Section Summary

The central dogma describes the flow of genetic information in the cell from DNA to RNA to proteins. Genes are used to make mRNA by the process of transcription; mRNA is used to synthesize proteins by the process of translation. The genetic code is the correspondence between the three-nucleotide mRNA codon and an amino acid. The genetic code is "translated" by the tRNA, which associates a specific codon with a specific amino acid. The genetic code is degenerate because 64 triplet codons in mRNA specify only 20 amino acids and three stop codons. This means that more than one codon corresponds to an amino acid. Almost every species on the planet uses the same genetic code.

Translation includes the mRNA template, ribosomes, tRNAs, and various enzymatic proteins. The small ribosomal subunit binds to the mRNA template. Translation begins at the initiating AUG on the mRNA. The formation of peptide bonds occurs between sequential amino acids specified by the mRNA template according to the genetic code. The ribosome accepts charged tRNAs, and as it moves along the mRNA, it catalyzes bonding between the new amino acid and the end of the growing polypeptide chain. The entire mRNA is translated in three-nucleotide "steps" of the ribosome. When a stop codon is encountered, a protein binds allowing the translation components to separate and frees the new protein.

Exercises

1. The RNA components of ribosomes are synthesized in the ________.
    a. cytoplasm
    b. mitochondria
    c. nucleolus
    d. endoplasmic reticulum
2. How long would the peptide be that is translated from this mRNA sequence: 5'-AUGGGCUACCGAUAG-3'?
    a. 0
    b. 2
    c. 3
    d. 4
3. Transcribe and translate the following DNA sequence:
    5'-TACGCCGGTTATATTGCA-3'

Answers

1. (c)
2. (d)
3. The mRNA would be: 5'-AUG-CGG-CCA-AUA-UAA-CGU-3'. The protein would be: Meth-Arg-Pro-Ile. Even though there are six codons, the fifth codon corresponds to a stop, so the sixth codon would not be translated.

Glossary

anticodon: three consecutive nucleotides on tRNA that complement the codon on a mRNA

codon: three consecutive nucleotides in mRNA that specify the addition of a specific amino acid or the release of a polypeptide chain during translation

genetic code: the amino acids that correspond to three-nucleotide codons of mRNA

peptide bond: a covalent bond that exists between the amino group of one amino acid and the carboxyl group of a second amino acid

ribosomal RNA (rRNA): ribosomal RNA; molecules of RNA that combine to form part of the ribosome

stop codon: one of the three mRNA codons that specifies termination of translation

start codon: the AUG (or, rarely GUG) on an mRNA from which translation begins; always specifies methionine

translation: process of producing a protein from the nucleotide sequence code of an mRNA transcript

transfer RNA (tRNA): transfer RNA; an RNA molecule that contains a specific three-nucleotide anticodon sequence to pair with the mRNA codon and also binds to a specific amino acid

10.5 How Genes Are Regulated

Learning objectives

By the end of this section, you will be able to:

- *Discuss why cells do not express all of its genes all of the time*
- *Describe how prokaryotic gene expression occurs at the transcriptional level*
- *Understand that eukaryotic gene expression occurs at the epigenetic, transcriptional, post-transcriptional, translational, and post-translational levels*
- *Be able to define and explain all bolded terms*

All organisms and cells control and regulate the transcription and translation of their DNA into protein. The process of turning on a gene to produce mRNA and then protein is called **gene expression**. All living cells control when and how its genes are expressed. For gene expression to occur, there must be mechanisms that control the following processes (1) when to turn on a gene to make mRNA and then protein (2) how much or what quantity of protein needs to be made, and (3) the ability to stop making that protein once it is no longer needed by the cell.

By regulating gene expression, cells can conserve energy and space. If an organism was to express every single gene at all times, it would require a significant amount of energy. It is much more energy efficient to only turn on the genes when they are required. In addition, only expressing a subset of genes in each cell saves space because DNA must be unwound from its tightly coiled structure to be transcribe and translated. Cells would have to be enormous if every gene were expressed in every cell all the time.

The control of gene expression is extremely complex and will only be covered briefly. To understand how gene expression is regulated, we must first understand how a gene codes for a functional protein in a cell. The process occurs in both prokaryotic and eukaryotic cells, just in slightly different manners.

Prokaryotic Gene Expression

Because prokaryotic organisms lack a cell nucleus, the processes of transcription and translation occur almost simultaneously. When the protein is no longer needed, transcription stops. This is primarily controlled by regulating transcription. Prokaryotic cells use a few methods to control gene expression at the transcriptional level.

One gene control example, the *lac* operon, was discovered using *E. coli* in the 1950s and 1960s by French researchers. The *lac* operon is a stretch of DNA that codes for proteins involved in absorption and metabolism of lactose, including the enzyme lactase. One promotor controls transcription of operon sequences. The *lac* operon is controlled using levels of lactose, a disaccharide, in *E. coli's* environment. When lactose is not present, transcription of the *lac* operon genes decreases, and the lactase translation slows. A repressor protein binds to the DNA preventing RNA polymerase from binding to the promoter. Thus, mRNA is not made and lactase translation is low. When lactose is present, the genes are transcribed at a higher rate and more