DP Biology – B1.1

Carbohydrates and lipids

- How do differences in form give carbohydrates and lipids different functions?
- In what ways do lipids and carbohydrates differ as energy stores?

SL statements B1.1.1–13. Textbook pp. 181–204.

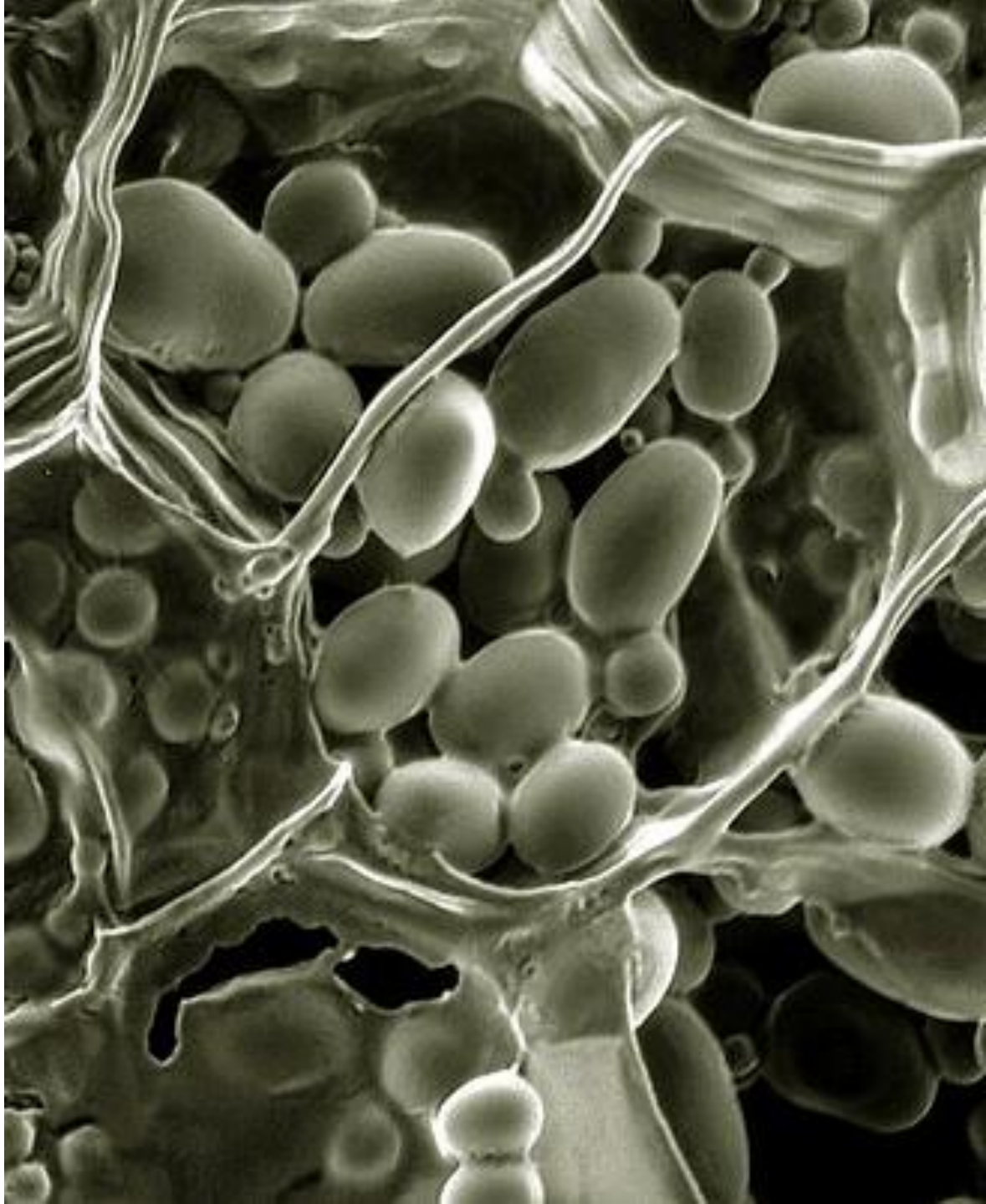


Image: starch grains from a potato, electron micrograph. Philippa Uwins, CC BY-SA 3.0.

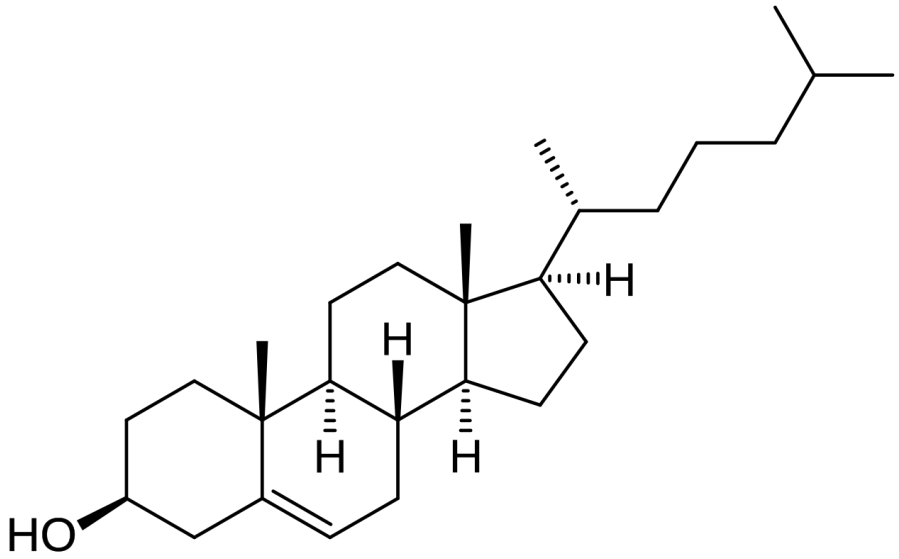
Objectives for each class

Class	Statements	By the end of the class, you can...
1	B1.1.1–3	Explain why carbon forms so many compounds, and how condensation and hydrolysis work
2	B1.1.4–7	Relate the structure of monosaccharides and polysaccharides to their functions, and explain glycoproteins
3	B1.1.8–11	Explain how triglycerides form, how saturation affects them, and why they suit energy storage
4	B1.1.12–13	Explain how phospholipids form bilayers, and why steroids pass through them

Overview of this chapter

Part	Statements	What it covers
Carbon and polymers	B1.1.1–3	Bonds, condensation and hydrolysis
Carbohydrates	B1.1.4–6	Glucose, starch, glycogen and cellulose
Recognition	B1.1.7	Glycoproteins and ABO antigens
Lipids	B1.1.8–11	Triglycerides, fatty acids and adipose tissue
Membranes	B1.1.12–13	Bilayers and steroids

Why carbon is the basis of life



Cholesterol: rings and a branched chain. BorisTM, public domain.

- A **covalent bond** is a pair of shared electrons, and it is strong
- Carbon can form up to **four** single bonds, or a mix of single and double bonds
- It bonds with other carbon atoms and with other non-metals
- So it can form chains, branches and rings

Arrangement	Example
Unbranched chain	Fatty acids in a triglyceride, amylose in starch
Branched chain	Amylopectin in starch; glycogen
Single or multiple rings	Glucose has one ring; steroids such as cholesterol have four

Condensation links monomers into polymers



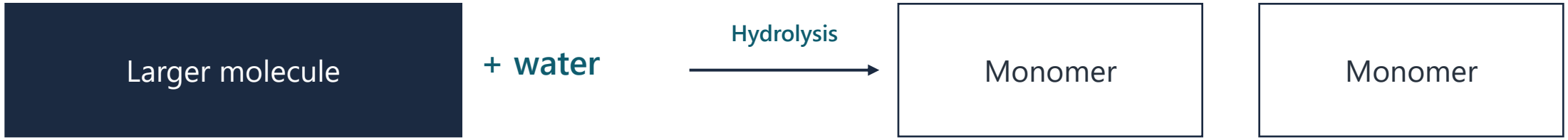
Monomer	Polymer	Bond formed
Monosaccharide	Polysaccharide	Glycosidic bond
Amino acid	Polypeptide	Peptide bond
Nucleotide	Nucleic acid	Sugar-phosphate bond

Key idea

An -H from one monomer and an -OH from the other form a water molecule. Energy from ATP is needed to build these large molecules.

Hydrolysis breaks polymers into monomers

B1.1.3



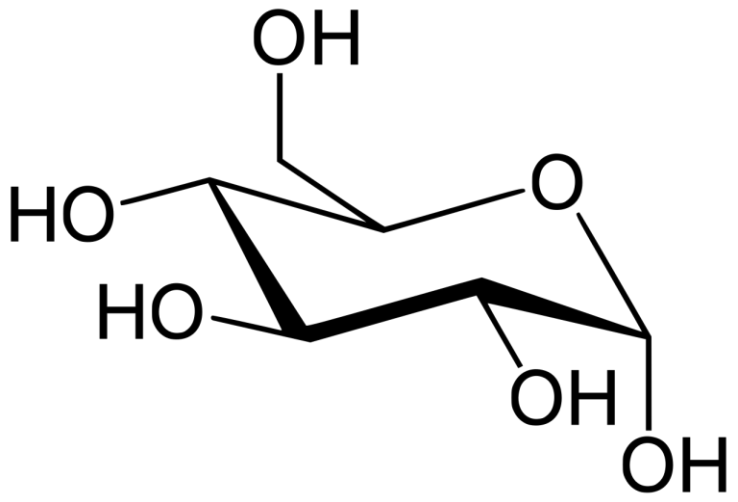
- Water molecules are split, and they supply the -H and -OH groups
- Each product becomes a complete monomer
- This is what happens in **digestion**, catalysed by enzymes
- In decomposers, it happens outside the cell, and the monomers are absorbed

Common mistake

Hydrolysis uses water and condensation releases water. Look at the word: hydro means water, and lysis means splitting.

Monosaccharides: form and function

B1.1.4



Alpha-glucose, a hexose. Yikrazuul, public domain.

Property of glucose	Why it is useful
Soluble	It dissolves in water
Transportable	It is carried in blood and in phloem sap
Chemically stable	It can be stored and moved without reacting
Yields energy	Oxidation in respiration releases energy

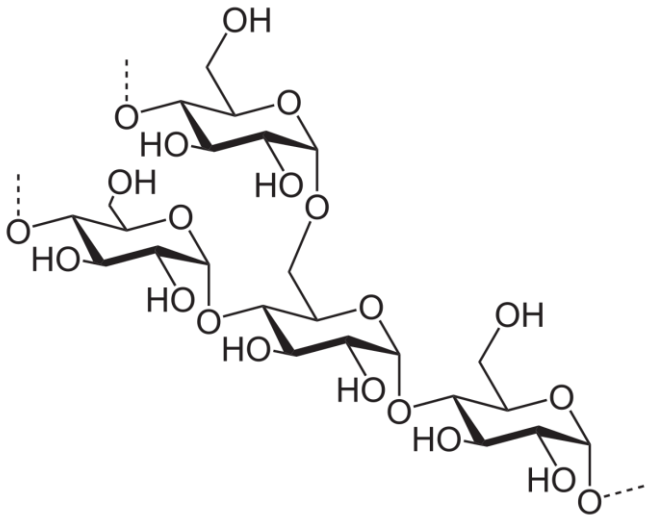
- Monosaccharides are single sugar units
- In ring form, **pentoses** such as ribose have 5 carbons, and **hexoses** such as glucose have 6

Activity

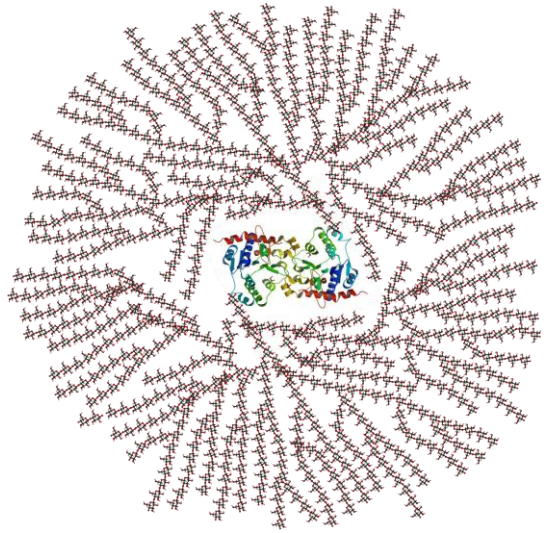
From a molecular diagram, count the carbon atoms. Remember that one carbon lies outside the ring in a hexose.

Starch and glycogen store energy

B1.1.5



Part of amylopectin, in starch. NEUROtiker, public domain.



Branched glycogen. Mikael Haggstrom, public domain.

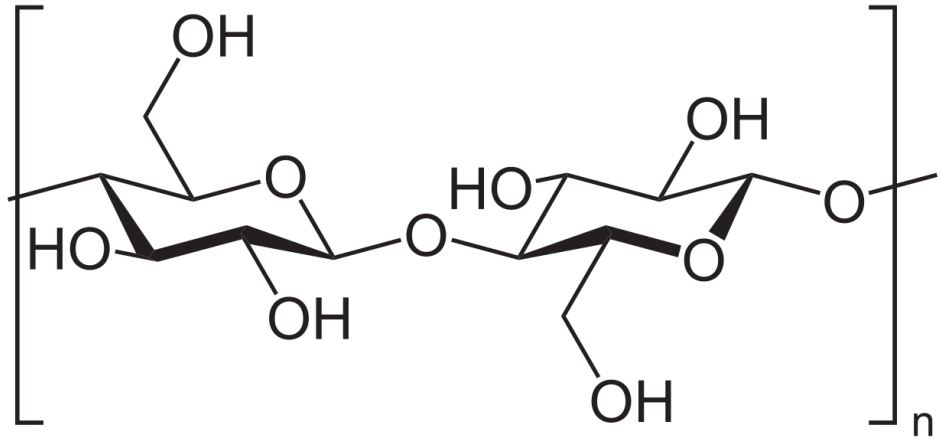
	Why useful
Compact	Coiled and branched
Insoluble	Too large to dissolve, so no osmotic effect
Mobile	Alpha-glucose easily added or removed

	Starch	Glycogen
Where	Plants	Animals
Form	Amylose coils; amylopectin branches	More highly branched

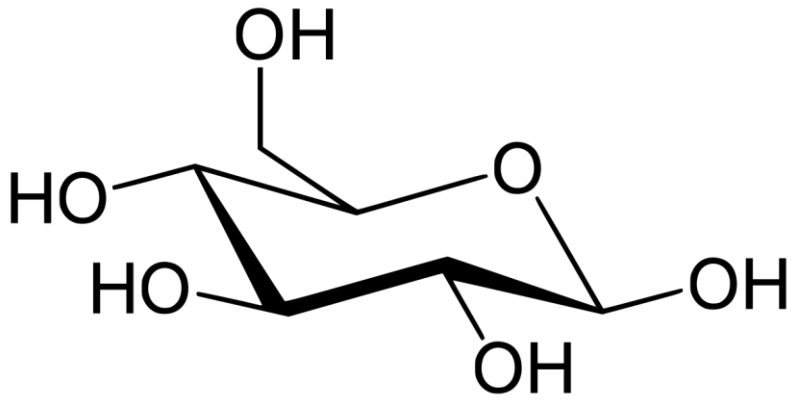
Branches provide many ends, where enzymes can add or remove glucose quickly.

Cellulose: a structural polysaccharide

B1.1.6



Part of a cellulose chain. NEUROtiker, public domain.



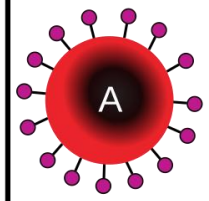
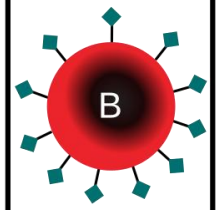
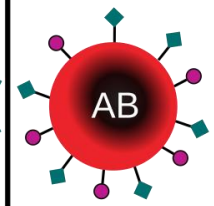
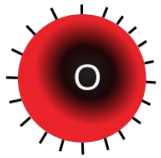
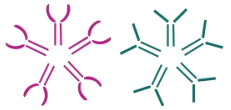
Beta-glucose. Yikrazuul, public domain.

- Each **beta-glucose** is turned by 180 degrees relative to its neighbour, giving a **straight chain**
- Chains lie side by side, and **hydrogen bonds** link them into bundles
- These bundles are very strong, and they form plant cell walls

Key idea

Starch and cellulose are both made of glucose. A small difference in the monomer changes the shape of the polymer, and therefore its function.

Glycoproteins: cell-cell recognition

	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in red blood cell	A antigen	B antigen	 A and B antigens	None

ABO antigens on red blood cells. InvictaHOG, public domain.

- A **glycoprotein** is a protein with a carbohydrate chain attached
- It is in the membrane, with the carbohydrate facing out
- Other cells can recognize these chains
- ABO antigens differ by the sugars at the ends of their chains

Question

A person of group A receives blood of group B. Explain why the immune system reacts to these cells, using the word antigen. Who could safely donate to a person of group AB?

Lipids are hydrophobic

B1.1.8

- **Lipids** dissolve in non-polar solvents, and are only sparingly soluble in water
- They have many non-polar C-H bonds, which do not attract water
- They include fats, oils, waxes and steroids

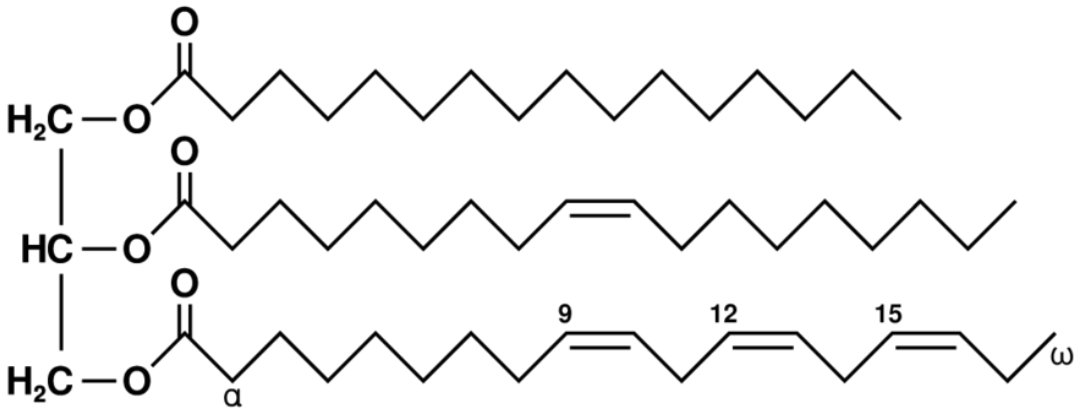
Lipid	Example of its use
Fats and oils	Energy stores; insulation in animals
Waxes	Waterproof layer on leaves and feathers
Steroids	Hormones such as testosterone

Link

This links directly to A1.1.5. Being insoluble is the property that makes a lipid useful as a store and as a barrier.

Forming triglycerides and phospholipids

B1.1.9



	Triglyceride	Phospholipid
Glycerol	One	One
Fatty acids	Three	Two
Phosphate	None	One

A triglyceride: glycerol plus three fatty acids. Wolfgang Schaefer, public domain.

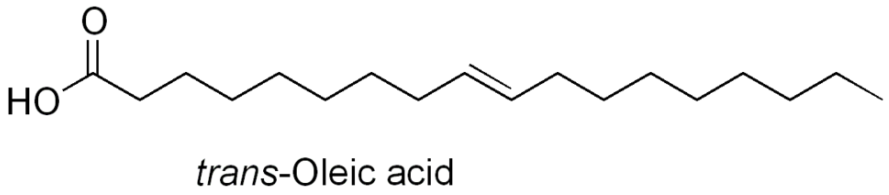
- Each fatty acid joins to glycerol by **condensation**, which releases a water molecule
- A triglyceride forms 3 ester bonds, releasing 3 water molecules

Activity

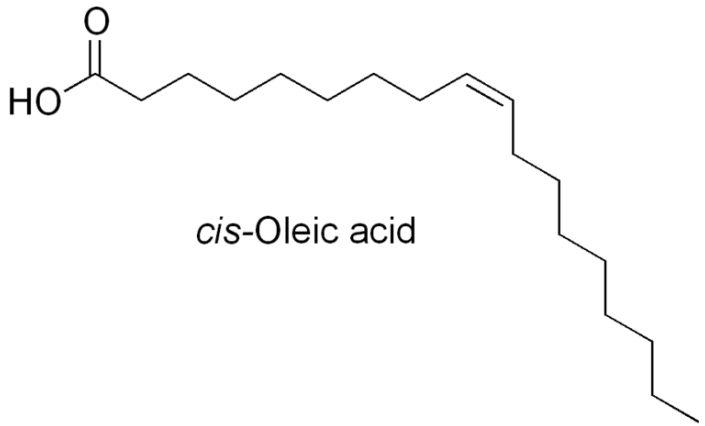
Draw a simplified reaction for each one, using a rectangle for glycerol and zigzag lines for fatty acids.

Saturated and unsaturated fatty acids

B1.1.10



trans-Oleic acid



cis-Oleic acid

Shapes of unsaturated fatty acids. Edgar181, public domain.

Type	C=C bonds	Melting point
Saturated	None	Highest: chains pack closely
Mono-unsaturated	One	Lower: chain has a kink
Poly-unsaturated	Two or more	Lowest: more kinks

Why it matters

Plants store energy in oils, as these stay liquid at low temperatures. Endotherms, such as mammals, store fats, which suit their warm bodies. Fats are solid at room temperature but liquid in the body.

Triglycerides in adipose tissue



Walruses, with thick blubber. Andrew Trites, NOAA, CC BY 2.0.



Adipose tissue. Chalova.lina, CC BY 4.0.

- **Long-term energy store**: insoluble, and with much energy per gram
- **Thermal insulator**: fat conducts heat poorly

Link to habitat

Blubber is thickest in endotherms in cold water, where water conducts heat away quickly. An insulating layer is less useful to animals in warm climates, which often store fat in one place, such as a hump.

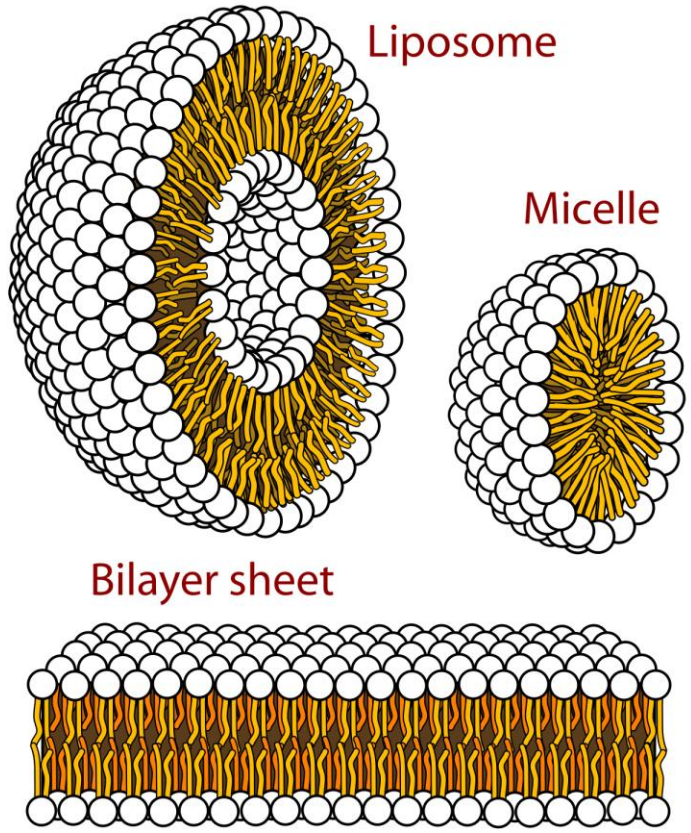
Comparing energy stores

B1.1.11

	Triglycerides	Carbohydrates (glycogen, starch)
Energy per gram	About twice as much	About half as much
Length of storage	Long-term	Short-term
Mobilization	Slower to mobilize	Faster to mobilize
Solubility	Insoluble	Glucose is soluble; polymers are not
Stored in humans	Adipose tissue	Liver and muscle

Answer to the guiding question: lipids store more energy, and carbohydrates release it faster.

Phospholipid bilayers



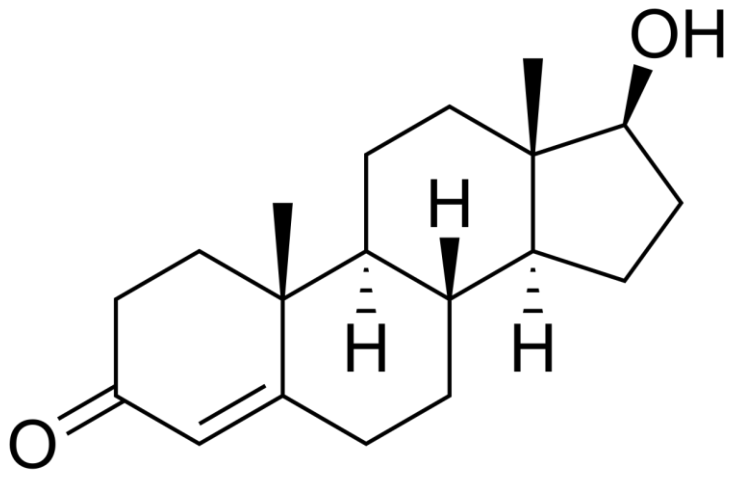
Phospholipids in water. LadyofHats, public domain.

- A phospholipid has a hydrophilic **phosphate head** and two hydrophobic **fatty acid tails**
- A molecule with both types of region is **amphipathic**
- In water, heads face out, towards water, and tails face in, away from it
- So phospholipids form a **bilayer** without needing energy

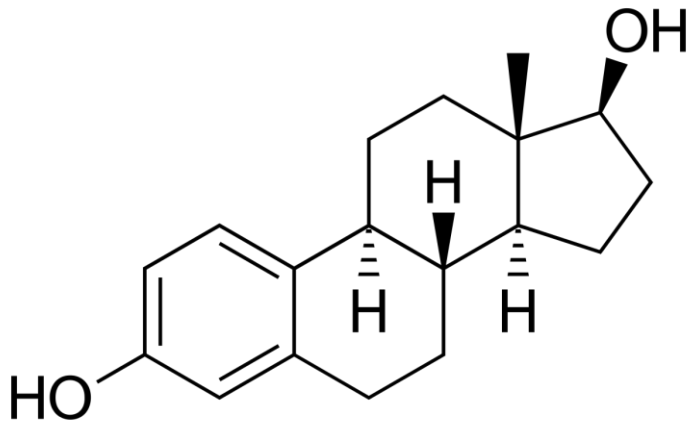
Key idea

This self-assembly is why membranes form so readily. It is also a possible step in the origin of the first cells (A2.1, at HL).

Steroids pass through the bilayer



Testosterone. NEUROtiker, public domain.



Oestradiol. NEUROtiker, public domain.

- Steroids are lipids with **four fused rings** of carbon atoms: three of six carbons and one of five
- They are non-polar, so they can pass through the hydrophobic core of a membrane
- This is why **oestradiol** and **testosterone** act on receptors inside cells

Activity

Practise identifying steroids from molecular diagrams. Look for the pattern of four rings, and do not expect to learn the side groups.

Check that you can explain

1. Four features of carbon bonding
2. Condensation and hydrolysis
3. How to identify pentoses and hexoses
4. Why glucose is suited to its uses
5. Starch, glycogen and cellulose
6. The role of glycoproteins
7. Hydrophobic properties of lipids
8. Forming triglycerides and phospholipids
9. Saturation and melting point
10. Why triglycerides store energy and insulate
11. How bilayers form
12. Why steroids pass through membranes

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. State the type of reaction that links two amino acids, and the molecule that it releases.
2. Give two ways in which the structure of glycogen suits it to energy storage.
3. Explain why a phospholipid is described as amphipathic.

Image credits

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