

# Study Outline Chapter 08

## Structure and Function of the Genetic Material (pp. 207- 215)

- Genetics is the study of what genes are, how they carry information, how their information is expressed, and how they are replicated and passed to subsequent generations or other organisms.
- DNA in cells exists as a double-stranded helix; the two strands are held together by hydrogen bonds between specific nitrogenous base pairs: AT and CG.
- A gene is a segment of DNA, a sequence of nucleotides, that codes for a functional product, usually a protein.
- When a gene is expressed, DNA is transcribed to produce RNA; mRNA is then translated into proteins.
- The DNA in a cell is duplicated before the cell divides, so each daughter cell receives the same genetic information.

## Genotype and Phenotype (p. 208- 209)

- Genotype is the genetic composition of an organism, its entire complement of DNA.
- Phenotype is the expression of the genes: the proteins of the cell and the properties they confer on the organism.

## DNA and Chromosomes (p. 209)

- The DNA in a chromosome exists as one long double helix associated with various proteins that regulate genetic activity.
- Bacterial DNA is circular; the chromosome of *E. coli*, for example, contains about 4 million base pairs and is approximately 1000 times longer than the cell.

## DNA Replication (pp. 209- 211)

- During DNA replication, the two strands of the double helix separate at the replication fork, and each strand is used as a template by DNA polymerases to synthesize two new strands of DNA according to the rules of nitrogenous base pairing.
- The result of DNA replication is two new strands of DNA, each having a base sequence complementary to one of the original strands.
- Because each double-stranded DNA molecule contains one original and one new strand, the replication process is called semiconservative.
- DNA polymerase proofreads new molecules of DNA and removes mismatched bases before continuing DNA synthesis.
- Each daughter bacterium receives a chromosome identical to the parent's.
- Information contained in the DNA is transcribed into RNA and translated into proteins.

## RNA and Protein Synthesis (pp. 211- 215)

- During transcription, the enzyme RNA polymerase synthesizes a strand of RNA from one strand of double-stranded DNA, which serves as a template.
- RNA is synthesized from nucleotides containing the bases A, C, G, and U, which pair with the bases of the DNA strand being transcribed.

- The starting point for transcription, where RNA polymerase binds to DNA, is the promoter site; the region of DNA that is the end point of transcription is the terminator site.
- Translation is the process in which the information in the nucleotide base sequence of mRNA is used to dictate the amino acid sequence of a protein.
- The mRNA associates with ribosomes, which consist of rRNA and protein.
- Three-base segments of mRNA that specify amino acids are called codons.
- The genetic code refers to the relationship among the nucleotide base sequence of DNA, the corresponding codons of mRNA, and the amino acids for which the codons code.
- The genetic code is degenerate; that is, most amino acids are coded for by more than one codon.
- Of the 64 codons, 61 are sense codons (which code for amino acids), and 3 are nonsense codons (which do not code for amino acids and are stop signals for translation).
- The start codon, AUG, codes for methionine.
- Specific amino acids are attached to molecules of tRNA. Another portion of the tRNA has a base triplet called an anticodon.
- The base pairing of codon and anticodon at the ribosome results in specific amino acids being brought to the site of protein synthesis.
- The ribosome moves along the mRNA strand as amino acids are joined to form a growing polypeptide.
- Translation ends when the ribosome reaches a stop codon on the mRNA.
- In prokaryotes, translation can begin before transcription is complete.

### **The Regulation of Bacterial Gene Expression (pp. 215- 221)**

- Regulating protein synthesis at the gene level is energy-efficient because proteins are synthesized only as they are needed.
- Constitutive enzymes produce products at a fixed rate. Examples are genes for the enzymes in glycolysis.
- For these gene regulatory mechanisms, the control is aimed at mRNA synthesis.

#### **Repression and Induction (pp. 216- 219)**

- Repression controls the synthesis of one or several (repressible) enzymes.
- When cells are exposed to a particular end-product, the synthesis of enzymes related to that product decreases.
- In the presence of certain chemicals (inducers), cells synthesize more enzymes. This process is called induction.
- An example of induction is the production of  $\beta$ -galactosidase by *E. coli* in the presence of lactose, so lac-tose can be metabolized.

#### **The Operon Model of Gene Expression (pp. 219- 221)**

- The formation of enzymes is determined by structural genes.
- In bacteria, a group of coordinately regulated structural genes with related metabolic functions, and the promoter and operator sites that control their transcription, are called an operon.

- In the operon model for an inducible system, a regulatory gene codes for the repressor protein.
- When the inducer is absent, the repressor binds to the operator, and no mRNA is synthesized.
- When the inducer is present, it binds to the repressor so that it cannot bind to the operator; thus, mRNA is made, and enzyme synthesis is induced.
- In repressible systems, the repressor requires a corepressor in order to bind to the operator site; thus, the corepressor controls enzyme synthesis.
- Transcription of structural genes for catabolic enzymes (such as  $\beta$ -galactosidase) is induced by the absence of glucose. Cyclic AMP and catabolic activator protein (CAP) must bind to a promoter in the presence of an alternative carbohydrate (such as lactose).
- The presence of glucose inhibits the metabolism of alternative carbon sources by catabolic repression.

### **Mutation: Change in the Genetic Material (pp. 221- 229)**

- A mutation is a change in the nitrogenous base sequence of DNA; that change causes a change in the product coded for by the mutated gene.
- Reduction of a substrate refers to its gain of one or more electrons.
- Many mutations are neutral, some are disadvantageous, and others are beneficial.

#### Types of Mutations (pp. 221- 223)

- A base substitution occurs when one base pair in DNA is replaced with a different base pair.
- Alterations in DNA can result in missense mutations (which cause amino acid substitutions) or nonsense mutations (which create stop codons).
- In a frameshift mutation, one or a few base pairs are deleted or added to DNA.
- Mutagens are agents in the environment that cause permanent changes in DNA.
- Spontaneous mutations occur without the presence of a mutagen.

#### Mutagens (pp. 224- 226)

- Chemical mutagens include base-pair mutagens (for example, nitrous acid), base analogs (e.g., 2-aminopurine and 5-bromouracil), and frameshift mutagens (e.g., benzpyrene).
- Ionizing radiation causes the formation of ions and free radicals that react with DNA; base substitutions or breakage of the sugar-phosphate backbone results.
- Ultraviolet (UV) radiation is nonionizing; it causes bonding between adjacent thymines.
- Damage to DNA caused by UV radiation can be repaired by enzymes that cut out and replace the damaged portion of DNA.
- Photoreactivation enzymes repair thymine dimers in the presence of visible light.

#### The Frequency of Mutation (p. 226)

- Mutation rate is the probability that a gene will mutate when a cell divides; the rate is expressed as  $10$  to a negative power.
- Mutations usually occur randomly along a chromosome.

- A low rate of spontaneous mutations is beneficial in providing the genetic diversity needed for evolution.

#### Identifying Mutants (pp. 226- 227)

- Mutants can be detected by selecting or testing for an altered phenotype.
- Positive selection involves the selection of mutant cells and the rejection of nonmutated cells.
- Replica plating is used for negative selection; to detect, for example, auxotrophs that have nutritional requirements not possessed by the parent (nonmutated) cell.

#### Identifying Chemical Carcinogens (pp. 227- 229)

- The Ames test is a relatively inexpensive and rapid test for identifying possible chemical carcinogens.
- The test assumes that a mutant cell can revert to a normal cell in the presence of a mutagen, and that many mutagens are carcinogens.
- Histidine auxotrophs of *Salmonella* are exposed to an enzymatically treated potential carcinogen, and reversions to the nonmutant state are selected.

#### **Genetic Transfer and Recombination (pp. 229- 237)**

- Genetic recombination, the rearrangement of genes from separate groups of genes, usually involves DNA from different organisms; it contributes to genetic diversity.
- In crossing over, genes from two chromosomes are recombined into one chromosome containing some genes from each original chromosome.
- Mechanisms for genetic transfer in bacteria involve a portion of the cell's DNA being transferred from donor to recipient.
- When some of the donor's DNA has been integrated into the recipient's DNA, the resultant cell is called a recombinant.

#### Transformation in Bacteria (pp. 230- 232)

- During this process, genes are transferred from one bacterium to another as 'naked' DNA in solution.
- This process was first demonstrated in *Streptococcus pneumoniae*, and occurs naturally among a few genera of bacteria.

#### Conjugation in Bacteria (pp. 232- 234)

- This process requires contact between living cells.
- One type of genetic donor cell is an F<sup>+</sup>; recipient cells are F<sup>-</sup>. F cells contain plasmids called F factors; these are transferred to the F<sup>-</sup> cells during conjugation.
- When the plasmid becomes incorporated into the chromosome, the cell is called an Hfr (high frequency of recombination) cell.
- During conjugation, an Hfr cell can transfer chromosomal DNA to an F<sup>-</sup> cell. Usually, the Hfr chromosome breaks before it is fully transferred.

#### Transduction in Bacteria (pp. 234- 235)

- In this process, DNA is passed from one bacterium to another in a bacteriophage and is then incorporated into the recipient's DNA.
- In generalized transduction, any bacterial genes can be transferred.

### Plasmids and Transposons (pp. 235- 237)

- Plasmids are self-replicating circular molecules of DNA carrying genes that are not usually essential for the cell's survival.
- There are several types of plasmids, including the F factor, dissimilation plasmids, plasmids carrying genes for toxins or bacteriocins, and resistance factors.
- Transposons are small segments of DNA that can move from one region to another region of the same chromosome, or to a different chromosome or a plasmid.
- Transposons are found in the main chromosomes of organisms, in plasmids, and in the genetic material of viruses. They vary from simple (insertion sequences) to complex.
- Complex transposons can carry any type of gene, including antibiotic-resistance genes, and are thus a natural mechanism for moving genes from one chromosome to another.

### Genes and Evolution (p. 237)

- Diversity is the precondition for evolution.
- Genetic mutation and recombination provide a diversity of organisms, and the process of natural selection allows the growth of those best adapted for a given environment.