Chapter 7 The Blueprint of Life: From DNA to Protein

Summary Outline

7.1 Overview
- A. Definitions
  1. A **genome** is the complete of genetic information for a cell.
  2. **Replication** is the process of duplicating double-stranded DNA.
  3. **Transcription** is the process of copying the information encoded on DNA into RNA.
  4. **Translation** is the process of interpreting the information carried by messenger RNA in order to synthesize the encoded protein.
- B. Characteristics of **DNA**
  1. A single strand of **DNA has a 5 prime end and a 3 prime end**.
  2. The **two strands of DNA** in the **double helix are antiparallel**.
  3. The separating of double-stranded DNA is called **denaturing** or **melting**.
- C. Characteristics of **RNA**
  1. A **single-stranded RNA** fragment is transcribed from one of the two strands of DNA.
  2. There are three different functional groups of RNA molecules:
     a) **Messenger RNA (mRNA)**
     b) **Ribosomal RNA (rRNA)**
     c) **Transfer RNA (tRNA)**
- D. **Regulating** the **expression of genes**
  1. Protein synthesis is generally controlled by regulating the synthesis of mRNA molecules.
  2. mRNA is short-lived because RNases degrade it within minutes.

7.2 **DNA replication**
- A. DNA replication is generally **bi-directional**.
- B. Replication of double-stranded DNA is **semiconservative**.
- C. The DNA chain always elongates in the **5′ to 3′ direction**.
- D. **Base pairing** rules determine the **specific nucleotides** that are added.
- E. DNA replication begins at the origin of replication.
- F. **DNA polymerase** synthesizes DNA in the 5′ to 3′ direction, using one strand as a **template** to generate the **complementary strand**.
- G. The **bi-directional progression of replication** around a circular DNA molecule creates two **replication forks**.
- H. Enzymes involved in DNA replication include:
  1. **DNA polymerase**
  2. **Primase**
  3. **DNA ligase**
  4. **DNA gyrase**

7.3 Gene expression
- A. **Transcription**
  1. **RNA polymerase** catalyzes transcription, producing a single-stranded RNA molecule that is complementary and antiparallel to the DNA template.
  2. In prokaryotes, an mRNA molecule can be **monocistronic** or **polycistronic**.

3. Transcription begins when RNA polymerase recognizes and binds to a sequence of nucleotides on the DNA called a **promoter**; it is the **sigma subunit** of the enzyme that recognizes the promoter sequence.
4. **RNA is synthesized in the 5′ to 3′ direction**.
5. A **transcription terminator** causes RNA polymerase to fall off the DNA template and to release the newly synthesized RNA.

B. **Translation**
1. The information encoded on mRNA is deciphered using the **genetic code**.
2. **Ribosomes** are the **sites at which translation** occurs.
3. **tRNAs carry specific amino acids**.
4. **Initiation of translation** begins when **the ribosome binds to the ribosome-binding site** on the mRNA molecule; this occurs even while the mRNA is still being synthesized. **Translation starts** at the **first AUG downstream** of that site.
5. The ribosome moves along the mRNA in the **5′ to 3′ direction** so that **one codon is translated at a time**. Translation terminates when the ribosome reaches a **stop codon**.
6. Proteins are often modified after they are synthesized.

7.4 **Differences** between **eukaryotic** and **prokaryotic gene expression**
A. Eukaryotic mRNA is processed; **a cap and a poly A tail are added**.
B. Eukaryotic genes often contain **introns** that are **removed** from precursor mRNA by a process called **splicing**.
C. In eukaryotic cells, the **mRNA must be transported** out of the nucleus before it can be translated in the cytoplasm. Eukaryotic mRNA is **typically monocistronic**.

7.5 **Genomics** DNA sequence is analyzed and compared to other known sequences by searching a computerized database.

7.6 **Regulating gene expression**
A. Principles
1. Genes encoding **constitutive enzymes** are always active.
2. Genes encoding enzymes that can be **induced** are turned on only by certain conditions; those that can be **repressed** are turned off by certain conditions.

B. Mechanisms to **control** transcription
1. Global control is the simultaneous regulation of numerous genes unrelated in function.
2. Many genes have a **regulatory region** near their promoter to which a specific protein can bind, controlling transcription.
3. An **operon** is a set of adjacent genes coordinately controlled by a regulatory protein and transcribed as a single polycistronic message.
4. A **repressor** is a regulatory protein that blocks transcription (negative control) by binding with the **operator** of the operon.
5. An **inducer** is molecule that binds with the repressor and changes its shape so that it can no longer bind with the operator.
6. An **activator** is a regulatory protein that enhances transcription (positive control).

C. The **lac operon** is an important model for understanding the control of gene expression in bacteria
D. **Catabolite repression** turns off certain genes when more readily degradable energy sources such as glucose are available.

7.7 Sensing and responding in response to environmental fluctuations
A. **Signal transduction**
1. **Two-component regulatory systems** utilize a sensor that recognizes changes outside the cell and then transmits that information to a response regulator.

2. Bacteria that utilize **quorum sensing** synthesize a soluble compound, a homoserine lactone, which can move freely in and out of a cell and functions when it reaches a critical concentration.

B. **Natural selection**—The expression of some genes changes randomly.