After studying this topic you should be able to:

- Describe the functions and structures of the four main groups of biological molecules (carbohydrates, proteins, lipids, and nucleic acids) and give examples.

- Describe the monomers of each group (or, in the case of lipids, their components).

You will not be required to draw structures of the monomers that make up carbohydrates, proteins, or nucleic acids, or the components of lipids, but you should be able to recognize them if shown.

You are not required to know the details of the four levels of protein structure, although you should be able to recognize them.

### Introducing carbohydrates

Carbohydrates are a group of substances used as both energy sources and structural materials in organisms.

All carbohydrates contain carbon, hydrogen and oxygen.

There are three main groups of carbohydrates:

- **Monosaccharides** – these are simple sugars (one single molecule = monomer) e.g. glucose
- **Disaccharides** – these are ‘double sugars’, formed from two monosaccharides
- **Polysaccharides** – these are large molecules formed from many monosaccharides (polymer – made of many monomers)

### Glucose - Monosaccharide

Glucose is a very important monosaccharide. It contains six carbon atoms so it is a hexose sugar. Its general formula is \( \text{C}_6\text{H}_{12}\text{O}_6 \).

Glucose is the major energy source for most cells. It is highly soluble and is the main form in which carbohydrates are transported around the body of animals.

The structure of glucose can be represented in different ways:

- **Straight chain**
- **Ring**
- **Ring (simplified)**

### Definition

**Monomer** – A chemical subunit that serves as a building block of a polymer.

**Polymer** - A large molecule consisting of many identical or similar molecular units, called monomers, covalently joined together in a chain.

### The formation of disaccharides

**How are disaccharides formed?**

Disaccharides are ‘double sugars’ formed when two monosaccharide molecules join together with a glycosidic bond.

Click “play” to find out more.
Polymers – building & breaking

Condensation and Hydrolysis

Dehydration reaction (condensation/synthesis)
Monomers link to form Polymers
Water is removed/produced (1 for every covalent bond formed)
Opposite to Hydrolysis reaction

Hydrolysis Reaction
Polymer breaks down into Monomers
Water is added/consumed (1 for every covalent bond broken)
Opposite to Dehydration reaction

Maltose, sucrose and lactose - Disaccharides

- **Maltose** (malt sugar) is formed from two glucose molecules joined by a covalent bond
- **Sucrose** (table sugar) is formed from glucose and fructose
- **Lactose** (milk sugar) is formed from galactose and glucose

What are polysaccharides?

Polysaccharides are polymers containing many monosaccharides (monomers) linked by covalent bonds. Polysaccharides are formed by condensation reactions.

Polysaccharides are mainly used as an energy store and as structural components of cells.
The major polysaccharides are starch and cellulose in plants, and glycogen in animals.

VIDEO - Formation of Polymers
Polymerisation 4.37
=http://www.youtube.com/watch?v=UNsNGVSVDfK
The structure of starch

What is the structure of starch?

Starch is a polysaccharide made of many alpha glucose molecules arranged into two different structural units: amylose and amylopectin.

Check Understanding so far!

During a dehydration reaction ________ join to form a ________. _______ is produced during this reaction.

During a hydrolysis reaction a________ breaks up to form ________. Water is ______ during this reaction.

Properties and uses of starch

Starch is the major carbohydrate storage molecule in plants.

Starch is a polymer which is formed from monomers (small subunits) of glucose made during photosynthesis.

It is broken down during respiration to provide energy and is also a source of carbon for producing other molecules.

What is cellulose?

Cellulose is another polysaccharide and is the main part of plant cell walls. It is the most abundant organic polymer.

Unlike starch, cellulose is very strong, and prevents cells from bursting when they take in excess water.

Cellulose consists of long chains of glucose molecules joined by covalent bonds.

The glucose chains form rope-like microfibrils, which are layered to form a network.

What is glycogen?

Animals do not store carbohydrate as starch but as glycogen.

Glycogen has a branched structure.

Glycogen is stored as small granules, particularly in muscles and liver.

Glycogen is less dense and more soluble than starch, and is broken down more rapidly. This indicates the higher metabolic requirements of animals compared with plants.
Summary Carbohydrates

Carbohydrates are made from m____s______.
Glucose is a m____ of Starch, Cellulose and Glycogen which are all types of p_______.
The main function of Starch (plants) and Glycogen (animals) is e______ s_______.
The main function of Cellulose is to provide s_______.

Learning Outcomes

After studying this topic you should be able to:

- Describe the functions and structures of the four main groups of biological molecules (carbohydrates, proteins, lipids, and nucleic acids) and give examples.
- Explain why lipids are not considered true polymers.
- Describe the monomers of each group (or, in the case of lipids, their components).

X You will not be required to draw structures of the monomers that make up carbohydrates, proteins, or nucleic acids, or the components of lipids, but you should be able to recognize them if shown.

X You are not required to know the details of the four levels of protein structure, although you should be able to recognize them.

Introducing proteins

Proteins are a diverse group of large and complex polymer molecules, made up of long chains of amino acids.
They have a wide range of biological roles, including:

- structural: proteins are the main component of body tissues, such as muscle, skin, ligaments and hair
- catalytic: all enzymes are proteins, catalyzing many biochemical reactions
- signalling: many hormones and receptors are proteins
- immunological: all antibodies are proteins.

The 20 naturally-occurring amino acids

All amino acids have the same general structure: the only difference between each one is the nature of the R group. The R group therefore defines an amino acid.

The R group represents a side chain from the central ‘alpha’ carbon atom, and can be anything from a simple hydrogen atom to a more complex ring structure.

The 20 naturally-occurring amino acids

Click the name of an amino acid to find out more about its structure.
Peptide bonds and dipeptides

What is a peptide bond?
Two amino acids can join together to form a dipeptide, linked by a peptide bond.
Click "play" or either of the two amino acids to find out more.

Enzymes in action here
Dehydration of a protein

Hydrolysis of a protein

Polypeptides

When more amino acids are added together a polypeptide chain is formed.

A protein consists of one or more polypeptide chains folded into a highly specific 3D shape.

The structure of proteins

What is the structure of proteins?
Proteins have a unique 3D structure that enable them to carry out specific functions.
Click "play" or the amino acid to find out about the different levels of structure.

VIDEO - Proteins

Taking up Oxygen - Haemoglobin
http://www.youtube.com/watch?v=WXOBJEXxNEo
**Protein structure**

What is the structural order of proteins?

- **primary**
- **secondary**
- **tertiary**
- **quaternary**

**Bonds in proteins**

The 3D shape of a protein is maintained by several types of bond, including:

- **hydrogen bonds**: involved in all levels of structure.
- **hydrophobic interactions**: between non-polar sections of the protein.
- **disulfide bonds**: one of the strongest and most important type of bond in proteins. Occur between two cysteine amino acids.

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**Fibrous proteins**

Fibrous proteins are formed from parallel polypeptide chains held together by cross-links. These form long, rope-like fibres, with high tensile strength and are generally insoluble in water.

- **collagen** – the main component of connective tissue such as ligaments, tendons, cartilage.
- **keratin** – the main component of hard structures such as hair, nails, claws and hooves.
- **silk** – forms spiders’ webs and silkworms’ cocoons.

**Globular proteins**

Globular proteins usually have a spherical shape caused by tightly folded polypeptide chains.

The chains are usually folded so that hydrophobic groups are on the inside, while the hydrophilic groups are on the outside. This makes many globular proteins soluble in water.

- **transport proteins** – such as haemoglobin, myoglobin and those embedded in membranes.
- **enzymes** – such as lipase and DNA polymerase.
- **hormones** – such as oestrogen and insulin.

**Denaturing proteins**

If the bonds that maintain a protein’s shape are broken, the protein will stop working properly and is **denatured**.

Changes in temperature, pH or salt concentration can all denature a protein, although the specific conditions will vary from protein to protein.

Fibrous proteins lose their structural strength when denatured, whereas globular proteins become insoluble and inactive.

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**Proteins: true or false?**

Are these statements about proteins true or false?

1. Collagen and keratin are globular proteins.
2. Peptide bonds and hydrogen bonds are the only bonds that maintain a protein’s shape.
3. Polypeptides are made by condensation reactions between amino acids.
4. Changing just a single amino acid in a polypeptide may stop the protein working properly.
5. All proteins have a quaternary structure.
Protein Summary – Check Understanding

The monomer which makes up a protein is an a______ a_____.

Name 3 functions of proteins in the body.

Introduction to lipids

Lipids are a diverse group of compounds that are insoluble in water but soluble in organic solvents such as ethanol.

The most common types of lipid are triglycerides (sometimes known as true fats or neutral fats), but other important lipids include waxes, steroids and cholesterol.

Like carbohydrates, lipids contain carbon, hydrogen and oxygen, but they have a higher proportion of hydrogen and a lower proportion of oxygen.

The structure of triglycerides

What is the structure of triglycerides?

Triglycerides are made from a glycerol backbone joined to three fatty acid chains. Click "play" to find out more about each of these parts.

Saturated and unsaturated

Saturated and unsaturated fatty acids

Fatty acids are either saturated or unsaturated. Click a button to find out more.

Role of lipids

The major biological role of lipids is as an energy source. Lipids provide more than twice the amount of energy as carbohydrates – about 38 kJ/g.

Lipids are stored in adipose tissue, which has several important roles, including:

- heat insulation – in mammals, adipose tissue underneath the skin helps reduce heat loss.
- protection – adipose tissue around delicate organs such as the kidneys acts as a cushion against impacts.

The structure of phospholipids

What are phospholipids?

Phospholipids are a major component of cell membranes. Click "play" or the phospholipid to find out more about their structure and properties.
Why are fats excluded from dehydration reaction and hydrolysis?

They have a repeating unit of 3 fatty acid molecules bonded to a glycerol molecule. The fatty acids might be identical or each may be different.

Hydrolysis is ineffective against fats, because they are insoluble in water, which is an essential component of hydrolysis.

Plasma membrane
http://www.youtube.com/watch?v=Qqsf_UJcfBc

What are the features of these lipids?

Lipid 1/2
This is a molecule of

A

B

C

Homework

- Complete question 7 on Unit Assessment
- Complete Biological Molecules Question handout (bring to tutorial to mark!)
• Now that we know something about the main biological molecules it is appropriate to gain an understanding of the cell membrane before going on to the last important biochemical molecule.

TEACH ABOUT MEMBRANES BEFORE COMING BACK TO NUCLEIC ACIDS AND CELL STRUCTURE!

Learning Outcomes

After studying this topic you should be able to:
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Introduction to nucleotides

Nucleotides are nitrogen-containing organic substances that form the basis of the nucleic acids DNA and RNA.

All nucleotides contain the following three groups:

- a phosphate group
- a pentose sugar
- a nitrogen-containing base

In DNA the sugar is deoxyribose, whereas in RNA the sugar is ribose.

Bases

There are five bases, split into two types:

- adenine (A) and guanine (G) are purine bases.
- thymine (T), cytosine (C) and uracil (U) are pyrimidine bases.


VIDEO – Structure and Discovery of DNA

http://www.youtube.com/watch?v=VegLVn_1oCE
Determining the structure of DNA

The double-stranded structure of DNA was determined in 1953 by the American biologist James Watson and the British physicist Francis Crick.

X-ray diffraction studies by British biophysicist Rosalind Franklin strongly suggested that DNA was a helical structure.

The Austrian chemist Erwin Chargaff had earlier showed that DNA contained a 1:1 ratio of pyrimidine:purine bases.

How is DNA packaged?

In eukaryotic cells, DNA is packaged as chromosomes in the nucleus.

There is around 2 m of DNA in a cell, so to fit it needs to be tightly coiled and folded.

Eukaryotic DNA is associated with proteins called histones. Together, these form chromatin – the substance from which chromosomes are made.

In prokaryotic cells, DNA is loose in the cytoplasm – there are no histones or chromosomes.

Structure of DNA

What is the structure of DNA?

one complete turn = 10 base pairs / 3.4 nm

How is DNA packaged in eukaryotic chromosomes?

The length of the DNA molecule in an average human chromosome is about 4.8 cm long.

How is it packaged to fit into the nucleus of a cell?

DNA replication

How does DNA replicate?

DNA replicates by a semi-conservative method.

Click “play” or the DNA helix to find out more.
What is the genetic code?

The genetic code of an organism is the sequence of bases along its DNA. It contains thousands of sections called genes. Each gene codes for a specific polypeptide or protein.

- one gene
- thousands more bases in gene (not shown)

The sequence of bases in a gene codes for amino acids in proteins.

The genetic code is almost universal – the same sequence of bases codes for the same amino acids in all organisms.

The triplet code

Given that there are four bases in DNA, and these code for 20 amino acids, what is the basis for the genetic code?

- If one base = one amino acid, possible amino acids = 4
- If two bases = one amino acid, possible amino acids = 16 (4 x 4)
- If three bases = one amino acid, possible amino acids = 64 (4 x 4 x 4)

The existence of a three-base (triplet) code was confirmed by experiments by Francis Crick and his colleagues in 1961. The triplet code is degenerate, which means that each amino acid is coded for by more than one triplet.

What is mRNA?

When a polypeptide is required, the triplet code of its gene is converted into a molecule of messenger RNA (mRNA).

This process is called transcription and is the first stage of protein synthesis.

- It is single stranded, not double stranded
- It contains ribose instead of deoxyribose
- It contains uracil instead of thymine.

Key Words – Proteins and Lipids

- Amino acid
- Base
- DNA
- Double helix
- Hydrolysis
- Monomer

Make sure you learn underlined words

Nucleic Acid/ DNA Summary – Check Understanding

The monomer that makes up DNA (polymer) is called a n_______.

The three parts of a n_______ are a b_____, a p_______ group and a s_______

The four bases that make up the sequence of DNA are _______ and_______.

DNA codes for p_______ which are made from a_______ a_______ monomers.
Revise Biological molecules and water

Watch for good revision

Biological Molecules - You Are What You Eat: Crash Course Biology #3 on youtube
http://www.youtube.com/watch?v=H8WJ2KENIK0