بسم الله الرحمن الرحيم

BioChemistry | Lecture 12

Nucleic acids pt.2 & Amino acids pt.1

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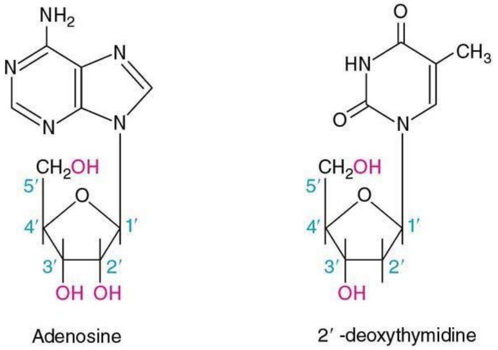
NAMING OF NUCLEOTIDES



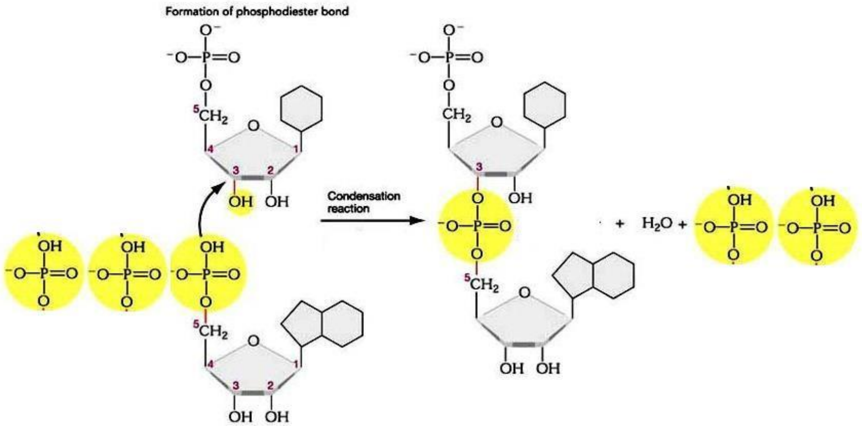
BASES	NUCLEOSIDES	NUCLEOTIDES*
DNA		
	Deoxyribonucleosides	**Deoxyribonucleotides**
Adenine (A)	Deoxyadenosine	Deoxyadenosine 5′-monophosphate (dAMP)
Guanine (G)	Deoxyguanosine	Deoxyguanosine 5′-monophosphate (dGMP)
Cytosine (C)	Deoxycytidine	Deoxycytidine 5′-monophosphate (dCMP)
Thymine (T)	Deoxythymidine	Deoxythymidine 5′-monophosphate (dTMP)
RNA		
	Ribonucleosides	**Ribonucleotides**
Adenine (A)	Adenosine	Adenosine 5′-monophosphate (AMP)
Guanine (G)	Guanosine	Guanosine 5′-monophosphate (GMP)
Cytosine (C)	Cytidine	Cytidine 5′-monophosphate (CMP)
Uracil (U)	Uridine	Uridine 5′-monophosphate (UMP)

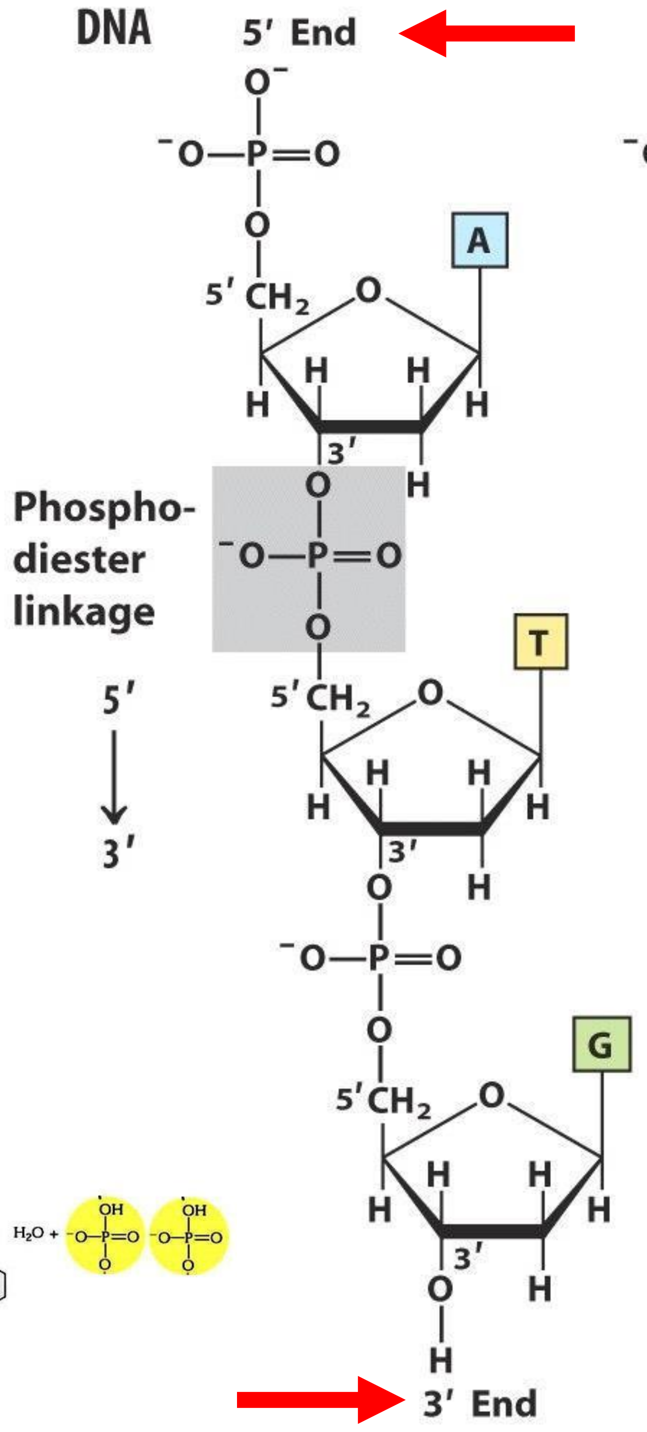
1. Look for the phosphate
   1. No: nucleoside
   2. Yes: nucleotide
2. Look at C2 of the sugar
   1. H: deoxyribose
   2. OH: Ribose
3. Look at the base
   1. Single ring (pyrimidine): C, T, or U
   2. Double ring (purine):A or G

NUCLEIC ACID POLYMER

- Hydroxyl group attached to the 3’ carbon of a sugar of one nucleotide forms a bond to the phosphate of another nucleotide.
- A single nucleic acid strand is a phosphate-pentose polymer (a polyester) with purine and pyrimidine bases as side groups.
- The links between the nucleotides are called phosphodiester bonds.

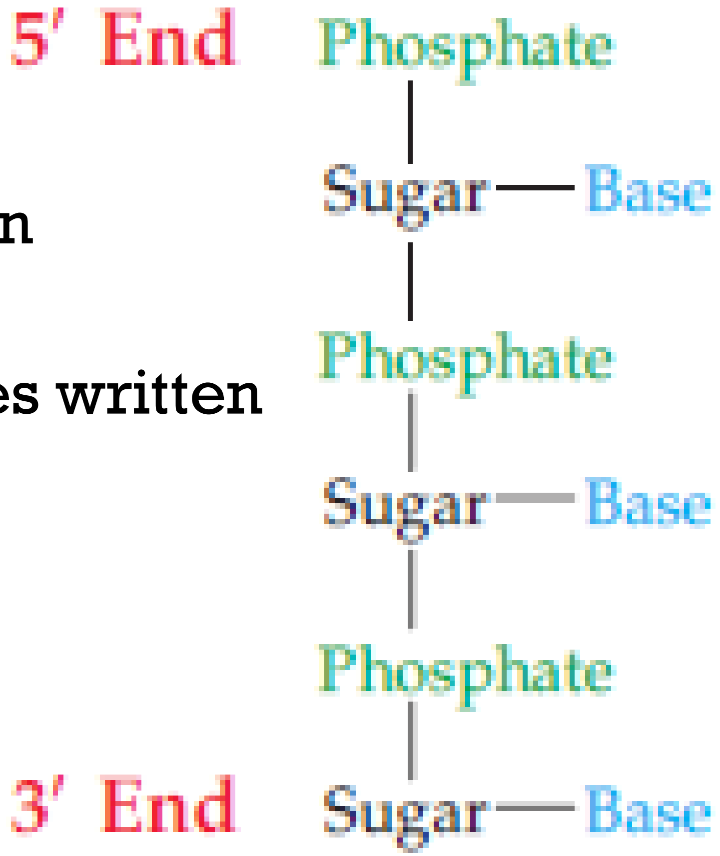
- The direction of the bond is 3’ to 5’ (from carbon #3 to carbon #5),
- The direction of the whole molecule will be 5’ to 3’ (that’s when u r producing the molecule not the bond)
- so reading the molecule is from 3’ to 5’ . If u don’t see the numbers (5’,3’), reed it by convention left to right ☺





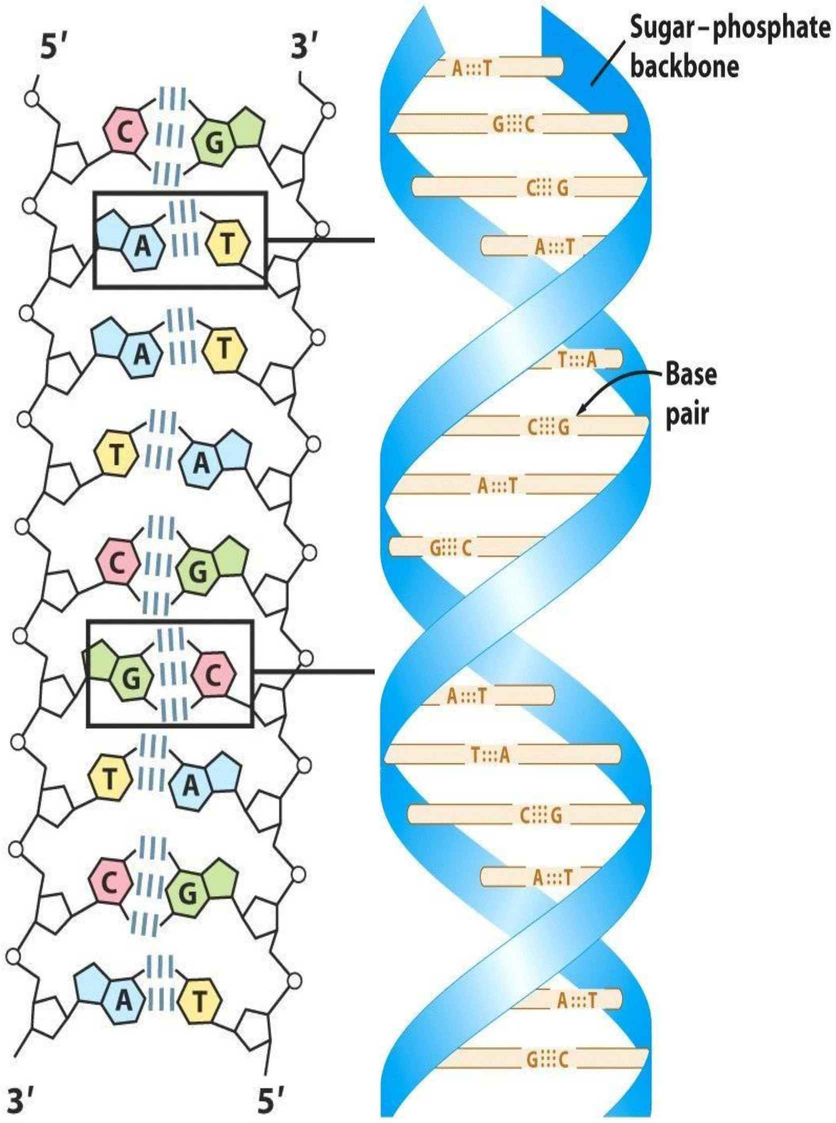
DIRECTIONALITY

- A nucleic acid strand has an end-to-end chemical orientation:
  - The 5’ end has a free phosphate group on the 5’ carbon
  - The 3’ end has a free hydroxyl group on the 3’ carbon
  - This directionality has made polynucleotide sequences written and read in the 5'→3' direction (from left to right).
  - Example: the sequence AUG is assumed to be (5')AUG(3’).



DNA STRUCTURE

- Two associated polynucleotide strands that wind togethe (double helix)
- The sugar-phosphate groups are on the outside
- The bases project into the interior
- The sugar-phosphate groups are termed backbone
- The orientation of the two strands is antiparallel



Histones function :
DNA يلفه على الـ + neutralizes the charge
That's why we also have Mg^{2+} ,Ca^{2+} (+vely charged ions) & nucleus to bind to phosphate to increase the repulsion out of these molecules

Sugars connect monomers together to make **ONE STRAND**
The **TWO STRANDS** connect together through their nitrogenous bases (Hydrogen bonds)

BASE PAIRING

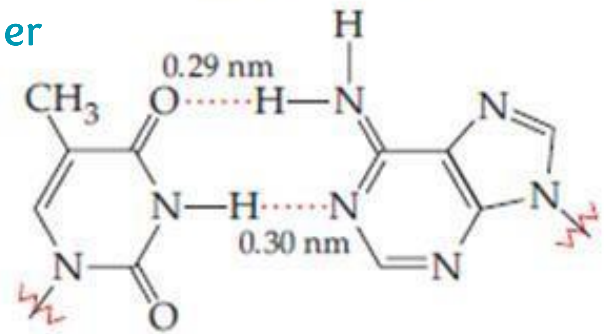
- In DNA, the larger purines (A or G) must pair with a smaller pyrimidines (C or T).
- A always hydrogen bonds with T and G with C, forming A·T and G·C base pairs.
- A is paired with T through two hydrogen bonds; G is paired with C through three hydrogen bonds.

Chargaff's rules

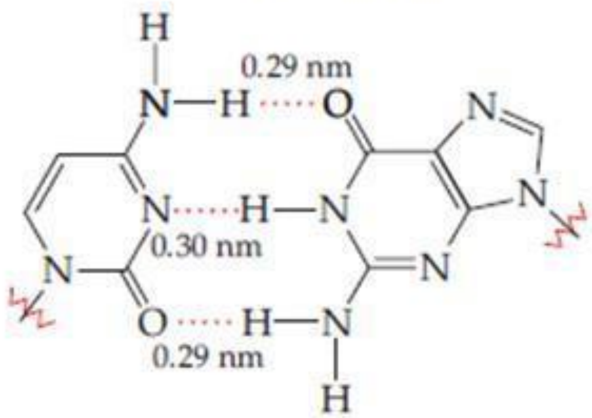
Pyrimidines (T + C) always equals purines (A + G).
T always equals A. C always equals G.
A + T is not necessarily equal to G + C.

Regions of DNA with a high C-G content are more stable and require more energy to separate due to the stronger bonding.
This is why some areas of the DNA with high C-G content, the strands are more tightly held together, making them harder to separate experimentally compared to regions with high A-T content.

Thymine–Adenine



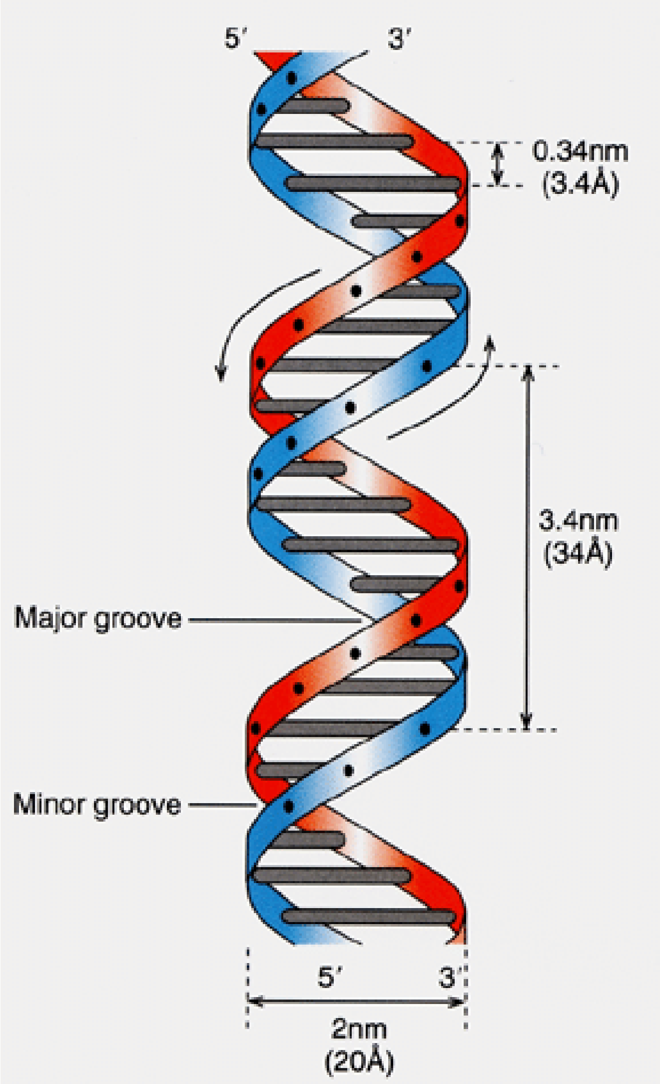
Cytosine–Guanine

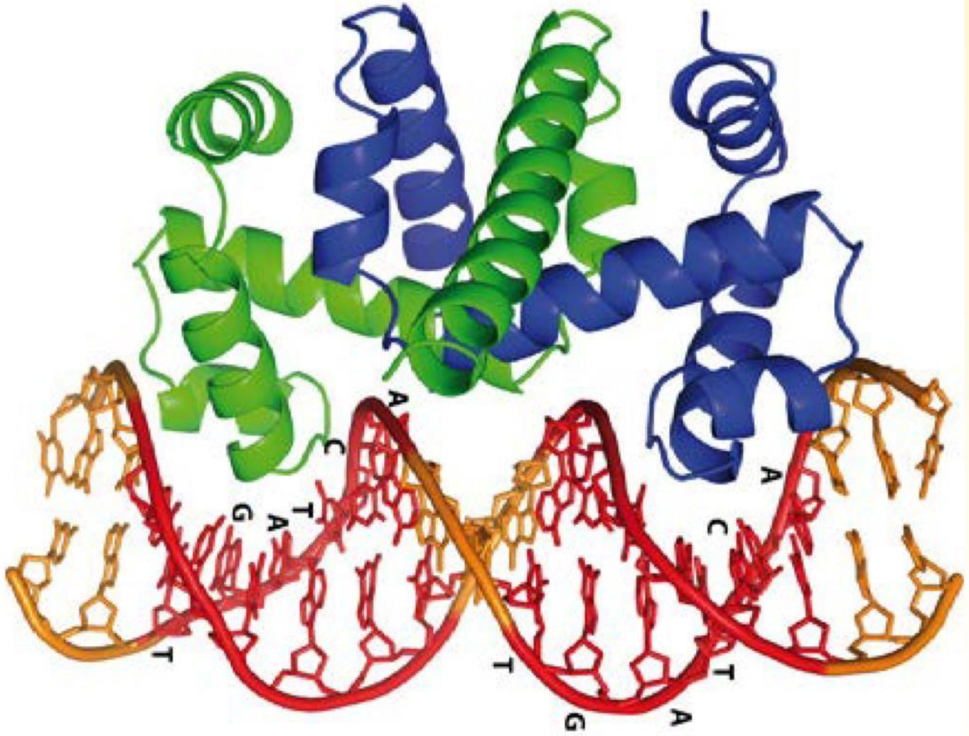


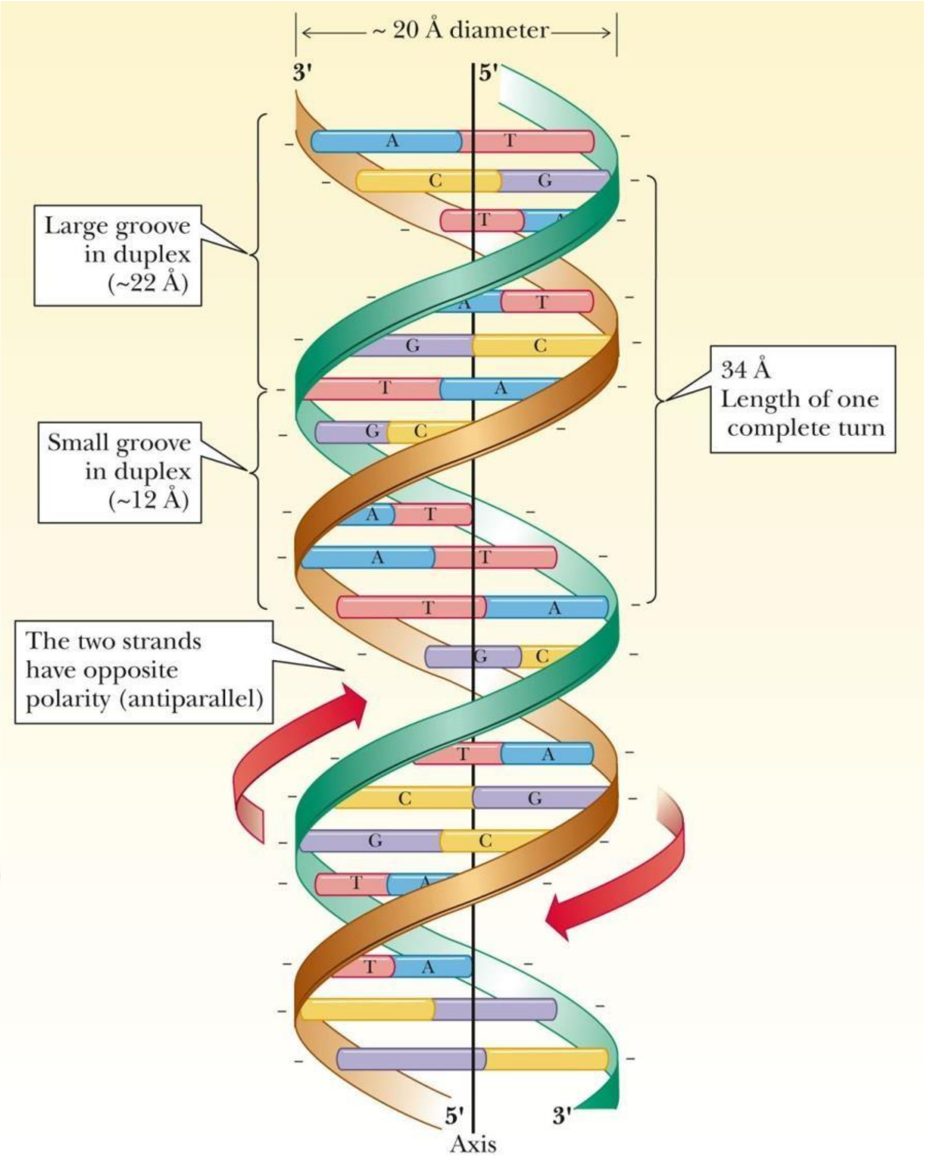
DNA GROOVES

Due to the helical structure of DNA, two types of grooves are formed: the major groove and the minor groove.

These grooves are the result of the asymmetrical spacing of the sugar-phosphate backbones around the double helix.

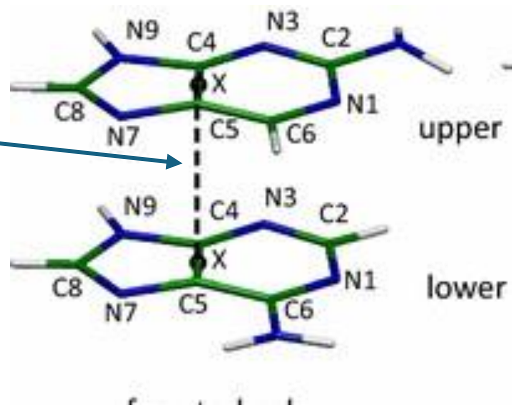






DNA- STABILIZING FORCES

DNA Bases are hydrophobic in nature, so they make hydrophobic interactions between them

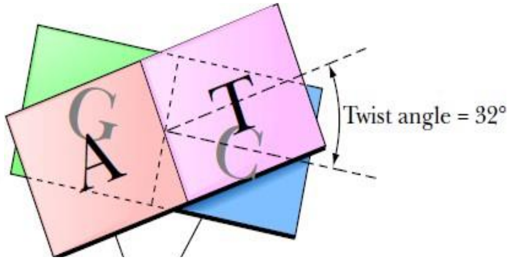


UP/ DOWN movement

- Hydrogen bonds

They are individually weak, but their large number across the DNA double helix contributes significantly to its overall stability.

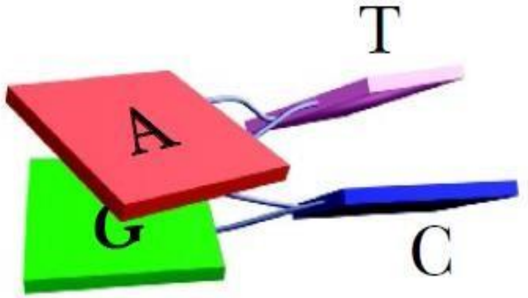
- Hydrophobic stacking: via hydrophobic interactions and van der Waals interactions
- Helical twists: Each base pair is rotated with respect to the preceding one for maximal base pairing



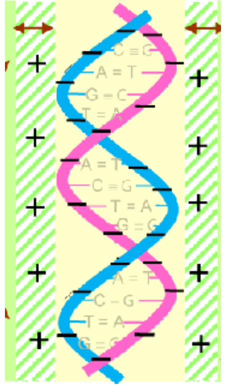
Rotational movement Y axis is rotation axis

- Propeller twists: The bases twist for optimal base stacking

One of bases is tilted up and other base is tilted down the rotational axes are Z and X



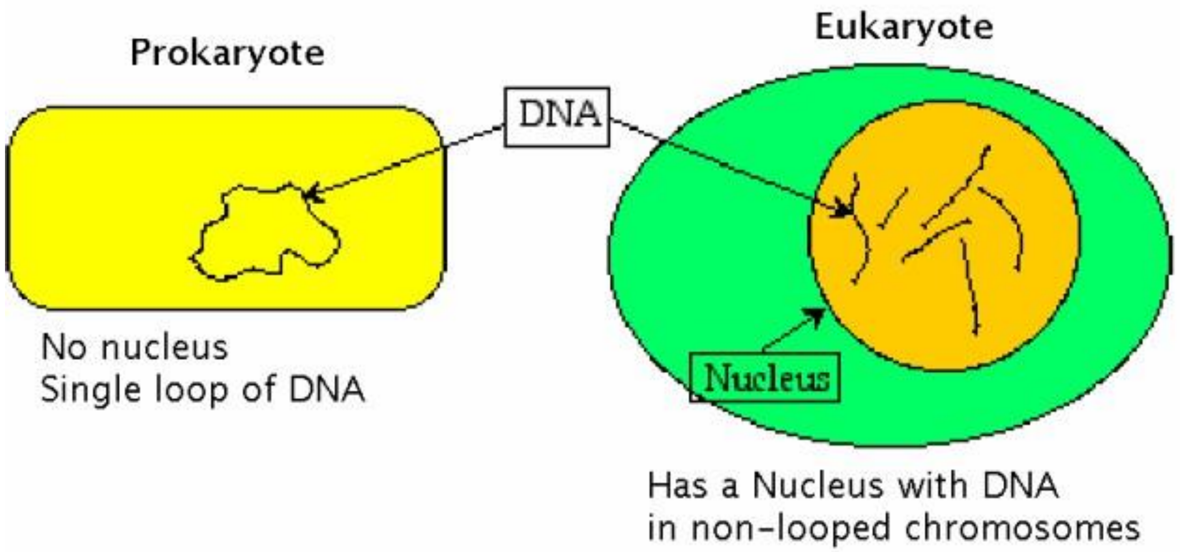
- DNA-binding proteins (e.g., histones)
- Ions such as Na^{+} or Mg^{2+} (and histones) reduce the repulsion created by the negatively-charged phosphates of the DNA



THE GENOME OF PROKARYOTES VERSUS EUKARYOTES

* DNA of all organisms are double strand

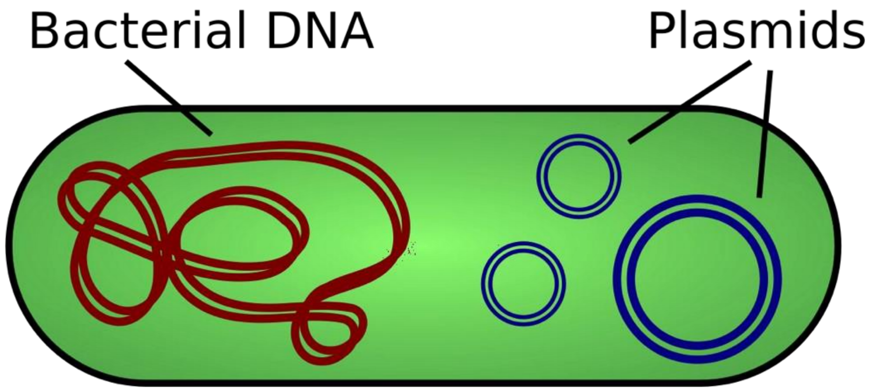
- Genome: the total genetic material of a living being (bacteria vs. human), a species (monkey vs. human) , an individual (me vs. you), or a cell (brain vs. liver), etc.
- Prokaryote: an organism that lacks a nucleus or other organelles.
- Eukaryote: an organism that has a true (clearly defined) nucleus.



BACTERIAL CHROMOSOME AND PLASMIDS

- The genetic materials of bacteria are of 2 types:
- 1. The chromosome: One circular chromosome of double-stranded DNA.
  - E.g. *Escherichia coli* contains > 4 × 10^6 bp (length of 2 mm) carrying 4200 genes.

Originally each cell of bacteria has one plasmid but don't forget that it could be transfered



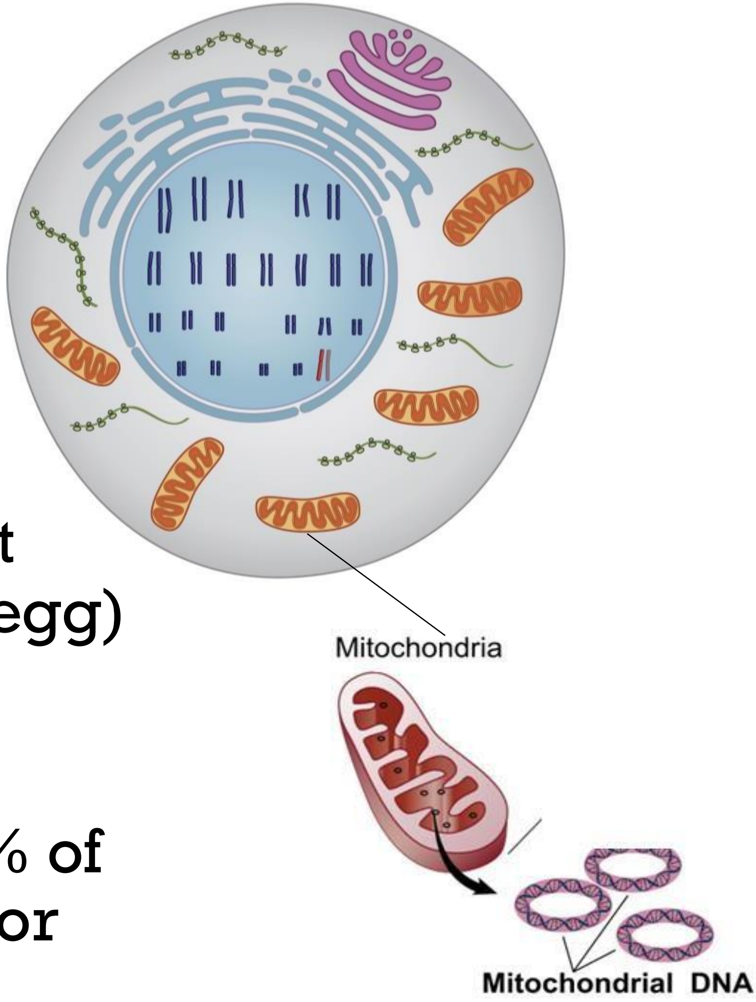
- 2. Plasmids:
  - 1) Small, circular DNA molecules
  - 2) Can replicate autonomously and independently
  - 3) Not infectious like viruses
  - 4) Can carry genes, some of which confer resistance to antibiotics
  - 5) Exist as different types but one plasmid type per cell
  - 6) Can exist as multiple copies
  - 7) Can transfer among bacterial cells

The plasmid can be used to produce proteins by adding the suitable genes and then let bacteria to Grow more and more and then you will have the required protein by separating methods

THE HUMAN GENOME

There is a difference between the number of nuclutides and the genes and this refers to that the most DNA regions are not coded

- The genetic material of humans is of 2 types:
- The nuclear genome: organized as linear chromosomes that consist of ~$3x10^9$ nucleotides in germline cells (sperm and egg) with a length of 1m per cell and that carry ~20000 genes
- The mitochondrial genome, which constitutes less than 0.1% of the total DNA in a cell (~16500 bp) and encodes 37 genes for proteins involved in the respiratory chain reaction

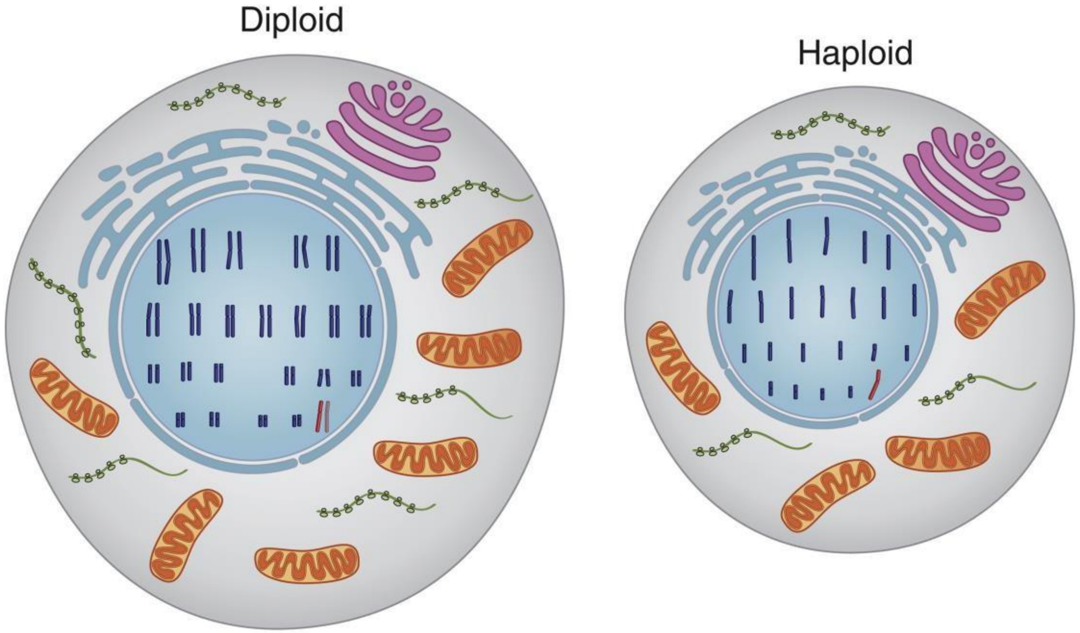


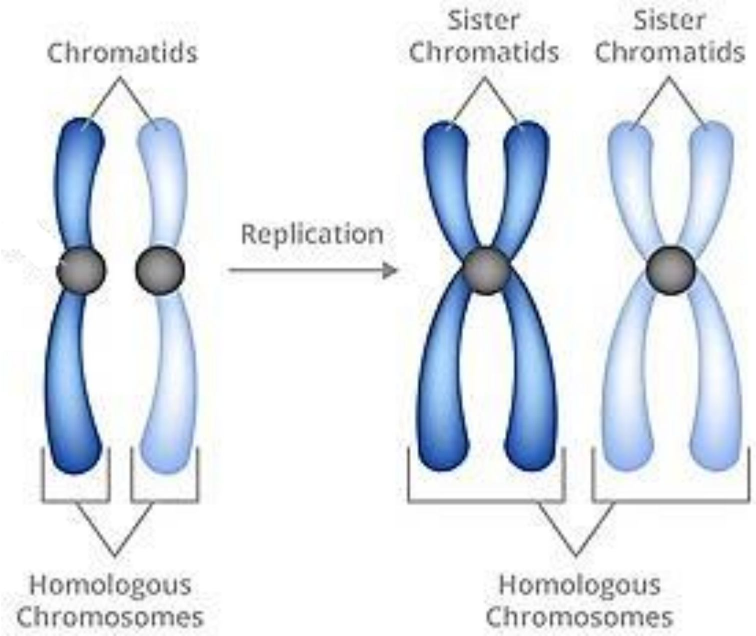
The mitochondrial DNA is **circular** .

The most of proteins that exist in mitochondria are produced in neucleus and then translocated into it, and without these proteins no function no ATP synthesis and therefor no life

MORE EUKARYOTIC TERMS

- Germline cells are haploid cells having one copy of every chromosome (either maternal or paternal) They exist in sperms or ova
- Somatic cells are diploid having two copies of every chromosome (maternal AND paternal) called homologous chromosomes
- Each chromosome can be made of one chromatid or sister chromatids

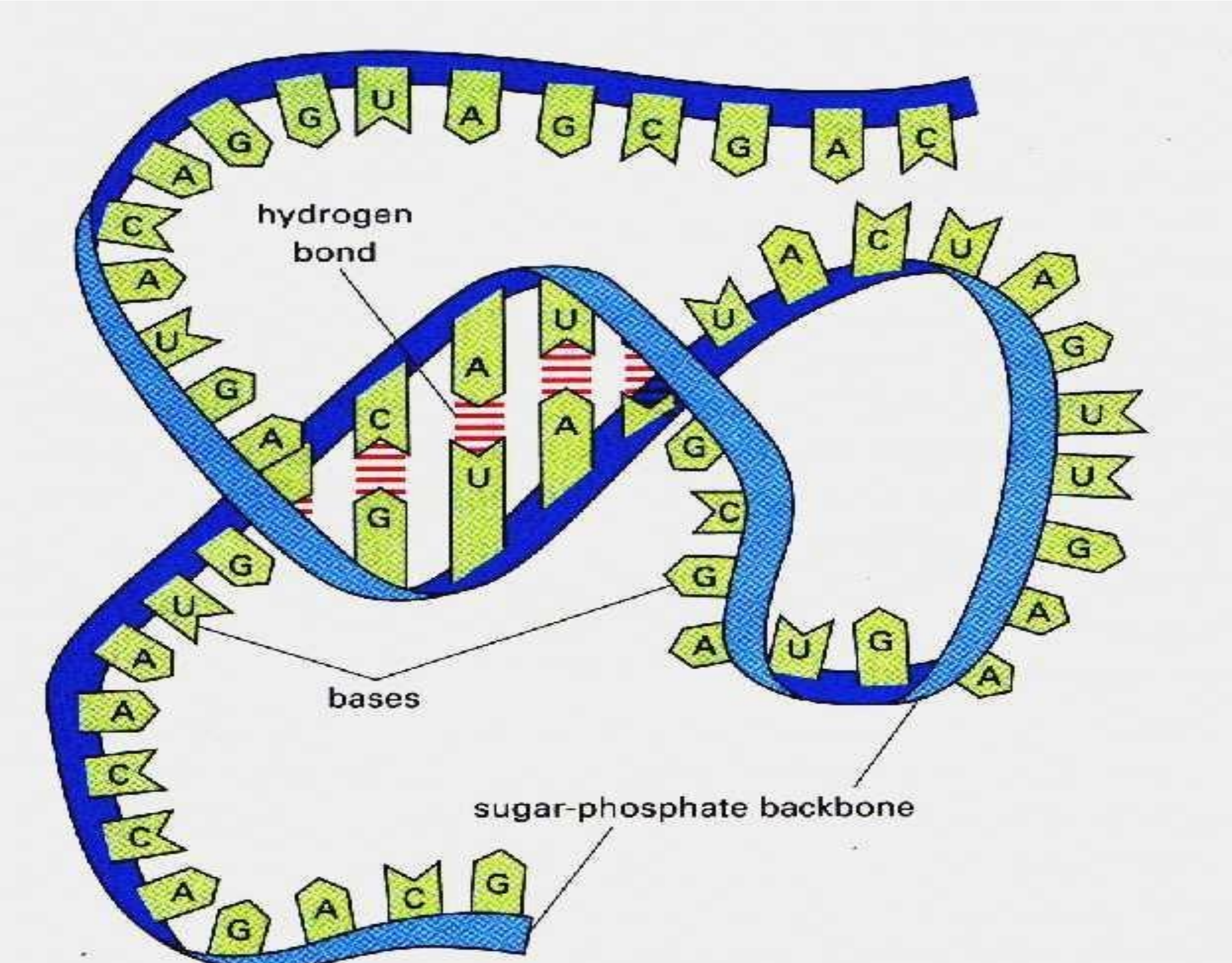




RNA STRUCTURE

- Note: RNA is usually single-stranded and does not have a specific structure

Unlike DNA, RNA contains uracil (U) instead of thymine (T).
Although RNA is primarily single-stranded, it can form regions of intra-strand base pairing due to complementary sequences within the same strand



*RNA as enzymes will be explained in enzymes section

TYPES OF RNA

There are many types of RNA; some have well-defined functions, while others still have unknown or unclear roles.

Symbol	Non-Coding RNAs	Functions
tRNA	Transfer RNA	mRNA translation (structural)
rRNA	Ribosomal RNA	mRNA translation (structural)
miRNA	micro RNAs	Post-transcriptional transposon repression
piRNA	Piwi-interacting RNA	DNA methylation, transposon repression
siRNA	Short interfering RNA	RNA interference
snoRNA	Small nucleolar RNAs	RNA modification, rRNA processing
PROMPT's	Promoter upstream transcripts	Associated with chromatin changes
tiRNAs	Transcripton initation RNAs	Epigenetic regulation
lincRNAs	Long intergenic ncRNA	Epigenetic regulators of transcription
rasiRNA	Repeat associated small interfering RNA	Involved in the RNA interference (RNAi) pathway
eRNA	Enhancer-like ncRNA	Transcriptional gene activation
T-UCRs	Transcribed ultraconserved regions	Regulation of miRNA and mRNA levels
NATs	Natural antisense transcripts	mRNA stability
PALRs	Promoter-associated long RNAs	Chromatin changes
tasiRNA	Trans-acting siRNA	Represses gene expression
lncRNA	Long noncoding RNA	Regulation of gene transcription

MicroRNAs (miRNAs) bind to mRNA and act as inhibitors of the translation process.

If we want to study the effect of specific gene, we must inhibit it and that could happen in two manners:

1. Knockout: removing the gene entirely
2. Knockdown: just inhibit the gene without removing it, this is done by adding complementary RNA which binds to mRNA; thus, it will not be translated to protein

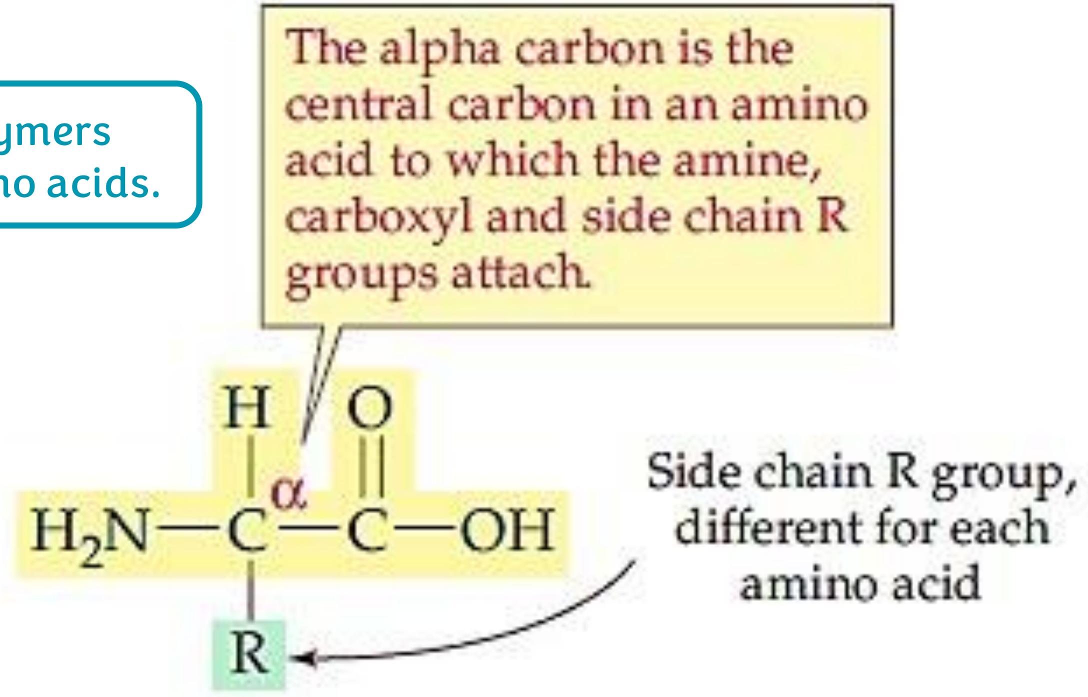
siRNA functions primarily in post-transcriptional gene silencing by guiding the degradation of specific messenger RNA (mRNA) molecules. This mechanism is part of the broader pathway called RNA interference (RNAi). And it a kind of knockdown .

Amino Acids

Protein structure and function

Proteins are polymers made up of amino acids.

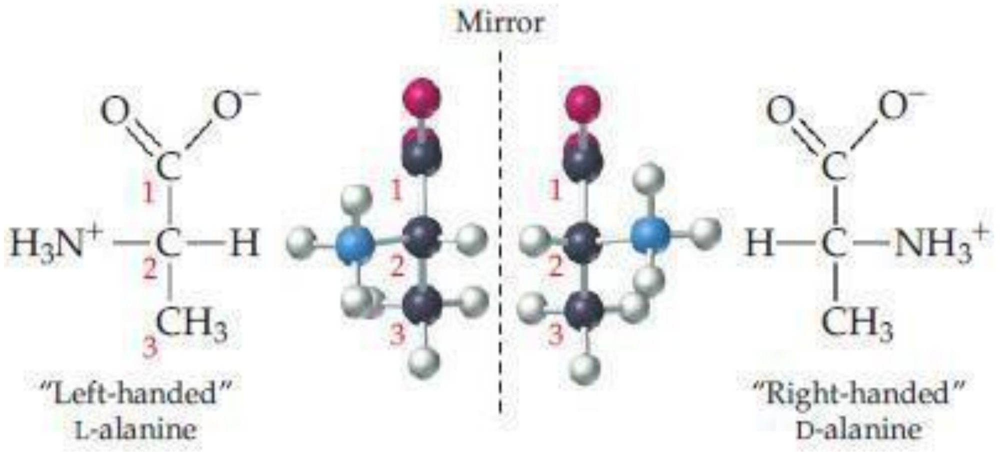
- Greek: proteios, primary (importance)
- 50 % of body's dry weight is protein
- Free vs. attached (**residue**), **D vs. L**



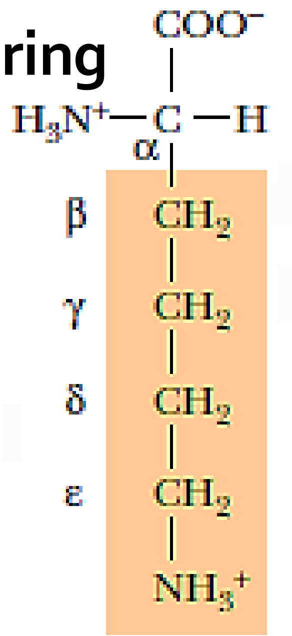
An α-amino acid

TYPE	FUNCTION	EXAMPLE
Enzymes	Catalysts	*Amylase*—begins digestion of carbohydrates by hydrolysis
Hormones	Regulate body functions by carrying messages to receptors	*Insulin*—facilitates use of glucose for energy generation
Storage proteins	Make essential substances available when needed	*Myoglobin*—stores oxygen in muscles
Transport proteins	Carry substances through body fluids	*Serum albumin*—carries fatty acids in blood
Structural proteins	Provide mechanical shape and support	*Collagen*—provides structure to tendons and cartilage
Protective proteins	Defend the body against foreign matter	*Immunoglobulin*—aids in destruction of invading bacteria
Contractile proteins	Do mechanical work	*Myosin and actin*—govern muscle movement

Alanine, a chiral molecule



Carbon Numbering



Protein structure and function

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Proteins are essential because their function depends on their structure.
Unlike carbohydrates, proteins can change their shape when they bind to other molecules. This structural flexibility allows them to perform complex and specific functions.
A key example is hemoglobin, a protein that transports oxygen. It binds and releases oxygen by changing its shape, enabling efficient oxygen delivery throughout the body.
This **ability to undergo structural changes** is what makes proteins uniquely suited for roles such as signaling, transport, catalysis, and regulation.

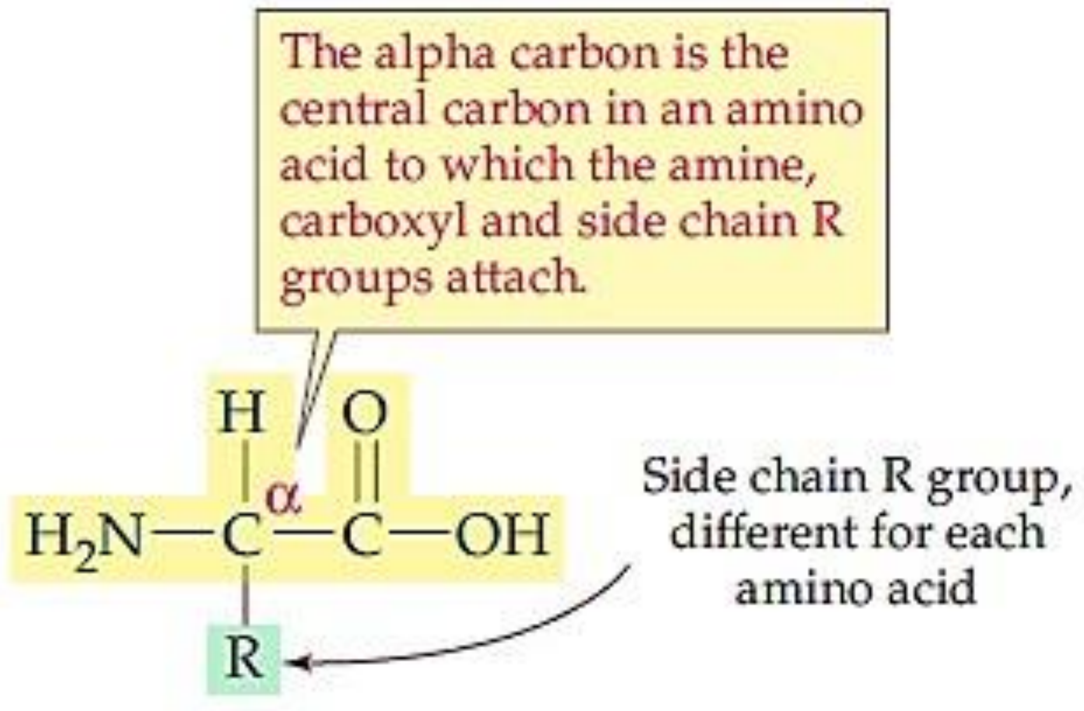
Protein structure and function

From the name "amino acid," we can tell that the molecule contains both an amino group and an acidic group.

All amino acids share the same basic structure, called the "backbone," which includes:

The general structure of an amino acid includes:

- An amino group (−NH_2)
- A carboxylic group (−COOH), which is what gives the molecule its acidic properties.
- A central carbon (called the alpha carbon), usually chiral
- A hydrogen atom
- A side chain (R group), which varies between amino acids



An α-amino acid

If the side chain in an amino acid is a hydrogen (as in glycine), the central carbon will have two hydrogen atoms attached. This means the carbon is not chiral.

Protein structure and function

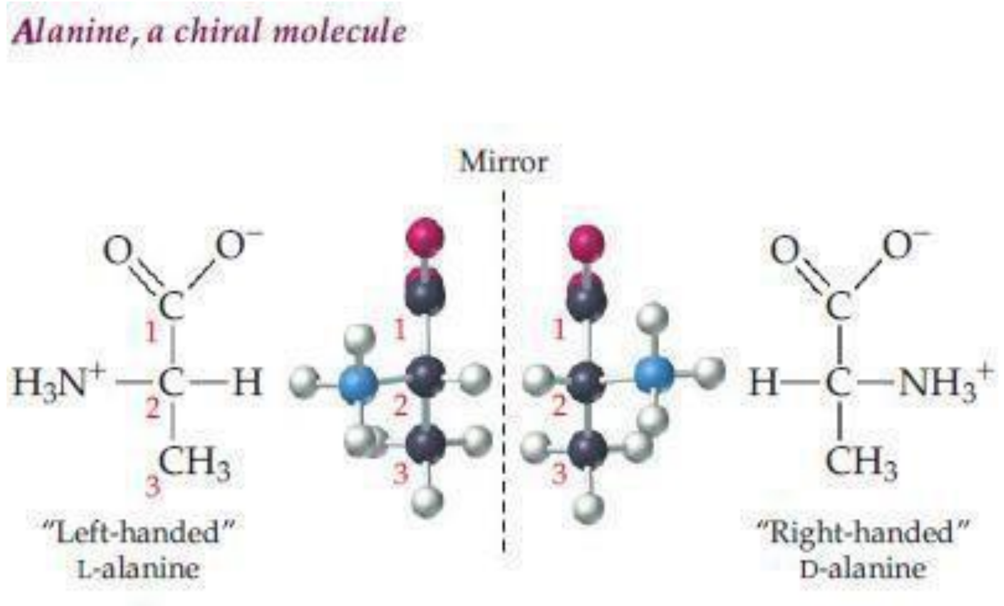
Chirality is important for biomolecules like amino acids and sugars because it determines their D or L form.

Sugars exist in two chiral forms: D and L.

In biological systems, only **D-sugars** are commonly used.

Amino acids also exist in D and L forms. However, **only L-amino acids** are incorporated into proteins.

This stereospecificity is due to the structure of enzymes and ribosomes, which are designed to recognize and process only L-amino acids.
D-amino acids are not used in protein synthesis because they do not fit into the active sites of these biological molecules.



Classification (according to the polarity of R group)

- There are many amino acids found in nature and in the human body, but only 20 standard amino acids are used in building proteins.

- These 20 amino acids are called proteinogenic amino acids, and they are the only ones encoded by the genetic code.
  This is because the genetic code provides 64 codons (on the mRNA): 61 code for these 20 proteinogenic amino acids, and 3 signal termination.

- Other amino acids may exist in the body and have various roles, but they are not incorporated into proteins because they lack codon representation.

The 20 standard amino acids, along with their three-letter abbreviations and structures must be memorized. ☺

For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1	#20	the genetic code provides only 20 codons (on the tRNA) that correspond to these amino acids	the genetic code provides only 64 codons (on the mRNA): 61 code for these 20 proteinogenic amino acids, and 3 signal termination
V1 → V2			

Additional Resources: رسالة من الفريق العلمي:

قال شيخ الإسلام إبن تيمية رحمه الله
"وصاحب الهوى يعميه الهوى ويصمّه ، فلا يستحضر الله ورسوله في ذلك ، ولا يطلبه ، ولا يرضى برضا الله ورسوله ، ولا يغضب لغضب الله ورسوله ، بل **يرضى إذا حصل ما يرضاه بهواه ويغضب إذا حصل ما يغضب له بهواه** .."
[منهاج السنة النبوية (٢٥٦/٥)]