* operon, which is the *lacY* gene, the enzyme β-galactosidase permease will be nonfunctional. Lactose will not be able to enter the cell and will accumulate in space found between cells, assuming that initially this enzyme is expressed. Furthermore, the other genes found in the *lac* operon will not be expressed either. Since lactose will not be able to enter the cell, it cannot bind to the *Lac*I protein; therefore, transcription will be blocked.
   (c) If RNA polymerase has difficulty binding to the promoter, then transcription will not take place. The level of lactose will accumulate in the cell initially to a certain point. Since the permease is now not being expressed, lactose will accumulate between cells as well.
5. If the levels of tryptophan are high, then tryptophan need not be produced by the *trp* operon. Tryptophan will bind to the repressor protein, changing its conformation. The *trp* repressor–tryptophan complex can now bind to the operator of the *trp* operon, blocking transcription of the genes needed to synthesize tryptophan. If the levels of tryptophan are lowered, there is not enough tryptophan available to bind to the repressor protein. The repressor protein changes shape without tryptophan and can no longer bind to the operator. RNA polymerase is able to transcribe the tryptophan synthesizing genes.

Applying Inquiry Skills

6. (a) Molecule A is acting as a corepressor molecule. When the levels of molecule A are low, the transcription of the genes is high, indicating that its presence does not block transcription. Conversely, when the levels of molecule A are high, gene transcription is low, indicating that it's presence has blocked transcription in some manner. Molecule B is acting as an inducer. When the levels of molecule B are low, the transcription of genes is low also, indicating that molecule B must be present for the transcription of the genes to take place.
   (b) Molecule A's system resembles the *trp* operon, while molecule B's resembles the *lac* operon.
   (c) Generally, when an operon controls the genes responsible for the synthesis of a protein, the protein acts as a corepressor. When an operon controls the genes responsible for the degradation of a protein, the protein acts as an inducer.

5.6 MUTATIONS

Explore an Issue Debate: Cell Phones and Brain Cancer

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Statement: The electromagnetic radiation associated with the use of cell phones does not contribute to the development of brain cancer.

Student answers will vary. A list of points and counterpoint follows:

Point	Counterpoint
Mice used in studies do not absorb energy in the same manner as humans do. It is questionable when one extrapolates directly to humans.	DNA is the same molecule in humans and mice.
Mice in cancer studies are usually transgenic: They are bred to be susceptible to cancers in the immune system. Hence, studies involving mice may not reflect accurately the effect of cell phone usage on cancer rates.	An Australian study conducted that found that mice who were subjected to pulsed digital radiation for two and a half hours a day doubled their incidence of cancer. The rate was much higher than the control group of transgenic mice who were not exposed to any radiation.
Definitive studies that can conclusively illustrate the effects of cell phone usage on humans have yet to be executed. More than 75 studies have been conducted over the last five years.	It takes many years for cancer to surface (5 to 20 years); hence, it is not possible to have a definitive study—yet the risk of brain cancer is still a possibility.

Section 5.6 Questions

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Understanding Concepts

1. mutation: a change in the DNA sequence that is inherited
   frameshift mutation: a mutation that causes the reading frame of codons to change, usually resulting in different amino acids being incorporated into the polypeptide
   point mutation: a mutation at a specific base pair in the genome
   nonsense mutation: a mutation that converts a codon from an amino acid into a termination codon
   missense mutation: a mutation that results in the single substitution of one amino acid in the resulting polypeptide
2. Nitrogen-base additions can be more harmful than nitrogen-base substitutions, because a nitrogen-base substitution can result in the expression of a different amino acid codon. Depending on where the amino acid falls within the protein, it may play a minor role in altering protein performance. A nitrogen-base addition changes the reading frame, resulting in a completely new sequence of amino acids being expressed, which can render the protein inactive. There are some exceptions to the nitrogen-base substitution scenario. If a nitrogen-base substitution results in a nonsense mutation, the results are similar to a nitrogen-base addition scenario.
3. A nonsense mutation is more harmful than a missense mutation. A nonsense mutation results in the termination of translation and therefore the protein that is to be translated is not fully synthesized, rendering it inactive. A missense mutation results in one amino acid change. The result is a protein that may or may not function to full capacity, depending on where the amino acid substitution has fallen. A missense mutation can be just as harmful as a nonsense mutation, but there is the slight chance that it will not.
4. Three factors that produce gene mutations are UV radiation, X rays, and chemicals such as pesticides.
5. The stop codons are UGA, UAA, and UAG. Using Figure 7, Section 5.2, p. 240 of the Student Text, the following codons can be changed by one base and become stop codons: UAU, UAC, UGU, UGC, UGG, UUA, UCA, UUG, UCG, CGA, AGA, GGA, CAA, CAG, AAA, AAG, GAA, and GAG. These codons differ by one nitrogenous base from a stop codon.

Applying Inquiry Skills

6. AUG–UUU–UUG–CCU–UAU–CAU–CGU (Native Strand)
   met–phe–leu–pro–tyr–his–arg

   (a) New protein: met–phe–leu–pro–tyr–his–arg
   The mutation has no effect since UAU and UAC both code for tyrosine.
   (b) New protein: met–phe–leu–pro–STOP
   The mutation is a nonsense mutation. UAA is a stop codon so the protein is not fully translated and is therefore nonfunctioning.
   (c) New protein: met–phe–leu–ala–leu–leu–leu
   The addition causes a frameshift mutation resulting in different amino acids.
   (d) New protein: met–phe–leu–pro–ile–ile
   The deletion causes a frameshift mutation resulting in different amino acids.
   (e) New protein: cys–tyr–tyr–phe–val–phe–val
   The inversion results in a different protein being synthesized.
7. (a) Arginine can change to leucine with the following substitutions: CGU to CUU, CGC to CUC, CGA to CUA, and CGG to CUG.
   (b) Cysteine to glutamic acid cannot be changed with one base pair substitution.
   (c) Serine can be changed to threonine with the following substitutions: AGU to ACU and AGC to ACC.
   (d) Isoleucine can be changed to serine with the following substitutions: AUU to AGU and AUC to AGC.

Making Connections

8. A food dye that has been identified as a chemical mutagen poses greater dangers for a developing fetus than for an adult. A fetus is undergoing rapid developmental growth within the uterus. The rate of mitosis for all cells is much faster than that within an adult. The effects of the mutagen can vary depending on which stage of development the fetus is in. If the mutagen affects nondifferentiated cells (cells that will eventually become specialized cells such as liver, heart, kidney etc.), it may impart a serious mutation that will lead to abnormal development. An adult also undergoes mitosis but does so to replace existing cells. If a mutation takes place in an adult, chances are it will be limited to the one cell and its daughter cells in the future; therefore, it will be localized to one area. In a fetus, a mutation will affect all cells since undifferentiated cells can become many different types of cells.

9. Student answers will vary. Some suggestions include wearing sunscreen, not using pesticides on lawns, washing all food thoroughly before ingestion, and avoiding unnecessary X rays.

5.7 KEY DIFFERENCES BETWEEN EUKARYOTES AND PROKARYOTES

Section 5.7 Questions

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Understanding Concepts

1. Endosymbiosis is a relationship shared between two organisms where one organism lives within the other organism. This relationship is beneficial to at least one of the organisms.
2. Prokaryotes are able to undergo coupled transcription-translation because they lack a nuclear membrane and their DNA lacks introns. Because prokaryotes lack introns, there need not be any splicing modifications made to the mRNA transcript; ribosomes transcribe directly from the mRNA transcript. Because prokaryotes have no nuclear membrane, ribosomes have access to the mRNA transcript as soon as it is made. The mRNA does not have to be complete before a ribosome attaches itself to it and starts translating.
3. The following reasons suggest that mitochondria may have once been free-living entities. First, mitochondria possess their own genomes, which is very similar to that of bacterial cells. Second, mitochondria replicate by the process of fission. Third, mitochondria possess their own system of DNA synthesis, transcription, and translation, indicating that mitochondria may have been free-living cells. Nucleomorphs may have also existed as free-living entities as well. Nucleomorphs organize their DNA into three chromosomes. The DNA within a nucleomorph replicates autonomously.

Making Connections

4. Student answers will vary depending on research. Mitochondria produce the energy requirements for a cell; therefore, it may have been to the prokaryotic cells advantage to engage in an endosymbiotic relationship with the mitochondria and exploit its ability to produce ATP. Cryptomonads, which are small biflagellate alga, may have entered into an endosymbiotic relationship with the small, compartmentalized structure found within them for the same reasons. The small, compartmentalized structure contains a chloroplast. The cryptomonads can exploit the energy produced by the compartmentalized structure's chloroplast.
5. Student answers will vary, but answers should include some of the following points. Eukaryotes are more complex than prokaryotes. Structurally, eukaryotes have membrane-bound organelles, whereas prokaryotes have no membrane-bound organelles. Eukaryotic DNA is more complex than prokaryotic DNA in terms of its coding. Eukaryotic DNA contains introns and exons, whereas prokaryotic DNA is all coding. The introns in eukaryotic mRNA must be excised before it is allowed to exit the nucleus. Coupled transcription-translation can take place in prokaryotes since there are no introns or nuclear membrane to worry about. There is much more eukaryotic DNA than prokaryotic DNA. Eukaryotic DNA is organized into many chromosomes and is linear; prokaryotic DNA is circular.

5.8 GENE ORGANIZATION AND CHROMOSOME STRUCTURE

Section 5.8 Questions

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Understanding Concepts

1. (a) A histone is a positively charged protein that DNA is bound to in a chromosome; a nucleosome is a complex of eight histones enveloped by DNA
   (b) A telomere is a long sequence of repetitive, noncoding DNA that is found at the end of chromosomes, while a centromere is a constricted region of a chromosome that holds two replicated chromosome strands together
   (c) A LINE is a DNA sequence of 5000 to 7000 nucleotides that are repetitive and alternate with other DNA sequences within the genome of higher organisms. A SINE differs from a LINE by the length of nucleotides. SINEs are approximately 300 nucleotides long.