Chapter 13: RNA and Protein Synthesis

Class	Biology

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13.1 — RNA

The Role of RNA

DNA could be copied with its two strands.

- One is a template
- The other strand is copied by **DNA polymerase**

RNA (Ribonucleic Acid) → nucleic acid with a long chain of nucleotides

> Genes contain **coded DNA**.

- Tell the ribosomes how to build proteins

Comparing RNA and DNA

1. RNA has a **ribose** sugar
2. RNA is **single**-stranded
3. RNA contains **uracil** in place of thymine

> DNA has to stay **in the nucleus** while RNA can go **outside the nucleus to the ribosomes**.

Functions of RNA

RNA functions as a *disposable copy of DNA*.

- Main Purpose: protein synthesis

Messenger RNA (mRNA): RNA molecules that carry copies of genetic instructions for assembling proteins

Ribosomal RNA (rRNA): components of the subunits of ribosomes where proteins are synthesized

Transfer RNA (tRNA): RNA molecules that transfer each amino acid to the ribosome as it is specified by the genetic code

RNA Synthesis

Transcription

Transcription → segments of DNA serve as templates to produce complementary DNA molecules

- Prokaryotes: produced in the cytoplasm
- Eukaryote: produced in the nucleus (cytoplasm for protein synthesis)

Transcription requires the use of **RNA polymerase** (an enzyme).

- Binds to a strand of DNA and makes a complementary strand using the present nucleotides

Promoters

RNA polymerase binds to *promoters*.

- **Promoters:** regions of DNA with specific base sequence
    - Show where to begin making DNA
    - Also show where to stop making DNA

RNA Editing

RNA molecules can have some bits taken out.

- **Introns:** portions that are cut out and discarded
- **Exons:** remaining portions that are spliced back together to form the final mRNA

RNA editing allows for **one** gene to make **multiple** mRNA molecules.

13.2 — Ribosomes & Protein Synthesis

The Genetic Code

Proteins are made by joining amino acids into **polypeptides** (long chains).

- Order → shape, chemical properties, function of a protein

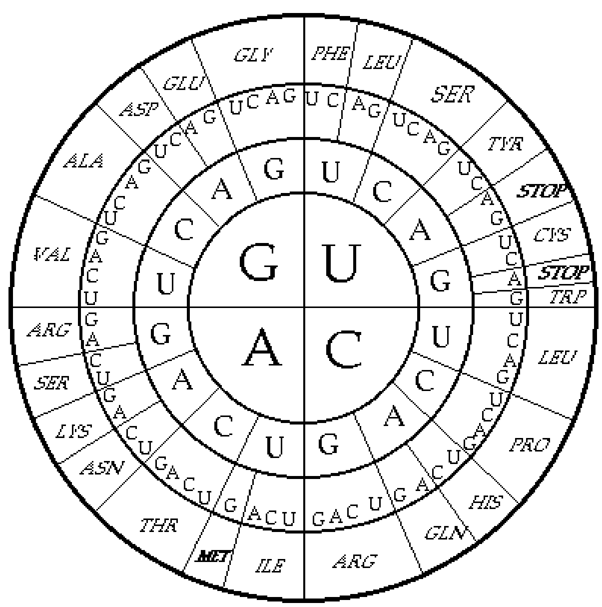
Genetic Code: language of [A], [T], [C], and [G]

- Read three letters at a time
- *"Word"* → three bases (**codon**)

Reading Codons

There are **64** possible codons.

- Multiple codons can code for the same amino acid



Start and Stop Codons

Methionine (AUG) → **start codon**

- Three **stop codons**

Start and stop codons begin and end protein synthesis.

Translation

Ribosomes assemble **amino acids** into **polypeptides**.

- **Translation:** the decoding of an mRNA message into a protein

1. Messenger RNA enters the cytoplasm
2. Translation begins at AUG (methionine / the start codon)
3. tRNA anticodons match up to the mRNA codons
4. tRNA brings a corresponding amino acids
5. Next codon is read
6. Next tRNA anticodon is found
7. Previous tRNA leaves but amino acid stays
8. Peptide bond forms
9. Continues until stop codon
10. Polypeptide is broken off

The Molecular Basis of Heredity

Central Dogma of Molecular Biology: Information → DNA → RNA → protein

- **Gene Expression:** the way in which DNA, RNA & proteins are involved in putting genetic information into action

13.3 — Mutations

Types of Mutations

Mutations: heritable changes in genetic information

- **Gene Mutations:** mutations that change a single gene
- **Chromosomal Mutations:** mutations that change a whole chromosome

Gene Mutations

Point Mutations: gene mutations that involved changes in a few nucleotides (occur at a single point in the DNA sequence)

- **Substitution** → one base is changed to a different base
- **Frameshift Mutations** → shift the “reading frame” of the genetic message
    - **Insertions** → a base is added
    - **Deletions** → a base is removed

> **Frameshift mutations** can alter a protein so much that it is unable to perform its normal functions.

Chromosomal Mutations

- Changes in the number or structure of chromosomes

Deletion → loss of a part of a chromosome

Duplication → an extra copy of a part of a chromosome

Inversion → reversed direction of parts of a chromosome

Translocation → one part of a chromosome breaks off and attaches to another

Effects of Mutations

Mutations can occur due to *natural* or *artificial means*.

- Mostly harmless

Mutagens

Mutagens: chemical or physical agents in the environment (ex. specific pesticides, natural plant alkaloids)

Harmful & Helpful Mutations

- Some mutations have no effect & some disrupt gene function completely

> Mutations are the source of genetic variability in organisms.

Polyploidy: the condition in which an organism has extra sets of chromosomes

13.4 — Gene Regulation & Expression

Prokaryotic Gene Regulation

Prokaryotes only use the genes necessary for survival.

> DNA-binding proteins in prokaryotes regulate genes by controlling transcription

- Switch genes on and off

Operon: a group of genes that are regulated together

- Genes have related functions
- Ex. *lac* operon → E.coli’s 3 genes that must be turned on together to use lactose as food

Promoters and Operators

Promoters (P): sites where RNA polymerase can bind to begin transcription

Operators (O): sites where DNA-binding protein can bind to DNA

- *Lac* Repressor → binds to the O region and prevents the gene's transcription
  - Has a binding site for lactose, which *turns off* the repressor and allows for transcription

Eukaryotic Gene Regulation

Most eukaryotic genes are controlled *individually*.

TATA Box: a short region of [T] and [A] bases that signal RNA polymerase to begin transcription before a gene

Transcription Factors

Multiple **transcription factors** affect transcription.

- Ex. opening up chromatin, attracting RNA polymerase, blocking access to genes

> Some transcription factors are activated by **chemical signaling.**

- Ex. steroid hormones

Cell Specialization

Complex gene regulation allows for different cells to perform different functions.

RNA Interference

microRNA (miRNA) → small, interfering RNA molecules

- Produced by transcription and form loops

- *Dicer* enzyme splits them apart
- Attach to a *silencing complex*
    - Destroys any mRNA with a complementary sequence

microRNA stops some mRNA from producing proteins.

- Shuts down the expression of a gene

RNA Interference (RNAi): blocking gene expression by means of an *miRNA silencing complex*

- Can allow scientists to turn on and off certain genes (even for virus and cancer cells)

Genetic Control of Development

Differentiation: becoming specialized in structure and function

- Regulated by transcription factors and repressors

Homeotic Genes

Edward B. Lewis → found that some specific genes control specific body part identities

- **Homeotic Genes:** a set of master control genes that regulate organ development in specific parts of the body

Homeobox and Hox Genes

Homeobox Genes → code for transcription factors that activate other genes important in cell development & differentiation

- Expressed in certain regions of the body

Hox Genes → determine the identities of each segment a fly's body

- Group of *homeobox genes*

- Similar groups in humans that show traits in order (head to toe)

Environmental Influences

The environment can also be a factor in cell development in differentiation.

- Ex. warmer temperature can speed up metamorphosis in tadpoles