Macromolecules

Polymers vs Monomers

Defintion

Macromolecules
Large structures consisting of one or more Polymer

Polymers
Formed by chains of Monomers

Monomers
Building blocks of Polymers
Some have functions of their own

Condensation Reaction
The binding of two substances by removing a small molecule.

Dehydration

- The **binding** of multiple monomers to form a polymer by **removing** extra H_2O .
- Dehydration is a type of condensation reaction, one where the small molecule being removed is specifically water.
- One monomer loses a H and the other loses an OH
- Literally means "**To remove** (de-) **water** (hydrate)"

Hydrolysis

- The **separation** of a polymer into its monomers by adding H_2O
- Literally means **water** (hydro) **separation** (lysis).
- One chain receives a H and the other receives an OH (Splitting the added water)

Classification of Macromolecules

- Carbohydrates
  - Monosaccharides

	Triose	Tetrose	Pentose	Hexose	Heptose
Aldose	✔	✔	✔	✔	✔
Ketose	✔	✔	✔	✔	✔

  - Disaccharides
  - Polysaccharides

	No Branching	Some Branching	Extensive Branching
α bonding	✔	✔	✔
β bonding	✔	✔	✔

- Lipids
  - Fats
    - Unsaturated Fats
      - Trans Fats
    - Saturated Fats
  - Phospholipids
  - Steroids
- Proteins
  - Amino Acids
    - Polar Amino Acids
    - Nonpolar Amino Acids
    - Electrically Charged Amino Acids
      - Acidic Negative
      - Basic Positive
- Nucleic Acids
  - DNA
  - RNA
    - mRNA
    - rRNA
    - tRNA
  - Nucleotides
    - Nucleosides
      - Pentose
      - Nitrogenous Base

        - Pyrimidines
        - Purines
    - Phosphate group

The Four Macromolecules

1. Carbohydrates
2. Lipids
3. Proteins
4. Nucleic Acids

	Carbon	Hydrogen	Oxygen	Nitrogen	Phosphorus	Sulfur
Carbohydrates	Always	Always	Always	Never	Never	Never
Lipids	Always	Always	Always	Never	Never	Never
Proteins	Always	Always	Always	Always	Never	Sometim
Nucleic Acid	Always	Always	Always	Always	Always	Never

	Monomer	Polymer	Linkage
Carbohydrates	Monosaccharides	Polysaccharides	Glycosidic Linkages
Lipids	Fatty Acids	Triacylglycerols	Ester Linkages
Proteins	Amino Acids	Polypeptides	Peptide Bonds
Nucleic Acid	Nucleotides	Polyneucleotides	Phosphodiester Linkages

Carbohydrates

There are three kinds of carbohydrates

- Monosaccharides
- Disaccharides
- Polysaccharides

Carbs are sugars (mono and di) and polymers of sugars (poly)
They provide quick energy and also serve as structural support

Monosaccharides

Monosaccharides are normally charachterized by the amount of Carbons in the backbone and where the carbonyl group ($C = O$) is located

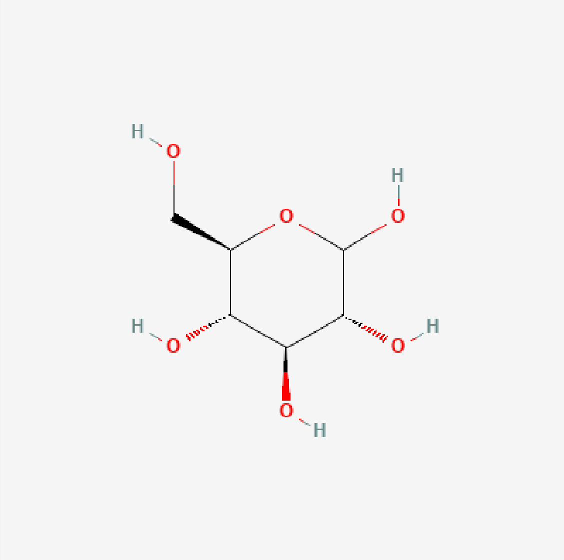
Def

Monosaccharides

Literally means "**single sugar**"

It is the **monomer** of disaccharides and polysacchrides

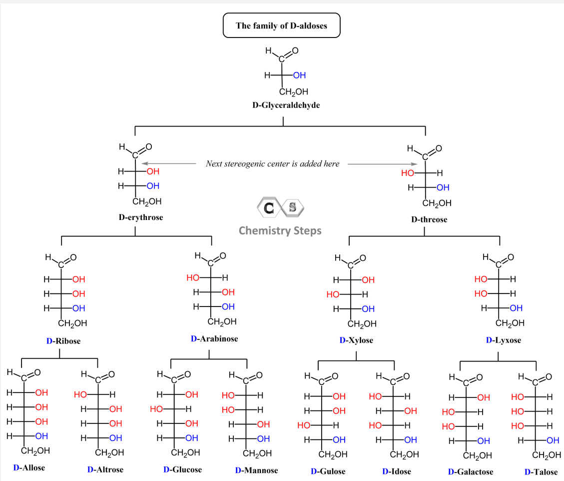
Usually are found multiples of CH_2O



D-Glucose ($C_6H_{12}O_6$), one of the most basic Monomers in real life.

Aldose

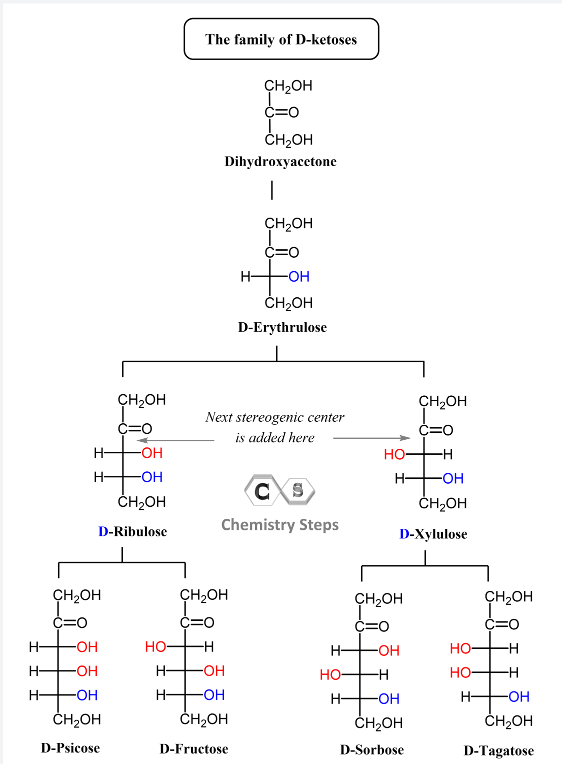
A Monosaccharide containing a Carbonyl group at the end of the carbon skeleton



Each time a new stereogenic center is added just below the carbonyl group generating two additional stereoisomers.

Ketose

A Monosaccharide containing a Carbonyl group within carbon skeleton



Each chiral center is added below the carbonyl group generating two additional stereoisomers.

Triose
A Monosaccharide containing a 3 Carbon long skeleton

Tetrose
A Monosaccharide containing a 4 Carbon long skeleton

Pentose
A Monosaccharide containing a 5 Carbon long skeleton

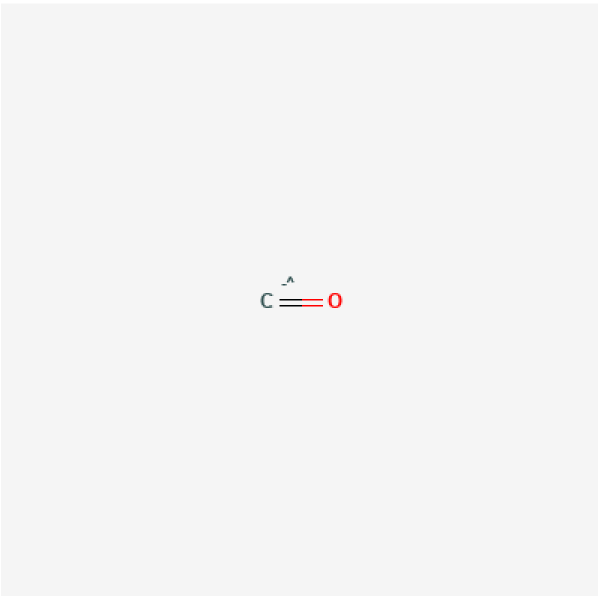
Hexose
A Monosaccharide containing a 6 Carbon long skeleton

Heptose
A Monosaccharide containing a 7 Carbon long skeleton

Characteristics of a monosaccharide

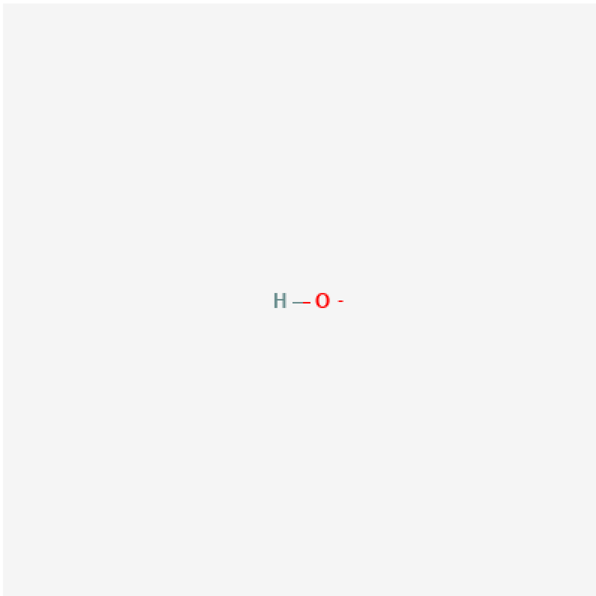
Contains certain groups of atoms

A Carbonyl group ($C = O$)



The Carbon will be bonded to two other atoms

Multiple Hydroxyl groups ($-OH$)



The Oxygen will normally be bonded to the Carbon Skeleton

Has a Carbon Skeleton ranging from 3 to 7 Carbons long

Trioses (Thee carbon)

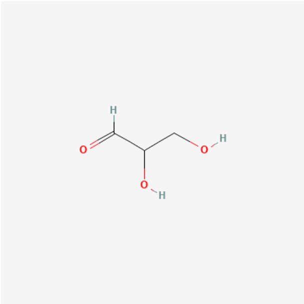
Glyceraldehyde (Alsdose)

Pentoses (Five carbon)

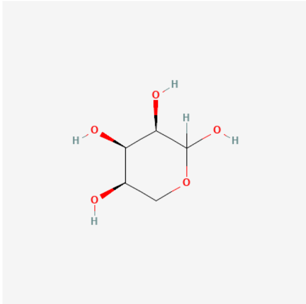
Ribose (Alsdose)

Hexoses (Thee carbon)

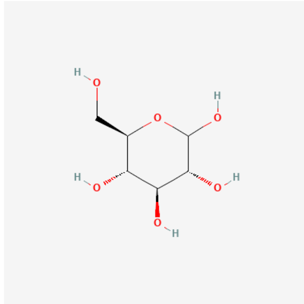
Glucose (Alsdose)



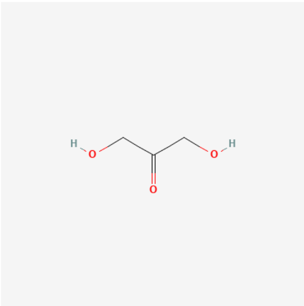
Dihydroxyacetone (Ketose)

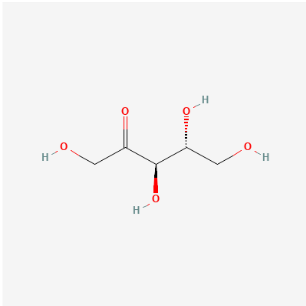


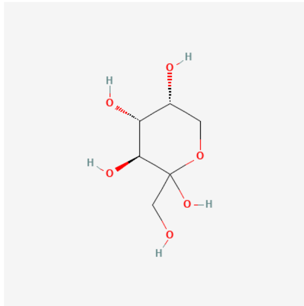
Ribulose (Ketose)



Fructose (Ketose)







Disaccharides

Def

Disaccharides
Are "**double sugars**", simply two monosaccharides glycosidically linked together.

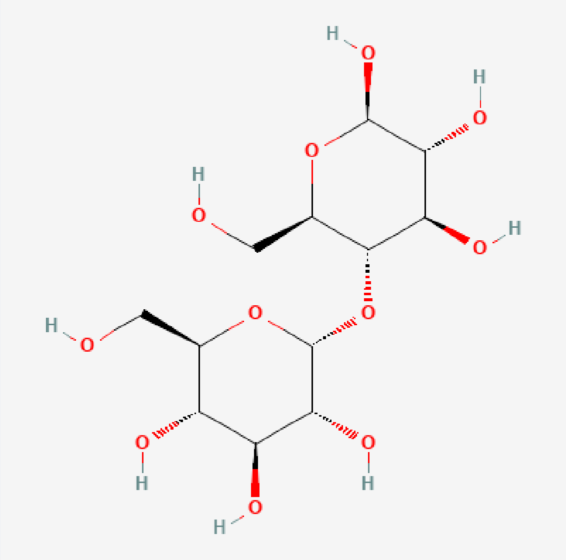
Glycosidic Linkage
A covalent bond formed between two monosaccharides by dehydration.

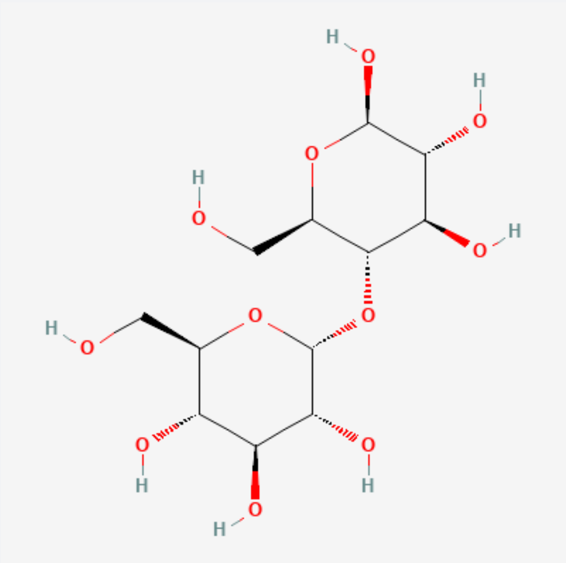
Disaccharides are normally used as a **mean to transport energy** within an organism.

Example

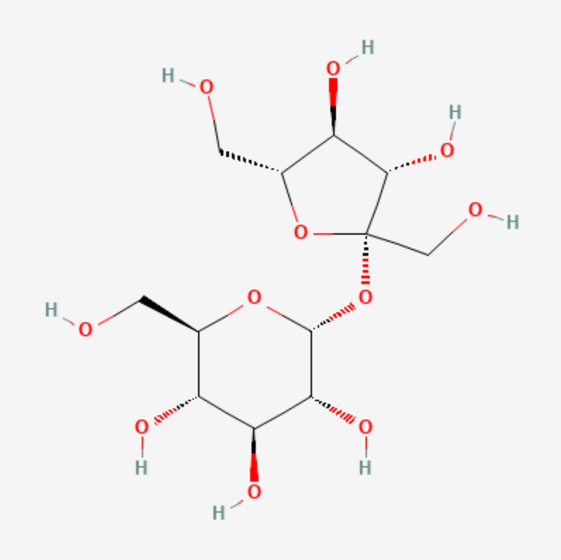
Maltose

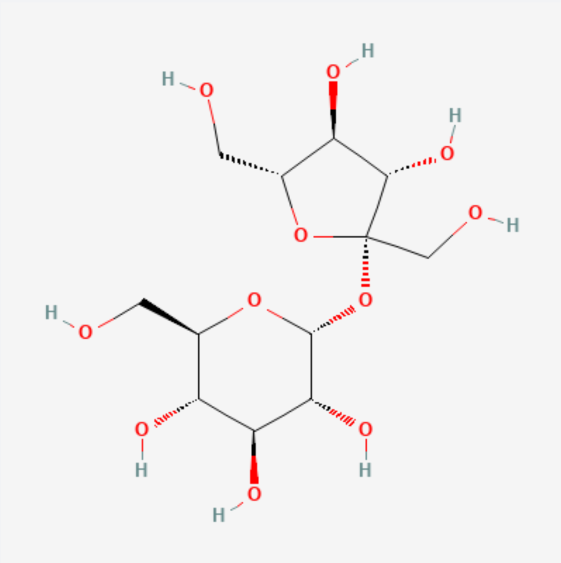
Sucrose





Maltose is a disaccharide of two glucose molecules





Surcrose is a disaccharide of a glucose and fructose molecule

Polysaccharides

Polysaccharides are normally characterized by two things

- α or β bonding
- Amount of branching

Def

Polysaccharides
Are long chains of monosaccharides linked with glycosydic bonds

Polysaccharides are normally used to **store energy** and serve as **building material** for organism (like cellulose in a cell wall)

Example

Starch

- Plants use starch to store energy (monomers are α **glucose**)
- Starch tends to be not as branched

Glycogen

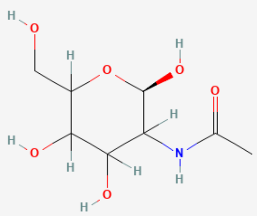
- Humans store glycogen in muscles to provide energy when needed.
- Is made from α **glucose**
- It is extensively branched so that it can be easily broken down when necessary.

Cellulose

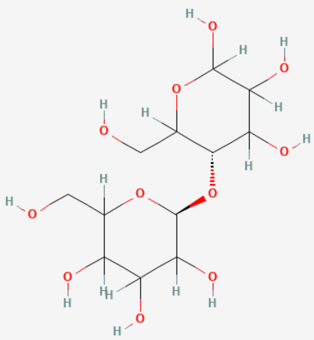
- Plants use cellulose as a building material to provide structure in the cell wall (monomers are β **glucose**)
- Cellulose is never branched
- Is hard to digest and most animals cannot break down cellulose to produce usable energy.

Chitin

- Insects use Chitin as an exoskeleton due to its strong structure.
- Uses β **chitin** as its monomer, making it hard to digest as well



The chitin monomer has a similar structure to cellulose except it contains a nitrogen attachment on the carbon backbone



The difference between α Glucose and β Glucose

α Glucose will always bond on the same side, while β Glucose will bond in alternating patterns.

A similar thing is found for proteins, if bonded like an α then it will form α helices, while β bonding will form $\beta pleats.

Lipids

There are three kinds of Lipids

1. Fats
2. Phospholipids
3. Steroids

Def

Lipids

- Are a group of macromolecules defined by being hydrophobic
- Are very diverse
- Contains a lot of Hydrocarbons ($C-H$)

Ester Linkages
A bond between a **Hydroxyl group (OH)** and a **Carboxyl group ($COOH$)**
Formed by a dehydration reaction

Carboxyl group ($COOH$)

- A group of atoms which is a combination of a **carbonyl group ($C-O$)** and a **hydroxyl group (OH)**
- The bonding will look similar to $O-C-OH$ where the central carbon will be bonded to something else, often a carbon backbone

Fats

Fats are used for:

- **Storing energy**: Organisms store large amounts of energy in the hydrocarbon chains of fats. Fats contain twice the amount of energy for the same weight as compared to Phospholipids.
- **Insulation**: Fats provide insulation from heat or cold as well as protection to vitals in the body.

There are two kinds of Fats

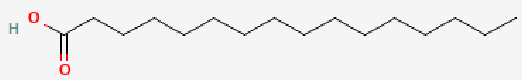
1. Unsaturated Fats
2. Saturated Fats

Def

Fats

- A large molecule formed by a dehydration reaction between **Glycerol** and **Fatty Acids**
- There will always be one glycerol and **three** fatty acids
- Are sometimes called **Triglycerides** or **Triglycerols** because of the three fatty acids
- Are Completely nonpolar and hydrophobic

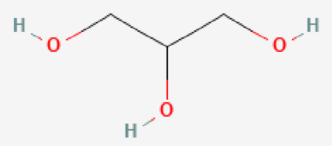
Fatty Acids
A carbon skeleton usually **16-18** carbons long ending with a carboxyl group
These are often referred to as the "tails" of the Fat



Palimitic Acid
A common fatty acid that is bonded with glycerol to form a fat.
Notice the Carboxyl (COOH) on the end

Glycerol ($C_3H_8O_3$)
An alcohol that holds together all the fatty acids to form fats.

Glycerol
Contains three Hydroxyl groups (OH) to ester link with the fatty acids



Unsaturated Fats

- Fats that contain unsaturated fatty acids, which contain double bonds.
- Often **Liquid** at room temperature due to not being able to pack closely together.

Saturated Fats

- Fats of which all their Fatty Acids are saturated and do not contain double bonds and are perfectly straight.
- Often **Solid** at room temperature due to being space efficient.

Unsaturated Fats

Unsaturated Fats' Fatty Acids often contain "kinks" in them from **cis-double bonding** in the carbon skeleton, disallowing them to pack closely, leading them to be liquid at room temperature.

Unsaturated Fats may also contain **trans-double bonding**, classifying these fats as **trans fats**.

Def

Cis-double bonding

- Happens when two **Carbons are double bonded** and the remaining bonds to these Carbons are on the **same side** of the molecule.

- Since the other molecules are on the same side of the molecule, it **forces the molecule to bend** in the other direction

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Trans-double bonding

- Happens when two Carbons are double bonded and the remaining bonds are on **opposite sides** of the molecule.
- Since the extra bonds are on opposite sides, they balance out and this double bond **does not cause bending** of the molecule.

Trans Fats
Saturated Fats of which their Fatty Acids contain trans-double bonding, which may allow them to be straight and unbent.
Trans Fats have also been linked to coronary heart disease due to blockage of blood vessels

Saturated Fats

Saturated Fats' Fatty Acids are completely straight and are called **Hydrogen saturated**, because each carbon in the skeleton is bonded to two Hydrogens as well as two Carbons, disallowing any double bonding from happening in the skeleton (which cause kinks).

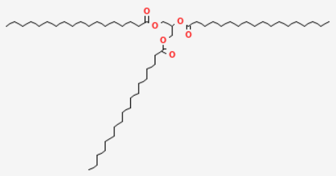
Saturated fats have also been linked to negative health side effects, especially with causing issues of blood flow.

Def

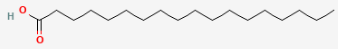
Hydrogen saturated fatty acid
Where every Carbon on a fatty acid's Carbon skeleton is bonded to two Hydrogens, as well as the two neighbouring carbons.
This allows the fatty acid to be straight as there is no double bonding.

Example

← Tristearin
A saturated fat made of three **Stearic acid** fatty acids.



Stearic acid →
A saturated fatty acid with a 18C backbone



Phospholipids

Are used for:

1. Making up the cell membrane

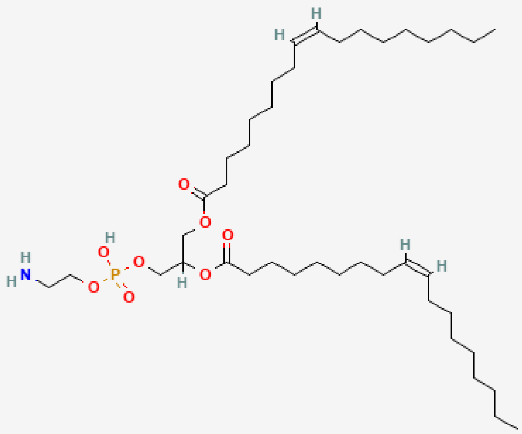
Phospholipids are similar to Fats as they are also made of **glycerol and three connecting molecules**, connected by **Ester Linkages**
When Phospholipids are put in water, they will self assemble into a **bilayer** because of the uneven polarity of the molecules.

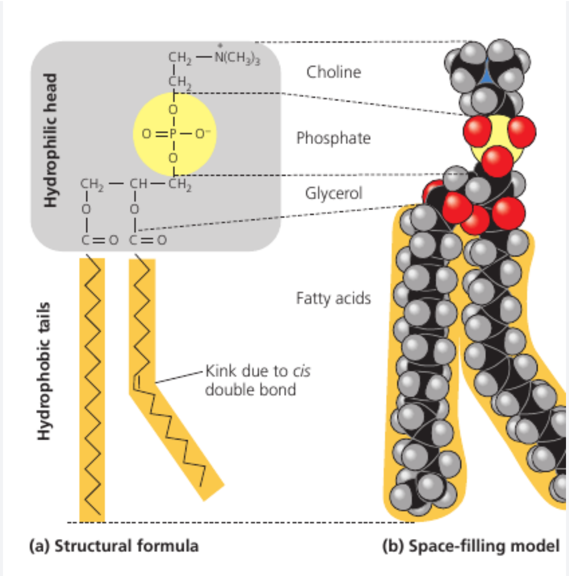
Composed of:

1. Glycerol
2. Two Hydrophobic fatty acids tails
3. Phosphate group
4. Occasionally a hydrophilic molecule

Example

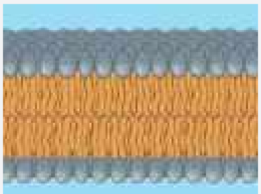
Dioleoyl phosphatidylethanolamine
An example phospholipid that has two bent tails and a hydrophobic head





Def

Phospholipid Bilayer
A membrane made of **two layers of phospholipids** where the hydrophobic heads are pointing to the surface of the layer and the hydrophobic tails are facing each other on the interior of the layer.
Looks something like o=|=o where the **o** are the heads and the **=** are the tails.



Steroids

Lipids that are characterised by their **four fused rings**: three six atom rings then a five atom ring. On the last ring (ring D).
One fatty acid is often attached and is called the **functional group** of the steroid

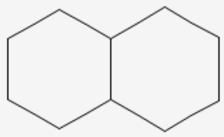
Def

Fused Rings
Rings of atoms that share a side.

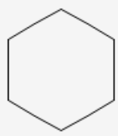
Example

Decahydronaphthalene
A molecule consisting of two

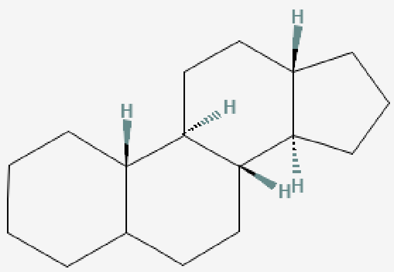
fused cyclohexane rings



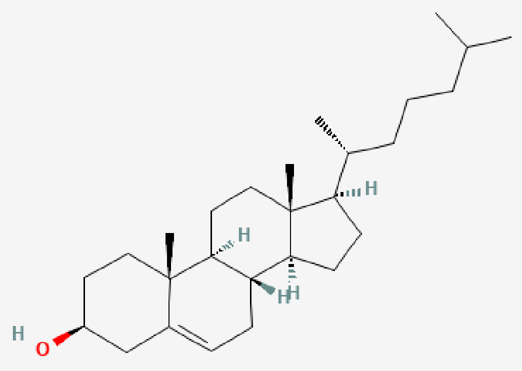
Cyclohexane
A molecule consisting of only a ring of 6 carbons and attaching hydrogen



Example



Gonane
The simplest steroid consisting of only three rings of cyclohexane followed by one ring of cyclopentane.
Gonane has no attached fatty acid or functional group



Cholesterol
A very important steroid of which many other important ones are made from.

Proteins

Are used for:

1. Being Enzymes
2. Storage
3. Defence
4. Transport
5. Hormones
6. Receptors
7. Motor / Movement
8. Structure

Def

Protein
Proteins are the primary macromolecule and consist for more than half of the dry mass of an organism
Proteins are made of one or more Polypeptides

Polypeptides
Polymers (chains) of Amino Acids
literally means many peptides

Amino Acids
The Monomers of Proteins and Polypeptides.

Peptide Bonding

- A bond between each Amino Acid formed through dehydration synthesis
- Bonds the Nitrogen in the **Amino group** to the Carbon in the **Carboxyl group**

Amino Acids

Can be categorised as:

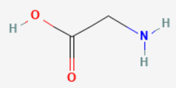
1. Nonpolar (hydrophobic)
2. Polar (hydrophilic)
3. Electrically Charged (hydrophilic)
    1. Acidic (Negative)
    2. Basic (Positive)

Consists of:

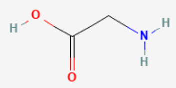
1. Amino Group ($-\mathrm{NH_2}$)
2. Carboxyl Group ($-\mathrm{COOH}$)
3. α Carbon (C)
4. Hydrogen (H)
5. **R group**, also called the **side chain**

The α Carbon is bonded to all the amino group, carboxyl group, R chain, and one hydrogen.
The R chain is what differentiates the different Amino acids, as the rest of the molecule is exactly the same.

Example



Glycine
The most basic Amino Acid, with its side chain consisting of only a single Hydrogen atom. Notice the amino group ($-\mathrm{NH_2}$), carboxyl group ($-\mathrm{COOH}$), and α carbon.

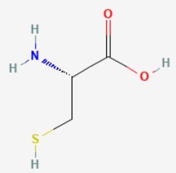


Polar Amino Acids

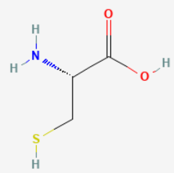
Can be recognised by having a side chain that ends with a **hydroxyl group ($-\mathrm{OH}$)**, **Amino group ($-\mathrm{NH_2}$)**, or **Sulfhydryl group ($-\mathrm{SH}$)**

Cysteine is only classified as Polar because the sulfyhydryl group is only weakly polar

Example



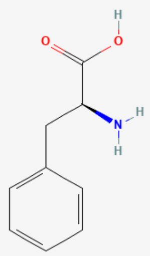
Cysteine
A (weakly) Polar Amino acid with the chain ending in a sulfhydryl group



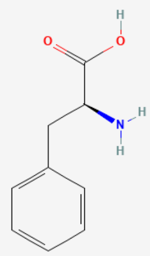
Nonpolar Amino Acids

Can be recognised by having a non-charged nonpolar tip of the side chain

Example



Phenylalanine
A nonpolar amino acid



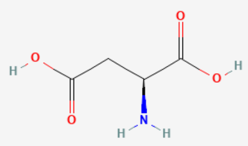
Electrically Charged Amino Acids

Acidic (Negative)

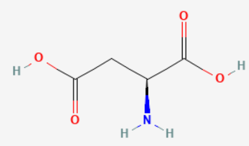
Can be recognised by having a negatively charged tip of the side chain by lacking additional Hydrogen bonds.

Example

Aspartic acid
A negatively charged amino acid



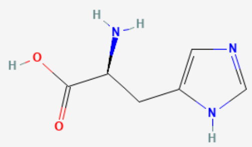
Notice how the tip has a negatively charged Oxygen due to missing an additional Hydrogen



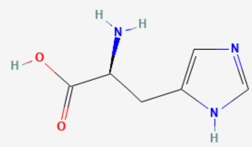
Basic (Positive)

Can be recognised by having a positively charged tip of the side chain by having additional Hydrogen bonds.ttps://duckduckgo.com/?t=ffab&q=sparknotes&ia=web

Example



Histidine
A positively charged amino acid
Notice how the tip has a Nitrogen with additional bonds to Hydrogen, making it a positively charged molecule.



Polypeptides

Are chains of amino acids, bonded through **Peptide Bonding** from the **N-terminus** to the **C-terminus**

Def

N-terminus
The side of a polypeptide chain (or amino acid) that ends in the **Amino group (** $-\mathrm{NH_2}$**)**

C-terminus
The side of a polypeptide chain (or amino acid) that ends in the **Carboxyl group (** $-\mathrm{COOH}$)

Structures in a Protein

Primary Structure

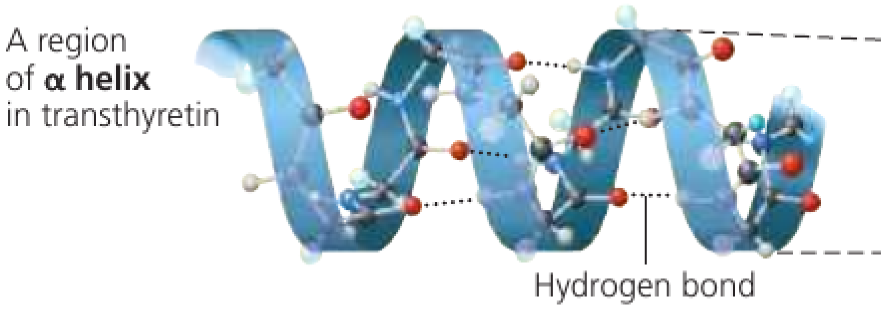
- Primary Structures are defined as a linear string of amino acids, which make up polypeptide chains.
- Bonded by Peptide Bonding

Secondary Structure

- Parts of the polypeptide chain that "folds" into either α **helices** or β **pleated sheets**
- These structures are formed by the hydrogen bonding from one part of the chain to another. This happens because some parts of the chain is positive, negative, hydrophilic, or hydrophobic.

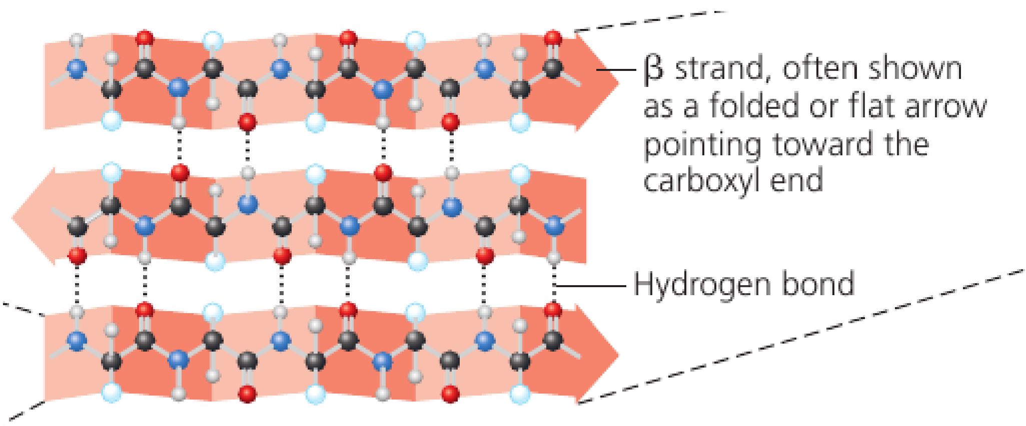
α Helices

Helices are spirals on the polypeptide chain formed by Hydrogen bonds formed with itself every four amino acids or so



β pleated sheets

Pleated sheets are formed when multiple β **strands** are bonded next to each other, forming a wide pleated sheet.
These β strands are on different parts of the polypeptide chain, but still bond to each other due to charges.



Def

β strands
An individual string of the polypeptide chain that is part of a β sheet.
Multiple strands are hydrogen bonded parallel to each other to form a singular sheet.

Tertiary Structure

- Tertiary Structures are the overall shape of a polypeptide
- These structures can happen for four reasons
    1. Hydrophobic Interactions
    2. Hydrogen bonding
    3. Ionic Bonding (from electrically charged amino acids)
    4. DIsulfide Bridges

Def

DIsulfide Bridge
An attraction between two sulphur atoms part of a sulfyhydryl groups ($-\mathrm{SH}$)
This kind of bonding only happens to the amino acid Cysteine

Quaternary Structure

- Some proteins are made of multiple polypeptide chains, so quaternary structures are simply the shape that forms as a result of these polypeptide chains interacting with each other.

Nucleic Acids

There are two kinds of Nucleic Acids

1. DNA (Deoxyribonucleic Acid)
2. RNA (Ribonucleic Acid)

Nucleic Acids are made up of **nucleotides** (the monomer), this makes Nucleic Acids polynucleotides, with bonds to each other called **phosphodiester linkages**

DNA

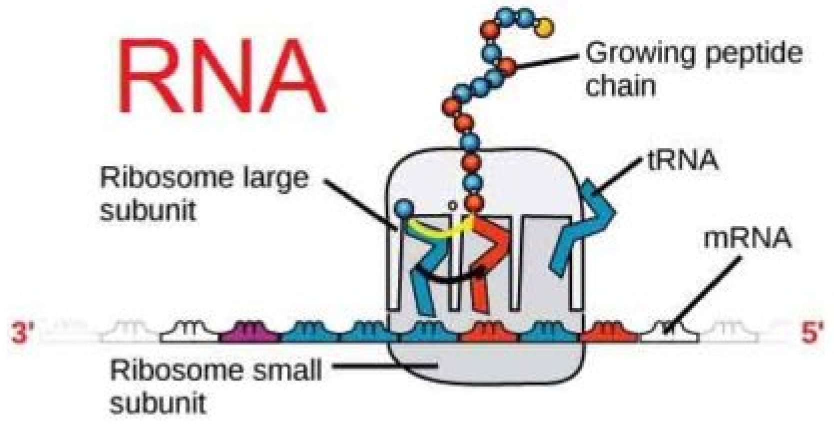
- DNA stores all the information for life
- This is what is inherited from parents
- DNA is just the instructions for what to do, it doesn't actually do it

- Forms a double helix and is anti-parallel

> **Def**
>
> **Anti-parallel**
> Two strands of DNA running beside each other but facing different directions
> Imagine two pencils next to each other but one points up and one points down

RNA

- RNA is an intermediary step to produce proteins from DNA
- The process to create proteins looks something similar to:
    - **DNA → RNA → Proteins**
- There are three kinds of RNA
    - mRNA (messenger RNA)
    - rRNA (ribosomal RNA)
    - tRNA (transfer RNA)



mRNA

- mRNA's function is to **hold a copy of DNA** and take it out of the nucleus to be used

rRNA

- rRNA **forms the proteins** inscribed on the mRNA
- It reads the mRNA and connects the correct Amino Acids together to form proteins

tRNA

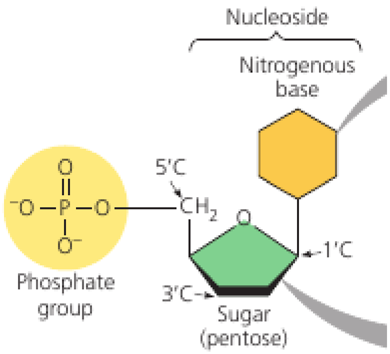
- tRNA **brings the correct Amino Acids** associated with the genetic sequence to the rRNA

- each tRNA matches its specific three nucleotide code to a specific amino acid

Nucleotides

Are made up of three parts:

1. Five carbon sugar (pentose)
2. Nitrogenous base (The part that can change)
3. One to three phosphate groups (one when its polymerised and three before)



Nucleosides

Def

Nucleoside
The combination of the pentose and nitrogenous base in a nucleotide
This excludes the phosphate group

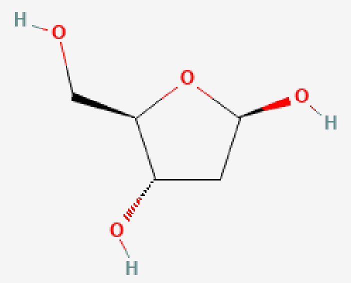
Pentose

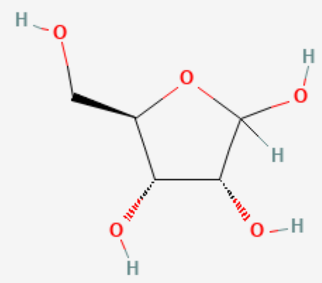
The pentose holds the Nitrogenous base to the Phosphate group
The pentose of a nucleotide can either be

1. Deoxyribose (for DNA)
2. Ribose (for RNA)

Example

Deoxyribose	**Ribose**





Notice how the structure is missing a singular Oxygen atom
This is why it is called de-oxy-ribose (Ribose missing Oxygen)

* It may appear that there are extra Hydrogens in this image, but the Hydrogens are just being abbreviated in the other image, they are still there

Nitrogenous Base

- The Nitrogenous base is the part of each Nucleotide that can differ
- The sequence of Nitrogenous bases are what actually store the information in the DNA and RNA.

There are two kinds of Nitrogenous Bases:

1. Pyrimidines
2. Purines

Curiously, when two nitrogenous bases are paired, the amount of oxygen will add up to two atoms.

Pyrimidines

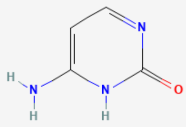
- Pyrimidines are constructed out of a single six-sided ring
- Smaller than Purines

Includes

1. Cytosine (C), pairs with Guanine by **three** Hydrogen Bonds
2. Thymine (T, for DNA), pairs with Adenine by **two** Hydrogen Bonds
3. Uracil (U, for RNA), pairs with Adenine by **two** Hydrogen Bonds

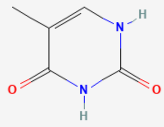
Example

Cytosine



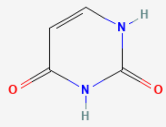
Contains **one** Oxygen Atom

Thymine



Contains **two** Oxygen Atoms

Uracil



Contains **two** Oxygen Atoms

Purines

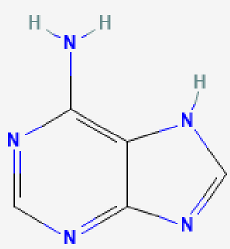
- Purines are constructed out of a side sided ring fused to a five sided ring
- Larger than Pyrimidines

Includes

1. Adenine (A), pairs with Thymine and Uracil by **two** Hydrogen Bonds
2. Guanine (G), pairs with Cytosine by **three** Hydrogen Bonds

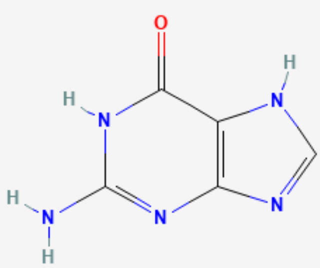
Example

Adenine



Contains **zero** Oxygen Atoms

Guanine



Contains **one** Oxygen Atoms

Phosphate group

The phosphate group in a nucleotide holds each nucleotide to each other, this is like the backbone of Nucleic Acids

The phosphate group is often represented as ($-\mathrm{OPO_3}^{2-}$)

One of the three Oxygens in the phosphate groups are bound to the Nucleoside