Taibah University

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College of Applied Medical Sciences

(Molecular & Medical Genetics)

MLT 331

Lecture 2

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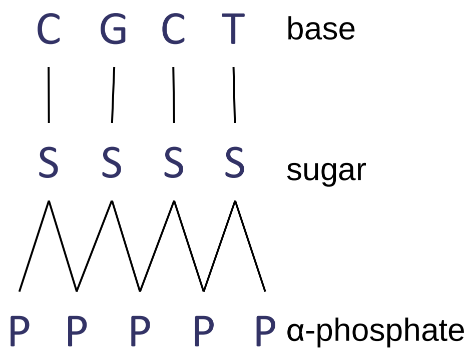
- To understand the structure and composition of Nucleic Acid
- To appreciate the makeup and composition of DNA & RNA
- To illustrate the difference between DNA & RNA

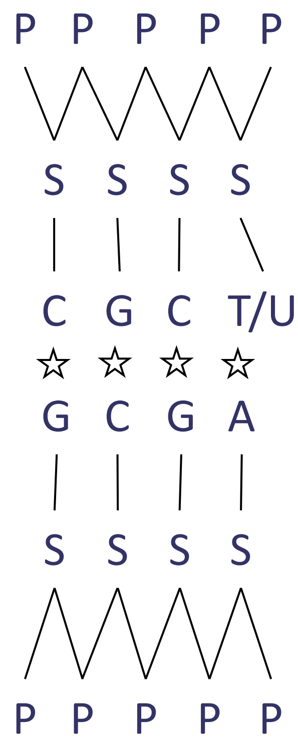
MOLECULAR STRUCTURE OF DNA & RNA

NUCLEIC ACID:

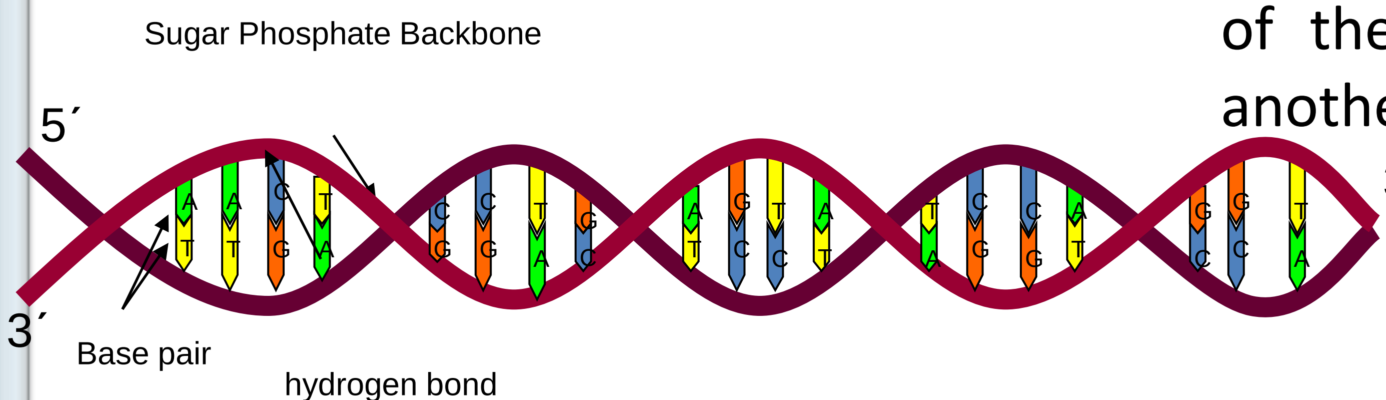
- Molecule of life
- Storage and transmission of genetic information
- Two types
  1) Deoxyribonucleic acid (DNA)
  2) Ribonucleic acid (RNA)
- Consists of long polymer of repeating units called nucleotides

- DNA is short for **Deoxyribonucleic acid**.
- DNA carry most of the **genetic information** required to produce the **three macromolecules** required for life.
- **Eukaryotic** DNA is mainly found in **Chromosomes** inside the cell **nucleus** and is called **Genomic DNA (g-DNA)**, but can also be found in the Mitochondria and is called **Mitochondrial DNA (mt-DNA)**.
- **Prokaryotic** DNA can be found as g-DNA, but also can be freely available in the cytoplasm as **Plasmid DNA**.



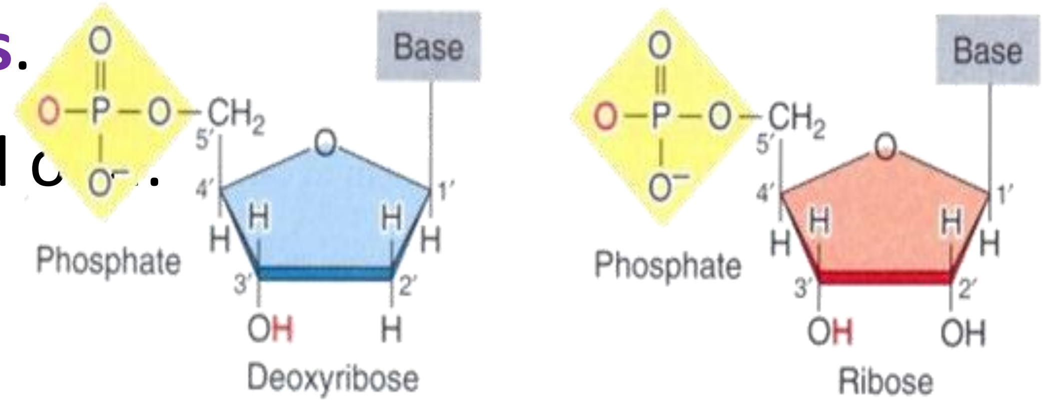


- DNA and RNA are simply long polymers of nucleotides called **<u>nucleotides</u>**.
- Only the **<u>α phosphate</u>** is included in the polymer.
- It becomes chemically bonded to the **<u>3' carbon</u>** of the sugar moiety of another nucleotide.



[read as **3 prime** and **5 prime**]

- Nucleic acid is composed of a long polymer of individual molecules called **nucleotides**.
- Each nucleotide is composed of:
  1. **Nitrogenous base**
  2. **Sugar molecule**
  3. **Phosphate molecule**.

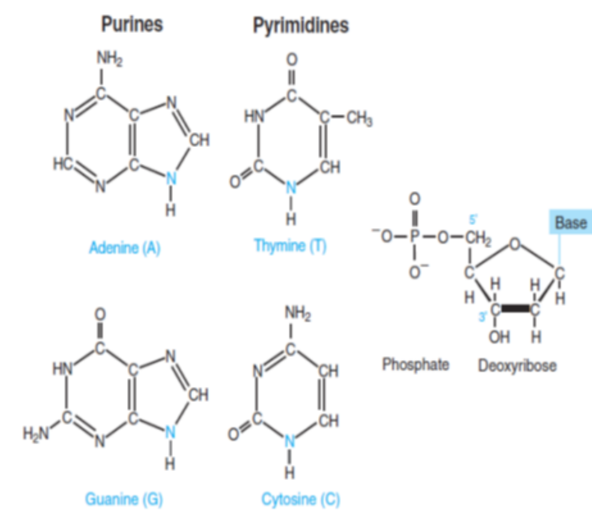


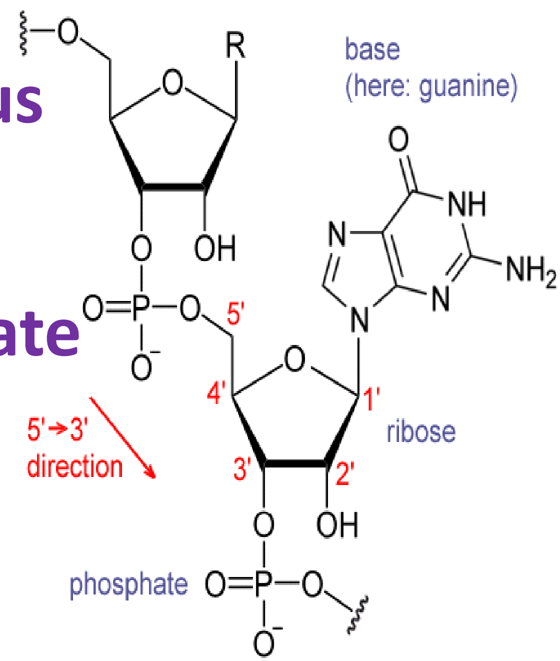
(a) Repeating unit of deoxyribonucleic acid (DNA)

(b) Repeating unit of ribonucleic acid (RNA)

- The nitrogenous bases fall into two types:
  1. **Purines:** adenine (A), and guanine (G)
  2. **Pyrimidines:** cytosine (C), thymine (T), and uracil (U)

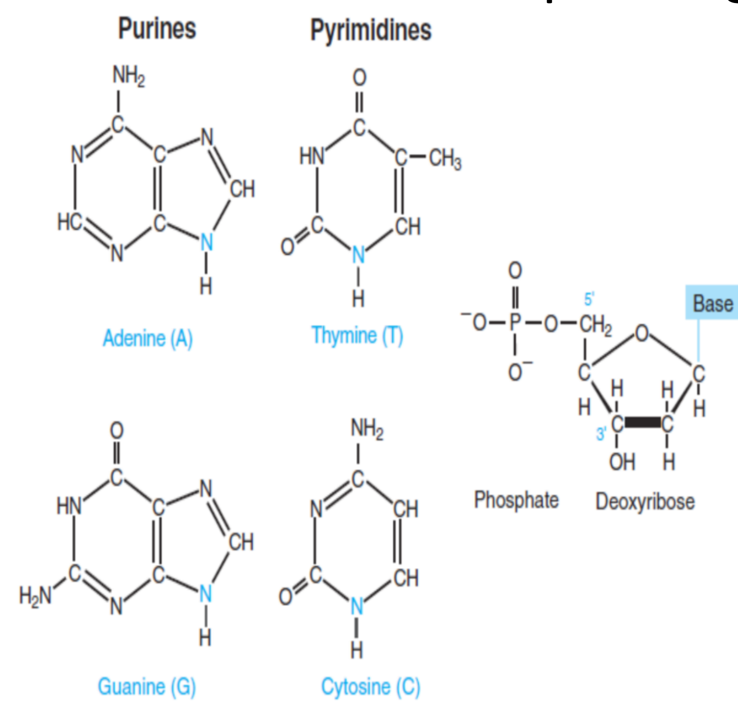
- The sugar molecule composing the **DNA** strand is **Deoxyribose**.
- The sugar molecule composing the **RNA** strand is **Ribose**.
- Both sugar molecules are **pentose** sugars (five-carbon sugars)
- The Carbon **#1** is attached the **nitrogenous** base
- The Carbon **#3** is attached to the **phosphate** group
- The carbon **#5** is attached to the **growing chain** of polypeptides





Base Pairs in DNA:

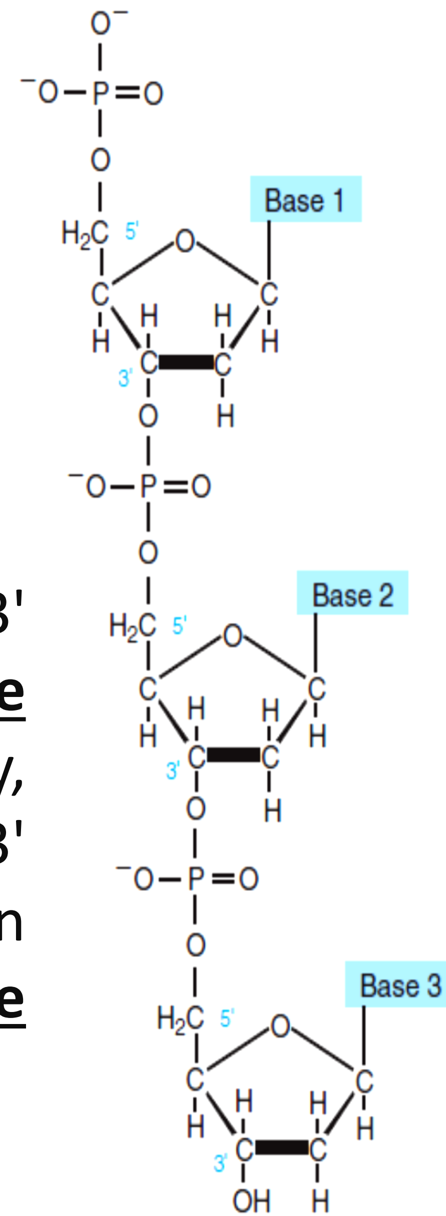
The four bases of DNA and the general structure of a nucleotide in DNA. Each of the four bases bonds with deoxyribose (through the nitrogen shown in blue) and a phosphate group to form the corresponding nucleotides.



Base Pairs in RNA:

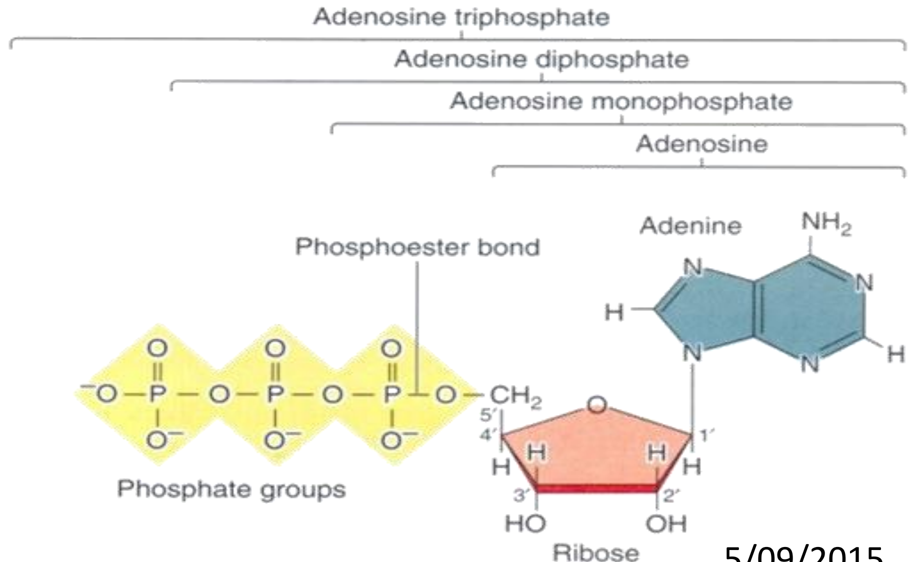
An important structural feature of RNA that distinguishes it from DNA is the presence of a hydroxyl group at the 2' position of the ribose sugar.

Nucleic Acid Strand:



- The **arrangement** of the bases in the DNA molecule is **not random**.
- **Guanine** in one chain **always pairs with** **Cytosine** in the other chain, and **Adenine** **always pairs with** **Thymine** (**Uracil** in RNA), so that this base pairing forms two **complementary** strands.
- Polynucleotide is connected by a series of 5' to 3' phosphate linkages. **Polynucleotide sequences are referenced in the 5' to 3' direction**. Typically, polynucleotides will contain a 5' phosphate and 3' hydroxyl terminal groups. The common representation of polynucleotides is as an **arrow** with the **5' end at the left and the 3' end at the right**.

- The **native** state of DNA, as elucidated by Watson and Crick in 1953, is a **double helix**. The **helical structure** resembles a **right-handed spiral staircase** in which its two **polynucleotide chains** run in opposite directions, held together by **hydrogen bonds** between pairs of bases.
- Because of the **complementary** nature of the two strands of DNA, knowledge of the sequence of nucleotide bases on one strand **automatically allows** us to determine the sequence of bases on the other strand.



DNA MOLECULAR STRUCTURE

Watson-Crick model

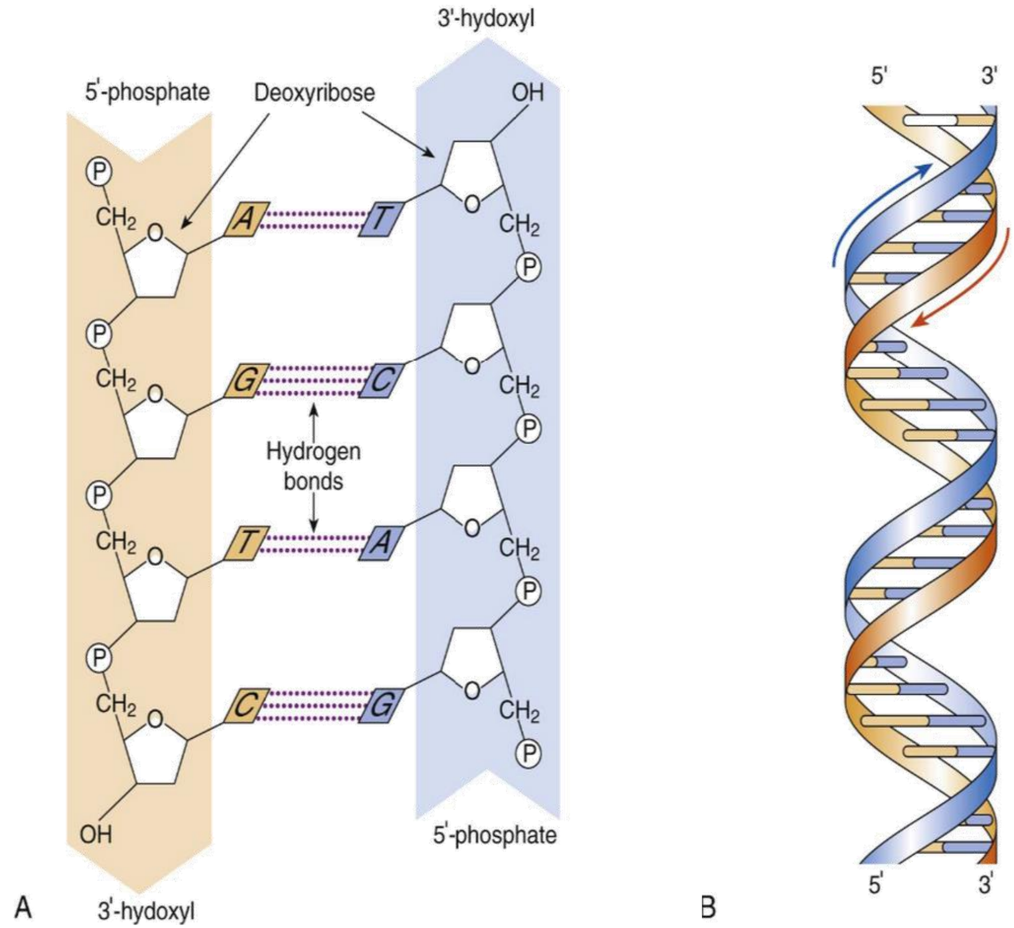
- Two DNA strands twisted together around central axis forming double helix (ds-DNA)
- Two DNA strands are antiparallel (opposite orientations)
  - One strand 5'-3'
  - Other strand 3'-5'
- Double stranded chains stabilized by hydrogen bond between opposite bases.
- Each strand of helix is complementary to the other (complementary base pairing)
- Adenine base in one strand forms 2 hydrogen bonds with Thymine (A = T) base on the opposite strand
- Guanine forms 3 hydrogen bonds with cytosine (G ≡ C)

- The **helical structure** resembles a **right-handed spiral staircase** in which its two **polynucleotide chains** runs in opposite directions, held together by **hydrogen bonds** between pairs of bases.

<u>DNA Double Helix:</u>

Sugar-phosphate backbone and nucleotide pairing of the DNA double helix.

P: phosphate
A: adenine
T: thymine
G: guanine
C: cytosine



SINGLE STRANDED DNA (ss-DNA) or RNA STRAND

Phosphate di-ester bond

- Formed between phosphate group on one nucleotide and sugar molecule on the adjacent nucleotide.
- A phosphate group connects two sugar molecules (di-nucleotides).
- Nucleotide linked together in a linear manner to form DNA or RNA strand.
- Phosphates and sugar molecules form backbone of DNA or RNA strand.

SS-DNA or RNA STRAND

- **Bases** project from the backbone.
- Backbone is (**-**) charged (**PO_4^-**).
- Orientation of nucleotides.
- Phosphodiester bond involves phosphate attachment to the 5’ carbon in one nucleotide and to the 3’ carbon in the other
- Strand direction is based on the orientation of the sugar molecules within the strand.

SS-DNA or RNA STRAND

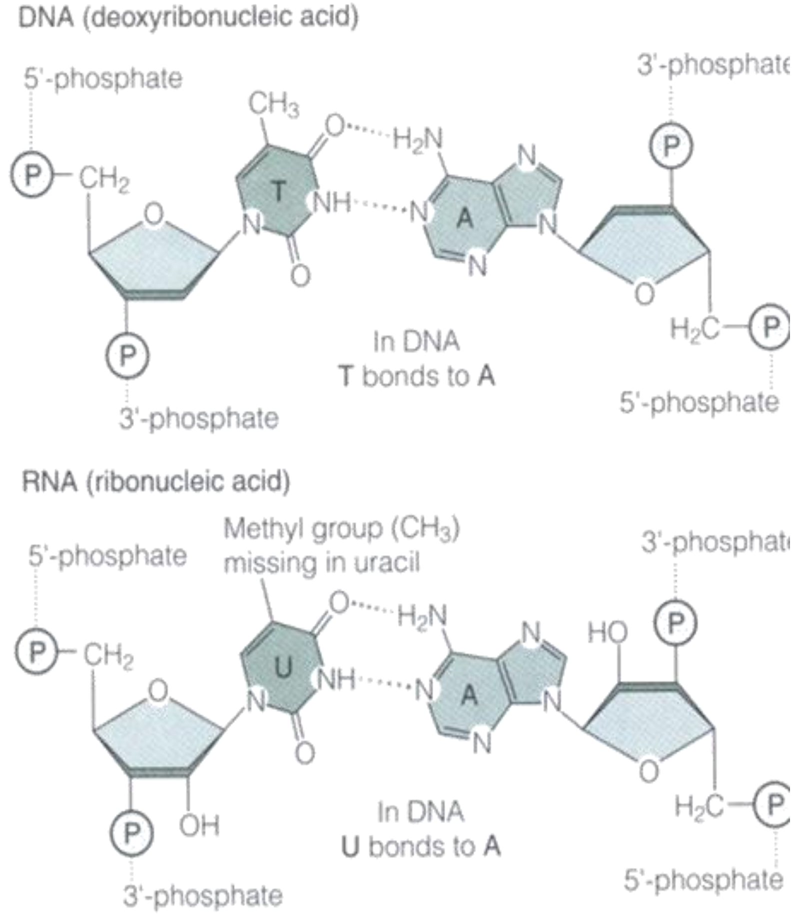
- Direction of strand is 5’- to -3’.
- Strand contains a specific sequence of bases
- Sequence of bases

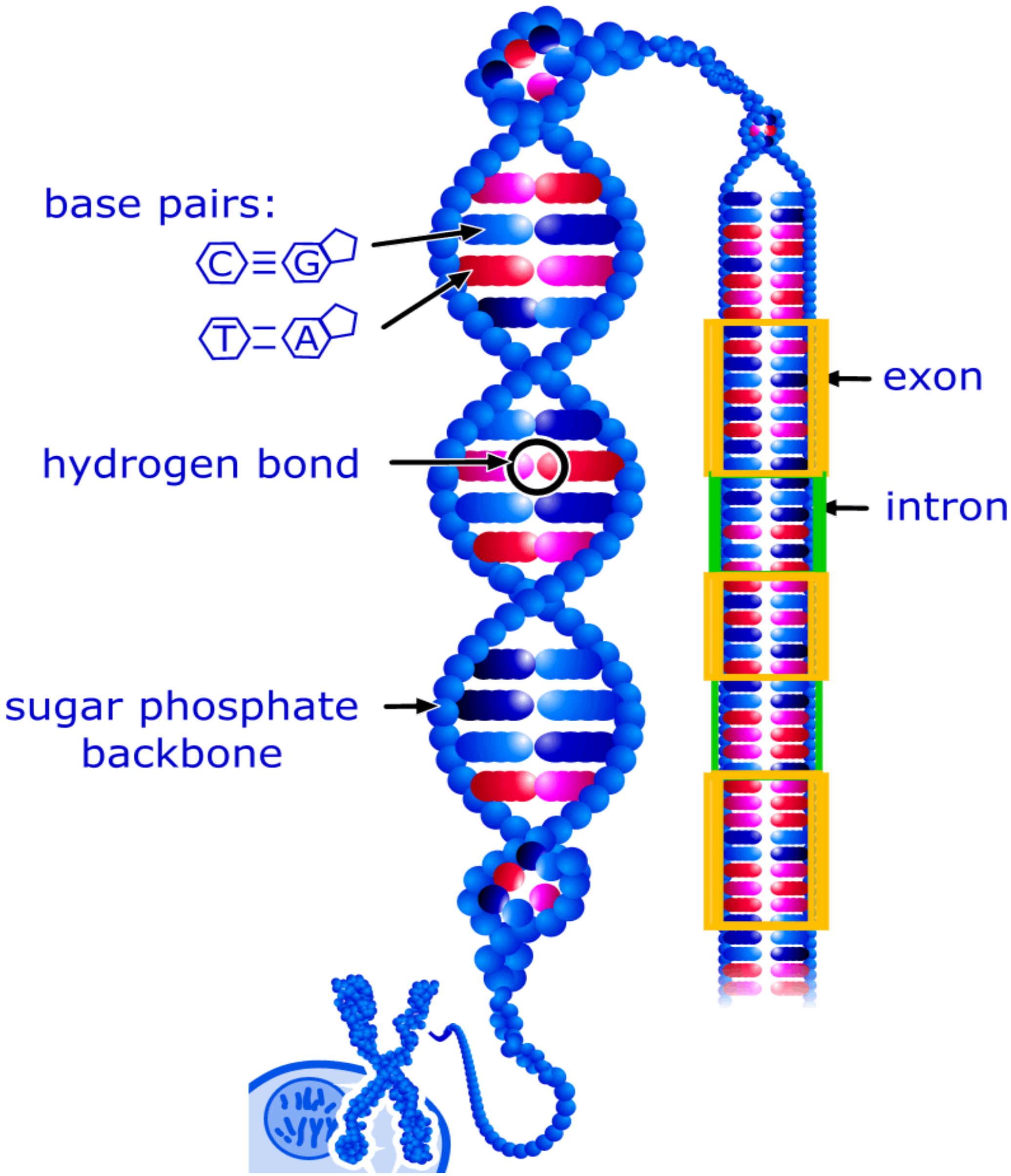
Thymine-Adenine
Cytosine-Guanine
abbreviated:

TACG

or

5’-TACG-3’



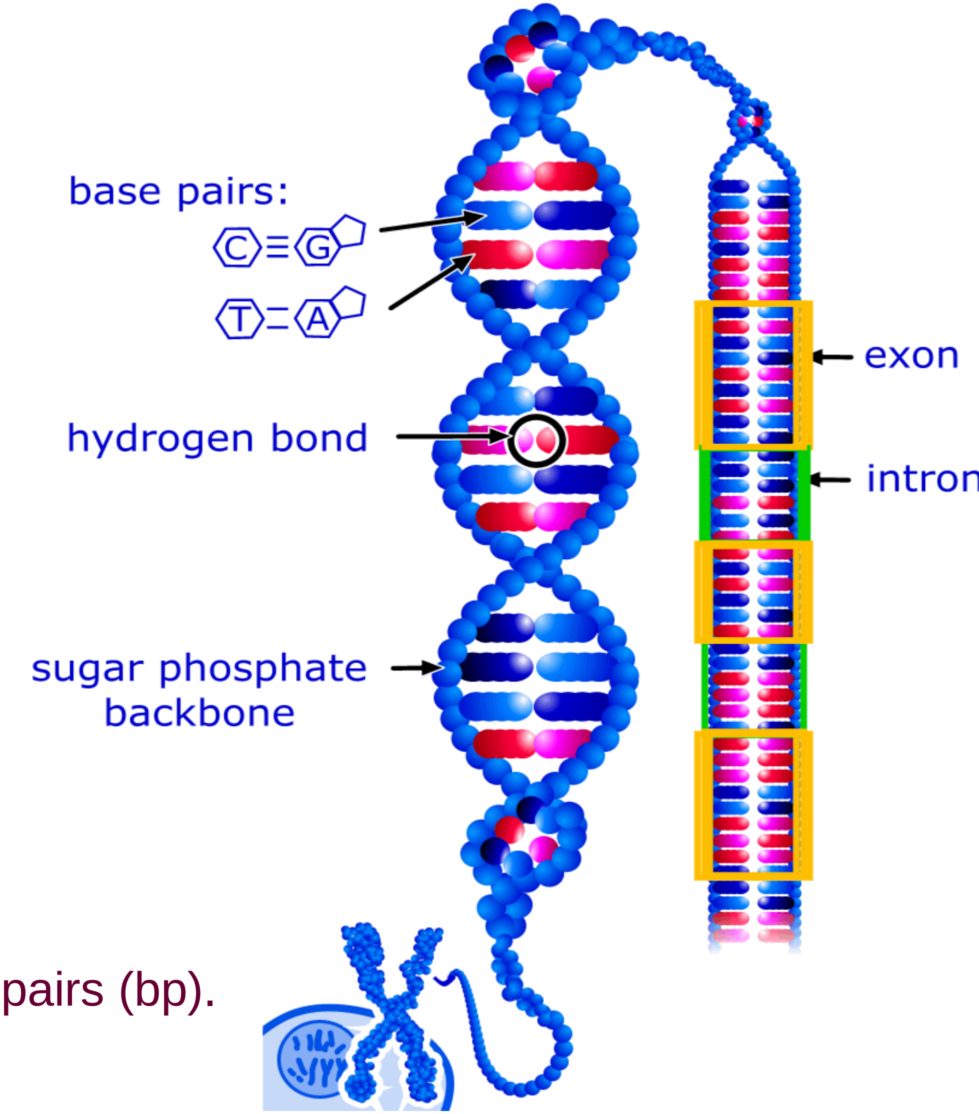


DNA

- ~3.2 billion base pairs in every cell build the human genome
- genes form only 1,5% of the human genome
- a gene is a segment of the DNA, that encodes the construction plan for a protein
- in humans there are ca. 30,000 genes only

DNA - Deoxyribonucleic acid

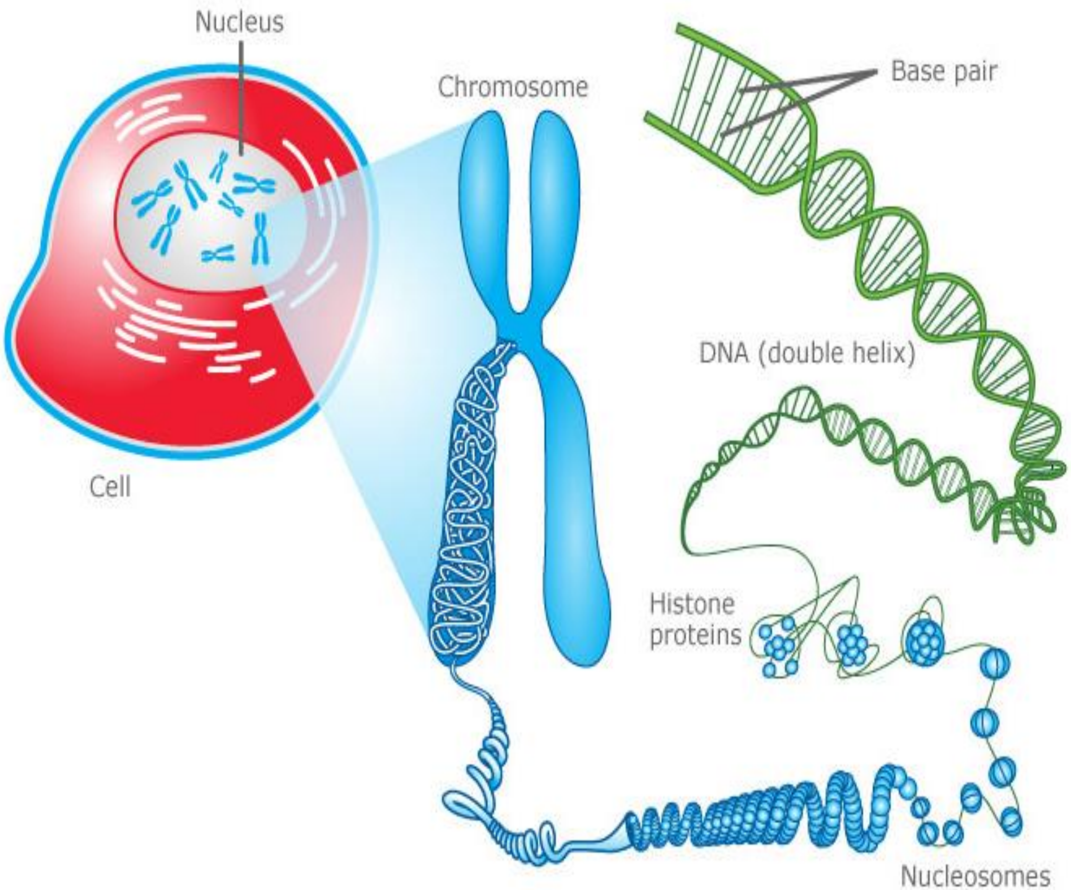
- Deoxyribonucleic acid (DNA) forms a double stranded helix.
- A sugar-phosphate backbone forms the outer shell on the helix
- The two strands of DNA run in opposite directions.
- Bases face towards each other and form hydrogen bonds
- carries the generic instructions (genes)



free Bases

Cytosine - C
Guanine - G
Adenine - A
Thymine - T

complementary base pairs (bp).



DNA

↓

RNA

↓

Protein

RNA – Ribonucleic acid

In RNA the base *Thymine* (T) is replaced by *Uracil* (U).
The other difference to DNA is that the sugar (*Pentose*) will be *Ribose* instead of *Deoxyribose*.
Ribose has an *additional hydroxyl group*.

Bases

Cytosine - C
Guanine - G
Adenine - A
Uracil - U

RNA transmits genetic information from DNA (via transcription) into proteins (by translation).
RNA is almost exclusively found in the single-stranded form.

RNA plays several roles in biology

- **Messenger RNA** (**m-RNA**) is transcribed directly from a gene's DNA and is used to encode proteins.

- RNA genes are genes that encode functional RNA molecules; in contrast to mRNA, these RNA do not code for proteins. The best-known examples of RNA genes are **transfer RNA** (**t-RNA**) and **ribosomal RNA** (**r-RNA**). Both forms participate in the process of translation, but many others exist.

- RNA forms the genetic material (genomes) of some kinds of viruses.

- **Double-stranded RNA** (**ds-RNA**) is used as the genetic material of some RNA viruses and is involved in some cellular processes, such as RNA interference.

- RNA is short for **Ribonucleic acid**.
- RNA is involved in many key and important biological functions including **coding**, **decoding**, **regulation**, and **expression** of **genes**.
- **Messenger RNA (m-RNA)** carries information required for **protein production** from DNA to the **ribosome** (in the Cytoplasm), the sites of protein synthesis (translation) in the cell.
- **Transfer RNA (t-RNA)** transfers a specific amino acid to a **growing polypeptide chain** (at the ribosomal site of protein synthesis) during translation.

- **MicroRNA** are a new class of small RNA molecules that **downregulate** the function of genes by **destroying mRNA** molecules before they reach the ribosomes. The process is called **RNA Interference (RNAi)**.
- Many types exist including:
    - **Short Interfering RNA (si-RNA)**
    - **Short Hairpin RNA (sh-RNA)**

- **5’** (5 prime) or 5’ end: The chain end **terminated** by the **5′ carbon atom** of the sugar molecule.
- **3’** (3 prime) or 3’ end: The chain end **terminated** by the **3′ carbon atom** of the sugar molecule.
- **Antiparallel**: In the DNA duplex, the **5′** end of one strand **is always opposite** the 3′ end of the other, that is, they have **opposite orientations**.
- **Base pair**: **two nitrogen bases** bound together to form a DNA ladder.
- **Complementary**: reefer's to the ability to **predict** the DNA sequence of one strand based on the sequence from the other one.

What you should remember:

1. Explain the structure of Nucleic Acid.
2. What are the differences between DNA & RNA?
3. Illustrate the pentose sugar backbone and the locations of nitrogen bases and phosphate groups.
4. How is the double helix formed?
5. Discuss the different types of RNA and their function.

SELF-TEST # 2

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