Chapter 2 Preview p. 47-49

I. Nucleic acids- DNA and RNA  fig 2.16

A. Nucleotides- the building blocks of heredity molecules DNA and RNA (nucleic acids)

a. Sugar- deoxyribose (DNA), or ribose (RNA)
b. Nitrogen containing base- 2 types
c. 2 double ringed purines = adenine and guanine,
d. 2 single ringed pyrimidines = uracil (only in RNA), thymine (only in DNA), and cytosine.

1. Nucleotide has 3 parts

B. DNA- the storage molecule for genetic information (genes)

1. 2 long strands of nucleotides wrapped around each other into a double helix.
2. A backbone of alternating sugar to phosphate with bases pointing inward to form the ‘rungs’ of the twisted helix ladder.
3. The helix is stuck together by hydrogen bonds between bases. Only pairing of A to T and G to C is possible (a large to a small base). This is called complementary base pairing.
4. Base pairing is the basis for the genetic code and therefore heredity.

C. RNA-

1. Differences from DNA
   a. Single stranded nucleic acid.
   b. The sugar is ribose.
c. The base uracil replaces thymine. fig. 2.17

2. 3 different types play a role in protein synthesis

a. messenger RNA (mRNA), ribosomal RNA (rRNA), transfer RNA (tRNA)

II. Structure and function of genetic material Chapter 8

A. Overview

1. Chromosomes are cellular structures made up of genes that carry heredity information. Fig. 8.1

a) A gene is a segment of DNA that codes for a functional product (protein). Average gene = 1000 base pairs. So, \(4^{1000}\) different possibilities for a gene product.

b) DNA is composed of repeating nucleotides containing the bases adenine (A), thymine (T), cytosine (C), or guanine (G); a deoxyribose sugar; and a phosphate group. Fig. 8.3

c) Bases occur in specific complementary base pairs, the hydrogen bonds connect strands of DNA.

Base pairing: A to T, G to C
d) DNA can be transcribed into RNA (transcription) and then RNA can be translated into protein (translation). Fig 8.2

\[\text{DNA transcription} \rightarrow \text{RNA translation} \rightarrow \text{protein}\]

2. Genotype and phenotype

a) The genotype is an organism’s genetic makeup, the information that codes for all the characteristics and potential properties of the organism. The collection of genes (DNA) for an organism.

b) The phenotype refers to an organism’s actual expressed properties, such as its ability to perform a chemical reaction. The collection of enzymatic or structural proteins. Fig. 8.5

3. DNA and chromosomes

a) DNA in chromosomes forms one long double helix.

b) Prokaryotes have a single circular chromosome attached to the plasma membrane. *E. coli* contains about 4 million base pairs. Fig. 8.7

c) Eucaryotes contain several chromosomes in a nuclear membrane. Each chromosome winds around proteins called histones. Other proteins influence genes to be functional or turned off. This regulation of gene expression governs the differentiation of eukaryotic cells into the different type of cells found in multicellular organisms.

4. DNA replication fig. 8.6

a) Replication begins as the 2 helical strands unravel at a replication fork where synthesis begins. Complementary pairing of bases yields a complementary copy of original DNA. Steps 1-2

b) DNA polymerase synthesizes the leading strand in a continuous strand. Step 3

Since DNA polymerase can only read in one direction, in the lagging strand, DNA polymerase enzymes form short strands of DNA. Short strands are joined into continuous DNA by DNA ligase enzymes. Process is started by RNA polymerase with an RNA primer. Steps 4-6

c) Each new double-stranded DNA molecule has one original strand and so is called semiconservative replication. Replication errors are limited by proofreading properties of DNA polymerase.

5. RNA and protein synthesis fig. 8.8
a) Transcription is a process where mRNA is synthesized from DNA as a complementary base pair copy. Thymine is replaced by uracil.

1) RNA polymerase binds DNA at the promoter site to begin transcription. The RNA polymerase and newly formed mRNA are released from the DNA at the terminator site.

Deoxyribose is placed by ribose.

b) Translation is the process where the language of nucleic acids is translated into the language of proteins. The language of mRNA is in codons, groups of 3 nucleotides such as CUG (leucine). Each codon codes for a particular amino acid. There are 64 codons but only 20 amino acids, so there are multiple codons for each amino acid. This is called a degeneracy of the code.

1) Sense codons code for amino acids. Fig. 8.9

2) Nonsense codons signal the end of synthesis of a protein. E.g. UAA, UAG Fig.8.10 step 7

3) Translation occurs at the ribosomes that move along mRNA. Amino acids are transported to the ribosomes by tRNA. Each tRNA molecule is specific for an amino acid and contains an anticodon (complementary to a codon). Fig. 8.10 steps 2-6

4) In eukaryotic cells, regions of genes that code for proteins are often interrupted by noncoding DNA. These areas called introns must be removed so that the exons (regions of expressed DNA) can be reassembled into functional or mature mRNA. Fig 8.12
III. Regulation of bacterial gene expression.

Energy is conserved by making only the proteins needed at the time.

If a gene produces a product at a fixed rate, it is constitutive. 60-80% of genes are not regulated making basic, life sustaining proteins.

A. *Repression and induction*

1. An inducer is a substance (substrate) whose presence results in increased transcription of a gene with resulting formation or increase in amount of an enzyme. These are inducible enzymes, controlled by a genetic response termed enzyme induction. E.g., lactase production in response to lactose.

2. A repressor is a protein that through genetic regulation decreases enzyme synthesis. This is termed enzyme repression. The repressor blocks the ability of RNA polymerase to initiate transcription of the repressed gene(s). It occurs if cells are exposed to an overabundance of a metabolic end-product in a pathway. Fig. 8.13

B. *Operon model of gene expression. Protein synthesis in bacteria is controlled by the operon model. Fig. 8.14.*

1. Example: E. coli lac operon for induction of enzymes for lactose catabolism.

3 enzymes are needed for lactose uptake and utilization in E. coli that are coded for by 3 structural genes close together on the bacterial chromosome.

An operator site (on off switch) and a promoter site (region where RNA polymerase initiates transcription) is located next to the structural genes. These DNA sites are the operon.

Farther away is a gene that codes for repressor protein. When lactose is present it is transported into the cell and converted to the inducer allolactose that binds with the repressor protein so it cannot bind to the operator site. The operator then induces structural genes to transcribe mRNA and to produce enzymes to utilize lactose, an inducible enzyme system. fig 8.15

IV. Mutation: change in the base sequence of DNA genetic material

A. *Types of mutations fig. 8.16, 8.17*

1. Base substitution, or point mutation is when a single base in DNA is replaced with a different one. May result in incorporation of an incorrect amino acid in the protein, known as a missense 8.17b. The most common mutation.
Sometimes this will create a stop codon, which stops protein synthesis too soon, termed a nonsense mutation 8.17c.

2. Deletion or addition of base pairs results in a frameshift mutation, causing a long stretch of missense and an inactive protein product. 8.17d Example: Huntingtons’s disease with extra bases in gene.

3. Spontaneous mutations occur without intervention of mutation causing agents. This is the raw material for evolution.

**B. Mutagens are chemicals and radiation that can cause mutations.**

1. Chemical mutagens. Fig. 8.18. 8.19
   
a) base pair mutagen causes a base to pair with the wrong base, e.g., nitrous acid causes adenine to pair with cytosine.

   b) base analogs are structurally similar to bases and are incorporated into DNA by error. E.g. 5-bromouracil replaces thymine. Some are antiviral drugs such as AZT azidothymidine treats HIV.

   c) frameshift mutagens (cause a bulge in DNA) can be carcinogens. E.g. aflatoxin (a mold toxin).

2. Radiation. Fig. 8.20
   
a) Ionizing radiation such as X rays and gamma rays damage DNA. Cause high energy electrons, some leave molecule, now a free radical with unpaired electron.

   b) ultraviolet light (nonionizing radiation). Light-repair enzymes can repair ultraviolet damage. Thymine dimmers form. Fig. 8.20

C. Frequency of mutation is low, only about once in 1 billion base pair replications. Mutagens increase rate of error 10 to 1000 times. In a population of $10^7$ cells a few mutants are produced each generation.

D. Identifying mutants which occur at low rates can be easily detected with bacteria because large populations grow quickly.

1. Positive (direct) selection is illustrated by plating bacteria on a medium containing penicillin. Resistant mutants can be isolated directly.

2. Negative (indirect) selection selects a cell that cannot perform a function. Grow colonies on a nutritionally complete medium. Transfer colonies with felt pad to minimal medium which lacks essential nutrient. An auxotrophic
mutant will fail to appear on minimal medium. An auxotroph is a mutant bacteria having a nutritional requirement not found in parent strain. E.g. missing an enzyme for production of a required amino acid. Fig. 8.18

E. Identifying chemical carcinogens fig. 8.22

1. The Ames test uses bacteria to screen for potential carcinogens. Assumption: exposure of mutant bacteria to mutagenic substances may cause new mutations that reverse the effect (the phenotype) of the mutation. Specifically, the test measures the reversion of histidine auxotrophs of Salmonella to histidine synthesizing cells after treatment with a mutagen.

Many chemicals must be activated by animal enzymes to become mutagenic, so rat liver extract (containing many enzymes) is added to bacteria culture with chemical. About 90% of chemicals found by Ames test to be mutagenic have also shown to be carcinogenic in animals.

V. Genetic transfer and recombination

A. Overview- genetic recombination is the rearrangement of genes to form new combinations. Chromosomes can break so that some genes are reshuffled in a process called crossing over. Recombination is usually beneficial in nature. Fig. 8.23.

In bacteria, a donor cell gives a portion of its total DNA to a different recipient cell, now called a recombinant.

B. Transformation in bacteria occurs when naked DNA in solution is transferred from one bacteria to another competent bacteria (a bacteria that can have DNA pass through the cell wall). Small pieces of DNA can be incorporated into the other bacteria. These are usually closely related bacteria. Examples are Neisseria, certain Streptococcus and Staphylococcus. E. coli can be treated to take up DNA. Fig. 8.24, 8.25

C. Conjugation in bacteria requires contact between living cells of opposite mating types (F+, F-). Conjugation is mediated by plasmids which are circular pieces of DNA that replicate independently from the cell’s chromosome. They carry genes that are usually not essential for cell growth. Plasmids carry genes for sex pili. Plasmids may be inserted into the chromosome. Subsequent conjugation may transfer part or all of the combined chromosome and plasmid. Fig. 8.26, 8.27

D. Transduction in bacteria occurs when bacterial DNA is transferred from the donor cell to the recipient cell inside a virus that infects bacteria (bacteriophage). During phage development inside the infected cell, the
bacterial chromosome breaks apart and some fragments might happen to be packaged inside phage protein coats and are subsequently transferred to other bacteria when infected with the phage.

E. **Plasmids** are gene containing circular pieces of DNA about 1-5% the size of bacterial chromosome. *Not essential for cell growth.*

1. Dissimilation plasmids code for enzymes to utilize unusual sugars or hydrocarbons.
2. Synthesis of bacteriocins, toxic proteins that kill other bacteria.
3. Resistance factors (R factors) carry genes for antibiotic resistance and other antimicrobial factors. Fig. 8.29

F. **Transposons** are small segments of DNA that move from one region of DNA to another (same chromosome, other chromosome, plasmid). *Also called “jumping genes”. Frequency rates comparable to spontaneous mutation rates in bacteria. Transposons contain the information for their own transposition. Transposons can potentially move genes between organisms, even species, via plasmids or viruses. Powerful evolutionary mechanism. Fig. 8.30.*