RIBONUCLEIC ACID (RNA)

DR. A. TARAB

DEPT. OF BIOCHEMISTRY

HKMU
• Ribonucleic acid (RNA) is a polymeric molecule
• It is implicated in a varied sort of biological roles in **coding**, **decoding**, **regulation**, and **expression** of genes
• **DNA** and RNA are **nucleic acids**, and, along with **proteins** and **carbohydrates**, constitute the three major **macromolecules** essential for all known forms of **life**
• Like DNA, RNA is assembled as a chain of nucleotides, but unlike DNA it is more often found in nature as a single-strand folded unto itself, rather than a paired double-strand

• Cellular organisms use messenger RNA (mRNA) to convey genetic information (using the letters G, A, U, and C to denote the nitrogenous bases guanine, adenine, uracil and cytosine) that directs synthesis of specific proteins
• Many **viruses** encode their genetic information using an RNA **genome**

• Some RNA molecules play an active role within cells by catalyzing biological reactions, controlling **gene expression**, or sensing and communicating responses to cellular signals

• One of these active processes is **protein synthesis**, a universal function whereby mRNA molecules direct the assembly of proteins on **ribosomes**
• This process uses transfer RNA (tRNA) molecules to deliver amino acids to the ribosome, where ribosomal RNA (rRNA) links amino acids together to form proteins.
Comparison with DNA

• The chemical structure of RNA is very similar to that of DNA, but differs in three main ways:

• 1. Unlike double-stranded DNA, RNA is a single-stranded molecule in many of its biological roles and has a much shorter chain of nucleotides

• However, RNA can, by complementary base pairing, form intrastrand double helixes, as in tRNA
2. While DNA contains deoxyribose, RNA contains ribose (in deoxyribose there is no hydroxyl group attached to the pentose ring in the 2' position). These hydroxyl groups make RNA less stable than DNA because it is more prone to hydrolysis.

3. The complementary base to adenine is not thymine, as it is in DNA, but rather uracil, which is an unmethylated form of thymine.
Like DNA, most biologically active RNAs, including mRNA, tRNA, rRNA, small nuclear RNAs (snRNAs), and other non-coding RNAs, contain self-complementary sequences that allow parts of the RNA to fold and pair with itself to form double helices.

Analysis of these RNAs has revealed that they are highly structured.
Unlike DNA, their structures do not consist of long double helices but rather collections of short helices packed together into structures akin to proteins.

In this fashion, RNAs can achieve chemical catalysis, like enzymes.

For instance, determination of the structure of the ribosome—an enzyme that catalyzes peptide bond formation—revealed that its active site is composed entirely of RNA.
• Each nucleotide in RNA contains a ribose sugar, with carbons numbered 1' through 5’
• A base is attached to the 1' position, in general, adenine (A), cytosine (C), guanine (G), or uracil (U)
• Adenine and guanine are purines, cytosine and uracil are pyrimidines
• A phosphate group is attached to the 3' position of one ribose and the 5' position of the next
• The phosphate groups have a negative charge each at physiological pH, making RNA a charged molecule (polyanion)
• The bases form hydrogen bonds between cytosine and guanine, between adenine and uracil and between guanine and uracil
Chemical structure of RNA
Synthesis of RNA

- Synthesis of RNA is usually catalyzed by an enzyme—**RNA polymerase**—using DNA as a template, a process known as **transcription**
- Initiation of transcription begins with the binding of the enzyme to a **promoter** sequence in the DNA (usually found "upstream" of a gene)
- The DNA double helix is unwound by the **helicase** activity of the enzyme
• The enzyme then progresses along the template strand in the 3’ to 5’ direction, synthesizing a complementary RNA molecule with elongation occurring in the 5’ to 3’ direction

• The DNA sequence also dictates where termination of RNA synthesis will occur
Types of RNA

- Messenger RNA (mRNA) is the RNA that carries information from DNA to the ribosome, the sites of protein synthesis (translation) in the cell.
- The coding sequence of the mRNA determines the amino acid sequence in the protein that is produced.
- Many RNAs do not code for protein however (about 97% of the transcriptional output is non-protein-coding in eukaryotes).
• These so-called **non-coding RNAs** ("ncRNA") can be encoded by their own genes (RNA genes), but can also derive from mRNA **introns**.

• The most prominent examples of non-coding RNAs are **transfer RNA** (tRNA) and **ribosomal RNA** (rRNA), both of which are involved in the process of translation.
In translation

- **Messenger RNA** (mRNA) carries information about a protein sequence to the **ribosomes**, the protein synthesis factories in the cell.
- It is **coded** so that every three nucleotides (a codon) correspond to one amino acid.
- In **eukaryotic** cells, once precursor mRNA (pre-mRNA) has been transcribed from DNA, it is processed to mature mRNA.
• This removes its **introns**—non-coding sections of the pre-mRNA

• The mRNA is then exported from the nucleus to the cytoplasm, where it is bound to ribosomes and **translated** into its corresponding protein form with the help of tRNA

• In prokaryotic cells, which do not have nucleus and cytoplasm compartments, mRNA can bind to ribosomes while it is being transcribed from DNA
• After a certain amount of time the message degrades into its component nucleotides with the assistance of ribonucleases

• Transfer RNA (tRNA) is a small RNA chain of about 80 nucleotides that transfers a specific amino acid to a growing polypeptide chain at the ribosomal site of protein synthesis during translation.
• It has sites for amino acid attachment and an **anticodon** region for **codon** recognition that binds to a specific sequence on the messenger RNA chain through hydrogen bonding

• **Ribosomal RNA** (rRNA) is the catalytic component of the ribosomes