Mohammad's notes

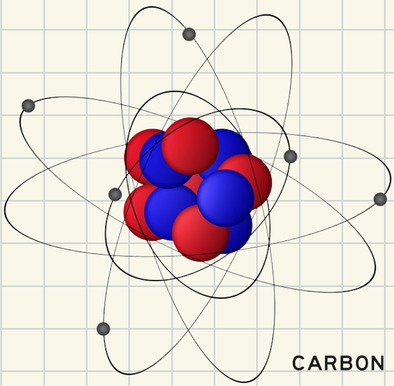
B1.1 - carbohydrates and lipids

B1.1.1-Chemical properties of a carbon atom allowing for the formation of diverse compounds upon which life is based

B1.1.1—Chemical properties of a carbon atom allowing for the formation of diverse compounds upon which life is based
Students should understand the nature of a covalent bond. Students should also understand that a carbon atom can form up to four single bonds or a combination of single and double bonds with other carbon atoms or atoms of other non-metallic elements. Include among the diversity of carbon compounds examples of molecules with branched or unbranched chains and single or multiple rings. **NOS:** Students should understand that scientific conventions are based on international agreement (SI metric unit prefixes "kilo", "centi", "milli", "micro" and "nano").

*general information

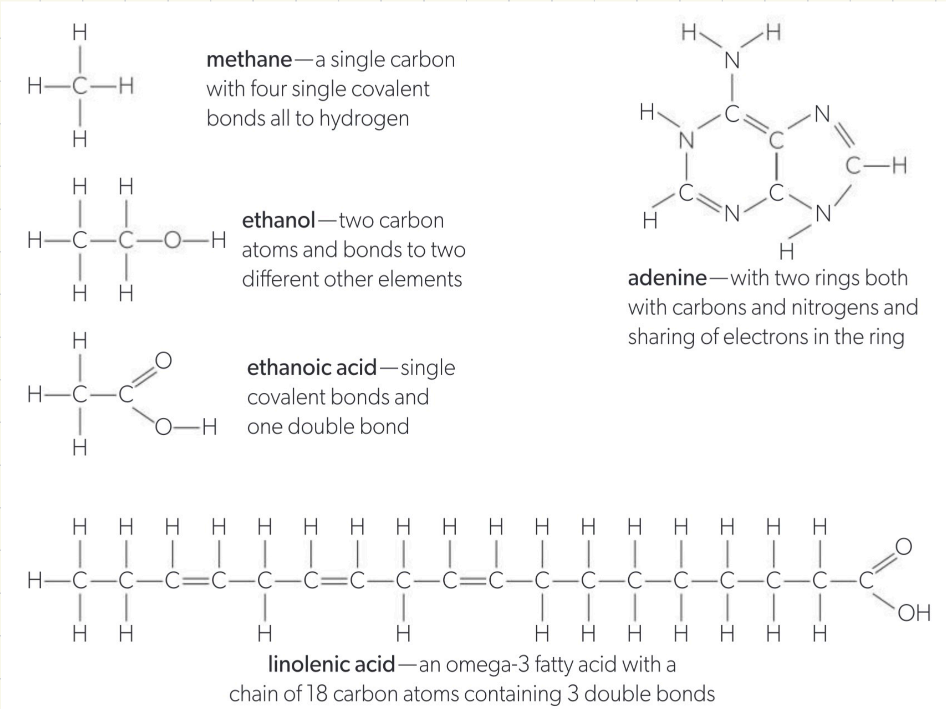
Carbon atoms can form covalent bonds with other atoms. A covalent bond is formed by sharing a pair of electrons between two adjacent atoms. The negatively charged shared electrons are attracted to the positively charged nuclei of both atoms. Covalent bonds are the strongest type of bond between atoms. This means stable molecules based on carbon can be produced.



Each carbon a Tom can form four covalent bonds. Carbon atoms can form covalent bonds with other carbon atoms or with hydrogen, oxygen, nitrogen, or phosphorus.

Single covalent bonds allow both of the bonded atoms to rotate. A chain of covalently bonded atoms is not straight.

Some common naturally occurring carbon compounds:



methane—a single carbon with four single covalent bonds all to hydrogen

ethanol—two carbon atoms and bonds to two different other elements

ethanoic acid—single covalent bonds and one double bond

adenine—with two rings both with carbons and nitrogens and sharing of electrons in the ring

linolenic acid—an omega-3 fatty acid with a chain of 18 carbon atoms containing 3 double bonds

* actual information

The majority of molecules within all living organisms can be categorized into one of four biochemical groups:

- carbohydrates
- lipids
- proteins
- nucleic acids

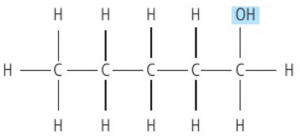
All contain carbon

These four types of molecules interact with each other in order to carry out the metabolism of each cell.

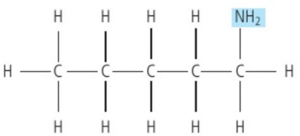
Oxygen, nitrogen, phosphorus are also common within living organisms. And are found in carbohydrates, lipids, proteins, nucleic acids, forming covalent bonds with carbon.

Element	Number of covalent bonds
Hydrogen	1
Oxygen	2
Nitrogen	3
Carbon	4
Phosphorus	5

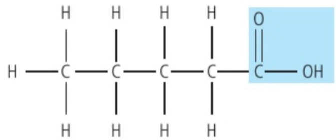
Functional groups: (memorizing these will help a lot)



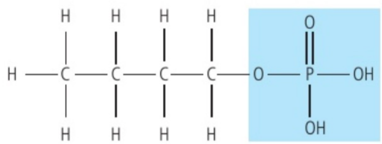
hydroxyl or alcohol (OH)



amino or amine (NH_2)



carboxyl (COOH)



phosphate (H_2PO_4)

Review on basic terms and concepts:

Monosaccharides:

Simple sugars; basic unit of carbohydrates
Example: glucose, fructose, galactose.

Disaccharide:

Formed when two monosaccharides combine through condensation

Examples:

Glucose+ glucose = maltose
Glucose + fructose = sucrose
Glucose + galactose = lactose

Polysaccharide:

Long chain of monosaccharides
Serves as energy storage (like starch or glycogen) (or like cellulose)

Monomer:

A single unit that can be bonded to other similar units to form a polymer

Example:

- monosaccharides (for carbohydrates)
- amino acids (for proteins)
- nucleotides (for nucleic acids)
- fatty acids (part of lipids, not true monomers)

Polymer:

- large molecules made by linking together many monomers.

Examples: carbohydrates, proteins, nuclei acids

$$\text{monomer} \underset{\text{condensation} \,\to\, \text{anabolic}}{\overset{\text{hydrolysis} \,\to\, \text{catabolic}}{\rightleftarrows}} \text{polymer}$$

Common categories of molecules:

Category	Subcategory	Example molecules
Carbohydrates	Monosaccharides	Glucose, galactose, fructose, ribose
	Disaccharides	Maltose, lactose, sucrose
	Polysaccharides	Starch, glycogen, cellulose, chitin
Proteins		Enzymes, antibodies, peptide hormones
Lipids	Triglycerides	Fat stored in adipose cells
	Phospholipids	Lipids forming a bilayer in cell membranes
	Steroids	Some hormones
Nucleic acids	Nucleotides	Deoxyribonucleic acid (DNA), ribonucleic acid (RNA), adenosine triphosphate (ATP)

B1.1.2 and B1.1.3

B1.1.2—Production of macromolecules by condensation reactions that link monomers to form a polymer
Students should be familiar with examples of polysaccharides, polypeptides and nucleic acids.

B1.1.3—Digestion of polymers into monomers by hydrolysis reactions
Water molecules are split to provide the -H and -OH groups that are incorporated to produce monomers, hence the name of this type of reaction.

Most living organisms don't make macromolecules one atom at a time macromolecules are made out of monomers. When you ingest food many of the molecules of the food are in the form of macromolecules. Digestion breaks down macromolecules as a result of chemical reaction called hydrolysis reactions. Hydrolysis reactions break covalent bonds between monomers.

B1.1.3

Macromolecule	Monomer (building blocks)
Carbohydrates	Monosaccharides
Lipids	Glycerol, fatty acids, phosphate groups
Proteins (polypeptides)	Amino acids
Nucleic acids	Nucleotides

The resulting monomers are then asuitable size ot be absorbed into the bloodstream and circulated to body cels. After entering cels, often the monomers are built up into macromolecules again. This involves forming covalent bonds ni reactions called condensation reactions.

hydrolysis → catabolic → releases energy

monomer ⇄ polymer

condensation → anabolic → requires energy

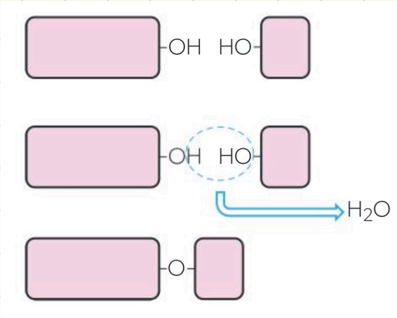
Condensation and hydrolysis reactions are, in many ways, the reverse of each other.

In a condensation reaction, a water molecule is always formed as part of the reaction.

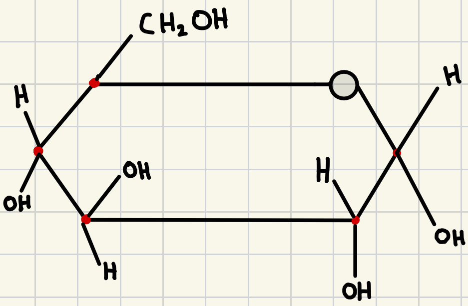
In a hydrolysis reaction, a water molecule is split into two components and each component is added in and becomes a part of the two new (smaller) molecules.

Both condensation and hydrolysis reactions require specific enzymes.

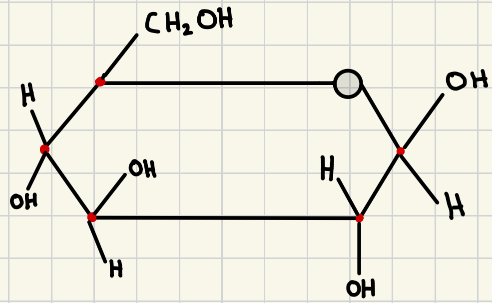
When polysaccharides, polypeptides and nucleic acids are constructed, the simpler molecule is always water its produced by removing a hydroxyl group from one of the molecules being linked and a hydrogen from the other.



Glucose is the monosaccharide used to make the polysaccharides glycogen, starch and cellulose.

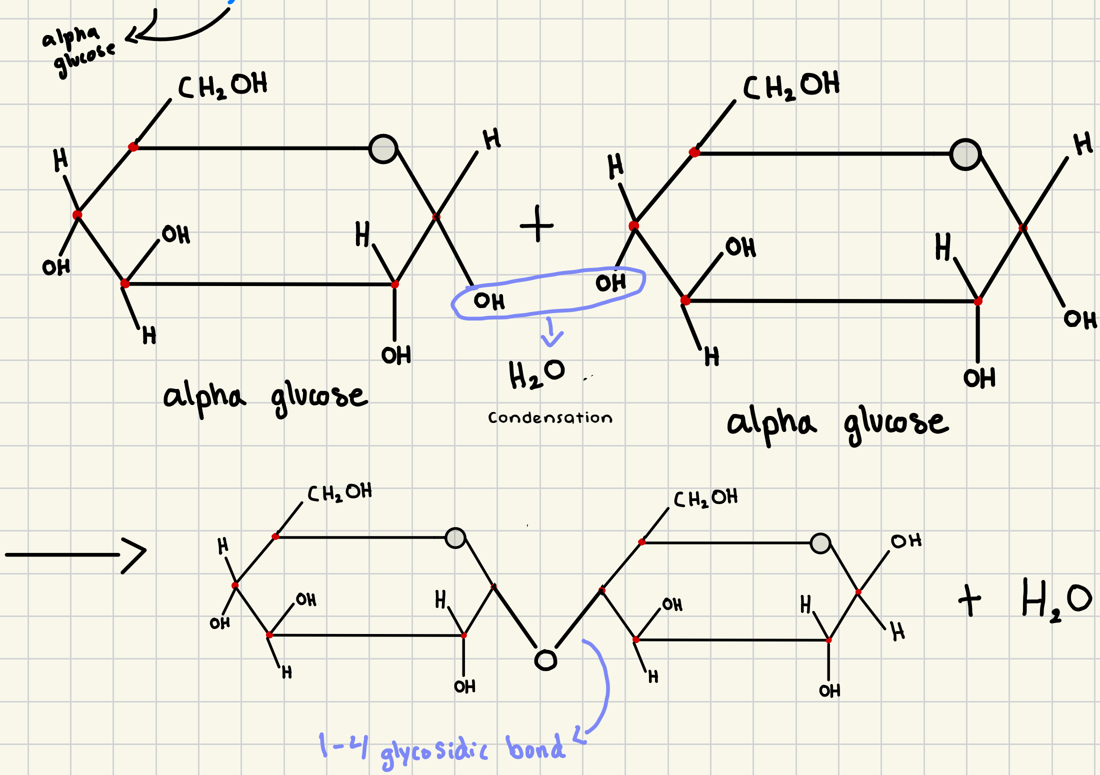


alpha glucose



beta glucose

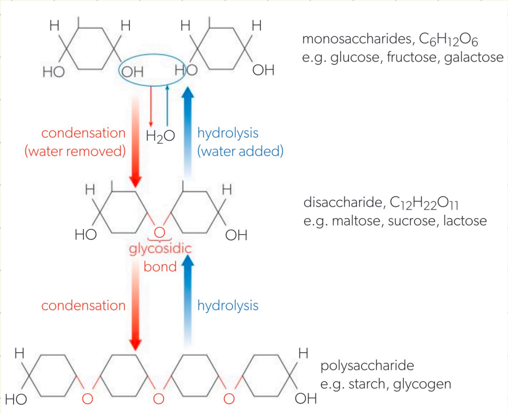
Glucose + glucose = maltose



Glucose molecules are linked up with glycosidic bonds. These are C-O-C linkages formed by condensation, using hydroxyl groups. The hydroxyl on C1 of a glucose is linked to the hydroxyl on C4, at the end of the growing chain.

In an unbranched chain, all the glycosidic bonds are 1 →4. To form branches, the C1 of a glucose is linked to the C6 of a glucose already in the chain. This 1→6 linkage forms a side-branch, and more glucose molecules can be added to it with 1→4 bonds.] B1.1.5

Cellulose molecules in plant cell walls are unbranched chains of B-glucose that can contain 15,000 or more glucose molecules. Glycogen molecules in liver or muscles cells are branched chains of a-glucose, with up to 60,000 glucose molecules.



Digestion of polymers into monomers by hydrolysis reactions

Polymers are deconstructed so the monomers in them can be reused to build new polymers or used as a force of energy

Hydrolysis reactions are used to deconstruct polysaccharides, polypeptides and nuclei's acids into monosaccharides, amino acids and nucleotides. These are reactions that occur during digestion.

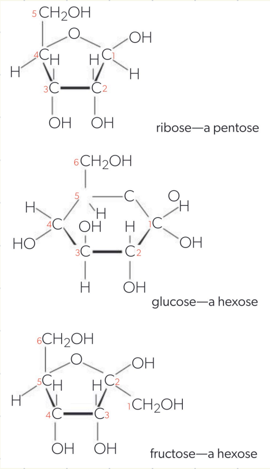
Digestion of polysaccharides, polypeptides and nuclei acids can be carried out by all cells. Decomposers release digestive enzymes into the environment around them in order to break down polymers by hydrolysis so they can absorb and use the monomers.

B1.1.4 - form and function of monosaccharides

B1.1.4—Form and function of monosaccharides
Students should be able to recognize pentoses and hexoses as monosaccharides from molecular diagrams showing them in the ring forms. Use glucose as an example of the link between the properties of a monosaccharide and how it is used, emphasizing solubility, transportability, chemical stability and the yield of energy from oxidation as properties.

* ASK

Monosaccharides have between three and seven carbon atoms. Pentoses have five carbons and hexoses. Both of them normally have molecules with a ring of atoms. There is one oxygen atom in the ring and four or five carbon atoms.


ribose—a pentose
glucose—a hexose
fructose—a hexose

Properties and uses of glucose:

• like all monosaccharides - glucose is soluble and is a relatively small molecule so it is easily transported. It circulates in blood.

• like most other carbohydrates, glucose is chemically very stable. This property is useful for food storages. However, glucose would cause osmotic problems if it was stored in cells in large quantities. Therefor it is converted to starch or glycogen.

• Glucose yields energy when it's oxidized. it can there for be used as a substrate for respiration.

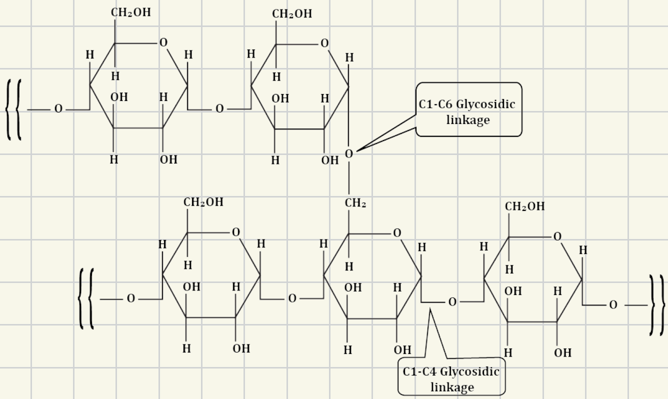
B1.1.5 - polysaccharides as energy storage compounds.

Starch and glycogen are used as energy stores. Starch in plants and glycogen in animals. Both of these substances are composed of large numbers of alpha-glucose molecules, which can be used a substrate in aerobic and anaerobic cell respiration.

There are two types of starch molecule:

- amylose is an unbranched chain of alpha-glucose linked by 1-4 glycosidic bonds. Because of the bond angles, the chain is helical rather than straight.

- amylopectin has the same structure is amylose but there are some 1-6 glycosidic bonds making the molecule branched.



Glucose can be removed from starch and glycogen molecules when it is needed. A hydrolysis reaction breaks a 1-4 glycosidic bond to separate one glucose molecule from the end of a chain. This allows its to be transported elsewhere or used in the cell.

Adding or removing glucose can happen more quickly with amylopectin than amylose because the branched structure provides more ends of chains.

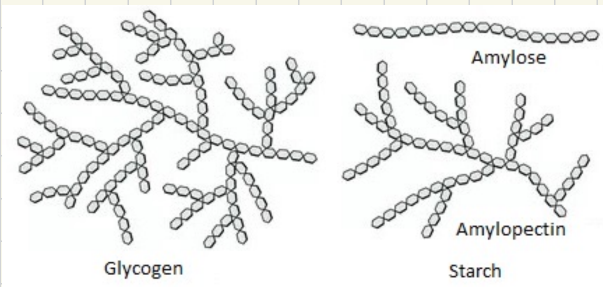
Glycogen has a similar structure to amylopectin: alpha glucose linked by 1-4 glycosidic bonds and branched by 1-6 bonding.

in glycogen, about 1 in 10 glucose molecules has a 1-6 bond, compared with about 1 in 20 in amylopectin, so glycogen molecules are more branched.

Glycogen can contain tens of thousands of glucose sub-units and amylopectin can contain more than a hundred thousand.

The very large size of the molecules give them much lower solubility than glucose, so they contribute little to the osmotic concentration of cells. This means Starch or glycogen can be used to store large amounts of glucose without the cell swelling up with water drawn in by osmosis.

The branched structure of glycogen and amylopectin makes them relatively compact due to their high molecular mass



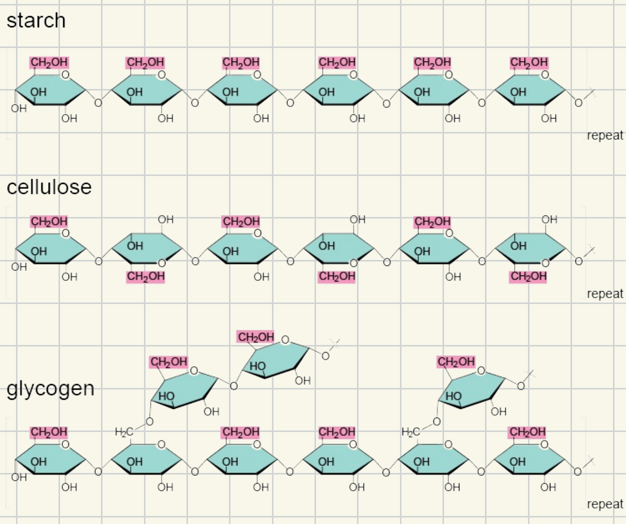
B1.1.5—Polysaccharides as energy storage compounds
Include the compact nature of starch in plants and glycogen in animals due to coiling and branching during polymerization, the relative insolubility of these compounds due to large molecular size and the relative ease of adding or removing alpha-glucose monomers by condensation and hydrolysis to build or mobilize energy stores.

B1.1.6 - structure of cellulose related to its function as a structural polysaccharide in plants

B1.1.6—Structure of cellulose related to its function as a structural polysaccharide in plants
Include the alternating orientation of beta-glucose monomers, giving straight chains that can be grouped in bundles and cross-linked with hydrogen bonds.

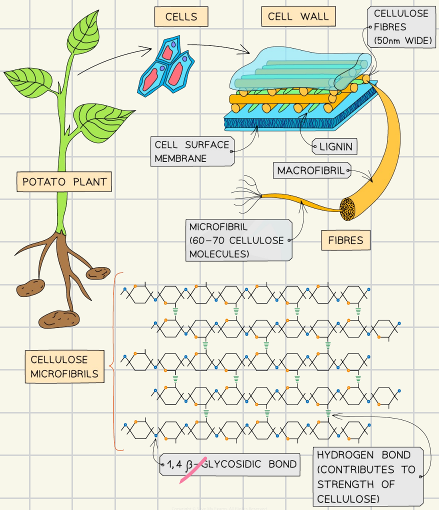
Cellulose, like starch and glycogen, is composed of glucose, but its properties are markedly different because it's a polymer of beta glucose rather than alpha glucose. Condensation reactions link Carbon 1, on a free beta glucose molecule to Carbon 4 on the beta glucose at the end of the growing cellulose molecule. All the links in cellulose are 14 glycosidic bonds, so it is an unbranched chain. A cellulose molecule can contain note than 10,000 beta molecules

In beta glucose the -OH group on carbon 1 is angled upwards. The -OH group on Carbon 4 is angled downwards. To bring these -OH groups together and allow a condensation reaction to occur, each beta glucose added to the chain has to be inverted in relation to the previous one. Therefor glucose molecules in cellulose face alternately upwards and downwards,



The chain of alpha-glucose in starch wind into a straight helix, but in cellulose the alternating orientation of beta-glucose results in a straight chain. This allows formation of bundles of molecules arranged in parallel. Hydroxyl groups are regularly spaced along each cellulose e molecule, allowing many hydrogen bonds to form between molecules. *ASK

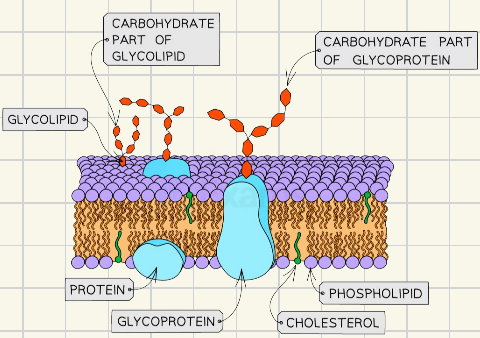
These bundles of cellulose are called microfibrils and are the basis of plant cell walls. microfibrils have a very high tensile strength because of the strong covalent bonds in the cellulose molecules, the number of molecules and the cross-links between them. The strength prevents plant cells from bursting-even under high pressure in the cell due to the entry of water by osmosis.



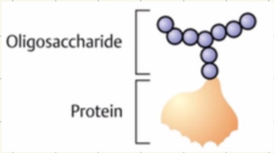
B1.1.7 - role of glycoproteins in cell-cell recognition.

B1.1.7—Role of glycoproteins in cell–cell recognition
Include ABO antigens as an example.

Glycoproteins are composed of polypeptides with carbohydrate attached. in most cases, the carbohydrate is an oligosaccharide; which is a short chain of monosaccharides linked by glycosidic bonds. Glycoproteins are a component of plasma membranes in animal cells and are positioned with the attached carbohydrate facing outwards.



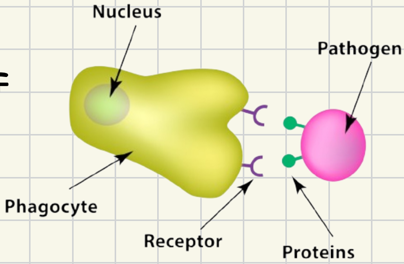
By displaying distinctive glycoproteins, cells allow other cells torecognize them. The glycoprotein on the surface of one cell is recognized by receptors on the surface of another cell. Glycoproteins are often a component of the extracellular surface of the plasma membrane of cells.



Cell to cell recognition helps with the organization of tissue and can also allow foreign cells or infected body cells to be identified and destroyed. The ABO antigens in red blood cells are an example of glycoproteins providing the means of cell-cell recognition.

*Additional Information

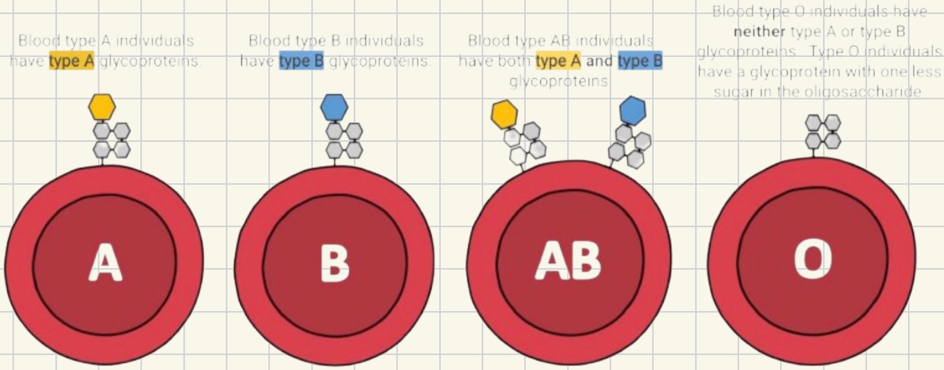
The glycoprotein on the surface of one cell is recognized by receptors on the surface of another. Cell-cell recognition is important because it allows the immune system cells to recognize other cells within its own body, versus foreign invaders, like bacteria, that may cause disease.



ABO glycoproteins

Red blood cells have glycoproteins on their plasma membrane that distinguish ABO blood type.

If blood containing glycoprotein A is transfused into a person who does not produce it themself, the blood will be rejected. Similarly, blood containing glycoprotein B is rejected if a person does not produce it themself. However, glycoprotein O does not cause rejection problems, because it has the same structure as A and B with one monosaccharide less, so is not recognized as foreign.



B.1.1.8 - hydrophobic properties of lipids

B1.1.8—Hydrophobic properties of lipids
Lipids are substances in living organisms that dissolve in non-polar solvents but are only sparingly soluble in aqueous solvents. Lipids include fats, oils, waxes and steroids.

Lipids are a diverse group of substances in living organisms that dissolve in non-polar substances in living organisms that dissolve in non-polar solvents. Ethanol, tuloune and propane are examples of non-polar solvents. Lipids are only sparingly soluble in aqueous solvents. For this reason, they are said to be hydrophobic. However, lipids are not repelled by water, they are just attracted to non-polar substances.

Fats, oils, waxes and steroids de classes of commonly occurring lipids

- oils have a melting point below 20°C, so they solidify at low temps.
- fats have a meting point between 20°C and 37°, solid at room temps and liquid at body temperatures.
- waxes have a melting point above 37°C liquifying at high temps.
- steroids have molecules with a characteristic four - ring structure

B1.1.9 - Formation of triglycerides and phospholipids by condensation reactions.

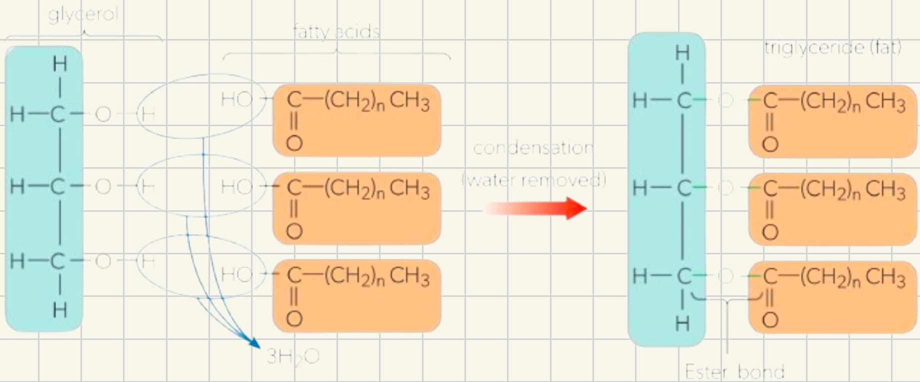
B1.1.9—Formation of triglycerides and phospholipids by condensation reactions
One glycerol molecule can link three fatty acid molecules or two fatty acid molecules and one phosphate group.

A triglyceride is made by combining three fatty acids with one glycerol. Each of the fatty acids is linked to the glycerol by a condensation reaction, so three water molecules are produced. The linkage formed between each fatty acid and the glycerol is an ester bond.

This type of bond is formed when an acid reacts with the hydroxyl group (-OH) in an alcohol. in this case, the reaction is between carboxyl -(COOH) group on a fatty acid and a hydroxyl on the Glycerol.

These groups are the only hydrophilic parts of fatty acid and glycerol molecules and are used up in the condensation reaction, so triglycerides use entirely hydrophobic.

Depending on the type of fatty acids they contain, triglycerides may be oils or fats.



Phospholipids have a similar structure similar to triglycerides. But there are two fatty acids linked to glycerol, with a phosphate group instead of a third fatty acid. The phosphate is hydrophilic, so phospholipid molecules are partly hydrophilic and partly hydrophobic,

B1.1.10 - difference between fatty acids

B1.1.10—Difference between saturated, monounsaturated and polyunsaturated fatty acids
Include the number of double carbon (C=C) bonds and how this affects melting point. Relate this to the prevalence of different types of fatty acids in oils and fats used for energy storage in plants and endotherms respectively.

Structure of Fatty Acids:

- Hydrocarbon Chain: Fatty acids consist of a long, unbranched chain of carbon atoms with hydrogen atoms covalently bonded. This structure is known as a hydrocarbon chain.

- Carboxyl Group: At one end of the fatty acid chain is a carboxyl group (-COOH), which is acidic in nature and gives the fatty acid its acidic properties.

- Methyl Group: The other end of the fatty acid chain has a methyl group ($-CH_3$).

Chain Length

- The length of the hydrocarbon chain can vary, but most fatty acids found in living organisms have between 14 and 20 carbon atoms.

Types of Bonds Between Carbon Atoms

- Single Bonds: Fatty acids with only single bonds between carbon atoms are called saturated fatty acids. These carbon atoms can bond with two hydrogen atoms each, making the fatty acid saturated with hydrogen.

- Double Bonds: Fatty acids with one or more double bonds between carbon atoms are called unsaturated fatty acids. The presence of double bonds means that fewer hydrogen atoms can bond to the carbon chain.

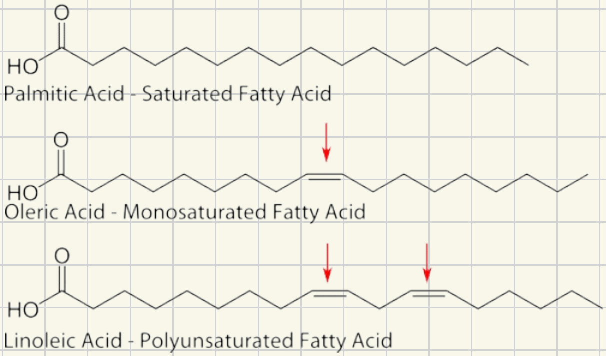
Monounsaturated Fatty Acids: These have one double bond in the carbon chain.

Polyunsaturated Fatty Acids: These have more than one double bond in the carbon chain.

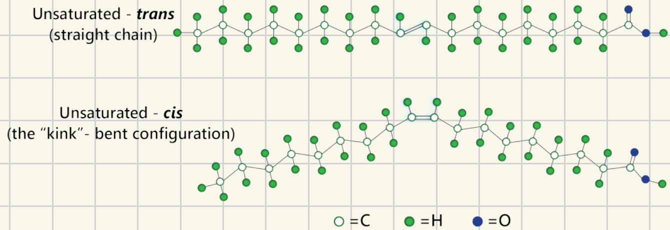
Saturation Levels:

- Saturated Fatty Acids: Contain the maximum amount of hydrogen atoms possible due to single bonds between carbon atoms.

- Unsaturated Fatty Acids: Contain less hydrogen because of the presence of double bonds.



Nearly all unsaturated fatty acids in living organisms have the hydrogen atoms on the same side of the two double bonded carbon atoms. These are called cis-fatty acids. The alternative arrangement is for the hydrogen to be on opposite sides. These are called trans-fatty acids.



In cis - fatty acids, there is a bend in the hydrocarbon chain at the double bond. this makes triglycerides containing cis-unsaturated fatty acids less good at packing together in regular arrays than saturated fatty acids, so they have a low melting point.

So, triglycerides with cis-unsaturated fatty acids are usually liquid at room temperatures- so they are oils

Trans-fatty acids do not have a bend in the hydrocarbon chain at the double bond: they have straight chains and a higher melting point. They are solid at room temperature.

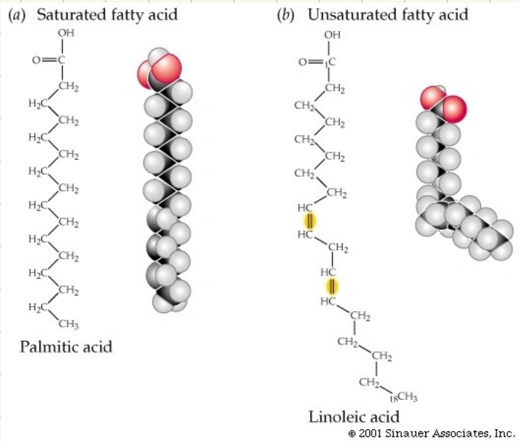
They are produced artificially by partial hydrogenation of vegetable or fish oils. This is done to produce solid fats for use in margarine and some other processed foods.

Examples of fatty acids:

Palmitic acid: saturated, non - essential

Linolenic acid: polyunsaturated, cis, essential, omega 3

Palmitoleic acid: monounsaturated, cis, non - essentials, omega 7



B1.1.11 - triglycerides in adipose tissues for energy storage and thermal insulation

B1.1.11—Triglycerides in adipose tissues for energy storage and thermal insulation
Students should understand that the properties of triglycerides make them suited to long-term energy storage functions. Students should be able to relate the use of triglycerides as thermal insulators to body temperature and habitat.

Triglycerides are used for energy storage in plants and animals .in animals, the triglycerides are fats and stored in specialized groups called adipose tissue. in humans, adipose tissue is located immediately beneath the skin and also around some organs including the kidney.

The properties of triglycerides make them particularly suitable for long-term energy storage.

Chemical Stability:

- Triglycerides are chemically stable, meaning they do not easily react or break down. This stability ensures that the stored energy remains available over time without degradation.

Immiscibility with Water:

- Triglycerides do not mix with water (they are hydrophobic), so they naturally form droplets within the cytoplasm. This separation prevents triglycerides from dissolving in the cell's watery environment and avoids osmotic imbalances or other potential effects on the cell.

High Energy Density:

- Triglycerides release twice as much energy per gram during cellular respiration compared to carbohydrates. This high energy density allows organisms to store significant energy in a smaller mass, which is especially advantageous for animals that need to move efficiently, such as birds and bats that require light bodies for flight.

Thermal Insulation:

- Triglycerides are poor conductors of heat, making them useful as thermal insulators. This helps animals conserve body heat, which is crucial for maintaining body temperature in cold environments.

Shock Absorption:

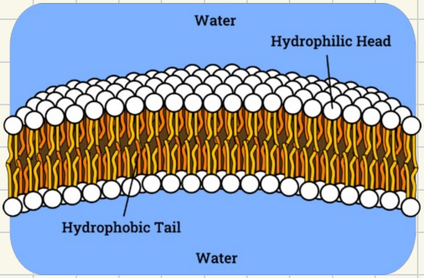
- At body temperature, triglycerides are in a liquid state, allowing them to act as a shock absorber. This cushioning effect protects vital organs, such as the kidneys, from physical impact.

Thermal insulation is needed most by animals that live in cold habitats and that maintain a body temperature much higher than the environment. Such animals have thick layers of subcutaneous adipose tissue. In marine mammals it is called blubber. In animals such as sea lions there are sometimes problems with overheating when adults emerge onto land to breed, because the thick layer of blubber impedes dissipation of heat produced by metabolism and the air is much warmer than the water in the ocean habitat. * ASK

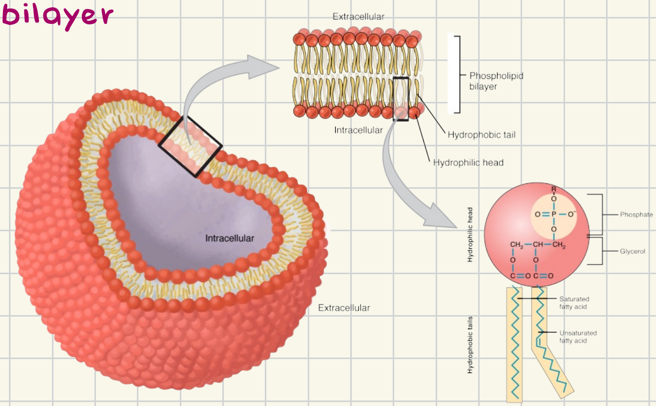
B1.1.12 - Formation of phospholipid bilayers as a consequence of hydrophobic and hydrophilic regions.

B1.1.12—Formation of phospholipid bilayers as a consequence of the hydrophobic and hydrophilic regions
Students should use and understand the term "amphipathic".

Phospholipids are amphipathic, which means that part of the phospholipid is hydrophilic and the other part is hydrophobic. The hydrophilic part is the phosphate group the hydrophobic part consists of the two hydrocarbon chains.



Phospholipid bilayer



The two parts of the molecule are often called the phosphate head and the hydrophobic hydrocarbon tails. When phospholipids are mixed with water the phosphate heads are attracted to the water but the hydrocarbon tails are attracted to each other more than to the water. Because of this the phospholipids become arranged into double layers, with the hydrophobic hydrocarbon tails facing inwards and the hydrophilic heads facing outwards to the water on either side. These double layers are called phospholipid bilayers. They are stable structures and they form the basis of all cell membranes.

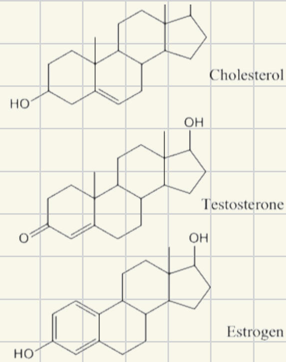
B1.1.13 - ability of non-polar steroids to pass through the phospholipid bilayer

B1.1.13—Ability of non-polar steroids to pass through the phospholipid bilayer
Include oestradiol and testosterone as examples. Students should be able to identify compounds as steroids from molecular diagrams.

Steroids are a group of lipids with molecules similar to sterol. they can be identified using these features:

- four fused rings of carbon atoms
- three cyclohexane rings and one cyclopentane ring
- 17 carbon atoms in total in the rings

There are hundreds of examples of steroids, which differ in the position of the c=c double bonds and in the functional groups such as -OH that are added to the four ring structure. steroids are mostly hydrocarbon and therefore hydrophobic. This allows them to pass through phospholipid bi-layers and enter or leave cells.



oestradiol and testosterone

The production and action of oestradiol and testosterone are similar. Both are produced by gonadal tissue and are involved in the development of primary and secondary sexual characteristics beginning at puberty.

Once inside the nucleus, the hormones direct the process of transcription, leading to the production of mRNA molecules.