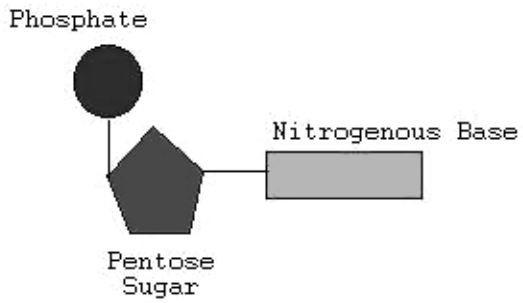
Unit 6 Notes – DNA and RNA Structure

B-4.1 Compare DNA and RNA in terms of structure, nucleotides, and base pairs.

Key Concepts:
Nucleic acids: deoxyribonucleic acid (DNA), ribonucleic acid (RNA)
Nucleotides: nitrogenous base, sugar, phosphate group
Complementary bases

Nucleic acids **are organic molecules that serve as the blueprint for proteins and, through the action of proteins, for all cellular activity.**

- There are two types of nucleic acids.
  - *Deoxyribonucleic acid (DNA)*
  - *Ribonucleic acid (RNA)*
- Both DNA and RNA are composed of small units called *nucleotides.* The nucleotides that compose nucleic acids have three parts:
  - A *nitrogenous base*
    - Cytosine (C)
    - Guanine (G)
    - Adenine (A)
    - Thymine (T) (DNA only)
    - Uracil (U) (RNA only)
  - A simple (pentose) *sugar*
    - Deoxyribose (DNA only)
    - Ribose (RNA only)
  - A *phosphate group*



The basic structure of the two molecules is different.

- DNA consists of two single chains which spiral around an imaginary axis to form a double helix with nitrogenous bases from each strand of DNA chemically bonded through the axis of the helix.
  - When the nitrogenous bases of two strands of DNA chemically bond through the center of the helix, each base can bond to only one type of base. Bases that bond are called *complementary bases.*
    - Guanine (G) will only bond with Cytosine (C).
    - Thymine (T) will only bond with Adenine (A).
- RNA consists of a single chain of nucleotides with nitrogenous bases exposed along the side.
  - When the nitrogenous bases of RNA chemically bond to a strand of DNA, each RNA base can bond with only one type of DNA base. Bases that bond are called *complementary bases.*
    - Guanine (G) will only bond with Cytosine (C).

- Uracil (U) will only bond with Adenine (A).

Comparison of DNA and RNA

	DNA	RNA
Type of base composing nucleotides	Cytosine (C) Adenine (A) Guanine (G) Thymine(T)	Cytosine(C) Adenine (A) Guanine (G) Uracil (U)
Type of sugar composing nucleotides	deoxyribose	ribose
Molecule structure and shape	Double helix	Single chain

B-4.2 Summarize the relationship among DNA, genes, and chromosomes.

Key Concepts:
Chromosome DNA Gene

DNA, genes, and chromosomes compose the molecular basis of heredity

- A *chromosome* is a structure in the nucleus of a cell consisting essentially of one long thread of DNA that is tightly coiled.
- *DNA*, composed of nucleotides, provides the blueprint for the synthesis of proteins by the arrangement of nitrogenous bases.
  - The code for a particular amino acid (the base unit of proteins) is determined by a sequence of three base pairs on the DNA molecule.
- A *gene* is a specific location on a chromosome, consisting of a segment of DNA, that codes for a particular protein.
  - The particular proteins coded by the DNA on the genes determine the characteristics of an organism.
  - Each chromosome consists of hundreds of genes determining the many proteins for an individual organism.

B-4.3 Explain how DNA functions as the code of life and the blueprint for proteins.

Key Concepts:
Genetic code: sex chromosomes, autosomal chromosomes (autosomes)
DNA replication

DNA, which comprises the organism's chromosomes, is considered the "code of life" (*genetic code*) because it contains the code for each protein that the organism needs.

- The specificity of proteins is determined by the order of the nitrogenous bases found in DNA.
  - In order to construct the specific proteins needed for each specific purpose, cells must have a blueprint that reveals the correct order of amino acids for each protein found in the organism (thousands of proteins).
  - A gene is a segment of DNA that codes for one particular protein.
- Each cell in an organism's body contains a complete set of chromosomes.
  - The number of chromosomes varies with the type of organism. For example, humans have 23 pairs of chromosomes; dogs have 39 pairs; potatoes have 24 pairs.
  - One pair of chromosomes in an organism determines the sex (male, female) of the organism; these are known as *sex chromosomes*. All other chromosomes are known as autosomal chromosomes, or *autosomes*.
  - Cells (except for sex cells) contain one pair of each type of chromosome.
    - Each pair consists of two chromosomes that have genes for the same proteins.
    - One chromosome in each pair was inherited from the male parent and the other from the female parent. In this way traits of parents are passed to offspring.
    - For example, human cells have 46 chromosomes (23 pairs).
- Each chromosome consists of thousands of genes. This is because there are so many unique proteins that each organism needs to produce in order to live and survive.
  - Organisms that are closely related may have genes that code for the same proteins that make the organisms similar. For example, all maple trees have many of the same genes.
  - Each individual organism has unique characteristics and those unique characteristics arise because of the differences in the proteins that the organism produces.
  - Organisms that are not closely related share fewer genes than organisms that are more closely related. For example, red maple trees share more genes with oak trees than with earthworms.

DNA can function as the code of life for protein synthesis or the process of DNA replication, which ensures that every new cell has identical DNA.

- *DNA replication* is carried out by a series of enzymes. The first enzyme unzips the two strands of DNA that compose the double helix, separating paired bases.
- Each base that is exposed can only bond to its complementary base.
  - Adenine (A) can only bond to thymine (T)
  - Cytosine (C) can only bond to guanine (G)
- Each of the separated strands serves as a template for the attachment of complementary bases, forming a new strand, identical to the one from which it was "unzipped".
- The result is two identical DNA molecules.

B-4.4 Summarize the basic processes involved in protein synthesis (including transcription and translation).

Key Concepts:
Protein synthesis
Transcription: messenger RNA (mRNA)
Translation: ribosomal RNA (rRNA), codons, transfer RNA (tRNA), anticodon site, peptide bond, stop codon

When a particular protein is needed, the cell must make the protein through the process of *protein synthesis.* DNA molecules (which contain the code) do not leave the nucleus of the cell, but protein synthesis must occur in the ribosomes which are located outside of the nucleus in the cytoplasm. Therefore, the code must be carried from the nucleus to the cytoplasm.

Transcription

Transcription is the process by which a portion of the molecule of DNA is copied into a complementary strand of RNA. Through the process of transcription, the DNA code is transferred out of the nucleus to the ribosomes.

- Through a series of chemical signals, the gene for a specific protein is turned on. An enzyme attaches to the exact location on the DNA molecule where the gene is found, causing the two strands of DNA to separate at that location.
- Complementary RNA nucleotide bases bond to the bases on one of the separated DNA strands.

DNA nucleotide bases exposed on the separated strand	RNA nucleotide which bonds
Adenine (A)	Uracil (U)
Thymine (T)	Adenine (A)
Cytosine (C)	Guanine (G)
Guanine (G)	Cytosine (C)

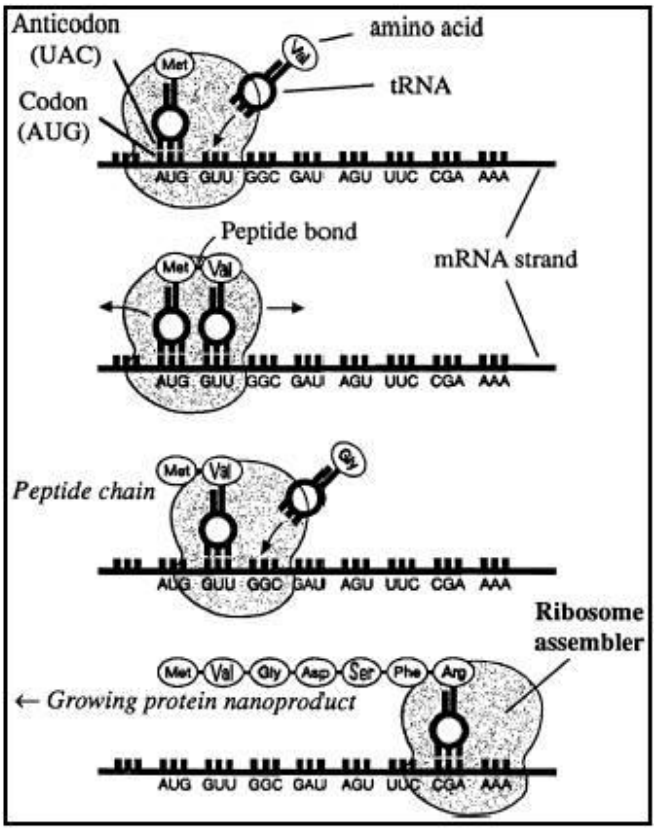
- Nucleotides of RNA bond together, forming a single-stranded molecule of RNA that peels away from the DNA strand and the two DNA strands rejoin. This is called *messenger RNA* (*mRNA*).
- The messenger RNA (mRNA) is formed complementary to one strand of DNA.
- The mRNA strand leaves the nucleus and goes through the nuclear membrane into the cytoplasm of the cell.

Translation

Translation is the process of interpreting the genetic message and building the protein and begins when the mRNA attaches to a ribosome, which contains proteins and *ribosomal RNA (rRNA),* in the cytoplasm.

- The function of ribosomes is to assemble proteins according to the code that the mRNA brings from the DNA.
- Each three-base nucleotide sequence on the mRNA is called a *codon*. Each codon specifies a particular amino acid that will be placed in the chain to build the protein molecule.
  - For example, if the DNA sequence was GAC, then the RNA sequence becomes CUG and the amino acid that is coded is Leucine.
    TEACHER NOTE: mRNA codons for specific amino acids can be found in tables in most textbooks.
  - The sequence of mRNA nucleotides determines the order of the amino acids in the protein chain which, in turn, distinguishes one protein from another in structure and function.
- Another type of RNA, *transfer RNA (tRNA)*, is vital in assembling amino acids into the correct sequence for the required protein by transferring amino acids to the ribosomes when needed. There are twenty different types of tRNA molecules, one for each amino acid.
  - At one end of each tRNA is an *anticodon site*, which has the 3-nucleotide bases complementary to the codon of mRNA.
  - The other end of the tRNA molecule has a specific amino acid attached determined by the anticodon.

- The translation process takes place as follows:
  - The tRNA with its attached amino acid pairs to the codon of the mRNA attached to a ribosome.
  - When a second tRNA with its specific amino acid pairs to the next codon in sequence, the attached amino acid breaks from the first tRNA and attaches to the amino acid of the second tRNA.
  - The ribosome forms a *peptide bond* between the amino acids, and an amino acid chain begins to form.
  - The empty tRNA moves off and picks up another matching amino acid from the cytoplasm in the cell.
  - This sequence is repeated until the ribosome reaches a *stop codon* on the mRNA, which signals the end of protein synthesis.



B-4.8 Compare the consequences of mutations in body cells with those in gametes.

Key Concepts :

Mutation: mutagen, mutant cell, gene mutation, chromosomal mutation, nondisjunction

Beneficial mutations

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A *mutation* is the alteration of an organism's DNA. Mutations can range from a change in one base pair to the insertion or deletion of large segments of DNA. Mutations can result from a malfunction during the process of meiosis or from exposure to a physical or a chemical agent, a *mutagen.*

Most mutations are automatically repaired by the organism's enzymes and therefore have no effect. However, when the mutation is not repaired, the resulting altered chromosome or gene structure is then passed to all subsequent daughter cells of the *mutant cell*, which may have adverse or beneficial effects on the cell, the organism, and future generations.

- If the mutant cell is a body cell (somatic cell), the daughter cells can be affected by the altered DNA, but the mutation will not be passed to the offspring of the organism.
  - Body cell mutations can contribute to the aging process or the development of many types of cancer.
- If the mutant cell is a gamete (sex cell), the altered DNA will be transmitted to the embryo and may be passed to subsequent generations. Gamete cell mutations can result in *genetic disorders*.
  - If the mutation affects a single gene, it is known as a *gene mutation*.
    - For example, the genetic basis of sickle-cell disease is the mutation of a single base pair in the gene that codes for one of the proteins of hemoglobin.
    - Other examples of genetic disorders are Tay-Sachs disease, Huntington's disease, cystic fibrosis, or albinism.
  - If the mutation affects a group of genes or an entire chromosome, it is know as a *chromosomal mutation.*
    - *Nondisjunction* results in an abnormal number of chromosomes, usually occurring during meiosis.
      - Examples of abnormalities in humans due to nondisjunction of sex chromosomes are Klinefelter's syndrome (male) and Turner's syndrome (female).
      - Examples of abnormalities in humans due to nondisjunction of autosomal chromosomes include Down syndrome.

In some cases mutations are beneficial to organisms. *Beneficial mutations* are changes that may be useful to organisms in different or changing environments. These mutations result in phenotypes that are favored by natural selection and increase in a population.