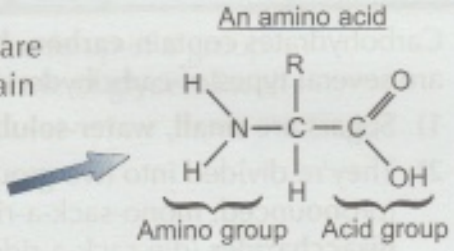
Proteins

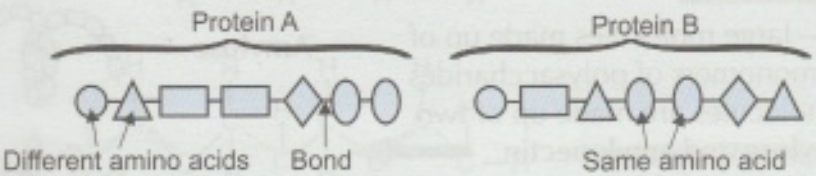
Proteins are Made of Amino Acids

Proteins are composed of long chains of **amino acids**. There are **twenty different** amino acids used in proteins. They all contain carbon, hydrogen, oxygen and nitrogen, and some contain sulfur. All have the **same structure** as the one in the diagram but **R** can be one of twenty different chemical groups.



Proteins are Held Together by Peptide Bonds

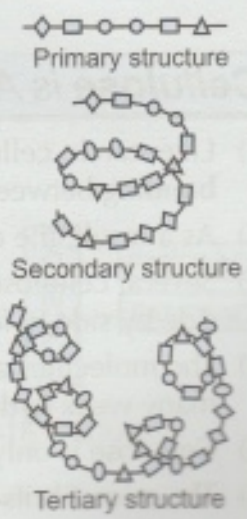
1) The chains of amino acids are attached to each other by **strong peptide bonds**.
2) The amino acids can be arranged in any sequence and proteins can be up to **several hundred** amino acids long.
3) The number of different proteins that are possible is almost unimaginable. Consider that there are several thousand ways of arranging a chain of just three amino acids, with each combination forming a different protein. Add one more amino acid to the chain and the number of possibilities leaps into the hundreds of thousands.
4) It's the **order** of the amino acids in a protein that determines its **structure** and it's the structure of a protein that determines **how it works**.



(N.B. Each different shape represents a different amino acid.)

Each Protein has its Own Special Shape

1) The order in which the amino acids are arranged in a protein chain is called the **primary structure**.
2) Some chains **coil up** or **fold** into pleats that are held together by weak forces of chemical attraction called **hydrogen bonds**. The coils and pleats are the **secondary structure** of a protein.
3) Some proteins (especially enzymes) have a **tertiary structure**. The coiled chain of amino acids is folded into a **ball** that's held together by a mixture of weak chemical bonds (e.g. hydrogen bonds) and stronger bonds (e.g. disulfide bonds).
4) If the protein has a roughly spherical shape it's called a **globular protein** (e.g. enzymes are classed as globular proteins).



The name's Bond. Peptide Bond...

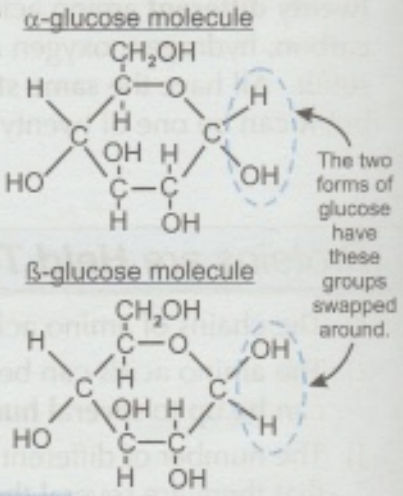
1) What is the primary structure of a protein?
2) What type of bond holds together the secondary structure of a protein?

Carbohydrates

Carbohydrates Contain Three Elements

Carbohydrates contain **carbon**, **hydrogen** and **oxygen**. There are several types of carbohydrate, e.g. sugars, starch and cellulose.

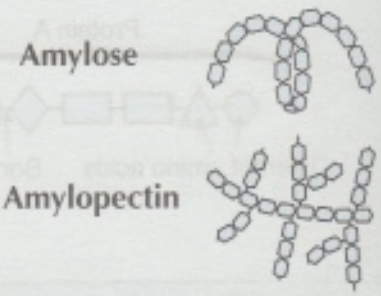
1) Sugars are **small**, **water-soluble** molecules that taste sweet.
2) They're divided into two groups: **monosaccharides** (pronounced: mono-sack-a-rides) and **disaccharides** (die-sack-a-rides).
3) Monosaccharides are the single units from which all the other carbohydrates are built. **Glucose** and **fructose** are both monosaccharides. Glucose has two forms — **alpha** (α) and **beta** (ß).
4) Disaccharides are formed when **two monosaccharides** are joined together by a chemical reaction. A molecule of **water** is also formed (so it's called a **condensation reaction**).



GLUCOSE + GLUCOSE → MALTOSE (a disaccharide) + WATER
GLUCOSE + FRUCTOSE → SUCROSE (a disaccharide) + WATER

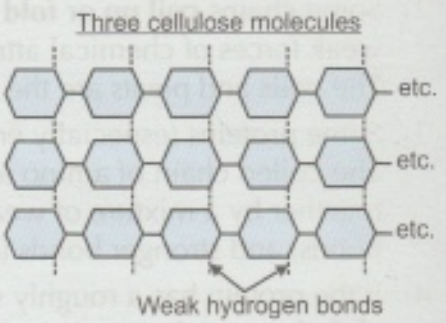
Starch is a Polysaccharide

Polysaccharides are **polymers** — large molecules made up of **monomers** (smaller units). The monomers of polysaccharides are **monosaccharides**. **Starch** molecules are made up of two different polysaccharides — **amylose** and **amylopectin**, which are polymers of glucose. The insoluble, compact starch molecules are an ideal way of **storing glucose**. Starch is **only** found in plant cells.



Cellulose is Also a Polysaccharide

1) Like starch, cellulose is a polymer of glucose, but the **bonding** between the glucose units is different.
2) As a result, the cellulose molecules are **long** and **straight**.
3) Several cellulose molecules can lie side by side to form **microfibrils**.
4) The molecules are held together by many weak **hydrogen bonds**.
5) Cellulose is only found in plant cells.
6) The microfibrils **strengthen** the plant cell wall.



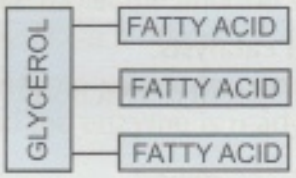
A poly-sack-a-ride — a bunch of kids on a helter skelter...

1) Name two monosaccharides.
2) Which disaccharide is composed of two molecules of glucose?
3) Name two polysaccharides.

Lipids

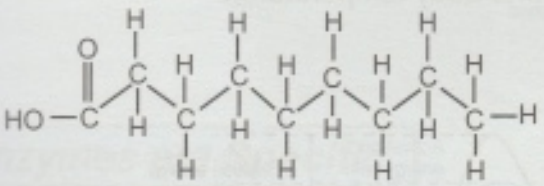
Lipids Contain *Carbon*, *Hydrogen* and *Oxygen*

Lipids are **oils** and **fats**. Plant oils and animal fats are mostly made up of a group of lipids called **triglycerides**. A triglyceride consists of a molecule of **glycerol** with **three fatty acids** attached to it.

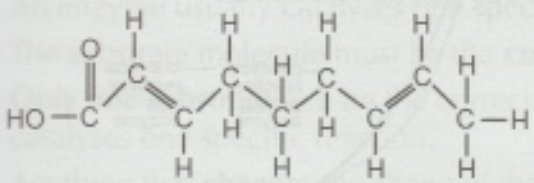


A **triglyceride**

A fatty acid molecule is a long chain of **carbon atoms** with an **acid group** (-COOH) at one end. **Hydrogen atoms** are attached to the carbon atoms. If every carbon atom in the chain is joined by a **single bond**, we say that the fatty acid is **saturated**. If one or more of the bonds is a **double bond**, it's said to be **unsaturated**. A fatty acid with many double bonds is **polyunsaturated**.



Saturated fatty acid

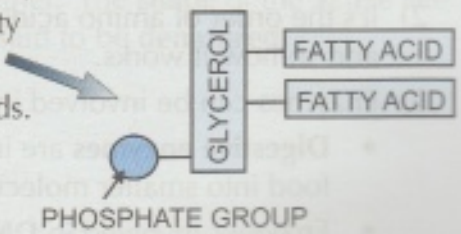


Unsaturated fatty acid

Phospholipids are a *Special* Type of *Lipid*

Phospholipids (pronounced: foss-foe-lip-id) are like triglycerides, but instead of having three fatty acid chains, they have **two** fatty acid chains and a **phosphate** group.

Cell membranes are made from a **double layer** of phospholipids.



Acid chain and the phospholipids — sounds like a punk band...

1) Which elements are fatty acids composed of?
2) What's the difference between saturated fatty acids and unsaturated fatty acids?
3) What's the difference between triglycerides and phospholipids?

Enzymes

Enzymes Help to Speed up Biochemical Reactions

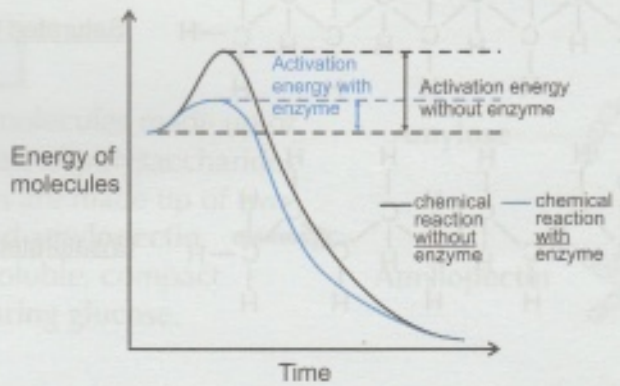
1) In a living cell, thousands of **biochemical reactions** take place every second. The sum of these reactions is called **metabolism**. A single chain of these reactions is called a **metabolic pathway**.
2) Without enzymes, these reactions would take place very **slowly** at normal body temperature.

1) Enzymes are **biological catalysts**.
2) They **increase** the **rate** (speed) of reactions.

How do Enzymes Act as Catalysts?

1) Even reactions that release energy require an **input of energy** to get them going, e.g. the gas from a Bunsen burner doesn't burn until you provide heat energy from a match.
2) This input energy is called the **activation energy**. A reaction that needs a high activation energy can't start at a low temperature of 37 °C (i.e. body temperature).
3) Enzymes **reduce** the activation energy.

This graph shows the activation energies of a reaction **with** and **without** an enzyme:



Enzymes are Proteins

1) All enzymes are **globular proteins** (because they're roughly spherical).
2) It's the order of amino acids in an enzyme that determines its **structure**, and so how it works.
3) Enzymes can be involved in **breaking down** molecules or **building** molecules. For example:
   - **Digestive enzymes** are important in the digestive system, where they help to break down food into smaller molecules, e.g. carbohydrases break down carbohydrates.
   - Enzymes involved in **DNA replication** help to build molecules, e.g. DNA polymerase.

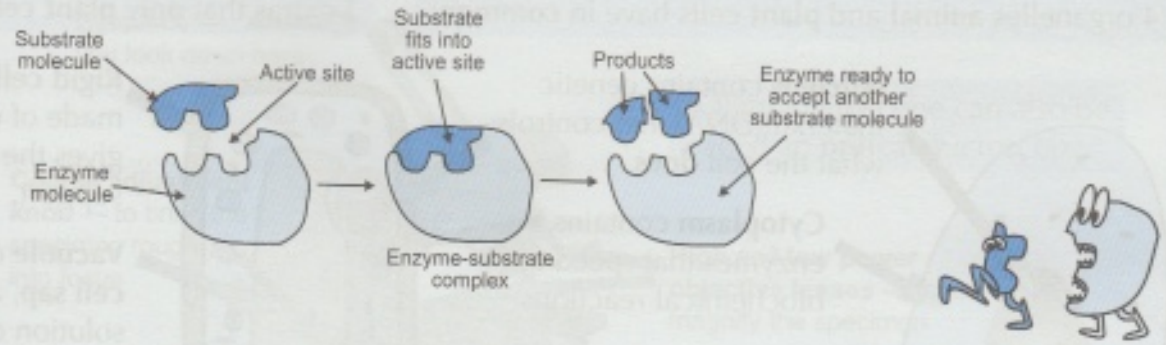
I could really use a catalyst to help me write this gag...

1) What is the function of enzymes?
2) What is activation energy?
3) What do digestive enzymes do?

Enzymes

Enzymes have an Active Site

1) A substance that's acted upon by an enzyme is called its **substrate**.
2) The **active site** is a region on the surface of the enzyme molecule where a substrate molecule can attach itself. It's where the catalysed reaction takes place.
3) The shape of the substrate molecule and the shape of the active site are **complementary**, i.e. they fit each other.
4) Almost as soon as the **enzyme-substrate complex** has formed, the products of the reaction are released and the enzyme is ready to accept another substrate molecule.



Enzymes are Specific

1) An enzyme usually catalyses one **specific** chemical reaction.
2) The substrate molecule must be the **correct shape** to fit into the active site.
3) **Only one substrate** will be the correct shape to fit, so each enzyme only catalyses one specific reaction.
4) Anything that **changes** the shape of the active site will **affect** how well the enzyme works.

The Effect of Temperature on Enzyme Activity

As temperature **increases**, enzyme reactions become **faster**, because the molecules have more **energy**. However, at high temperatures the atoms of the enzyme molecule vibrate more rapidly and **break** the weak bonds that hold the **tertiary structure** together. The **shape** of the active site **changes** and the substrate can no longer fit in. The enzyme is said to be **denatured**.

The Effect of pH on Enzyme Activity

Acids and **alkalis** can denature enzymes. Hydrogen ions (H^+) in acids and hydroxyl ions (OH^-) in alkalis disrupt the **weak bonds** and change the shape of the active site.

Lonely enzyme seeking complementary substrate...

1) Why are enzymes described as 'specific'?
2) Explain why a denatured enzyme will not function.
3) Describe the effect of pH on enzyme activity.

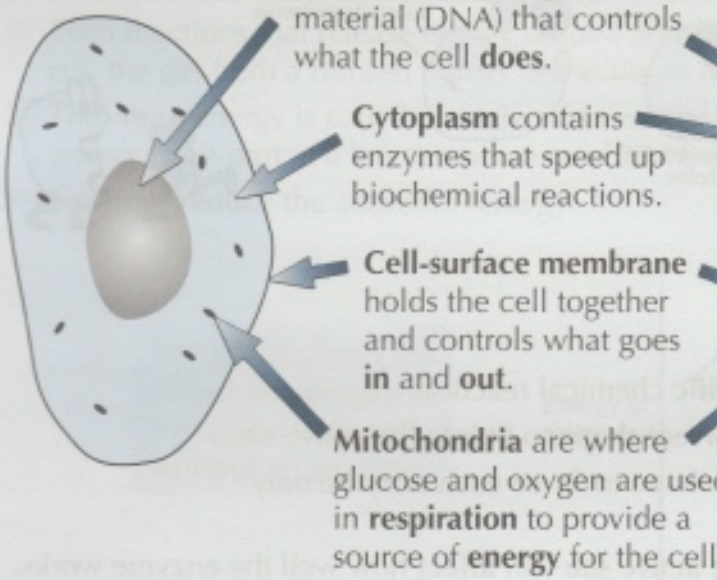
Eukaryotic and Prokaryotic Cells

Organisms can be *Prokaryotes* or *Eukaryotes*

1) **Prokaryotic** (pronounced like this: pro-carry-ot-ick) organisms are prokaryotic cells (i.e. they're **single-celled** organisms) and **eukaryotic** (you-carry-ot-ick) organisms are made up of eukaryotic cells.
2) Both types of cells contain **organelles**. Organelles are parts of cells — each one has a **specific function**.

Eukaryotic cells are **complex** and include all **animal** and **plant** cells.
Prokaryotic cells are **smaller** and **simpler**, e.g. **bacteria**.

4 organelles **animal** and **plant** cells have in **common**:



Nucleus contains genetic material (DNA) that controls what the cell **does**.

Cytoplasm contains enzymes that speed up biochemical reactions.

Cell-surface membrane holds the cell together and controls what goes **in** and **out**.

Mitochondria are where glucose and oxygen are used in **respiration** to provide a source of **energy** for the cell.

3 extras that **only plant cells** have:

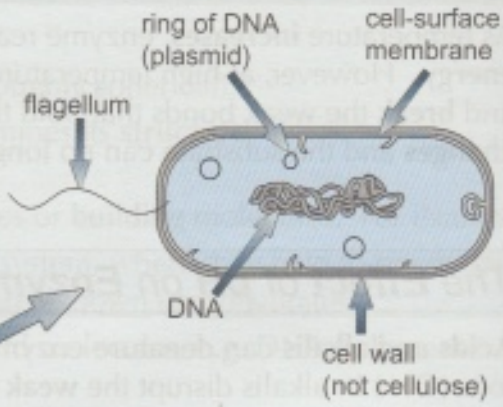
Rigid cell wall made of **cellulose**, gives the cell support.

Vacuole contains **cell sap**, a weak solution of sugar and salts.

Chloroplasts contain **chlorophyll** for **photosynthesis**. They're found in the **green** parts of plants, e.g. leaves and stem.

Bacterial Cells are *Prokaryotic*

1) Prokaryotes like bacteria are roughly a **tenth the size** of eukaryotic cells.
2) Prokaryotic cells **don't contain** a nucleus, mitochondria or chloroplasts.
3) As they **don't** have a nucleus, their **DNA floats freely** in the **cytoplasm**. Some prokaryotes also have **rings of DNA** called **plasmids**.
4) Some prokaryotes have a **flagellum** which **rotates** and allows the cell to **move**.
5) The diagram shows a bacterial cell as seen under an **electron microscope** (see next page).



Bacterial cheerleaders — they never stop swirling their flagella...

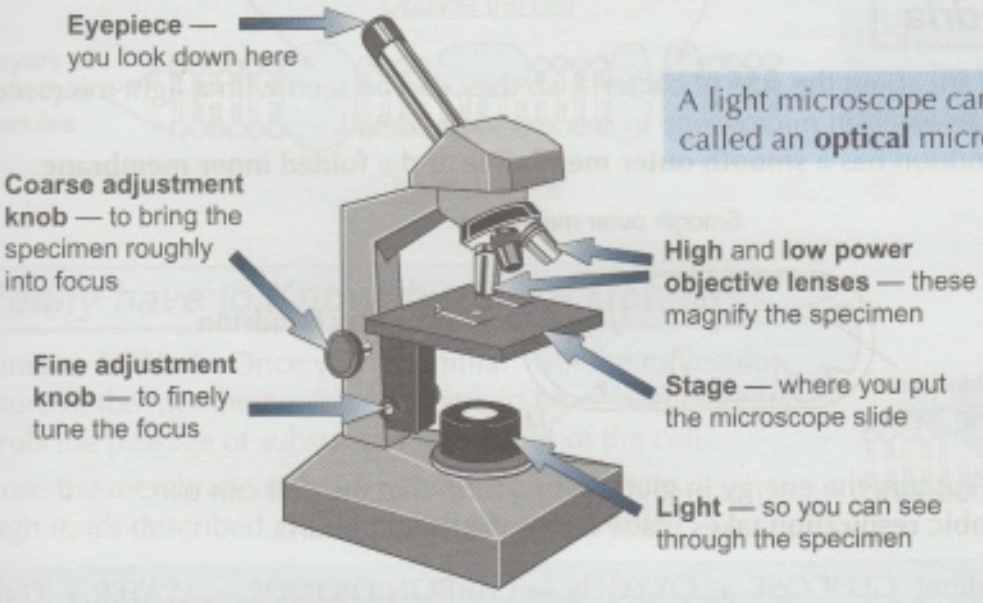
1) Give an example of a prokaryotic cell.
2) Name four organelles that plant and animals cells both have.
3) What is the function of mitochondria?

Microscopes

You Can See Cell Structure with a Light Microscope

A **light microscope** can magnify up to 1500 times and allows you to see individual animal and plant cells along with the organelles inside them.

1) If the cells have been **stained** you can see the dark-coloured **nucleus** surrounded by lighter-coloured **cytoplasm**.
2) Tiny **mitochondria** and the black line of the **cell membrane** are also visible.
3) In plant cells, the **cell wall**, **chloroplasts** and the **vacuole** can be seen.



A light microscope can also be called an **optical** microscope.

Electron Microscopes have a Greater Magnification

1) The detailed **ultrastructure** of cells was revealed in the 1950s when the **electron microscope** was invented.
2) An electron microscope can **magnify** objects more than 500 000 times and, more importantly, it allows **greater detail** to be seen than a light microscope. For example, it allows you to see the detailed **structures inside organelles** such as mitochondria and chloroplasts.
3) The image that's recorded is called an **electron micrograph**.

I put a slide on the stage and then slid straight off the edge...

1) Name three things visible with a light microscope in both animal and plant cells.
2) Which type of microscope must be used to show the detailed ultrastructure of a cell?
3) What is the image recorded by an electron microscope called?

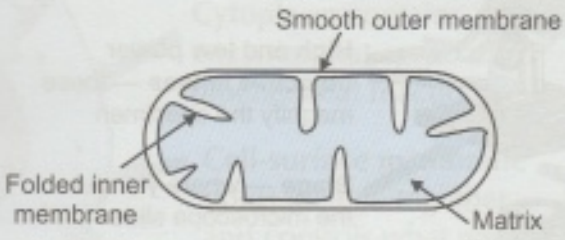
Functions of the Nucleus, Mitochondria and Cell Wall

Nucleus

1) The **nucleus** is the control centre of the cell.
2) It contains **DNA** (deoxyribonucleic acid): the coded information needed for **making proteins**.
3) During **cell division** the chromosomes carrying the long DNA molecules coil up, becoming shorter and thicker and visible with a light microscope.
4) Electron micrographs show that there's a **double membrane** around the nucleus.

Mitochondria

Mitochondria are about the size of bacteria, so they can be seen with a light microscope, but you need an electron microscope to see any of the detail.
Each mitochondrion has a **smooth outer membrane** and a **folded inner membrane**:



A **mitochondrion**

Their job is to capture the energy in glucose in a form that the cell can use.
To do this **aerobic respiration** takes place inside the mitochondria.

Word equation: GLUCOSE + OXYGEN → CARBON DIOXIDE + WATER + (ENERGY)

The energy released by respiration ends up in molecules of **ATP** (adenosine triphosphate). ATP is used in the cell to provide the energy for **muscle contraction**, **active transport** (called active uptake in some text books) and **building large molecules** from small ones, as well as many other processes.

Cell Wall — Plants

1) The plant cell wall is relatively rigid and provides **support** for the cell.
2) It mainly consists of bundles of long, straight **cellulose molecules**.
3) The cellulose molecules lay side by side to form **microfibrils**.

Doctor, doctor my DNA is getting shorter and thicker...*

1) Which organelle acts as the control centre of the cell?
2) In which organelle does aerobic respiration occur?
3) Describe the membranes of a mitochondrion.
4) What is the word equation for aerobic respiration?
5) Name the molecule used to provide energy for processes in the cell.
6) Name the molecule that is found in bundles in plant cell walls.

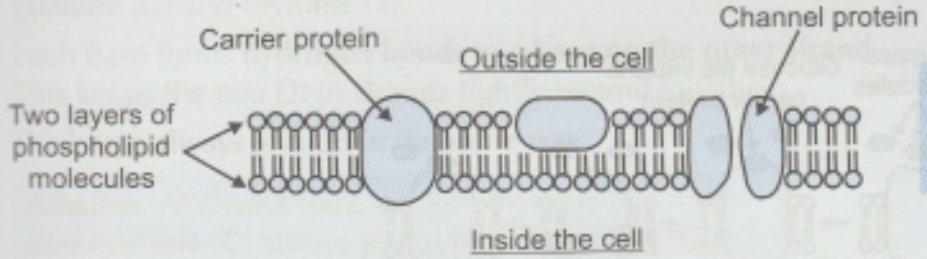
*...that's the least of your worries — you're going to divide soon.

Cell Membranes

Structure of the Cell-Surface Membrane

The **cell-surface membrane** is the very thin structure around an individual cell.

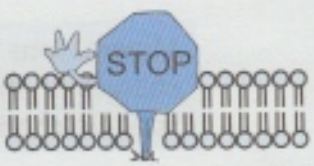
1) Electron micrographs show that the cell-surface membrane consists of a double layer of **phospholipid** molecules tightly packed together.
2) Bigger **protein molecules** are embedded in the phospholipid molecules.
3) Some proteins go **all the way through** the membrane and some only go **halfway**.
4) Membranes surrounding the **organelles** inside cells have the **same** structure.



Cell-surface membranes can also be called **plasma membranes**.

Do I Really have to Know this Much Detail?

1) The answer is "Yes". Once you're familiar with the molecular structure of the membrane you can explain how the membrane **controls** the passage of substances **in** and **out** of the cell.
2) Because the membrane only allows certain substances through it, it's described as being **partially permeable**.



Substances Pass Through Membranes by Four Methods

1 Diffusion

1) The particles of liquids and gases are constantly **moving about**. This movement causes the particles to spread from an area of **higher** concentration to an area of **lower** concentration.
2) Particles will **diffuse** through the cell membrane as long as they are small enough to pass through the very small gaps **between** the phospholipid molecules. Water, oxygen and **carbon dioxide** molecules can do this.
3) The cell **doesn't** need to provide any energy for this process.

The difference in concentration is sometimes called a **concentration gradient**, e.g. a big difference in concentration is a big concentration gradient.

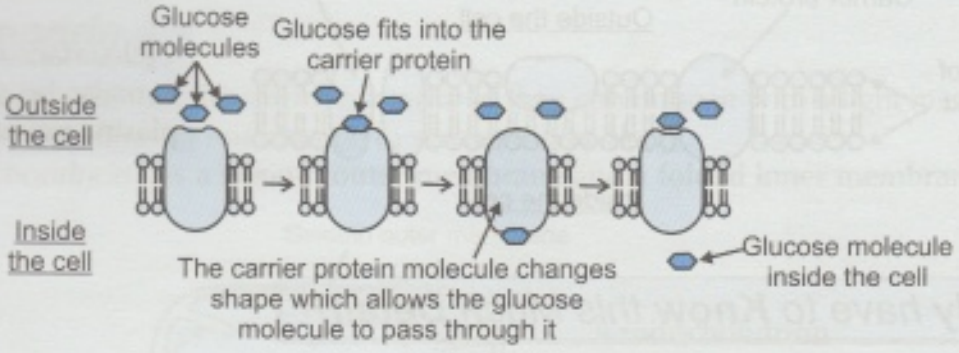
2 Osmosis

1) **Osmosis** is the diffusion of **water** molecules across a partially permeable membrane from a region of **higher concentration** of water molecules to a region of **lower concentration** of water molecules. The cell **doesn't** need to provide energy.
2) The concentration of water molecules is also referred to as the **water potential**. At AS and A-level, you tend to talk about water moving from a region of **higher water potential** to a region of **lower water potential**.

Cell Membranes

3 Facilitated Diffusion

1) Glucose and many other water soluble molecules are **too big** to diffuse across the membrane by themselves. They must be helped across by **carrier proteins**.
2) Each substance has its **own specific** carrier protein.
3) For example, a molecule of glucose fits onto the outside end of a **glucose carrier protein**.
4) This causes the protein to **change shape**, allowing the glucose molecule to diffuse through it into the cytoplasm of the cell. The cell **doesn't** need to provide any energy.



Mineral ions like sodium (Na^+) and potassium (K^+) have electrical charges on them, so they also need help to cross the membrane. Specific **channel proteins** in the membrane allow them to diffuse through.

4 Active Transport (or Active Uptake)

1) When a cell needs to move substances across the membrane from a region of **low** concentration to a region of **higher** concentration, it must provide **energy**.
2) The substance fits into a **specific carrier protein**, then molecules of **ATP** (see page 8) provide the energy to change the shape of the protein.
3) As it changes shape the protein **actively transports** the substance across the membrane.
4) These special **carrier proteins** are sometimes called "**pumps**" because they're moving substances **against** a concentration gradient.

Active transport — isn't that just riding a bike?

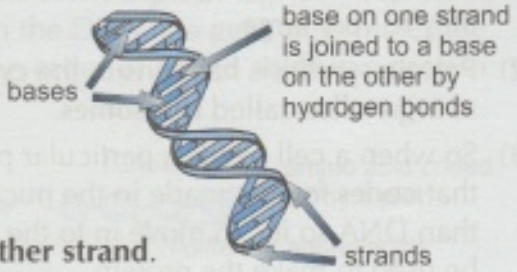
1) Name the two types of molecule that make up the cell membrane.
2) Give four ways substances can cross cell membranes.
3) What do you call the diffusion of water molecules through the cell membrane?
4) Give another term for the concentration of water molecules.
5) Name the two types of protein involved in facilitated diffusion.
6) Why does active transport require ATP?

DNA and Protein Synthesis

*DNA is Made Up of **Nucleotides** Containing **Bases***

1) **DNA** is a **double helix** (a double-stranded spiral). Each of the two DNA strands is made up of lots of small molecules called **nucleotides**.
2) Each **nucleotide** contains a part called a **base**. DNA has just **four** different bases.
3) These bases are: **adenine** (**A**), **cytosine** (**C**), **guanine** (**G**) and **thymine** (**T**).
4) Each base forms **hydrogen bonds** to a base **on the other strand**. This keeps the two DNA strands **tightly wound** together.
5) The bases **always** join up in the **same way**.

A DNA Double Helix



Adenine (**A**) always joins up with **thymine** (**T**), and **cytosine** (**C**) always joins up with **guanine** (**G**).

These pairs of bases are called **complementary bases**. They join together because they **complement** each other in shape — this is called **complementary base pairing**.

*Proteins are Made by **Reading the Code** in **DNA***

1) **DNA** controls the production of **proteins** (**protein synthesis**) in a cell.
2) A **section of DNA** that codes for a particular **protein** is called a **gene**.
3) Proteins are made up of **chains** of **amino acids**. Each different protein has its own particular **number** and **order** of amino acids.
4) This gives each protein a different **shape**, which means each protein can have a different **function**.
5) It's the **order** of the **bases** in a **gene** that decides the order of **amino acids** in a **protein**.
6) Each gene contains a **different sequence** of **bases** — which is what allows it to code for a **unique protein**.

'**Codes for**' just means '**contains the instructions for**'.

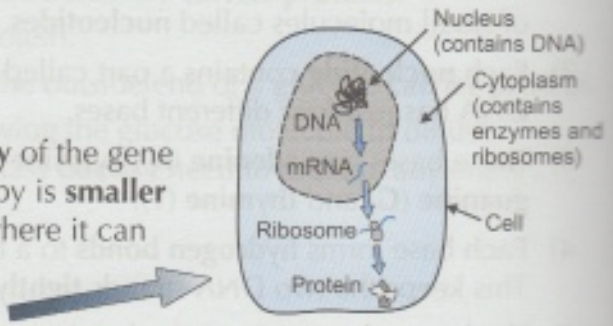
Pro-teen synthesis — supporting youth electronic music-making...

1) What is the name given to the double-stranded structure of DNA?
2) How many different bases are there in DNA?
3) Give the names of the bases in DNA.
4) How do the strands of DNA stay together?
5) What is complementary base pairing?
6) What is a gene?
7) What determines the order of amino acids in a protein?

RNA and Protein Synthesis

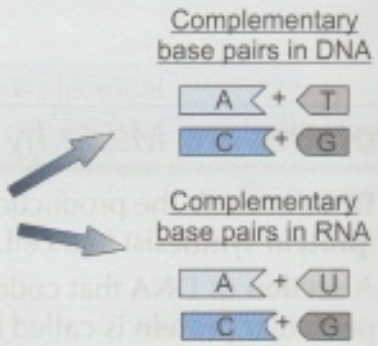
RNA is Needed to Make Proteins

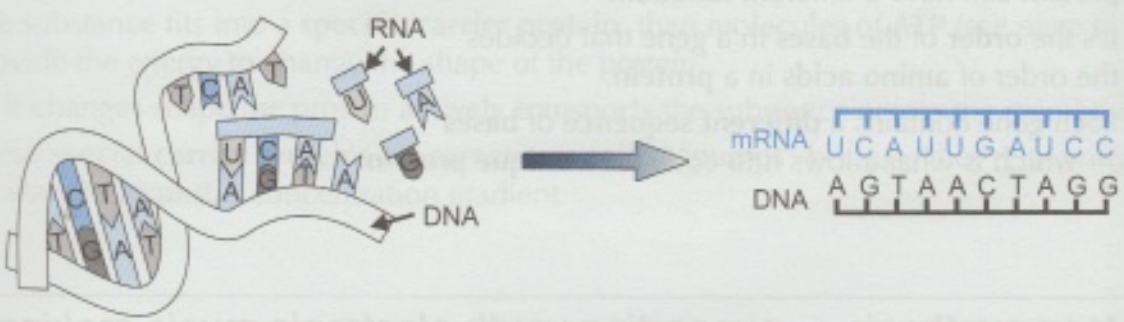
1) DNA molecules (and so genes) are found in the **nucleus** of a cell, but they can't move out of the nucleus because they're very **large**.
2) Protein synthesis happens in the **cytoplasm** at organelles called **ribosomes**.
3) So when a cell **needs** a particular protein, a **copy** of the gene that codes for it is made in the nucleus. This copy is **smaller** than DNA so it can move in to the cytoplasm, where it can be used to make the protein.
4) The copy of the gene is made from a molecule called **messenger RNA** (mRNA).



DNA is Used as a Template to Make an mRNA Molecule

1) The DNA in the gene acts as a **template**.
2) RNA, like DNA, is made up of **nucleotides**, which each have a **base**.
3) The bases on RNA nucleotides line up next to their **complementary** bases on the DNA template.
   - In RNA, there's **no thymine** (**T**), so the base **uracil** (**U**) binds to any **adenine** (**A**) in the DNA instead.
   - Once the bases on the **RNA** nucleotides have **paired up** with the bases on the **DNA** strand, the RNA nucleotides join together to make an **mRNA molecule**.
4) Eventually, a **whole copy** of the gene is made and the **sequence** (order) of **bases** in the mRNA copy is complementary to the sequence of bases in the DNA template.





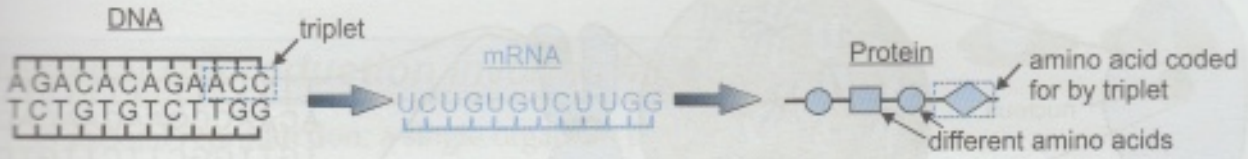
Complimentary RNA — oh, you do look dashing Mr Ribo Some...

1) Why does a copy of a gene need to be made for protein synthesis?
2) What does the 'm' in mRNA stand for?
3) In RNA, which base is complementary to adenine?
4) Give the mRNA sequence that would be complementary to the DNA sequence: ATTGCGCA

Mutations

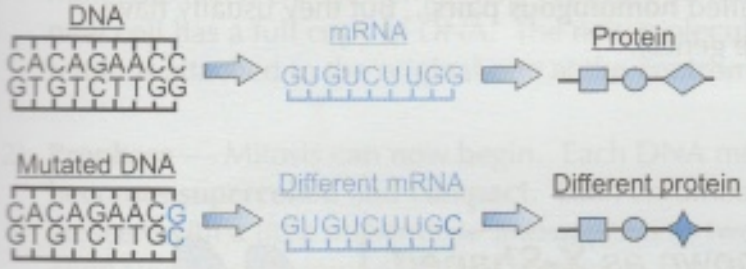
The Order of Bases Determines the Order of Amino Acids

Three bases in a row (a **triplet**, e.g. GCT) codes for **one amino acid** — this is called the **genetic code**. **Different amino acids** are coded for by **different triplets**, e.g. TAT = tyrosine, AGT = serine. The **order of the bases** (and so triplets) in the DNA of a gene determines the order of bases in its mRNA copy, and that determines the **order of amino acids** in a protein:



Mutations Change the Order of Bases in DNA

1) **Mutations** are changes to the **base** sequence (order) of DNA.
2) For example, one base can be **substituted** (swapped) for another one. This can cause the base triplet to **change**. E.g. if C is substituted for A, GCT becomes GAT.
3) So mutations can change the **amino acids** in the protein that the gene codes for.
4) A change in the amino acids can cause a **different protein** to be produced. Sometimes the different protein can be **harmful** (see below).



Mutations happen **spontaneously** (randomly), but how **frequently** they happen can be increased by **mutagenic agents** — factors that increase mutations, e.g. UV radiation in sunlight.

Mutations can be Harmful

1) Mutations can cause **cancer** because **cell division** is controlled by **proteins**. If mutations occur in the **genes** for these proteins, they can **alter** the proteins so they **no longer work**. This can lead to **uncontrolled cell division**, and the development of a **tumour** (cancer).
2) Mutations also cause **genetic disorders** — mutations that result in **altered** genes and proteins can be **inherited** (passed on from your parents), e.g. cystic fibrosis.

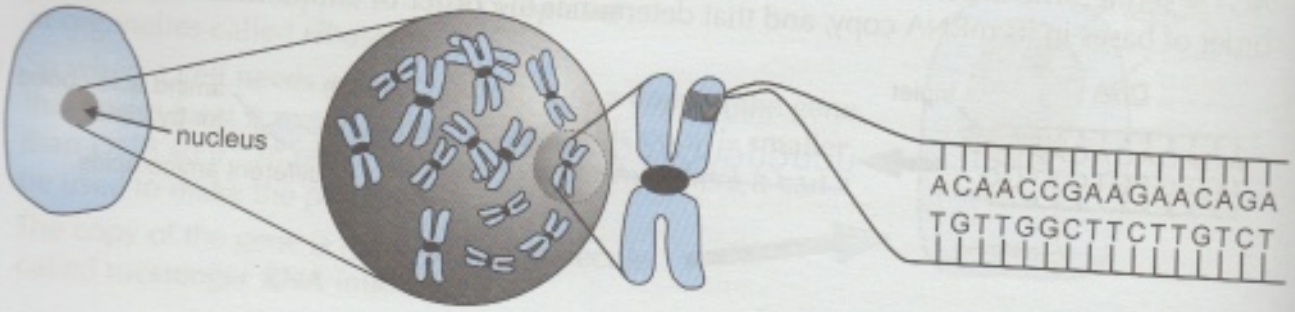
DoNAtello, LeAmino... it's the Teenage Mutant Protein Makers...

1) How many bases code for one amino acid?
2) What are mutations?
3) What do mutagenic agents do?

Chromosomes

DNA is Found on Chromosomes

DNA is found in the **nucleus** of **eukaryotic cells**. It has to be **wound up** into chromosomes to fit in. Each human chromosome contains between a couple of hundred and a few thousand genes.

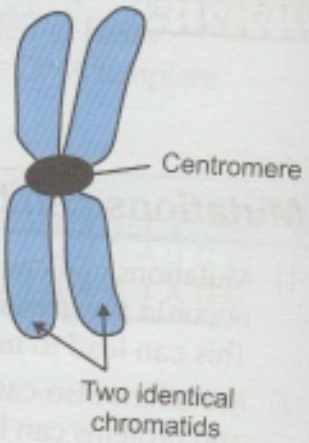


Homologous Pairs

Humans have **23 homologous pairs** of chromosomes (46 in total), e.g. two number 1s, two number 2s, two number 3s, etc. One from each pair comes from your mother and one comes from your father. Both chromosomes in a pair are the **same size** and carry the **same genes** (which is why they're called **homologous pairs**). But they usually have **different alleles** (different versions of the genes).

Chromosomes are Often Shown as X-Shaped

In loads of books chromosomes are shown as **X-shaped**. An X-shaped chromosome is actually **one chromosome** attached to an **identical copy** of itself. Don't get it confused with a homologous pair of chromosomes. They're only X-shaped just after the DNA has been **replicated** (e.g. in cell division). Each side of the X is referred to as a **chromatid** and the bit in the middle where they're attached is called the **centromere**.



It's in his DNA, D, D, D, DNA...

1) Where is DNA found in a eukaryotic cell?
2) How many homologous pairs of chromosomes do human cells have?
3) Are homologous pairs of chromosomes identical? Explain your answer.
4) What is a chromatid?
5) What is the name of the region where two identical chromatids are joined?

Cell Division — Mitosis

Mitosis is Needed for Growth and Repair

1) If you have **damaged** tissue, the cells around the damaged area divide by **mitosis** to replace the damaged cells.
2) Cells **also** divide by mitosis to produce new tissue for **growth**.

Asexual Reproduction Involves Mitosis

1) In **asexual reproduction**, a single organism produces offspring by dividing into two organisms or by splitting off a piece of itself.
2) All the offspring are **genetically identical** to each other and to the parent.
3) The cells divide by **mitosis** (like most cells).

Bacteria and many plants reproduce asexually.

In Mitosis the DNA Copies Itself, Then the Cell Divides Once

Mitosis is split up into **four** stages: **prophase**, **metaphase**, **anaphase** and **telophase**. **Before** mitosis starts, there's a period called **interphase**.

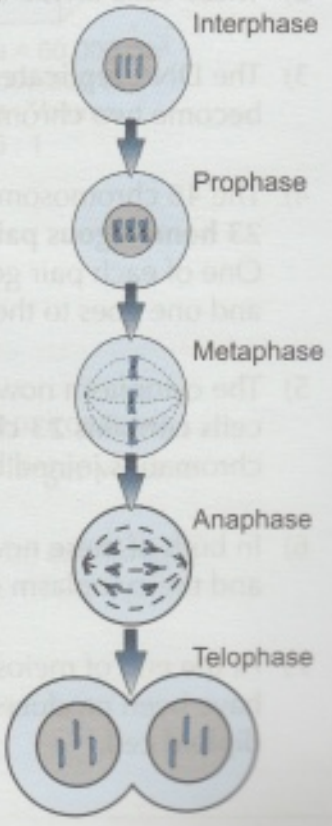
1) **Interphase** — Before the cell starts to divide, every DNA molecule (each chromosome) must **replicate** so that each new cell has a full copy of DNA. The new molecule remains attached to the original one at the **centromere**.

2) **Prophase** — Mitosis can now begin. Each DNA molecule becomes **supercoiled** and **compact**. Each chromosome can now be seen with a light microscope and appears as two **chromatids** lying side by side, joined by the centromere (i.e. X-shaped).

3) **Metaphase** — The **nuclear membrane** breaks down and the chromosomes **line up** along the **equator** (middle) of the cell.

4) **Anaphase** — The centromeres split and the **chromatids separate** and are dragged to opposite ends of the cell.

5) **Telophase** — A **nuclear membrane** forms around each set of chromatids (exact copies of the original chromosomes) and the **cytoplasm divides**.



Ouch, you stepped on my toe, sis... ba dum tsh

1) Give three uses of mitosis.
2) Why is DNA replicated before cell division can occur?
3) Do the homologous pairs separate in mitosis?
4) How many cells are produced when a cell divides by mitosis?

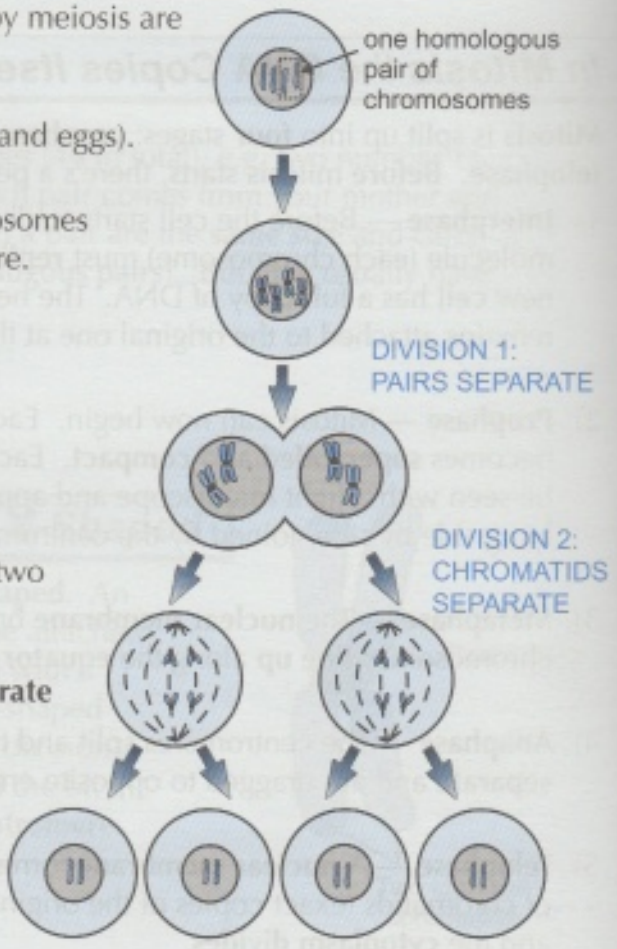
Cell Division — Meiosis

Sexual Reproduction Involves Meiosis

1) In **sexual reproduction**, the offspring are genetically different from their parents and from each other. This produces variation in a population.
2) Each parent produces sex cells (**gametes**) containing just **one set** of genetic material. This involves a special kind of cell division, called **meiosis**, and the gametes are described as being **haploid**.
3) During **fertilisation** the nuclei of the gametes join together to form a **zygote**. The zygote has **two complete sets** of genetic material, and is said to be **diploid**.
4) The zygote grows by simple cell division (**mitosis**) to form the **embryo**.

In Meiosis, DNA Copies Itself Then the Cell Divides Twice

1) The **only cells** in the human body that divide by meiosis are special cells in the **testes** and **ovaries**.
2) These cells divide to produce **gametes** (sperm and eggs).
3) The DNA **replicates**, so each of the 46 chromosomes become two chromatids joined by a centromere.
4) The 46 chromosomes sort themselves into the **23 homologous pairs**, then the **pairs separate**. One of each pair goes to one side of the cell and one goes to the other.
5) The cytoplasm now divides. Each of the new cells **contains 23 chromosomes** (consisting of two chromatids joined by a centromere).
6) In both of these new cells the **chromatids separate** and the cytoplasm divides to form two cells.
7) At the end of meiosis, **four haploid cells** have been produced from every original diploid cell.



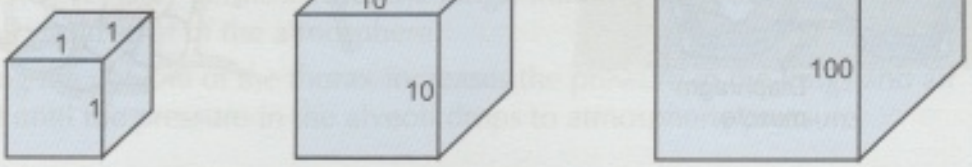
Worry not, before you know it your A-level testes will soon be ovaries...

1) Are gametes haploid or diploid?
2) Where in the human body does meiosis occur?
3) How many cell divisions are there in meiosis?
4) How many cells are produced when a cell divides by meiosis?

Size and Surface Area to Volume Ratio

Small Objects have Relatively Large Surface Areas

1) Have you ever wondered **why** there are no large single-celled organisms or why big animals are made up of **millions** of tiny cells instead of a few large ones?
2) The main reason relates to the changes in the **surface area to volume ratio** of an object as it increases in size.
3) Look at the three cubes in the diagram below. The **smallest cube** has the **biggest** surface area to volume ratio and the **biggest cube** has the **smallest** surface area to volume ratio.



Surface area = 6 cm²
Volume = 1 cm³
Surface area : Volume
6 : 1

Surface area = 600 cm²
Volume = 1000 cm³
Surface area : Volume
0.6 : 1

Surface area = 60,000 cm²
Volume = 1,000,000 cm³
Surface area : Volume
0.06 : 1

Surface Area is Important for Exchange

1) Cells or organisms need to **exchange materials** and **heat** with their environment.
2) **More** chemical reactions happen every second in organisms with a **larger volume** than in ones with smaller volumes.
3) Therefore **more** oxygen, nutrients, waste products and heat need to be exchanged across the membrane of cells of larger organisms.
4) With increasing volume this becomes an **ever-increasing problem**.

My surface area just keeps growing... so does my volume (it's the pies)...

1) Which has the bigger surface area to volume ratio, a small organism or a large organism?
2) An animal has a surface area of 7.5 cm² and a volume of 1 cm³. What is its surface area to volume ratio?
3) Which animal has the greatest surface area to volume ratio — Animal A (9.8 : 1), Animal B (0.98 : 1)?
4) Give three materials that need to be exchanged across the membranes of organisms' cells.