Biological Cell Introduction

It only takes one biological cell to create an organism. In fact, there are countless species of single celled organisms, and indeed multi-cellular organisms like ourselves.

A single cell is able to keep itself functional by owning a series of '*miniature machines*' known as *organelles*. The following list looks at some of these organelles and other characteristics typical of a fully functioning cell. The italic links for each lead to an extra description in the dictionary, as do all similar links in the tutorials;

- ***Mitochondrion***
  An important cell organelle involved in respiration
- ***Cytoplasm***
  A fluid surrounding the contents of a cell and forms a vacuole
- ***Golgi Apparatus***
  The processing area for the creation of a glycoprotein
- ***Endoplasmic Reticulum***
  An important organelle heavily involved in protein synthesis.
- ***Vesicles***
  Packages of substances that are to be used in the cell or secreted by it.
- ***Nucleus***
  The "brain" of a cell containing genetic information that determines every natural process within an organism.
- ***Cell Membrane***
  Also known as a plasma membrane, this outer layer of a cell assists in the movement of molecules in and out the cell plays both a structural and protective role
- ***Lysosomes***
  Membranous sacs that contain digestive enzymes

Cell Wall
A structure that characteristically is found in plants and prokaryotes and not animals that plays a structural and protective role.

Cell Specialisation

Cells can become specialised to perform a particular function within an organism, usually as part of a larger tissue consisting of many of the same cells working in tandem, for example;

- *Nerve cells* to operate as part of the nervous system to send messages back and forth via the brain at the centre of the nerve system.
- Skin cells for waterproof protection and protection against pathogens in the open air environment.
- *Xylem* tubes to transport water around plants and to provide structural support for the plant as a whole.

Cells combine their efforts in these tissue types to perform a common cause. The task of the specialised cell will determine in what way it is going to be specialised, because different cells are suited to different purposes, as illustrated in the above list and below example;

- Muscle cells are long and smooth in structure and their elastic nature allows these cells to perform flexible movements, just as they do in our own body's.
- Some *white blood cells* contain powerful digestive enzymes to eliminate pathogens by

breaking them down to the molecular level.
- Cells at the back of the eye are sensitive to light stimuli, and thus can *interpret* differences in light intensity which can in turn be interpreted by our nervous system and brain.

Many of these cells contain organelles, though after some cells are specialised, they do not possess particular characteristics as they do not require them to be there. i.e. efficiency is the key, no resources are wasted and the resources available are put to their idyllic optimum.

The Cell Membrane

The *cell membrane*, otherwise known as the plasma membrane is a semi-permeable structure consisting mainly of *phospholipid* (fat) molecules and proteins. They are structured in a *fluid mosaic model*, where a double layer of phospholipid molecules provide a barrier accompanied by proteins.

It is present round the circumference of a cell to acts as a barrier, keeping foreign entities out the cell and its contents (like cytoplasm) firmly inside the cell.

The plasma membrane allows only selected materials to pass in and out of a cell, and is thus known as a selectively permeable membrane. There are a number of methods that allow the exchange of materials in and out the cell possible, mentioned below.

Cell Transport

There are three methods in which ions are transported through the cell membrane into the cell,

- ***Active Transport*** - Active transport is the transport of molecules with the active assistance of a carrier that can transport the material against a natural *concentration gradient*.
- **Passive Transport** (*Diffusion*) - The movement of molecules from areas of high concentration (i.e. outside a cell) to areas of low concentration (i.e. within a cell) via a carrier. This process does not require energy.
- **Simple Diffusion** - The movement of molecules from areas of high concentration to areas of low concentration in a free state. *Osmosis* of water involves this type of diffusion through a selectively permeable membrane (i.e. plasma membrane)

The Breakdown of Materials in a Cell

In cells, sometimes it is required to breakdown more complex molecules into more simple molecules, which can then be 're-built' into what is needed by the body with these new raw materials.

'*Pinocytosis*' where to contents of a structure (such as bacteria) are *drank*, essentially by breaking down molecules into a drinkable form.

'*Phagocytosis*' where contents are 'eaten'. See cell defence for more information in regards to this.

Absorption and Secretion

Absorption is the uptake of materials from a cells' external environment. Secretion is the ejection of material.

This page is designed to give you an introductory overview of a single cell. The continuing cell biology tutorial elaborates on the concepts mentioned here, and will give you a fuller understanding of the biological cell at work.

Biological Energy - ADP & ATP

ATP stands for Adenosine Tri-Phosphate, and is the energy used by an organism in its daily operations. It consists of an *adenosine* molecule and three inorganic *phosphates*. After a simple reaction breaking down ATP to *ADP*, the energy released from the breaking of a molecular bond is the energy we use to keep ourselves alive.

ATP to ADP - Energy Release

This is done by a simple process, in which one of the phosphate molecules is broken off, therefore reducing the ATP from 3 phosphates to 2, forming ADP (Adenosine Diphosphate after removing one of the phosphates {Pi}). This is commonly wrote as ADP + Pi.

When the bond connecting the phosphate is broken, *energy* is released.

While ATP is constantly being used up by the body in its biological processes, the energy supply can be bolstered by new sources of glucose being made available via eating food which is then broken down by the digestive system to smaller particles that can be utilised by the body.

On top of this, ADP is built back up into ATP so that it can be used again in its more energetic state. Although this conversion requires energy, the process produces a net gain in energy, meaning that more energy is available by re-using ADP+Pi back into ATP.

Glucose and ATP

Many ATP are needed every second by a cell, so ATP is created inside them due to the demand, and the fact that organisms like ourselves are made up of millions of cells.

Glucose, a sugar that is delivered via the bloodstream, is the product of the food you eat, and this is the molecule that is used to create ATP. Sweet foods provide a rich source of readily available glucose while other foods provide the materials needed to create glucose.

This glucose is broken down in a series of *enzyme* controlled steps that allow the release of energy to be used by the organism. This process is called respiration.

Respiration and the Creation of ATP

ATP is created via respiration in both animals and plants. The difference with plants is the fact they attain their food from elsewhere (see photosynthesis).

In essence, materials are harnessed to create ATP for biological processes. The energy can be created via cell respiration. The process of respiration occurs in 3 steps (when oxygen is present):

- Glycolysis
- The Kreb's Cycle
- The Cytochrome System

The following page looks at the chemistry involved in respiration and the creation of ATP, and why oxygen is essential for respiration in the long term.

Cell Respiration

As mentioned in the previous page on ATP, the process of *respiration* is split into 3 distinct areas that occur at different parts of the cell. Respiration involves the *oxidation* of foodstuff (i.e. glucose) in order to create ATP.

Respiration can occur with or without oxygen, *aerobic* and *anaerobic* respiration respectively.

Glycolysis

Glycolysis occurs in the *cytoplasm* of a cell where a 6 carbon glucose molecule (the broken down food that you ate earlier) is broken down by enzymes into a 3 carbon *pyruvic acid*.

The execution of this process requires 2 ATP, and produces a net gain of 2 ATP.

The enzymes involved remove hydrogen from the glucose (oxidation) where they take these hydrogen atoms to the cytochrome system, explained soon.

In anaerobic respiration, this is where the process ends, glucose is split into 2 molecules of pyruvic acid. When oxygen is present, pyruvic is broken down into other carbon compounds in the Kreb's Cycle. When it is not present, the pyruvic acid is broken down into lactic acid (or carbon dioxide and ethanol).

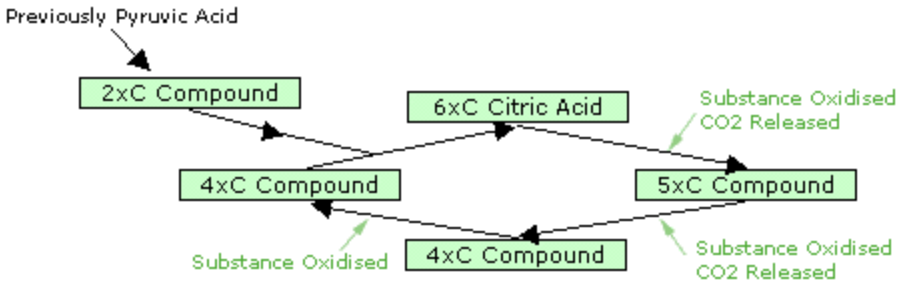
The Kreb's Cycle

When oxygen is present, respiration can harness more ATP from a single unit of glucose. The *pyruvic acid* from the *glycolysis* stage diffuses into a cell organelle called a mitochondrion (pl. *mitochondria*). These mitochondria are sausage shaped structures that host a large surface area

for the respiration to occur on.

The pyruvic acid is then subject to more enzymes which break it down into a 2 carbon compound, as seen below. The diagram illustrates the *Kreb's cycle*, consisting of three main actions

- The carbon element is in an infinite cycle where the 2 carbon compound derived from pyruvic acid binds with the 4 carbon compound that is always present in the cycle.
- CO^2 is released, where the oxygen that is present in *aerobic respiration* combines with carbon from the carbon compounds which is released as CO^2. Hence the need for animals to breath out and expel this CO^2.
- Enzymes oxidize the carbon compounds and transport the hydrogen atoms to the cytochrome system.



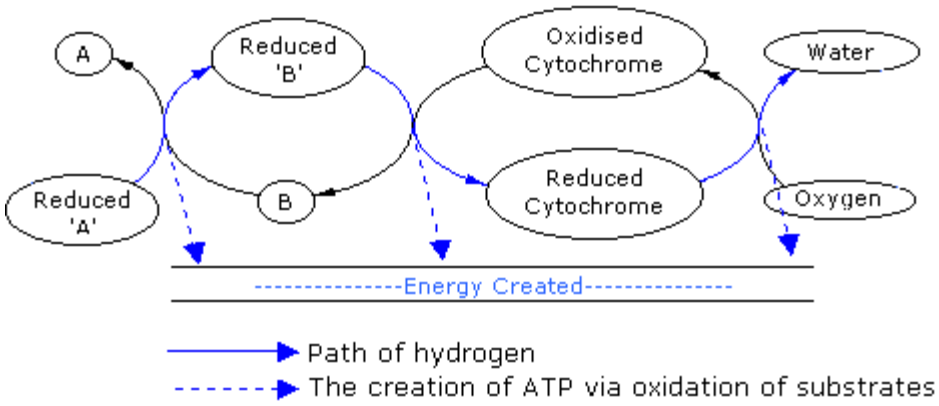
The Cytochrome System

The cytochrome system, also known as the hydrogen carrier system (or the *electron transport system*) are where the reduced hydrogen carriers transport hydrogen atoms from the glycolysis and Kreb's cycle stages. The cytochrome system is found in the many *cristae* of mitochondria, which are tiny stalked particles found on its outer layer.

The system contains many 'hydrogen acceptors' which hydrogen can be added to. By following the path of a hydrogen atom, we can see how the cytochrome system works:

- Some *coenzymes* from earlier stages (we shall call these A) are transferred to the next coenzymes (refer to them as B).
- B is then oxidised, therefore the coenzyme releases the hydrogen and energy is made available.
- The released hydrogen atom binds with 2 oxygen atoms (oxygen is available in aerobic respiration) which produces water, a by-product of respiration.

The diagram illustrates this flow of hydrogen within the cytochrome system and how energy is made available by the flow of these atoms. The green circles illustrate where energy is made available via oxidation.



Overall their is a gain of 38 ATP from one molecule of glucose in aerobic respiration. The food that we eat provides glucose required in respiration. In plants, energy is also acquired via respiration, but the mechanism of delivering glucose to the respiration process is a little different.

Photosynthesis is the process that plants undertake to create organic materials from carbon dioxide and water, with the help of sunlight- all of which is investigated on the next page of the tutorial.

Photosynthesis - Photolysis and Carbon Fixation

Photosynthesis is the means that primary producers (mostly plants) can obtain energy via light energy. The energy gained FROM light can be used in various processes mentioned below for the creation of energy that the plant will need to survive and grow.

Photosynthesis is a reduction process, where hydrogen is reduced by a coenzyme. This is in contrast to respiration where glucose is oxidised.

The process is split INTO two DISTINCT areas, *photolysis* (the photochemical stage) and the *Calvin Cycle* (the thermochemical stage). The diagram below gives a summary of the reaction, where light energy is used to initiate the reaction in its presence;

CO^2 + H^2O > glucose + oxygen

Photolysis

This part of photosynthesis occurs in the *granum* of *a chloroplast* where light is absorbed by *chlorophyll*; a type of photosynthetic pigment that converts the light to chemical energy. This reacts with water (H^2O) and splits the oxygen and hydrogen molecules apart.

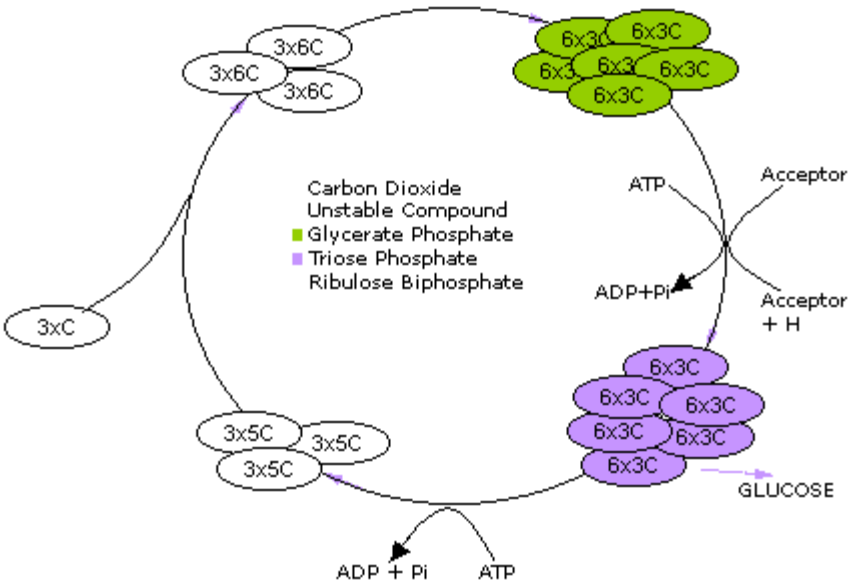
From this dissection of water, the oxygen is released as a by-product while the reduced hydrogen acceptor makes its way to the second stage of photosynthesis, the Calvin cycle.

Overall, since the water is oxidised (hydrogen is removed) and energy is gained in photolysis

which is required in the Calvin cycle

The Calvin Cycle

Also known as the carbon fixation stage, this part of the photosynthetic process occurs in the *stroma* of chloroplasts. The carbon made available FROM breathing in carbon dioxide enters this cycle, which is illustrated below:



Just like the *Kreb's Cycle* in respiration, a substrate is manipulated INTO various carbon compounds to produce energy. In the case of photosynthesis, the following steps occur, which create glucose for respiration FROM the carbon dioxide introduced INTO the cycle;

- Carbon FROM CO^2 enters the cycle combining with Ribulose Biphosphate (RuBP)
- A compound formed is unstable and breaks down FROM its 6 carbon nature to a 3 carbon compound called glycerate phosphate (GP)
- Energy is used to break down GP INTO triose phosphate, while a hydrogen acceptor reduces the compound therefore requiring energy
- Triose Phosphate is the end product of this, a 3 carbon compound which can double up to form glucose, which can be used in respiration.
- The cycle is completed when the leftover GP molecules are met with a carbon acceptor and then turned INTO RuBP, which is to be joined with the carbon dioxide molecules to re-begin the process.

The energy that is used up in the Calvin cycle is the energy that is made available during photolysis. The glucose that is made via GP can be used in respiration or a building block in forming *starch* and *cellulose*, materials that are commonly in demand in plants.

Limiting Factors in Photosynthesis

Some factors affect the rate of photosynthesis in plants, as follows

- *Temperature* plays a role in affecting the rate of photosynthesis. Enzymes involved in the photosynthetic process are directly affected by the temperature of the organism and its environment
- Light Intensity is also a *limiting factor*, if there is no sunlight, then the photolysis of water cannot occur without the light energy required.
- Carbon Dioxide concentration also plays a factor, due to the supplies of carbon dioxide required in the Calvin cycle stage.

Overall, this is how a plant produces energy which supplies a rich source of glucose for respiration and the building blocks for more complex materials. While animals get their energy FROM food, plants get their energy FROM the sun.

The next page investigates DNA structure and replication...

DNA Structure & DNA Replication

Previous pages in this tutorial have described the basics of a cell, the energy required by these cells and how energy is created in order for the cell to survive (via respiration and photosynthesis).

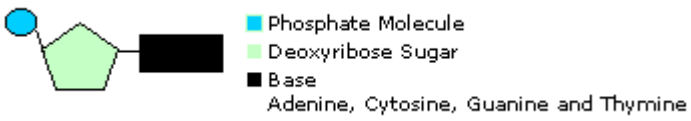
The structure, type and functions of a cell are all determined by *chromosomes* that are found in the *nucleus* of a cell. These chromosomes are composed of DNA, the acronym for deoxyribonucleic acid.

This DNA determines all the characteristics of an organism, and contains all the genetic material that makes us who we are. This information is passed on from generation to generation in a species so that the information within them can be passed on for the offspring to harness in their lifetime. The genetics and evolution tutorial goes into more detail about how this genetic information is passed on.

Structure of DNA and Nucleotides

DNA is arranged into a *double helix* structure where spirals of DNA are intertwined with one another continuously bending in on itself but never getting closer or further away (see diagram to the below right).

The following diagram illustrates a *nucleotide*, the building blocks of DNA

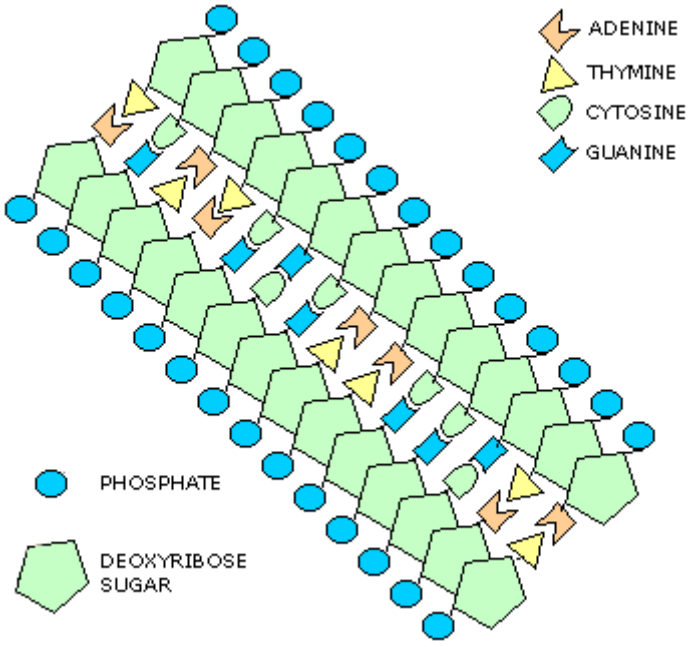


There are four different types of nucleotide possible in a DNA sequence, adenine, cytosine, guanine and thymine (can be replaced with A, C, G and T). There are billions of these nucleotides in our genome, and with all the possible permutations; this is what makes us unique. Nucleotides are situated in adjacent pairs in the double helix nature mentioned. The following rules apply in

regards to what nucleotides pair with one another.

- There are four possible types of nucleotide, adenine, cytosine, guanine and thymine.
- Thymine and adenine can only make up a base pair
- Guanine and cytosine can only make up a base pair
- Therefore, thymine and cytosine would NOT make up a base pair, as is the case with adenine and guanine.

This is illustrated in the below diagram, using correct pairings of nucleotides



The diagram is two dimensional, remember that DNA is structured in a double helix fashion, as shown to the above right. This continuous sequence, and the sequence they are in determine an organisms' structural, physical and anatomical features.

DNA Replication

Cells do not live forever, and in light of this, they must pass their genetic information on to new cells, and be able to replicate the DNA to be passed on to offspring. It is also required that fragments of DNA (genes) have to be copied to code for particular bodily function.

It is essential that the replication of it is EXACT. In order for replication to occur, the following must be available

- The actual DNA to act as an exact template
- A pool of relevant and freely available nucleotides
- A supply of the relevant enzymes to stimulate reaction
- ATP to provide energy for these reactions

When replicating, the double helix structure uncoils so that each strand of DNA can be exposed. When they uncoil, the nucleotides are exposed so that the freely available nucleotides can pair up

with them.

When all nucleotides are paired up with their new partners, they re-coil into the double helix. As there are two strands of DNA involved in replication, the first double helix produces 2 copies of itself via each strand.

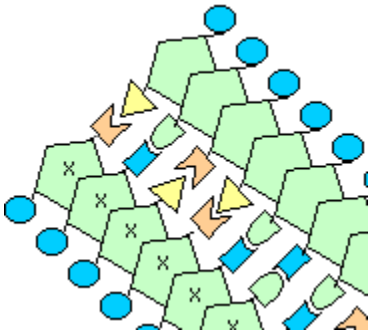
It is said that the replicated DNA is semi-conservative, because it possesses 50% of the original genetic material from its parent. These 2 new copies have the exact DNA that was in the previous one. This template technique allows genetic information to be passed from cell to cell and from parents to offspring.

The next page looks at protein synthesis, and how genetic information in a DNA strand can be used to code for a particular protein.

Protein Synthesis

If you have jumped straight to this page, you may wish to look at the previous page about DNA, which gives background information on protein synthesis.

As mentioned, a string of *nucleotides* represent the genetic information that makes us unique and the blueprint of who and what we are, and how we operate. Part of this genetic information is devoted to the synthesis of *proteins*, which are essential to our body and used in a variety of ways. Proteins are created from templates of information in our DNA, illustrated below:



The X marked nucleotides are an example of a DNA sequence that would be used to code for a particular protein, with the sequence of these nucleotides determining which protein it is.

The sequence of these nucleotides are used to create amino acids, where chains of *amino acids* form to make a protein.

mRNA

This genetic information is found in the nucleus, though protein synthesis actually occurs in *ribosomes* found in the *cytoplasm* and on rough endoplasmic reticulum. If protein is to be synthesised, then the genetic information in the *nucleus* must be transferred to these ribosomes.

This is done by *mRNA* (messenger ribonucleic acid). It is very similar to DNA, but fundamentally differs in two ways

- A base called *uracil replaces* all thymine bases in mRNA.
- The deoxyribose sugar in DNA in is *replaced* by ribose sugar in mRNA.

At the beginning of protein synthesis, just like DNA replication, the double helix structure of DNA uncoils in order for mRNA to replicate the genetic sequence responsible for the coding of a particular protein.

In the beginning, the DNA has uncoiled, allowing the mRNA to move in and transcribe (copy) the genetic information. If the code of DNA looks like this : G-G-C-A-T-T, then the mRNA would look like this C-C-G-U-A-A (remembering that uracil replaces thymine)

With the genetic information responsible for creating substances now available on the mRNA strand, the mRNA moves out of the nucleus and away from the DNA towards the ribosomes.

Read the next page to continue...

Role of Golgi Apparatus & Endoplasmic Reticulum in Protein Synthesis

Continued from the previous page that introduces protein synthesis...

mRNA and tRNA

mRNA leaves the nucleus and enters the *cytoplasm* where ribosomes can be found, the site of protein synthesis.

The mRNA strand is met in the ribosome by complimentary tRNA anticodons, which have opposing bases to that of the mRNA strand (the codons).

For example,
if the mRNA sequence is A-A-U-C-A-U, (codon)
then the tRNA sequence is U-U-A-G-U-A (anticodon)

Each *tRNA* molecule consists of 3 bases, deemed an *anticodon* which compliments the opposing bases on the mRNA strand. These in turn have the *amino acid* sequence to successfully code for a particular amino acid.

Each amino acid has a certain sequence of *bases* to make it unique. Therefore, as a summary:

- The initial DNA contained a certain sequence of nucleotides
- The mRNA has a pre-determined sequence (because it is transcribed from the DNA)
- Again, as a consequence the anticodons possess a pre-determined sequence due to the mRNA
- As each amino acid corresponds to a particular anticodon, a unique amino acid sequence

is created forming a protein

These amino acids (*peptides*) can combine to form a *polypeptide* chain (proteins), which are used in a variety of structures such as enzymes and hormones (explained in the next page [protein variety] page)

Ribosomes and Rough Endoplasmic Reticulum (RER)

Ribosomes are the site of protein synthesis, and can occur freely in the cytoplasm though more commonly on the outer surface of rough endoplasmic reticulum. The *endoplasmic reticulum* presents a large surface area on which these ribosomes can be situated, therefore allowing protein synthesis to occur on a large scale.

Rough endoplasmic reticulum is particularly abundant in growing cells which demand a high turnover of materials in its growth. Rough ER is responsible for transporting the newly synthesised proteins to the Golgi apparatus.

The Golgi Apparatus

The *Golgi apparatus* is composed of flattened fluid-filled sacs that controls the flow of molecules in a cell. This is also the case of protein. Carbohydrates are added to the protein to complete its production.

This finished product, glycoprotein, is 'pinched off' the Golgi apparatus, and is transported by a vesicle of the cell membrane. When this vesicle reaches the cell membrane, it binds to a receptor on the surface and excretes the protein, where it can then undergo its function.

These newly formed glycoproteins (proteins with added carbohydrates) are used in a variety of ways, and in light of this, there is a wide variety of proteins in relation to their function. This is investigated on the next page...

Protein Variety

As mentioned in the previous two pages investigating protein synthesis, each consists of a successive chain of amino acids. The sequence of these amino acids determine which type of protein it is. It is synthesised from a DNA strand, each DNA strand involved in protein synthesis is responsible for producing a unique protein.

Types of Protein

Over time and diversity of organisms, a huge amount of proteins exist and perform a unique function in the body. Primarily, their are three types of protein

- **Fibrous Proteins** - These fibre like proteins are used for structural purposes in organisms. This is because fibrous proteins are arranged in long strands and are insoluble in water. Examples of use include providing a barrier in the cell wall of plants and myosin in skeletal muscle
- **Globular Proteins** - The polypeptide chains (protein chains) in globular proteins are folded together into a knot like shape essential in the fact that are present in the following

  1. Enzymes - Biological catalysts, enzymes are responsible speeding up reactions in an organism
  2. Hormones - Hormones are chemical messengers responsible for initialising a response in organisms. Some hormones have a regulatory effect, explained in later chapters in the tutorial
  3. Antibodies - Antibodies are used to defend the body against foreign agents e.g. bacteria, fungi and viruses. The next page investigates these.
  4. Structural Protein - Globular proteins form part of the cell membrane, which has a structural role as well as a role in transporting ions in and out the cell.

- **Conjugated Proteins** - Conjugated proteins are essentially globular proteins that possess non-living substances, such as the haem found in haemoglobin, which possesses iron (a non-living substance)

Therefore proteins play a vital role in many of an organisms biological processes and their organs. The following page investigates cell defense against foreign agents, where proteins are playing their role in the form of antibodies...

Biological Viruses

The prime directive of all organisms is to reproduce and survive, which is also the case for viruses, which in most cases are considered a nuisance to humans.

Viruses - An Overview

Viruses possess both living and non-living characteristics. The unique characteristic that differentiates viruses from other organisms is the fact that they require other organisms to host themselves in order to survive, hence they are deemed *obligate parasites*.

Viruses can be spread in the following exemplar ways

- **Airborne** - Viruses that infect their hosts from the open air
- **Blood Borne** - Transmission of the virus between organisms when infected blood enters an organisms circulatory system
- **Contamination** - Caused from the consumption of materials by organisms such as water and food which have viruses within

Therefore viruses have many means of getting transmitted from one organism to another.

Cell Assimilation by a Virus

Viruses are tiny micro-organisms, and due to their size and simplicity, they are unable to replicate independently. Therefore, when a virus is situated in a host, it requires the means to reproduce before it dies out without producing more viruses.

This is done by altering the genetic make up of a cell to start coding for materials required to make more viruses. By altering the cell instructions, more viruses can be produced which in turn, can affect more cells and continue their existence as a species.

The following is a step by step guide of how an example bacteriophage (a virus that infects bacteria) takes control of its host cell and reproduces itself.

- The virus approaches the bacteria and attaches itself to the cell membrane
- The tail gives the virus the means to thrust its genetic information into the bacteria
- Nucleotides from the host are 'stolen' in order for the virus to create copies of itself
- The viral DNA alters the genetic coding of the host cell to create protein coats for the newly create viral DNA strands
- The viral DNA enters its DNA coat
- The cell is swollen with many copies of the original virus and bursts, allowing the viruses to attach themselves to other nearby cells
- The process begins all over again with many more viruses attacking the hosts' cells

Without a means of defence, the host that is under attack from the virus would soon die. The next page looks at how organisms defend themselves from these ruthless viruses.

Biological Cell Defense

Organisms must find a means of defence against antigens such a viruses described on the previous page. If this was not the case, bacteria, fungi and viruses would replicate out of control inside other organisms which would most likely already be extinct.

Therefore organisms employ many types of defence to stop this happening. Means of defence can be categorised into first and second lines of defence, with the first line usually having direct contact with the external environment.

First Lines of Defence

- *Skin* is an excellent line of defence because it provides an almost impenetrable biological **barrier** protecting the internal environment.
- *Lysozyme* is an enzyme found in tears and saliva that has **powerful digestive capabilities**, and can break down foreign agents to a harmless status before they enter the body.
- The **clotting of blood** near open wounds prevents an open space for antigens to easily enter the organism by coagulating the blood.
- *Mucus* and *cilia* found in the nose and throat can **catch** foreign agents entering these

open cavities then **sweep** them outside via coughing, sneezing and vomiting.
- The *cell wall* of plants consists of **fibrous** proteins which provide a **barrier** to potential parasites (antigens).

If these first lines of defence fail, then there are further defences found within the body to ensure that the foreign agent is **eliminated**.

Second Lines of Defence

Second lines of defence deal with antigens that have bypassed the first lines of defence and still remain a threat to the infected organism.

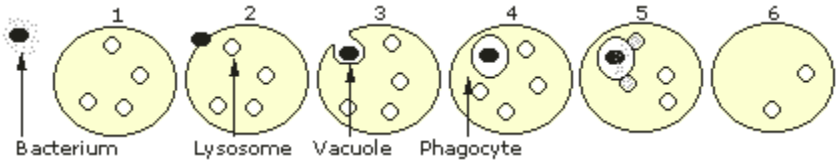
Interferons are a family of proteins that are released by a cell that is under attack by an antigen. These interferons attach themselves to *receptors* on the plasma membrane of other cells, effectively instructing it of the previous cells' situation.

This tells these neighbouring cells that an antigen is nearby and instructs them to begin coding for antiviral proteins, which upon action, defend the cell by shutting it down. In light of this, any invading antigen will not be able to replicated its DNA (or mRNA) and *protein coat* inside the cell, effectively preventing the spread of it in the organism. These antiviral proteins provide the organism with protection against a wide range of viruses.

This action brought about by interferon is a defensive measure, while *white blood cells* in the second line of defence in animals can provide a means of attacking these antigens.

One method of attacking antigens is by a method called *phagocytosis*, where the contents of the antigen are broken down by molecules called phagocytes.

These phagocytes contain digestive enzymes in their lysosomes (an organelle in phagocytes) such as lysozyme. White blood cells such as a *neutrophil* or a monocyte are capable of undergoing phagocytosis, which is illustrated below.



- The bacterium inside the cell gives out chemical messages that are picked up by the phagocyte.
- The bacteria targets the cell as a possible host and moves towards it.
- The cell is prepared for this and the bacterium becomes trapped in a vacuole that forms around it.
- The bacterium is a sitting duck that is harmless at present.
- The lysosomes detect the bacterium and the digestive enzymes inside them begin to break the bacterium down.
- The remnants of the lysosome and bacterium materials are absorbed into the cytoplasm.

The above illustrates one method of ridding an organism of an internal threat caused by an antigen. This is a non-specific response to an antigen. The next page looks at specific immunity

and focuses on plant defences.

Passive and Active Types of Immunity

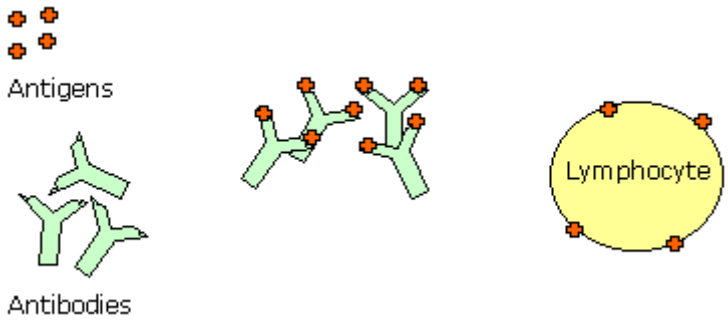
The previous page investigated the role of white blood cells in phagocytosis. *White blood cells* are also responsible for *antibody* formation. Certain antibodies are synthesised in response to the presence of certain *antigens*

Specific Immune Responses

Lymphocytes are a type of white blood cell capable of producing a *specific immune response* to unique antigens. Some of these lymphocytes are capable of entrapping antigens on their surface.

When lymphocytes catch these antigens they can then begin to code for unique antibodies, structures that are capable of catching these antigens.

The lymphocytes code for a particular antibody on response to a particular antigen. The antibody that is formed will be capable of catching free antigens therefore neutralising the threat as seen below.



B lymphocytes (B Cells) produce free moving antibodies as above while *T lymphocytes* (T Cells) produce antibodies on their surface.

Types of Immunity

When attacked an organism has several means in which it can prepare to defend itself in event of attack.

- *Active Immunity* - *Vaccines* are used for health purposes to expose our bodies to a particular antigen. These antigens are usually killed or severely weakened to decrease their potency. After destroying these pathogens, the body stores some T cells as memory cells, due to the fact they code for a particular antigen and can be when needed. This memory in T cells can be a means of artificially acquiring immunity while a genuine attack by a pathogen is a naturally acquired type of immunity.
- *Passive Immunity* - This is where immunity to particular antigens as a result of genetic

traits passed on from parents rendering the offspring immune to a particular pathogenic threat.

All of the information on this and the previous page are common methods of defence in red blooded animals, the following page investigates the defensive means of plants.

Plant Cell Defense

Hydrogen Peroxide

Plants release *hydrogen peroxide* in response to the presence of a fungal invasion, which attacks by piercing the cell wall of a plant and breaking it down.

This hydrogen peroxide (chemical symbol H^20^2) is a double edged sword in its defence against the antigen.

One Way : Hydrogen peroxide stops the breakdown of the cell wall

Certain pathogens will use pectinase, a digestive enzyme, to break down the cell wall barrier and invade the plant. The *pectinase* released by the fungus must be stopped. H^20^2 is involved in halting the action of this pectinase in the following example;

- The H^20^2 is created and moves to the cell wall - the site of the invasion.
- It reacts in contact with and enzyme called *peroxidase*, which promotes the breakdown of *pectinase*.
- The foreign chemical is rendered useless.
- Threat of the cell wall being compromised is removed.

Another Way : Some of the H^20^2 triggers the creation of phytoalexins

Phytoalexins are similar to the antiviral proteins previously mentioned as a secondary line of defence. Phytoalexins are a family of hormones that inhibit protein synthesis and thus "shut up shop" in the event of a pathogenic attack by halting the protein production process in our cells.

- Chemicals released by the fungus that are being used by it in its attack trigger a chemical response in the plasma membrane that makes the plant aware of the pathogens presence.
- Hydrogen peroxide from the plasma membrane triggers a chemical response to inform the nucleus of the infected cells of the current situation.
- mRNA from the nucleus is transported to ribosomes, as described in the protein synthesis section, where phytoalexins are to be produced (essentially protein synthesis coding for phytoalexins).
- The phytoalexins then take on a role similar to that of antiviral proteins, where the presence of a phytoalexin in a cell inhibits protein synthesis and therefore preventing growth of the foreign agent by removing all possible avenues of invasion for the pathogen, thus eliminating the threat.

Barriers Used by Plants in Defence

Lignin is a strong type of molecule that provides plants with a defensive structure similar to that of fibrous proteins. It acts as a barrier and can be found in wood and is characteristically found in plants that have recently endured pathogen attack.

Callose seals off sieve plates in the plant, effectively shutting off the transport of molecules around the organism. This is done to minimise the chance of the plant transporting infectious material around its own self, and halting the movement of materials that could be used by the pathogen in aid of replicating itself.

Ethylene promotes leaf abscission, and is done to sever the plant of dead or dying plant matter. This is done to prevent the spread of infected material, therefore sacrificing infected sections of plant is more economical than taking the risk of the infection spreading.

Galls and *tannins* are created by the plant to encapsulate foreign agents found within the plant. A gall is an instance where an infected cell becomes inflamed that contains tannins. These tannins play a protective role by segregating the foreign agent and its chemicals from the rest of the plant

All of the four previous pages have illustrated means of self defence against *pathogens* (fungi, viruses and bacteria).