2 Biomolecules

2.1 Testing for biomolecules

Food tests

1) Reducing sugars

- reduce soluble blue copper sulphate containing copper (II) ions to insoluble brick-red copper oxide, containing copper (I)
- the copper oxide is seen as a brick-red ppt

REDUCING SUGAR + Cu^{2+} ⟶ OXIDISED SUGAR + Cu^{+}

$\underbrace{Cu^{2+}}_{\text{BLUE}}$ $\underbrace{Cu^{+}}_{\text{BRICK-RED}}$

- add equal volumes of Benedict's reagent and the food sample to a test tube
- heat in a water bath at 80°C
- if reducing sugars are present, the following colour changes are observed:

BLUE ⟶ GREEN ⟶ YELLOW ⟶ ORANGE ⟶ BRICK-RED

— CONC. OF REDUCING SUGARS INCREASING ⟶

2) Non-reducing sugars

- e.g., sucrose
- disaccharide is first broken down into its 2 monosaccharide constituents in a hydrolysis reaction
- this is done by adding HCl, and then neutralising the acid with an alkali such as sodium bicarbonate
- constituent monosaccharides will be reducing sugars and their presence can be tested by Benedict's test

3) Starch

- add drops of iodine solution to the sample
- if blue-black colour is quickly produced, starch is present
- iodine solution is yellow brown

4) Lipids (emulsion test)

- sample is shaken with ethanol
- any lipids present will dissolve
- mixture of ethanol and sample is poured into a beaker containing water
- if lipids are present, a cloudy-white suspension is formed due to the lipids being unable to remain dissolved when mixed with water
- therefore, the lipid molecules form droplets throughout the liquid, this kind of mixture is called the emulsion

5) Proteins (Biuret test)

- all proteins have peptide bonds containing nitrogen atoms which form a purple complex with Cu^{2+} ions
- equal volumes of sample and Biuret reagent are mixed
- if proteins are present, the colour changes from blue to lilac
- instead of biuret reagent, KOH and dil. $CuSO_4$ can be used

For extra details on performing food tests, see paper 3 notes.

2.2 Carbohydrates and lipids

All living organisms are made of C, H, O + N molecules.

Carbohydrates

- composed of C, H, O
- divided into monosaccharides, disaccharides, polysaccharides

- **monomer** – one of many small molecules that combine to form a polymer, e.g. – monosaccharides, amino acids, nucleotides

- **polymer** – large molecule made from many similar repeating subunits, e.g. – polysaccharides, proteins, nucleic acids

- **macromolecule** – large molecule formed due to polymerisation of monomers, e.g. – polysaccharides, proteins (polypeptides), nucleic acids (polynucleotides)

Monosaccharides

Molecule consisting of a single sugar unit with the general formula $C(H_2O)_n$

- dissolves in water
- main types of monosaccharides – trioses (3C), pentoses (5C), hexoses (6C)
- glucose, fructose galactose, ribose, deoxyribose

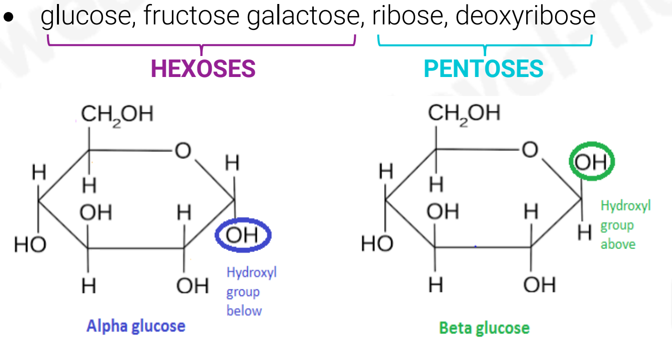


Image: https://tlamjs.com/2017/01/13/biological-molecules-carbohydrates/

Roles of monosaccharides

1) **source of energy in respiration** – C-H bonds can be broken to release a lot of energy which is transferred to help make ATP from ADP

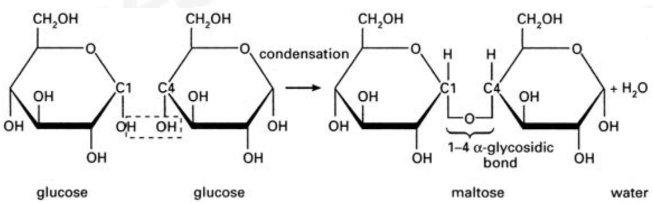
2) **building blocks for larger molecules** – glucose is uses to make the polysaccharides starch, glycogen, and cellulose; ribose is one of the molecules used to make RNA and ATP, deoxyribose is one of the molecules used to make DNA

Disaccharides

Sugar molecule consisting of 2 monosaccharides joined by a glycosidic bond.

MONOSACCHARIDE + MONOSACCHARIDE $\xrightarrow{\text{CONDENSATION}}$ DISACCHARIDE

GLUCOSE + GLUCOSE → MALTOSE
α-GLUCOSE + β-FRUCTOSE → SUCROSE
GLUCOSE + GALACTOSE → LACTOSE



Glycosidic bond formation

Image: https://dopeahmeanbio.wordpress.com/tag/glycosidic-bonds/

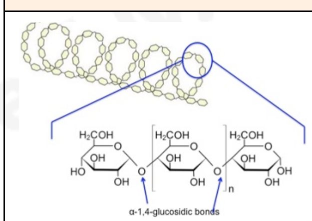
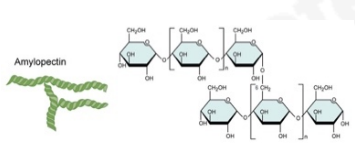
- H_2O molecule is removed; the bond formed by condensation is called a glycosidic bond

Polysaccharides

A polymer whose subunits are monosaccharides joined by glycosidic bonds

- e.g., starch, glycogen, cellulose (all polymers of glucose)
- not sugars
- if glucose itself accumulated in cells, it would dissolve and make the contents of the cell too concentrated which affects its osmotic properties
- storage polysaccharides – convenient, compact, inert, insoluble

1) Starch → amylose + amylopectin

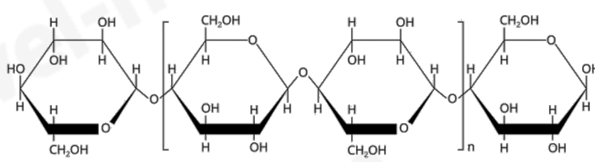
AMYLOSE	AMYLOPECTIN
 Image: https://www.e-education.psu.edu/	 Image: http://futurefoodchemist.weebly.com/
made by condensation reactions between 1,4 linked α-glucose molecules	also made of 1,4 linked α-glucose molecules
long, unbranching chain	chains are shorter than amylose and branch out to sides
chains are curved and coil into helical structures making the final molecule more compact	branches are formed by 1-6 linkages

2) Glycogen

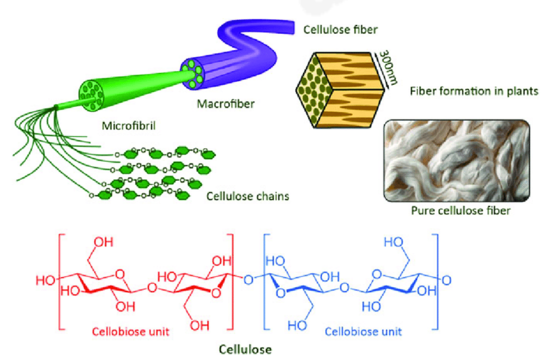
- made of chains of 1-4 linked α-glucose molecules with 1-6 linkages forming branches
- tend to be more branched than amylopectin molecules
- many ends due to branching aids in easy addition and removal of glucose
- compact and insoluble, doesn't affect the water potential (Ψ)

3) Cellulose → polymer of β-glucose

- in order to form a glycosidic bond with the 4th carbon atom where the OH group is below the ring; every other glucose is rotated 180°
- so successive glucose molecules are linked 180° to each other
- one oxygen is up and the other is down
- the molecules are still linked 1-4



- cellulose molecules become tightly cross-linked to form bundles called microfibrils
- microfibrils are held together in bundles called fibres by hydrogen bonding
- cellulose fibres have very high tensile strength – this makes it possible for a cell to withstand large pressures as a result of osmosis
- cellulose fibres, despite their strength, are freely permeable



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Dipoles and hydrogen bonds

- unequal distribution of charges in a covalent bond is called a dipole
- molecules which have groups with dipoles are polar

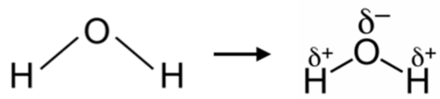


Image: https://alevelbiology.co.uk/notes/dipoles-of-water-molecules/

- in water, oxygen atom gets more electrons due to it being more electronegative and therefore gets a small negative charge denoted by delta (**δ**-)
- hydrogen atoms get less electrons and therefore get small positive charges (**δ**+)

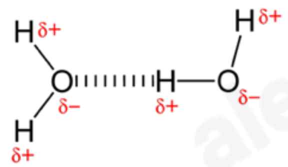


Image: https://courses.lumenlearning.com/cheminter/chapter/hydrogen-bonding/

- negatively charged oxygen of one molecule is attracted to a positively charged hydrogen of another, this attraction is called a hydrogen bond

Molecules which have groups with dipoles are polar

- they're attracted to H_2O molecules as they also have dipoles and are considered to be hydrophilic (water-loving)
- soluble in water
- e.g., glucose, amino acids, NaCl

Molecules which do not have dipoles are non-polar

- they're not attracted to water and hydrophobic (water-hating)
- insoluble in water
- e.g., oils, cholesterol

Lipids → 3 Fatty Acids + 1 Glycerol

Fatty acids

- contain the acidic group –COOH
- larger molecules in the series have long hydrocarbon tails attached to the acid which are 15-17 carbon atoms long
- of two types: saturated and unsaturated
- unsaturated fatty acids have C=C double bonds therefore don't have maximum amount of hydrogen atoms
- form unsaturated lipids
- mostly liquid

Alcohols & Esters

- alcohols contain hydroxyl group (–OH) attached to C atom
- reaction between (fatty) acid (–COOH) and alcohol (–OH) produces an ester
- the chemical link between acid and alcohol is called an ester linkage/bond and is formed by a condensation reaction

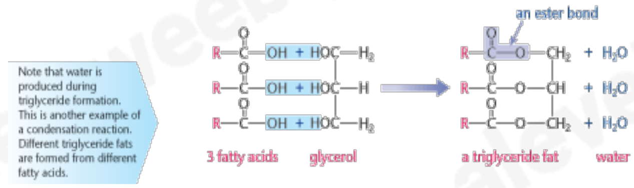


Image: https://revisionscience.com/

- glyceride is an ester formed by a fatty acid combining with the alcohol glycerol ($C_3H_8O_3$)
- glycerol has 3 hydroxyl groups; each one is able to undergo a condensation reaction with a fatty acid
- triglycerides are insoluble in water due to the non-polar nature of hydrocarbon tails – they don't have uneven distribution of charges and are hydrophobic

Roles of triglycerides

- energy reserves
- insulator
- protect vital organs

2.3 Proteins and water

Proteins

All proteins are made from the same monomer - amino acids.

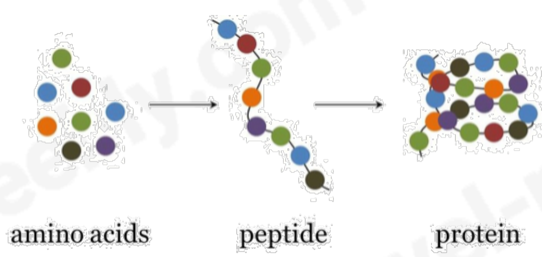
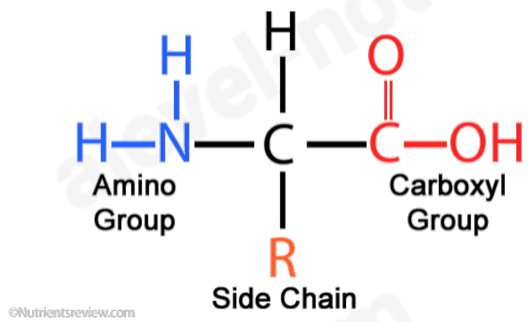


Image: https://beautiflworld.com/do-protein?print=print

Amino acids

All have a central carbon atom bonded to –

- an amine (–NH_2) group
- a carboxylic group (–COOH)
- a hydrogen
- a R-group that determines what type of amino acid it is



The peptide bond

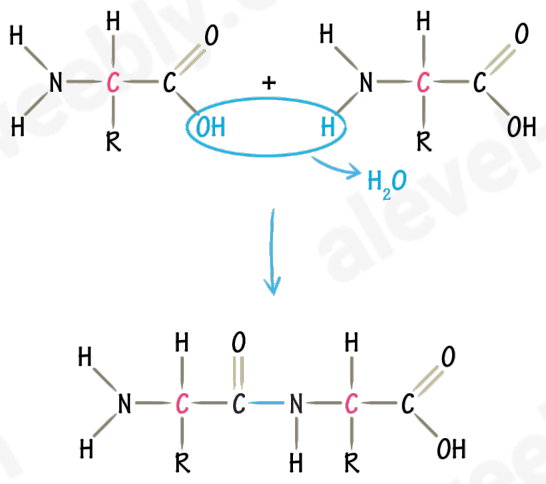
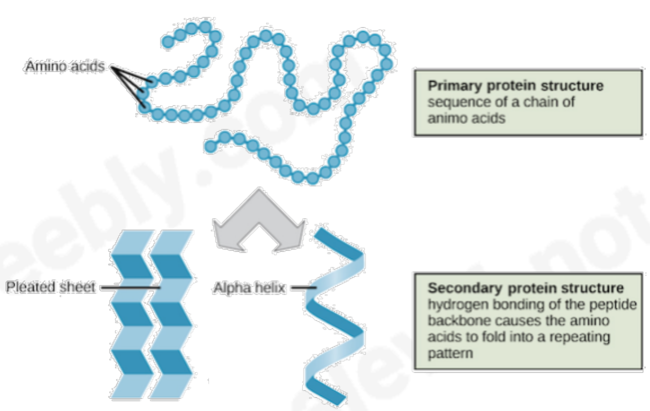


Image: https://www.drawittoknowit.com/

- a molecule made up of many amino acids linked together by peptide bonds is a polypeptide
- polypeptides can be broken down to amino acids by breaking the peptide bonds in a hydrolysis reaction
- this happens naturally in the stomach and small intestine during digestion

Structures of proteins



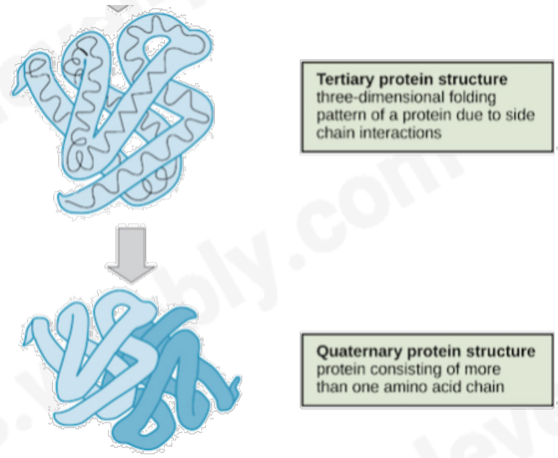
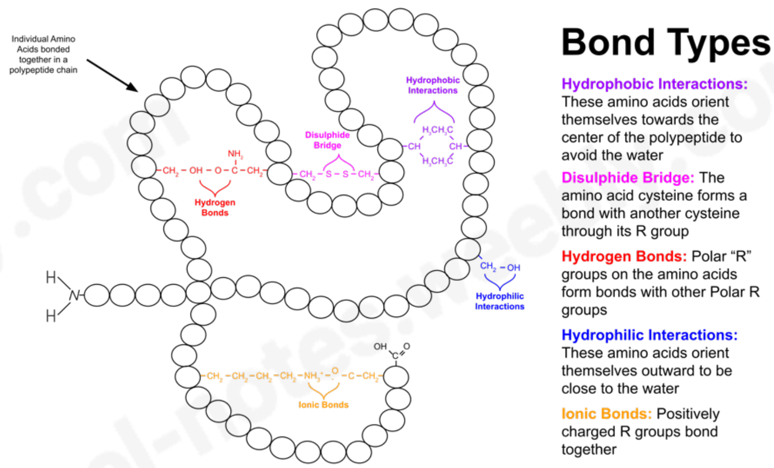


Image: https://www.khanacademy.org/

Bonds in the tertiary structure



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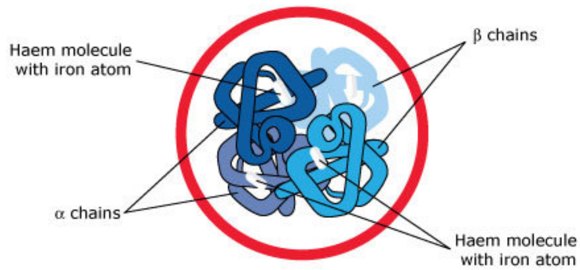
PROTEINS	
GLOBULAR	**FIBROUS**
spherical/balled shaped • curl up so that their non-polar, hydrophilic R-groups point to the centre of the molecule away from watery surroundings • polar, hydrophilic R-groups are on the outside which makes mixing + dissociating in water easier	proteins that form long strands
usually soluble	usually not soluble in water
precise shape, have roles in metabolic activities and are specific in nature	have structural roles
e.g., enzymes, haemoglobin, myoglobin	e.g., keratin, actin, myosin, collagen

Haemoglobin: a globular protein

- made of 4 polypeptide chains therefore they have a quaternary structure
- 2 of the haemoglobin chains, α-chains, are made of α-globin
- the other 2 chains, β-chains, are made of β-globin
- each polypeptide chain has a haem group attached (prosthetic group) to it
- haem contains charged particle of iron
- the haem group is also responsible for the colour of haemoglobin



Haemoglobin is made up of four chains (two α and two β), each one surrounding a haem molecule that holds a single iron atom.

- each polypeptide chain can carry one molecule of oxygen
- therefore, in total, haemoglobin can carry 4 molecules of oxygen or 8 oxygen atoms

Collagen: a fibrous protein

- found in skin, tendons, cartilage, bone, teeth, etc.
- a structural protein
- collagen molecule consists of 3 polypeptide chains, each in a helical shape

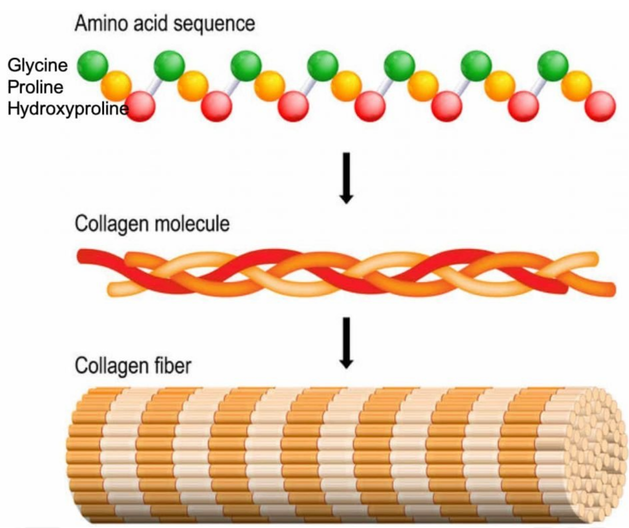


Image: https://rosemarycottageclinic.co.uk/

- helical polypeptides are wound together creating a triple helix
- strands are held together by hydrogen and some covalent bonds
- every 3rd amino acid in each polypeptide chain is glycine
- each 3 stranded molecule interacts with other collagen molecules running parallel to it
- covalent bonds form between R-groups of amino acids
- these cross-links hold many collagen molecules side by side forming fibrils
- many fibrils lie alongside each other forming strong bundles called fibres
- collagen is flexible but has tremendous tensile strength
- collagen fibres line up according to the forces they withstand