A Level Biology

The Second Year

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Energy & ATP

Keywords

- ATP
- activation energy
- ADP
- phosphorylation
- enzyme
- substrate
- glucose

ATP Structure

ATP is a nucleotide which itself is made up of an organic base, a five carbon sugar and phosphate groups.

Generic nucleotide:

- Organic base
- Pentose sugar
- Phosphate groups

ATP (Adenosine triphosphate)

- Adenine (Organic base)
- Ribose (Pentose sugar)
- three phosphate groups

ATP Importance

If the body released energy from glucose in a manner which was not controlled then it would cause cell death. This is because the uncontrolled increase in temperature leads to an increase in temperature which destroys cells.

To overcome this issue organisms use gradual energy release in order to produce ATP. To do this ADP is converted to ATP by the addition of a phosphate molecule. This process also uses up energy so the reaction is referred to as endergonic. The amount of energy needed to add a phosphate molecule to ADP is 30 kJ per mol, these phosphate groups are held together by high energy bonds.

Reversing this process is what releases energy - the ATP can be hydrolysed into ADP and phosphate in an exergonic reaction as energy is released. The hydrolysis of ATP into ADP is catalysed by the enzyme ATP-ase. Removing the phosphate group releases the same amount of (free) energy as was stored, 30 kJ per mol. When the additional phosphate is removed it can be transferred to another molecule making it more reactive and therefore lowering the activation energy of the new molecule.

Phosphorylation is the addition of a phosphate group. Here

it is ADP that is phosphorylated into ATP. In all there are three forms of phosphorylation:

- Oxidative Phosphorylation - Substrate-level phosphorylation - Photophosphorylation

Oxidative phosphorylation occurs on the membranes of mitochondria in aerobic respiration. This process also involves electron transport.

Photophosphorylation occurs on the membranes of chloroplasts since it is the type of phosphorylation that occurs in plants. Photophosphorylation is a part of photosynthesis.

Substrate-level phosphorylation occurs when the phosphate groups are taken from 'donor' molecules and transferred onto ADP to make ATP.

ATP Roles

ATP is involved in a variety of biological processes from movement through muscle contraction to the synthesis of materials needed by cells. It useful for creating large and complex molecules from much smaller and far simpler ones. For example ATP is used in the synthesis of polypeptides from amino acids and DNA from nucleotides. ATP is also used in active transport because it requires energy to move molecules up or against a concentration gradient. Specifically to change the shape of carrier proteins in the

cells plasma membrane. Cells also use ATP for secretion - the ATP is used for the packaging of secretory products into vesicles. But ATP is also used in larger, more complex systems than just single cells. It is also involved in Nerve transmission, powering sodium-potassium pumps which actively transport potassium ions across the plasma membrane.

ATP Uses

In using ATP as an intermediary between glucose and energy organisms benefit from several advantages.

- ATP Releases energy in small amounts when and where they are needed, conversely glucose contains large amounts of energy that are most likely not required immediately - this also prevents cell destruction from the excess heat that the energy in glucose would produce.
- ATP provides a common source of energy of a wide range of biological processes and chemical reactions. This is why it is sometimes referred to as the universal energy currency. Using ATP this way increases efficiency and give more control to the cell.
- To release energy from glucose a large number of enzymes are needed, this is not the case with ATP for which only one enzyme is required.

Respiration

Keywords

- Glycolysis
- Link
- Krebs
- Electron transport
- decarboxylated
- dehydrogenated
- decarboxylation
- dehydrogenation
- ATP
- ADP
- NAD
- FAD
- pyruvate
- acetyl CoA
- final electron acceptor
- chemiosmotic
- concentration gradient

Glycolysis

Glycolysis is the first stage of respiration and it occurs in the cytoplasm of the cell. The glucose molecule is firstly

combined with two ATP molecules to form hexose phosphate. This 'activates' the glucose and makes in more reactive. The hexose phosphate is then split into two molecules of triose phosphate. Triose phosphate is a three carbon sugar whilst hexose phosphate is a six carbon molecule.

Then the triose phosphate is converted into pyruvate through the removal of hydrogen. The removed hydrogen reduced a molecule of NAD to form reduced NAD which is often written as NADH. I doing this enough energy is released for the synthesis of four ATP molecules, this ATP is formed by substrate level phosphorylation. However the net gain of ATP molecules as a result of Glycolysis is only two as two ATP molecules are required at the beginning of the process to activate glucose.

The molecules of NADH that are produced during glycolysis have the potential to produce six further molecules of ATP provided that the conditions for aerobic respiration are maintained.

Link Reaction

After glycolysis energy is still stored in the pyruvate molecules that are produced as a result of glycolysis. This energy however can only be released in aerobic respiration and through the Krebs cycle. To join together the Krebs cycle and glycolysis there is another reaction called Link.

In the Link reaction pyruvate diffuses from the cytoplasm

to the mitochondrial matrix where it is first decarboxylated before it is dehydrogenated. Decarboxylation is the removal of carbon dioxide and dehydrogenation is the removal of hydrogen. The hydrogen released from the dehydrogenation of pyruvate is accepted by NAD to form reduced NAD (NADH).

This forms a two carbon acetate which binds with coenzyme A to form acetyl coenzyme A. It is the Acetyl CoA which enters the Krebs cycle.

Krebs Cycle

The acetyl CoA from glycolysis enters the Krebs cycle by combining with the four carbon acid RuBP to form a six carbon compound. As a result of this reaction the CoA is regenerated so that it can be used again (binding with acetate in the link reaction). This six carbon compound which is produced goes through a series of reactions during which carbon dioxide is removed (via decarboxylation) and hydrogen is removed (via dehydrogenation). As a result of the acetate fragment breaking down a four carbon molecule is left over which is converted in order to regenerate the original four carbon RuBP which combines with more acetyl CoA to keep the kerbs cycle going.

Two steps in the cycle involve decarboxylation whilst their are a total of four stages which involve the dehydrogenation of a molecule. The hydrogens which are produced are ‘collected’ by molecules of NAD to form three molecules of

reduced NAD and also by FAD to form only one molecule of reduced FAD.

Although there are a large number of steps in the krebs cycle the final amount of ATP produced in one loop of the cycle is just one molecule. Therefore from one pyruvate molecule entering the Krebs cycle the products are:

- one molecule of ATP - one molecule of reduced FAD - three molecules of reduced NAD

Note though that two pyruvate molecules are produced as a result of glycolysis so in fact two ATP molecules of ATP are produced from glycolysis products. Because two molecules of pyruvate (and therefore two molecules of acetyl CoA) enter the cycle it is carried out twice for every one molecule of glucose.

The Krebs cycle only produces one molecule of reduced FAD because there is only one place where FAD acts as a carrier molecule.

The purpose of the Krebs cycle is to allow access to the energy stored in the carbon bonds so that ATP and reduced NAD as well as reduced FAD can be formed. These carrier molecules (NAD and FAD) transport hydrogen to the electron transport chain in the inner mitochondrial membrane where they act as triggers for the start of the electron transport process. As a result of breaking the carbon bonds carbon dioxide is released from the system from decarboxlylation.

Electron Transport

Electron transport involves the transportation of electrons through a series of pumps and carriers which releases energy as an ATP molecule. The hydrogen atoms bound to reduced NAD and FAD are used in the electron transport chain. NAD and FAD are in fact coenzymes. It is the electrons in the hydrogen atoms that are the source of energy.

In the electron transport chain is the initial acceptor then for every two hydrogen atoms that are brought into the system enough energy is gained to allow the synthesis of three ATP molecules to occur. When FAD is the initial acceptor only two molecules of ATP are produced this is due to there being no pump associated with FAD so only two pumps out of a possible three are involved reducing the amount of ATP molecules produced to the number of pumps (two).

In order to explain the synthesis of ATP using the electron transport chain a model known as Chemiosmotic theory is used. This theory proposes that the energy for ATP synthesis is provided by an electrochemical gradient of protons across a cell membrane.

Chemiosmotic theory states that Hydrogen atoms first combine with NAD reducing it. This reduced NAD then 'donates' the electrons of the hydrogen atoms it carries to the first pump in the chain. This reoxidises the NAD and releases protons into the matrix of the mitochondrion. The

pump then pumps the protons into the inter membrane space. The electrons with a reduced energy level are then transferred by a carrier to the next pump along in the chain. This pump pumps more protons into the inter membrane space causing a build up of of proteins there. This high concentration builds because the inner membrane of the mitochondrion is impenetrable to protons except for at certain points. An example of one of these points is where the ATP synthase molecules is located. This 'channel' formed by the ATP synthase allows the protons to diffuse back into the matrix. It is the diffusion of protons through this channel that causes the ATP synthase to combine inorganic phosphate molecules with ADP in order to synthesise ATP.

The last pump in the electron transport chain has no where to move it's electrons too so instead they are bound to oxygen which combines with some of the protons to form a molecule of water in a reaction catalysed by an oxidase enzyme. This means that the final electron acceptor of the entire process is oxygen, without it protons would build up in the matrix reducing the concentration gradient between the matrix and the inter membrane space until the concentration gradient become no existent at which point no ATP would be produced.

This complete process is just phosphorylation. More specifically it is oxidative phosphorylation. It occurs on the membranes of the mitochondrion because the membranes have a large surface area on which the chemical reactions and processes that make up respiration can take place. It is

the Cristae of the mitochondrion which is lined with ATP synthase enzymes which actually produce the ATP.

Anaerobic Respiration

Anaerobic respiration is the the process of respiration that occurs in conditions where there is an absence of oxygen. Because of the absence of oxygen only glycolysis can take place. Both the link reaction and the Krebs cycle can not be carried out this is because the reduced NAD and FAD cannot be oxidised again - this means that they cannot pick up more hydrogen. Because of this the amount of ATP produced from one molecule of glucose falls all the way from thirty-eight to just two.

The anaerobic respiration which leads to the production of ethanol occurs in some microorganisms and also some higher plants such as water logged root cells. The anaerobic respiration which leads to the production of lactic acid occurs primarily in muscle tissue and is the result of heavy excersise.

The first of these anaerobic conditions is useful, it takes place in yeast to produce alcohol and carbon dioxide. This process is a fermentation. After glycolysis the pyruvate produced is decarboxylated (producing carbon dioxide) into ethanal. NAD still accepts the hydrogen released during glycolysis it is then transferred to the ethanal which causes it to be reduced into ethanol - also known as alcohol.

The second aerobic condition produces lactic acid in muscle tissue. The second condition occurs when not enough oxygen can reach muscle cells, this prevents them from producing the ATP they need by aerobic respiration so they can only use the ATP produced by glycolysis. The reduced NAD from glycolysis in this situation gives up its hydrogen atom to the pyruvate which causes it to reduced into lactate - which is lactic acid. It is this lactic acid which causes muscle cramps. At the point where aerobic respiration can start again the lactic acid will be broken down by the liver and converted into glycogen as an energy store for future use.

Budget for Energy

In order to budget for the amount of energy you need it is important to know exactly how many ATP molecules are produced from the breakdown of only one molecule of glucose.

In glycolysis a net total of two ATP molecules is produced. This is because two out of the maximum four produced are reused for the initial activation of the glucose molecule. Glycolysis also produces two reduced NAD molecules which have the potential to produce six more molecules of ATP through aerobic respiration.

The link reaction produces six molecules of ATP

Krebs cycle produces twenty-four molecules of ATP of

which two are made from substrate level phosphorylation.

Therefore the total amount of ATP produced from just one molecule of glucose is thirty-eight.

Respiratory Substrates

Sometimes a different respiratory substrate than glucose is used. Both proteins and fats can also be used as alternative respiratory substrates.

Fats are used as an energy store in many organisms and can also be used as a respiratory substrate when levels of carbohydrates of which glucose is an example fall too low. In order to be used the lipid has to be split into its individual components; glycerol and three fatty acids. This is done by hydrolysis after which the glycerol is converted into a three carbon sugar which allows it to enter the Krebs cycle through triose phosphate. The remaining fatty acid chains are long and can be broken down into a number of two carbon fragments which enter the respiration pathway as acetyl CoA. Because the fatty acid chains can vary in length the number of ATP molecules that can be produced also varies.

Because it is possible to produce such a large number of ATP molecules from a lipid one gram of fat certainly releases more that two times the energy of one gram of carbohydrate.

It is also possible to use proteins as a respiratory substrate

but only in extreme circumstances. An example of such an extreme circumstance is starvation. As a result of starvation tissue protein is used to supply energy as the energy provided in the diet is too little to be useful. In digestion the protein component of food is diverted to be used as an alternative respiratory substrate. The protein is first converted into the amino acids that make it up through the process of hydrolysation. It then travels to the liver where it is deaminated, that is the amine groups of the amino acids are removed. The removed amine groups are converted into urea and excreted and the residue is converted into either acetyl CoA, pyruvate of another of the Krebs cycle intermediaries so that it can enter the cycle. Using protein as a respiratory substrate is generally a last resort when both carbohydrate and fat resources have run out.

Photosynthesis

Keywords

- photosynthesis
- light-dependant
- light-independent
- Engelmann
- spectra
- pigments
- chlorophylls
- carotenoids
- Caroteins
- xanthophyll
- accessory pigments
- photophosphorylation

Pigments in photosynthesis

White light is a mixture of different wavelengths and in photosynthesis these different wavelengths of light are trapped by a number of different pigments. There are two main types of pigments in angiosperms (flowering plants). They are chlorophylls and carotenoids - the chlorophylls absorb light which is primarily in the in the red end of the

spectrum whilst carotenoids absorb wavelengths which are primarily in the blue end of the spectrum.

The carotenoid group can be split into a further two pigments, carotenes and Xanthophylls. These act as accessory pigments as opposed to primary pigments such as chlorophyll a.

Spectra

The important photosynthesis spectra are the absorption spectrum and the action spectrum. Both graphs are usually drawn together for easy comparison.

It can be shown that the different photosynthetic pigments absorb different wavelengths by preparing various pigment solutions and shining a light on them. The absorption spectrum is a graph that indicates how much light a given pigment absorbs in this situation. For example the graph shows that chlorophyll absorbs light at the red end of the spectrum - this can be seen on the graph by the peak at the end furthest from the y-axis. Similarly plotting the absorption spectrum for the other pigments produces a number of graphs with peaks at different points along the spectrum. Though this is useful for determining what wavelengths are being absorbed and by which pigments the data can not be used to determine if a particular light wavelength is actually used in the process of photosynthesis. A more useful graph for this purpose is the action spectrum. The action spectrum graph shows the rate of photosynthesis at

different wavelengths of light. More specifically it could be said that it shows the amount of carbohydrate that is produced by the plant when it is exposed to a given wavelength of light. Since carbohydrates are an eventual product of photosynthesis it can be used to determine which wavelengths of light are in fact used in photosynthesis.

The two graphs are easily compared as they are usually drawn together, if you were to compare the two it would show a correlation between the absorption and action spectra which gives the conclusion that the pigments are responsible for absorbing the wavelengths of light used in photosynthesis.

Note: It's probably better to say that the pigments absorb light 'energy' that absorb light. They actually absorb photons which are packets of light.

Use the light Luke

The photons of light from the light source (more often than not - the sun) are said to be 'harvested'. This harvesting is performed by photosystems of which there are two - photosystem one and photosystem two. These are sometimes referred to as PS700 and PS680 respectively. The numbers refer to the peak absorption wavelength of each photosystem. Both photosystems are formed around a molecule of chlorophyll a which is the reaction centre of the photosystem, surrounding the chlorophyll in a 'funnel'

are the accessory pigments clustered together in groups of many hundred molecules in the thylakoid membranes of chloroplasts. These groups are referred to as antenna complexes. Associated with each pigment is a protein which aids in the 'funnelling' of the photons in the chloroplast. In this way the pigments pass the absorbed energy from one molecule to the next through the antenna complex until it reaches the reaction centre - a molecule of chlorophyll a.

Phase 1 - Light Dependant

The light independent phase of photosynthesis involves several sub-processes. Photolysis - which is the splitting of water molecules using energy from photons (light) to produce hydrogen ions and electrons. The reduction of NADP into reduced NADP (NADPH) and finally the synthesis of ATP from ADP and inorganic phosphate as in respiration. Since plants make use of light energy in this process the type of phosphorylation is photophosphorylation.

The process starts when photons of light hit a photosystem they pass down to the primary pigment, chlorophyll a. The energy from the photon excites electrons in the molecule of chlorophyll causing them to gain energy and move to a higher energy level. This creates a movement of electrons which can be described as the Z-scheme because of the way the electrons change energy levels can be drawn as a sideways Z. The ATP produced by this process is made in one of two ways much like there is aerobic and anaerobic

respiration in photosynthesis there is cyclic and non-cyclic photophosphorylation. It is non-cyclic photophosphorylation which usually occurs.

Non-cyclic photophosphorylation involves both photosystem one and photosystem two. Photosystem two absorbs the photons first, the photons pass down the antenna complex to the reaction centre. This excites two electrons form chlorophyll a into a high energy state. This allows them to be picked up by electron acceptors, these electrons then get passed along a chain to electron carriers to photosystem one. On the way to photosystem one they also pass through a proton pump passing some of their energy to the pump as well as losing energy to each electron acceptor. The energy lost by the electrons along this chain is used to synthesise ATP from ADP. Photosystem one also absorbs some photons of light - again causing the excitement of two electrons into a higher energy state and allowing them to be accepted by another electron acceptor. Because photosystem two lost electrons at the start of the process the molecule of chlorophyll a in its reaction centre is now unstable, in order to re-stabilise the molecule electrons from photolysis (the splitting of water) are used. Photolysis causes water to be split into hydrogen, oxygen and electrons.

The electron acceptor which received electrons from photosystem one releases some of its electrons to the Hydrogen ions which are found outside the thylakoid membrane. This allows them to join with NADP to form reduced NADP. These electrons never return to a molecule of chlorophyll

so the system is non-cyclic.

Cyclic phosphorylation on the other hand only makes used of photosystem one. As in non-cyclic photophosphorylation the light energy is absorbed by the photosystem and passed to the chlorophyll a at the reaction centre. The second electron acceptor again accepts the high energy electrons created as a result of this, the electrons which are not used to produced reduced NADP by passing them to Hydrogen ions outside the thylakoid membrane are returned to photosystem one by passing along a chain of electron acceptors. The energy generated as a result of this 'passing around' of electrons is used to synthesise ATP.

Note though that cyclic photophosphorylation does not produced reduced NADP.

All the reactions of the light dependant phase of photosynthesis occur within the thylakoid membrane of the chloroplast. As the electrons are moving from one photosystem to another they pass though a proton pump which pumps protons from within the stroma across the membrane and into the thylakoid space. Like in respiration this creates an electrochemical gradient because of the build up of hydrogen ions in the thylakoid space. This electrochemical gradient forces hydrogen ions to diffuse back across the membrane through protein channels which provides energy to the ATP synthase to produce ATP from ADP and phosphate. The ATP as well as the NADP that is produced in this phase is used later on in the light dependant phase also.

Phase 2 - Light Independent

The light independent phase of photosynthesis makes used of the products from the light dependant phase - ATP and NADP. It occurs in the stroma of chloroplasts and involves a series of enzyme catalysed reactions which use ATP as a source of energy and NADP to reduce carbon dioxide in order to synthesise hexose sugar.

The light independent stage of photosynthesis is often referred to as the calvin cycle and was discovered by a scientist called Calvin and his associates Benson and Bassham using radioactive carbon 14 and the alga Chlorella. The cycle starts with a five carbon molecule called RuBP which acts as an acceptor molecule combining with carbon dioxide to form an unstable six carbon compound in a reaction that is catalysed by the enzyme RuBisCo. Because this six carbon compound is unstable it splits immediately into two molecules of GP. This molecule of GP is the phosphorylated by ATP and reduced by NADP into triose phosphate (TP). Some of the TP can be removed from the cycle and built into glucose phosphate and starch by condensation. However in order for the cycle to continue some of the TP must be reused. This is done by regenerating RuBP from the TP through a series of ATP powered reactions. The NADP is also remade and returns to the light dependant phase so that it can be reduced, and the reused again.

Synthesis

The TP that is removed from the light independent phase of photosynthesis (the calvin cycle) is metabolised into a number of products such as carbohydrates, proteins and lipids with which the plant can make all the chemicals it needs to live. However some inorganic ions which are nutrients needed by the plant can be a limiting factor in metabolism should they become in short supply.

Macronutrients such as magnesium, calcium and nitrogen are also required are needed in small amounts. Micronutrients such as copper and manganese are needed in much smaller amounts.

Nitrogen is taken into the plant by the roots in the form of nitrates. These nitrates are transported in the xylem and as amino acids in the phloem. Nitrogen is used for the synthesis of proteins and nucleic acids like DNA and RNA. If a plant has a nitrogen deficiency it shows symptoms such as reduced growth and chlorosis. Chlorosis is the yellowing of the leaves caused by a drop in chlorophyll production. (Chlorosis appears first in old leaves). Magnesium forms part of the chlorophyll molecule and is absorbed as magnesium ions. All of the plants tissues require magnesium because it also actives ATPase - it is transported as ions in the xylem. Magnesium deficiency can also lead to chlorosis which occurs between the veins of old leaves because existing magnesium is diverted towards newly formed leaves where it can be best put to use.

Photoperiodism

Keywords

- photoperiodism
- photoperiod
- phytochrome
- Pr
- Pfr
- short day
- long day
- day neutral

Introduction

Plants do not have a nervous system, as a result of this plants responses to stimuli are slow. Plants use chemicals which are similar to hormones to respond to the changes in their environment. One response is photoperiodism. Photoperiodism is response that triggeres the flowering process in some plants based on the length of night compared to daylight.

Types of Plant

Angiosperms (flowering plants) can be subdivided into groups based on the photoperiod which causes them to flower. There are day neutral plants whose flowering is unaffected by day length, Long-day plants (or short night plants) flower when the length of night (or dark period) is shorter than a specific length and the opposite - short day plants (or long night plants) which begin flowering when the dark period is greater than a specific length.

Phytochrome

Plants contain very small qunatities of a blue/green pigment phytochrome. Is is this photoreceptor which allows plants to measure day length. There are two forms of phytochrome, both absorb light and can be converted between the two forms. When light of a specific wavelength is absorbed each type of phytochrome changes into the other. The two forms are phytochrome 660 and phytochrome 730. The numbers indicate the wavelength of light each absorbs, 660nm light is red and 730nm is far red (almost infrared) light. phytochrome 660 is often written as Pr for red light and phytochrome 730 as Pfr for far red light.

Pfr (phytochrome 730) is unstable and eventually changes back into Pr (phytochrome 660) this process happens at night time because their is an absence of red light which would cause the Pr to become Pfr. As a result of this

breakdown the amount of Pr builds up. Since sunlight consists of more red light (660 nm) than far red light (730 nm) Pfr builds up during daylight hours.

This build up of each type of pythochrome can then be compared to determine the length of the day and trigger flowering, or not. The flowering process is thought to be started by a hormone referred to as florigen however florigen is a hypothetical hormone so not very much is known about it, even if it defininetly exists.

The photoperiod is measured by the leaves of a plant and then a message must be sent to the buds which then flower.

Photoperiodism

In short day plants the flowering process is triggered by far red light - that is they will flower when the levels of Pfr are sufficiently low whilst red light exposure prevents flowering from starting. For long day plants however high levels of Pfr are the trigger for flowering.

The whole photoperiod (which is usually a days long ie.e 24 hours) can be interupted by short dark periods and long day plants will still flower however if the dark period is interupted by exposure to red light flowering does not occur.

Microbiology

Keywords

- Bacillus
- Cocci
- Spirillum
- gram negative/positive
- Aseptic
- fermenter
- Batch culture
- Secondary metabolite

Classification

The term 'microorganism' covers a wide range of groups including fungi, Protoctists, Viruses and of course bacteria.

Bacteria can be classified in one of two ways either by their shape or by their reaction to the Gram staining process. Bacteria can be one of three shapes - spherical, rod shaped or spiral shaped. More scientifically they can either be Bacillus (rod shaped), Cocci (spherical) or Spirillum (screw) shaped. So for example Streptococcus is spherical because it is a Cocci.

The Gram staining process divides bacteria into two groups, gram positive or gram negative. The difference is caused by the structure of the bacterium's cell wall. A bacterium's cell wall is composed of polysaccharides and polypeptides known as murein or peptidoglycan. The polysaccharides are crossed linked to give the cell wall strength and shape it also prevents the cell from bursting (lysis) as a result of osmosis. The cell wall of bacteria which are gram negative is much more complex than that of gram positive bacteria. This is because the peptidoglycan is 'assisted' by liposaccharide molecules which protect the cell. This prevents the cell wall from retaining the crystal violet dye and causes them to be stained by the counter-stain so that they appear red/pink when they are viewed under a microscope. Gram positive bacteria lack the liposaccharide and so become stained by the crystal violet. This makes them purple under the microscope!

Gram-negative bacteria are not affected by the enzyme lysozyme which is antibacterial and is a component of our tears. Similarly they are also resistant to penicillin, unlike gram-positive bacteria which are far more susceptible to antibiotics (and lysozyme).

Growing

Micro-organisms are well known for their ability to reproduce quickly. In optimum conditions bacteria can divide in two every twenty minutes. They can also be grown in the

Lab on a variety of mediums given the right conditions.

Different micro-organisms require different conditions to grow optimally but can grow over a range of variables. In order to grow the conditions required include:

- a suitable pH, bacteria prefer a ph or 7.4 which is slightly alkaline whilst other micro-organisms like fungi prefer slightly acidic conditions.
- a suitable temperature, growth is normally regulated by a number of enzymes which can be denatured by high temperatures or inhibited by cold temperatures. The majority of bacteria grow in the temperature range of 25-45 degrees centigrade whilst pathogens (disease causing micro-organisms) have an optimum of 37 degrees centigrade which just so happens to also be our body temperature!
- Nutrients - Nitrogen, carbon (as glucose usually), vitamins and mineral salts. In a Lab setting the nutrients are often provided by the media in/on which the bacteria are grown such as agar.
- Oxygen - Most micro-organisms are 'obligate aerobes' and require oxygen for metabolism whilst others may grow better with oxygen but do not require it (these are 'facultative anaerobes'). Some can not grow in Oxygen at all such as *Clostridium* bacteria which is an 'obligate anaerobe'. *Clostridium* in fact cause the condition moist gangrene by destroying body tissue as a result of producing toxins in a wound.

Once the micro-organisms have been growing for some time the size of the microorganism population can be measured. This can be done either through a indirect method such as the 'cloudiness' of a culture (in other words its turbidity) or through a direct method such as a Total count or a Viable count. Total counts include both living and dead bacterium whilst viable counts only count the number of living 'viable' cells.

It is of course very difficult to count a large population of microorganisms so the culture is diluted and the result of counting the small sample of cells is multiplied to find the total population size. This gives a population density measured in organisms per centimetre cubed. The dilution is called a serial dilution - a serial dilution dilutes a culture by a factor of 10 each time.

Growth can be measured in many ways. One method is to make rough estimates by measuring the diameter of the colony from a central point. Then there is serial dilution (mentioned above), when a serial dilution is performed the assumption is made that the separate colonies of bacteria originated from a single cell through asexual reproduction. A more accurate method however is the hemocytometer which uses a specialised microscope slide to give total cell counts.

Technique

Aseptic techniques are techniques used to keep apparatus and other equipment sterile and free from microorganisms. This prevents both the bacterial cultures themselves and the environment from becoming contaminated.

To avoid contaminating pure cultures with other bacteria which may be found free in the environment all apparatus and the growing media should be sterilised before use and the cultures should be handled carefully making use of tools like sterile loops to prevent any later contamination.

To avoid contaminating the environment with experimental bacteria the contamination of people including yourself and the immediate environment i.e. the rest of the Lab must be prevented through correct handling of cultures. Also work surfaces should be sterilised before and after use with disinfectant. The most commonly used method for sterilising equipment is an autoclave. This is a [sealed] container into which equipment is placed before being heated to 121 degrees centigrade for 15 minutes whilst under steam pressure. This method ensures that even bacteria such as Clostridium (a gram positive bacteria) and other resistant endospores which are resistant to boiling are destroyed. Other materials can also be placed in the autoclave before disposal such as petri dishes.

Commercially however it is more likely that radiation will be used for the sterilisation process.

Note: Endospores are internal resting cells which protect

nuclear material through unfavourable conditions such as high temperature. When better conditions occur the endospore can form back into a bacterial cell.

Fermentation

Industrial fermentation is the process used to culture bacteria and fungi on a large scale, such as in the production of antibiotics like penicillin. There are several advantages for making use of microbes in the fermentation process. Mainly it is because the microbes grow quickly and lower temperatures can be used because enzymes do not have to be supplied which brings down cost.

A batch culture fermentation starts with a pure culture of the microorganism so that a pure product is harvested at the end. A batch culture fermenter is inoculated with the culture and the fermenter provides the suitable conditions for growth without competition so that the process can operate at maximum efficiency. As part of providing these ideal conditions forced aeration may also be used. Forced aeration has the added benefit of mixing the mixture improving the organisms contact with nutrients though this can also be done with a dedicated mixer.

Numerous conditions such as temperature and pH are also monitored be sophisticated monitors so that conditions can be controlled. For example air inlets may have spargers which allow for improved aeration. The temperature is also

controlled by a water jacket which removes excess heat produced during the entire process.

A good example of industrial fermentation is penicillin production. Penicillin is a secondary metabolite produced by the fungus Penicillium notatum. The Penicillium grows in the optimal conditions provided by the batch culture fermenter and after around 30 hours penicillin is produced (it is not produced immediately because it is a secondary metabolite) and the concentration of penicillin in the medium increases. Approximately a week later the culture fluid is extracted and then purified to give pure penicillin. The fermenter then has to be re-sterilised so that it can be used again - hence it is called batch fermentation.

Antibiotics are often secondary metabolites. They are produced when the organism such as Penicillium's life cycle reaches the point where conditions begin to change away from the optimum.

Continuous cultivation is the better method for collecting products which are primary metabolites. This is because continuous cultivation allows for production to continue for a longer period of time. This is the products. Insulin is one product which is produced this way.

Cycles

Keywords

- Nitrogen
- Carbon
- saprobionts
- fossil rules
- nucleic acid
- putrefaction
- nitrification
- Denitrification

The Carbon Cycle

The carbon cycle is the flow of carbon through living organisms and the environment.

Carbon dioxide is added to the air by the respiration of animals, micro-organisms and plants and naturally the burning of fossil fuels such as oil and coal.

For plants however the process of photosynthesis uses up a large amount (almost all) of the carbon dioxide that is released by the plant into the atmosphere. Plants use carbon for the production of carbohydrates, fats and proteins

which contributes to plant growth and therefore animal growth as we move up the food chain.

When plants and animals die their dead 'bodies' are acted on by saprobionts. Saprobionts are micro-organisms which obtain their food from the decaying remains of other organisms. These are found in the soil and release carbon dioxide as a gas back into the atmosphere.

For a long time the level of carbon dioxide globally in the atmosphere has risen. This is mainly because of human activities like burning fossil fuels and deforestation which removes a large number of photosynthesising species so less carbon dioxide can be removed from the atmosphere.

The Nitrogen Cycle

Like the carbon cycle the nitrogen cycle is the flow of nitrogen (both organic and inorganic) through organisms and their environment. Within the cycle there is an interchange between nitrogenous compounds which are solid an gaseous atmospheric nitrogen.

Nitrogen is used within living organisms to make amino acids which in turn are built up into proteins. Nitrogen is also used to produce nucleic acids; DNA and RNA.

Since neither plants nor animals can make use of gaseous nitrogen they must get their nitrogen source from a different compound. Plants get their nitrogen by taking in nitrates in solution through their roots. The organic nitrogen

which is then produced by plants is transferred to other organisms in the food chain when the plants are are eaten by animals.

As with carbon when plants and animals die the nitrogen remains 'locked' in their bodies and so must be decomposed along with excrement in order to release the nitrogen back into the soil.

The first process in the nitrogen cycle is Putrefaction. Putrefaction is where bacteria and fungi (which are decomposers) break down dead plants, animals and their excretory products into ammonium ions (which is why the process is sometimes also referred to as ammonification. Following this the ammonia is converted into nitrates (though nitrites) in the process of nitrification. Examples of the involved bacteria include Nitrosomonas which converts ammonium to nitrite and Nitrobacter which converts nitrite to nitrate. Both of these conversions require aerobic conditions.

The atmospheric nitrogen can also be converted straight into nitrogen compounds through a number of Nitrogen fixation methods. One is Lightning but there is also free living bacteria like Azotobacter which account for the majority of nitrogen fixation. Another bacteria is the symbiotic Rhizobium which is found in legumes (beans, peas and clover) which provide nitrogen to the plant as well as releasing some back into the soil.

Nitrogen can also be released back into the atmosphere through denitrification which involves more bacteria this

time in anaerobic conditions like water logged soil. Pseudomonas is one such bacteria that can reduce nitrates and ammonium (ions) back into nitrogen.

We can however improve nitrogen circulation through our farming practices. Planing clover fields encourages nitrogen fixation while ploughing fields aerates the soil to create aerobic conditions. Similarly draining land that is water logged reduces anaerobic conditions too. Farmers can also use the large amount of animal waste from the rearing of livestock as manure.

There are other ways that we can improve nitrogen too. We can fix atmospheric nitrogen ourselves using the Haber process to convert it into fertiliser. More microorganisms can also be used for making compost and finally sewage disposal increases the supply of organic nitrogen.

Populations

Keywords

- immigrate
- emigrate
- lag phase
- exponential phase
- stationary phase
- death phase
- density dependant
- density independent
- pesticides
- resistance

Controlling Population Growth

At any time, for any population the size of the population is found from the birth rate and death rate (though also organisms can immigrate into the population or emigrate out).

When a species encounters an area which it can colonise it grows following the S shaped curve which is typical for any new species. The S shape is caused by three components of the population growth. The first is the lag phase - when

a species first starts to colonise an area there are few individuals so growth is slow and the organisms must adapt and prepare to grow for example by synthesising enzymes and other metabolic activity. Following the lag phase is the exponential phase. The exponential phase occurs as the populations number increases and as long as their is no factor which might limit population growth more and more of the population starts to reproduce this causes the population to grown exponentially like an eˆx graph - though this can not be continued forever. Eventually the population has to stop growing, when it does it enters the stationary phase. During this phase the number of births is equal to the number of deaths and the population has reached its largest possible size. The largest size population can reach in an environment is known as the carrying capacity of that environment. After the stationary phase is the death phase, this is when the death rate is greater than the birth rate - it usually occurs when all the food has been used up.

The environment can also 'resist' population growth. This resistance includes a number of factors which affect population size such as disease, the weather or the build up of toxic waste. All of these factors slow down population growth.

Some factors may also cause the population to 'crash' such as density independent factors which affect all the organisms in an environment regardless of the population size. These effects are usually caused by a sudden change

in an abiotic factor like the breakout of a wildfire. Other factors are those which are density dependant and whose effect increases along with the size of the population. One such example of this is the loss of a food supply. The carrying capacity of the environment as mentioned above is caused by density dependant factors.

Naturally population sizes vary rather than remain constant. Whilst these variations are not often large and do not occur at random intervals then the population size of a species remains close to an equilibrium position - this is the carrying capacity of the environment and if the populations numbers increase above this value then a density dependant factor acts to limit the population growth either by increasing the death rate or reducing breeding rate. When the population falls back below the equilibrium position the density dependant factor no longer affects the growth rate allowing the number to increase once again. Population variations usually occur in line with another pattern such as the season cycle (Spring - Summer - Autumn - Winter) or amount of rainfall. Therefore it is said that population variation is a process regulated by negative feedback.

Negative feedback is where a monitored variable changes causing a response to be triggered and the result of the response counteracts the action which first affected the monitored variable.

Competition

In an environment plants and animals often have to struggle to survive. For plants the competition is often for space and nutrients (including water) as well as light. Animals also compete for space along with food and shelter. Often animals are also in competition for mates.

There are two different types of competition. Interspecific competition and intraspecific competition. The later is competition between individuals which are members of the same species. Such competition is dependant on density as when the population increases more members of the population do not survive. This is important because most organisms produce far more offspring than their habitat can support. If an organism is better adapted then it is more likely to win the competition and so survive.

Interspecific competition on the other hand occurs between members of a different species. Collectively each species occupies a given niche, this is the role that it carries out in the environment as well as the space it takes up. Two species can not occupy the same niche, one has to win.

Fighting Pests

A pest is any organisms which competes with or adversely affects a population of organisms that are important economically. These pests are usually fought with pesticides,

these are chemicals which are used to control organisms which spread disease such as mosquitos or those which damage farmers crops.

When pests attack crops and animals the result is a reduction in yield and a devastating economic loss to the farmer whose crops or animals were attacked. These pests are constantly competing with crop organisms for resources and can cause disease in 'helpful' organisms which usually live on the crop. They often make infection through pathogens more likely and can spoil food which is in transit or whilst the food is in storage.

If a pest is causing a large amount of because it is present in very large numbers then it is worth the farmers while to spend money on controlling the pest.

When controlling pests either of chemical or biological control can be used. Chemical control is the use of pesticides or insecticides which are designed to kill insects (or less commonly herbicides and fungicides) , this method has both its advantages and disadvantages.

The advantages of chemical control are that it is very effective - the pests population is controlled very quickly and at a comparatively low cost. It can also be applied on a small scale such as just one of the farmers fields. The chemicals can be sprayed onto the crop or applied as smokes in enclosed areas, even powders. The chemicals can also be applied to animals by being added to animal feed or sprayed directly onto the animal itself. None of these application methods require a high level of skill or

understanding, another advantage.

There are a number of disadvantages as well. A big problem when using pesticides is that the pest you are attempting to control can become resistant to the pesticide. This is where the organism becomes able to survive a dose of the chemical which would under normal conditions be lethal. Over exposure the these chemicals can also be hazardous to humans as well. Generally the chemicals which are used as pesticides are not specific enough and therefore can also kill off 'helpful' insects such as bees. They can also kill fish, birds and mammals by contamination of the food chain.

Likewise the use of biological controls where the inter-specific competition between a predator and it's prey is used to control the pest population also has advantages and disadvantages.

Firstly biological control can repair some of the damage done by chemical control methods such as allowing a resurgence of 'helpful' species. They are also usually highly specific to one pest (with the notable exception of the cane toad). In order to work correctly biological control methods must target one pest and not do any other damage to the ecosystem. Unlike chemical control biological control can also provide a long term pest control solution provided that a population equilibrium becomes established. This makes them suited to a wide range of environments including greenhouses (glasshouses). However unlike chemical control biological methods have high initial research cost so in the short term is an expensive solution though it becomes

cheaper as time passes.

The cost of biological control is also a disadvantage because of the frequent input needed to attain a balance and the high level of skill and knowledge required - such as knowing the detailed knowledge of the pests life cycle. This is due to the potential to release an organism (like the cane toad) which can itself become a pest after it exhausts its food supply or causes damage to the ecosystem. Because of this there are only a few success stories and we do not know the control agent for a large number of our existing pest problems.

Biological controls are also currently of little use to individuals except for in greenhouse/glasshouse scenarios because biological control introduction needs to be carried out on a large scale.

Biological controls work because the abundance of prey is a factor limiting the number of its predators, in a given food chain the predator-prey relationship causes the population of both predator and prey to vary. We have been making use of this relationship to control pests. A beneficial organism is released as a predator to the undesirable pest. The aim of biological control is to reduce the pest population to a sensible level at which they no longer cause any economic damage. Sometime insect parasites are used and sometimes microorganisms are used. Pests have always been regulated by their natural predators (they can have several) however through farming we have upset the system e.g. by creating large fields and removing hedges which reduced or in some

cases removes the natural habitat for predators.

Due to both methods having a number of advantages and disadvantages it is often considered that the best solution is to use a combination of biological and chemical control even though there have been some improvement in chemical pesticides like pyrethroids and organophosphates. These combined methods include producing pest resistant crops, changing cultivation techniques and the use of highly targeted chemicals. Such a solution is often referred to as an integrated pest control solution.

Control Systems

Keywords

- homeostasis
- negative feedback
- thermoregulation
- osmoregulation
- nitrogenous
- urea
- ultrafiltration
- selective reabsorption
- ADH
- pituitary gland
- metabolic water
- ultrafiltration
- Bowman's capsule
- basement membrane

Homeostasis

Homeostasis is by definition the maintaining of a consistent environment within a (living) organism. For example blood sugar concentration, kidney function and temperature are all maintained.

A self regulating system works on the principal of negative feedback. For any variable that needs to be controlled there is a set point which is the desired value for the variable and the one at which the system operates. This variable is monitored by a sensor which triggers when the variable deviates from the desired value. When a receptor detects a change from the normal it despatches instructions to a co-ordinator. This co-ordinator then in turn communicates with a number of effectors which carry out processes to correct the variable. Once the corrections have been effected and the variables value is at the desired value then the sensor is informed - this causes the detector to 'reset' and the process can begin again. This is what happened in most biological control systems.

The Kidney

The kidney performs two important functions. The first is the removal of nitrogenous waste from the body. There are three forms of nitrogenous waste. Urea which comes from amino acids, Uric acid which is from Nucleic acids and Creatinine from Creatine phosphate which is an energy store in muscles.

In humans it is urea that is produced. This is because the ammonia which is first produced is highly toxic so it is converted to urea which is less toxic and also soluble in water so we can remove it in our urine. If we have too much protein in our diet the excess has to be broken down

as we cannot store them. This happens in the liver where the amino acids which make up proteins are deaminated - removing their amine group. This forms ammonia which is quickly converted to urea so it can be removed.

The urea is produced by reacting deaminated amino acids with oxygen to produce ammonia which is added to carbon dioxide to crate urea. The other product of this process is keto acid which is converted into pyruvic acid (pyruvate) for use in respiration or is converted into fat for storage.

Unlike us birds produce thick urine made up of uric acid which is more complex than urea and therefore takes more energy to produce - it is also less toxic. Birds produce 'solid' urine because they carry very little water at it is heavy.

We have two kidneys which filter waste products from the blood. Both kidneys are made up of approximately one million seminiferous tubules which called nephrons. Each nephron contains a Bowman's capsule within which is a number of capillaries known collectively as the glomerulus. Blood is supplied to the nephron through the afferent arteriole, from the glomerulus the blood is taken by the efferent arteriole to two other separate capillary systems.

These capillary networks are the one which runs along beside the loop of Henle called the vasa recta and the capillary network serving the the proximal and distal convoluted tubules.

Ultrafiltration

Ultrafiltration is the process that occurs in the kidneys to remove small soluble molecules from blood plasma. It occurs under high pressure, hence the name ultrafiltration. Through ultrafiltration water, glucose, urea and various salts pass from the capillaries in the glomerulus to the Bowman's capsule. This fluid is known as glomerular filtrate or primary urine. From the Bowman's capsule the fluid passes through the proximal convoluted tubule and the loop on Henle, through the distal convoluted tubule into the collecting duct. By the time the fluid reaches the collecting duct it is no longer glomerular filtrate, it is urine.

The blood which enters the glomerulus is separated from the Bowman's capsule by a basement membrane through which only small molecules can pass - leaving large plasma proteins in the blood plasma. Proteins do however sometimes appear in urine - this is a symptom of high blood pressure as the pressure can force the large plasma proteins through the basement membrane. Damage to the basement membrane can also allow red blood cells into urine though it is more likely that the blood entered the urine from somewhere else.

The glomerulus is 'designed' specifically for ultrafiltration to take place. With the basement membrane acting as a 'sieve' between the capillaries and the nephron and two cell layers. The first cell layer is the actual wall of the capillary within which there are a number of small gaps then there

is the basement membrane which is sandwiched between the first layer and another layer which makes up the wall of the Bowman's capsule - this layer also has special epithelial cells known as podocytes.

The pressure that allows ultrafiltration to happen is primarily supplied by the hydrostatic pressure of the blood in the capillaries of the glomerulus. This pressure is increased due to the small diameter of the efferent arteriole and also due to the water potential of the blood due to the colloidal plasma proteins. This means that the pressure within the glomerulus can be varied by varying the diameter of either of the efferent or afferent arterioles.

Reabsorption

Of all the materials which were originally removed from the blood through ultrafiltration only all of the glucose is reabsorbed most of the salts and water are also reabsorbed into the blood. What is left over is urine which passes to the bladder.

This process occurs as the glomerular filtrate flows through the nephron. The glucose and water are reabsorbed in the proximal convoluted tubule though a small amount of water is also reabsorbed in the distal convoluted tubule along with some salts. Any remaining water is absorbed by the collecting duct in a process with the loop of Henle. Glucose and salts are reabsorbed by active transport whilst

the water is passively absorbed by osmosis after the salt is removed.

The purpose of the loop of Henle is to collectively concentrate salts in the medulla of the kidney, specifically within the tissue fluid. This high concentration of salt then causes an osmotic flow of water which passes from the collecting ducts. This acts to concentrate the urine and make it hypertonic in comparison with the blood. The loop of Henle works on a principle known as the hair-pin counter-current multiplier. As the fluid flows through the ascending limb of the loop sodium and chlorine ions are pumped from the limb to the surrounding medulla thereby creating a low water potential at the apex of the loop. Because the ascending limp is impermeable to water relative to the descending limb water leaves the glomerular filtrate from the descending limb at which point it is taken away by blood in the vasa recta. This causes the fluid in the descending limb to become more and more concentrated and the fluid flowing through the ascending limb to become more and more dilute. Altogether the large number of loops create a region of low water potential in the medulla so that as the collecting ducts carrying urine pass through the medulla water passes out through osmosis allowing the counter current mechanism to act as a fine control for osmoregulation.

In the proximal convoluted tubule the cells are adapted for absorption by having microvilli and a large number of mitochondria. The large number of mitochondria are re-

quired to provide ATP (from respiration which takes place within the mitochondrion) for active transport whilst the microvilli create a large surface area over which absorption can take place.

Osmoregulation

Osmoregulation is the homeostatic control of body water. Like most of the processes involved in homeostasis osmoregulation relies an a system of negative feedback. There are several components to the system, the first is the receptors responsible for detecting the change in water level - these are located in the hypothalamus at the base of the brain. Second is the posterior lobe of the pituitary which acts as the co-ordinator of the system and thirdly the collecting ducts of the kidneys which are the effectors; acting to change the water level.

Like the walls of the distal convoluted tubule the permeability of the collecting ducts can also be controlled by hormones. This hormone control alongside the build up of hypertonic (interstitial) fluids in the medulla from the loop of Henle is the factor which controls wether or not the body releases hypertonic or hypotonic urine.

ADH is the hormone which controls the permeability of the collecting duct walls. It makes the walls permeable so that water is reabsorbed. The result of this is that the urine has a concentration which is similar to that of other body fluids, i.e. it is hypertonic to them. Water reabsorption is

controlled by a feedback system, negative feedback acts to restore the normal osmotic concentration should the blood become more diluted or similarly if it becomes more concentrated.

There are several things that may cause a drop in the water potential of blood, excessive sweating, high salt intake and reduced water consumption. The level of salt (sodium chloride) in the blood is an indication of the volume of water in the body, it it this that the hypothalamus is sensitive to. If the water level in the blood is low osmotic receptors detect the drop in water potential which triggers nerve impulses which travel to the posterior pituitary gland. As a result of the nerve impulses the gland releases ADH into the blood. The ADH increases the distal convoluted tubule's and the collecting duct's permeability to water. This increase in permeability means more water is reabsorbed from these tubules into the region of high solute concentration found in the medulla from where it is reabsorbed into the blood such that the small volume of urine eventually released is concentrated.

Adaptations for Environments

Different animals produce different types of nitrogenous waste and so have different waste disposal mechanisms. The animals environment has a large role in the type of nitrogenous waste that is produced. For example aquatic organisms such as fish produce ammonia which is highly

toxic to us and also to fish however since fish are surrounded by water the ammonia can diffuse out of the fish across the gills where it is quickly diluted to a safe level.

Birds and insects on the other hand excrete uric acid which is almost entirely insoluble. It is also non-toxic unlike ammonia and urea. It does however have a large energy 'cost' associated with the process which produces it. The advantage to the bird is that little to no water is required for it to be excreted. This is important as it means that the animal can survive in dry environments and conserve water. For birds it also makes them lighter as the have to carry less heavy water around.

Mammals such as ourselves excrete urea in our urine. To produce urea does require energy but not as much as that which is required to produce uric acid. It is also less toxic than the ammonia which fish produce and so it can be kept in our tissues in higher concentrations albeit for only short periods of time.

In order for mammals to live in deserts and other arid conditions they have adapted to have the loop of Henle which has a large role in water absorption (see reabsorption in earlier in this section). The longer a mammals loop of Henle the greater the solute concentration that can build up in the medulla and also the greater amount of water that can be reabsorbed. The result is highly concentrated urine. Some mammals like the kangaroo rat have particularly long loops of Henle.

To survive with little or even no water some animals

must depend upon metabolic water. This metabolic water is produced by the breakdown of food reserves during respiration. Alongside this desert animals live underground during the day, their burrows are cool and humid so they lose less water through evaporation.

Nervous System

Keywords

- stimuli
- CNS
- effector
- receptor
- reflex
- hydra
- sensory
- motor
- relay
- action potential
- depolarised
- synapse
- photoperiodism
- phytochrome

Components

The nervous system consists of a number of components. Receptors - of which there are many including the specialised cells found in the skin and whole organs such as the eye. These receptors detect changes in the body or

within the surrounding environment. Receptors act much like transducers since they convert one form of energy into another. At the heart of the entire system is the central nervous system, consisting of the brain and spinal cord which processes the information provided to it by the receptors and starts a response. This is done via the sending of nerve impulses which can carry information towards or away from the central nervous system.

The actual muscle or gland which creates the change or response is referred to as the effector.

Reflex

A reflex is an involuntary response to a stimulus. Involuntary responses such as moving away from a hot surface are involuntary as the brain is not involved in the process.

A reflex is a series of events which form a 'reflex arc'. A reflex arc consists of a stimulus - the event which causes the response e.g. walking into a door. This event is detected by receptors which in the case of walking into a door are a number of pain receptors. The receptors are linked with sensory neurones which send signals to the spinal cord where a relay neurone joins it to a motor neurone which, in turn sends impulses to effectors such as muscles or glands eventually causing a response.

Lots of day-to-day actions are reflex actions since they are done without thinking. Swallowing and blinking are

examples but there are a large number of reflexes which serve to protect us such e.g. by preventing (skin) burning on a hot surface.

Although the brain is not normally involved in reflexes it can become involved and can modify the usual response. The brain does this through inhibitory nerve fibres and usually when it has extra 'data' available to it - such as a sound. So that the brain can intervene in reflexes the impulses that create them can also travel to the brain through ascending nerve fibres that originate in the spinal cord's grey matter.

Nerve Nets

The term Hydra refers to the genus of simple (and small) fresh-water dwelling animals which have radial symmetry. Radial symmetry is the property that an organisms has no left or right side - just a top and bottom.

Since hydra are 'simple' (though complicated in that they show morphallaxis and not senescence - they can regenerate and appear not to age) they do not have as many receptors and effectors as humans do. In general human senses are complex and require varying responses from different organs. Hydra on the other hand lack proper muscles and a brain. For this reason the nervous system of hydra is referred to as a nerve net. This nerve net is made up of nerve cells with short extensions joining them together

and connecting touch sensitive cells in the body wall and tentacles as well as photoreceptors.

The resulting system results in very slow nerve impulse transmission.

Neurones

Neurones are specialised cells designed to generate and then transmit action potentials (impulses) which consist of an electrical charge. In all there are three types of neurone. Sensory neurones - these carry impulses from the sensory organ to the central nervous system. Connecting neurones or relay neurones which receive the nerve impulses from the sensory neurones or intermediate neurones and passes the impulse to other relay neurones or to motor neurones. Motor neurones carry the nerve impulse from the central nervous system to the effector organ which is either a gland or a muscle.

All of the different neurone types are made up of a cell body, dendrites and axons. The cell body like most cells has a nucleus and a cytoplasm. The cytoplasm of a neurone has lots of ribosomes within it. These are groped together into Nissl granules which work to form neurotransmitter substances. Dendrites are short extensions which carry the impulse towards the cell body. Axons on the other hand carry impulses away from the cell body and are long, often myelinated extensions of the cytoplasm. The end of an axon is branched to form synapses with other neurones. Axons

are surrounded by Schwann cells which produce myelin (a lipid) which protects the axon and insulates it - hence they are referred to as myelinated. This myelin sheath is multilayered and speeds up the transmission of nervous impulses - it has at intervals a thin area called a node of ranvier which also assists in the transmission of impulses. The myelin sheath is only found in the nervous system of vertebrates.

Impulse

A nerve impulse consists of a minute electric charge of around 50 millivolts. Nerve impulses can be measured from the nerve using microelectrodes connected to a standard oscilloscope, this allows measurements to be taken of transmission speed and also to allow us to look at impulse patterns in nervous systems. It is the neurones which transmit the electrical impulses around an animal. Neurones do this by sending the electrical impulse along the membrane of the cell surface which covers the axon.

When nerves are not transmitting signals they are resting but are prepared to send a signal all of the time. This is done through the generation of resting potentials. When an axon is resting its inside is negative compared with the outside. This difference in charge occurs from the result of actively transporting sodium ions and potassium ions across the membrane. This process requires ATP as the ions are moving against a concentration gradient. Because of the

need for ATP and therefore oxygen, respiratory inhibitors and suffocation can damage the nervous system, particularly the brain. The sodium and potassium ions are both pumped across the membrane by proteins called sodium-potassium exchange pumps. The pumps work continuously in order to maintain the concentration of ions across the membrane.

The sodium ions are pumped out at an increased rate compared with the speed that the potassium ions are pumped in. Though both ions are positive the potassium ions diffuse out faster than the sodium ions diffuse in which creates a slight negative change inside the membrane because of the outward flow of positively charged potassium ions.

This process polarises the membrane because the net result is that the outside becomes slightly positive and the inside slightly negative.

Action Potential

The action potential is the change in the axon membranes potential difference that occurs when a nerve impulses is transmitted over that section of the membrane. When a nervous impulse begins the resting potential of the membrane changes. These changes are caused by changes in the permeability of the membrane to sodium ions which results in changes in the potential difference across the membrane - depolarising the membrane and starting an action potential. Action potentials last for approximately

3 milliseconds where the membrane is depolarised. The change in charge on the inside of the membrane is as large as from -70 mV to +40 mV. After the action potential has passed the membrane is returned to its resting potential i.e. it is re-polarised. The repolarisation is caused by the outward diffusion of potassium ions, initially too many potassium ions diffuse out but this is balanced out by the sodium/potassium pumps. Whilst this is occurring the membrane can not respond to another action potential so the frequency of the nerve impulse is limited as is its direction. The time delay is known as the refactory period.

Synapses

Where neurones meet there are often chemical synapses. The purpose of the synapses is to transmit action potentials between neurones. Synapses along with the refractory period ensure that the nervous impulse can only travel in one direction. The impulse can only travel in one direction because the synaptic vesicles containing the neurotransmitter are only found in the presynaptic knob and the corresponding receptors in the postsynaptic membrane. Synapses also serve two other important purposes - protection of the nervous system from overstimulation and to filter out low level stimuli. The nervous system is protected from overstimulation because of the time taken for the neurotransmitter to be regenerated, if synapse is repeatedly stimulated the neurotransmitter will run out - preventing

the impulse from crossing the synapse and so preventing a response.

The gap of a synapse, or the size of the synaptic cleft is approximately 20 micro meters across. When the action potential reaches the synaptic knob it causes voltage gated calcium channels to open. This causes Calcium ions to enter the cell and activate enzymes which move the synaptic vesicles containing the neurotransmitter to the presynaptic membrane where they fuse releasing the neurotransmitter in to the synaptic cleft. The neurotransmitter diffuses across the space and binds with receptors in the postsynaptic membrane. These receptors are ligand gated channels which open and cause sodium ions to enter the postsynaptic membrane. This in turn depolarises the cell, triggering the action potential again in the new neurone (as in sensory neurones the action potential is only restarted if the membrane becomes depolarised enough).

The neurotransmitter (e.g. Acetylcholine) is removed by enzymes in the synaptic cleft, this helps to prevent nerve impulses from 'colliding'. If too little of the neurotransmitter is released then the postsynaptic membrane is not stimulated and the action potential stops at the synapse. When acetylcholine is broken down it becomes ethanoic acid and choline. These molecules can diffuse across the presynaptic membrane to form Acetylcholine. This is a process which requires ATP - not only for regenerating the neurotransmitter but also for storing it back into vesicles.

Drugs

Some drugs can cause an increase in activity at the synapses. Often these drugs pretend to be naturally occurring neurotransmitters. For example a drug shaped like acetylcholine, a neurotransmitter in humans and other animals would effect the postsynaptic membrane in the same way as acetylcholine does (causing sodium ligend-gated channels to open). Other times drugs inhibit the enzymes which usually break down the neurotransmitter e.g. acetylcholinesterase.

Drugs affecting the nervous system can be classified as one of two types, excitory or inhibitory. Drugs which affect the central nervous system are referred to as Psychoactive drugs. This is because the alter brain functionality and can often change a persons mood and behaviour. There are many psychoactive drugs and they are for the most part, illegal e.g cannabis, ecstasy, heroine and cocaine. Originally many psychoactive drugs were developed for medicinal purposes, cannabis for example.

Excitory Drugs are those which cause an increase in the number of action potentials in the postsynaptic membrane whilst inhibitory drugs are those which reduce the number of action potentials that occur.

Continuing with the acetylcholine example - there are insecticides containing organophosphate compounds (some of which are now banned in the UK) which block the neurotransmitter break-down enzyme after they bind with the receptors of the post synaptic membrane this makes the

neurotransmitter last far longer than it would normally. Other organophosphate compounds like Sarin are used as chemical weapons because of their nerve agent properties. In humans preventing the action of cholinesterase causes the acetylcholine molecules to remain in the synaptic cleft resulting in repeated action potentials in the postsynaptic neurone. If this occurs at a neuromuscular junction then the muscle undergoes repeated contractions.

All or Nothing

No matter how large the stimulus the impulse that travels along the nerve always remains the same size. To judge how large a stimulus is (e.g. temperature) the frequency of the generated action potentials should be counted instead. Strong stimuli produce high frequency action potentials whist weak stimuli produce very few action potentials. It may even be that the stimulus is so weak that it doesn't initiate an action potential in the first place.

Once the action potential is generated it travels along the nerve, the speed at which it does this depends on two factors. The first is the axons diameter. If the axon has a large diameter the speed of the transmission will be larger whilst smaller axons reduce the speed of the impulse. Squid have large axons (thought to be needed for rapid escape from predators) that are visible to the human eye and are therefore useful for experiments. The other factor affecting nerve transmission speed is Myelination. Myelin insulates

the axon of the nerve cell so that action potentials can not occur in the myelinated portions of the nerve, only at the nodes of Ranvier. The result of this myelination is that the impulse only has to travel a short distance, skipping out the myelinated sections of the axon - a process called saltatory conduction.

Recap

Homeostasis (Recap)

- Homeostasis is the maintaining of a constant internal environment.
- Homeostasis uses negative feedback to produce an opposing change.
- The removal of metabolic waste products from the body is excretion.
- Different organisms produced different excretory products.
- The kidneys are the primary organism of the urinary system.
- Kidneys are made up of a number of nephrons.
- Within the kidneys small molecules pass are filtered from the blood through ultrafiltration.
- ultrafiltration takes place in the glomerulus.
- The product of ultrafiltration is glomerular filtrate.
- glomerular filtrate passes through the nephron and as it does so is converted to urine.
- Throughout this process substances which are needed are reabsorbed through selective reabsorption.
- The water potential of the blood is monitored by Osmoregulators.

- The osmoregulators are located in the hypothalamus.
- The reabsorption of water is controlled by the hormone ADH.
- ADH is secreted from the pituitary gland.

Microbiology (Recap)

- Bacteria can be classified with two methods, their shape, their reaction to the gram staining process. - In optimum conditions (which vary from bacteria to bacteria) bacteria can divide every 20 minutes. - Bacteria are cultured in a sterile environment using sterile techniques. - Bacteria can be counted with a viable count (living cells) or a total count (living and dead). - To get a sample of bacteria that can be counted a serial dilution must be used.
- Bacteria and fungi can be cultivated on an industrial scale.
- One example of this is the production of penicillin.
- Penicillin is produced by batch fermentation.
- Penicillin is a secondary metabolite.
- Secondary metabolites are only produced when the organisms is ‘stressed’ e.g when nutrients become depleted.
- On the sigmoid growth curve for bacteria this would be just as the log phase transitions into the stationary phase.

Nervous System (Recap)

- The nervous system is what controls an organisms actions.
- The nervous system detects stimuli through receptors.
- From the information received from receptors the system starts responses whcih are carried out by effectors.
- Receptors, neurones (motor, sensory and relay) and effectors form a reflex arc.
- Nerve transmission is caused by an action potential.
- This action potential is produced by changes in the permeability of the axon membrane to sodium ions.
- Both the diameter of the axon and the presence of the myelin sheath affect impulse tranmission speed.
- Synaptic transmission is affected by a number of drugs.
- The transfer of information between neurons happens through the secretion of a neurotransmitter across synapses.

Photoperiodism (Recap)

- Plant responses are slower than animal responses.
- Plant responses only involve hormones.
- Photoperiodism is the reponse of plants to the length of daylight and darkness.

- Photoperiodism involves a light *sensitive pigment known as phytochrome.
- Phytochrome exists in two forms.
- The relative amount of each form of phytochrome in each form is used by the plant to measure the day length.

Photosynthesis (Recap)

- Photosynthesis is the process by which plants synthesise organic molecules from carbon dioxide and water using energy provided by photons.
- Photosynthesis takes place in the chloroplast of the plant cell.
- In the chloroplasts are photosystems.
- These consist of Photosynthetic pigments grouped together.
- These are known as antenna complexes.
- These antenna complexes funnel photons of light to the reaction centre.
- The reaction centre consists of a molecule of chlorophyll a
- The absorption of the photons energy by the reaction centre causes two of chlorophyll a's electrons to become excited and move to a higher energy state.
- These electrons are then passed to a series of electron acceptors

- This results in the formation of ATP by photophosphorylation (since light is used)
- This is known as the light dependant phase of photosynthesis.
- It takes place entirely in the chloroplasts thylakoid membrane.
- The products of this (ATP and NADP) are used in the light independent phase.
- The light independent phase takes place in the stroma.
- As part of this carbon dioxide is fixed to convert it into carbohydrate using the products of the light dependant phase.
- The synthesis of ATP occurs in both cyclic and non-cyclic photophosphorylation.
- Photolysis takes place to replace lost electrons in chlorophyll.

Populations (Recap)

- A populations size is increased by birth and immigration.
- A populations size is decreased by death and emigration.
- A populations maximum size is determined by both the carrying capacity of the environment and environmental resistance.
- Population changes can be dependant or independent on density.

- A given population follows a pattern of growth that if graphed gives an S-shape curve.
- Pests can be controlled by either chemical or biological methods.
- Both methods have a number of advantages and disadvantages.
- In the nitrogen cycle several bacteria play an important role (which are they?)
- Organisms which are involved in the cycling of nutrients within ecosystems and referred to as decomposers.

Respiration (Recap)

- Respiration is a series of reactions which take place within the cells of organisms.
- As a result of these reactions energy is released from organic molecules like glucose.
- The energy released has the form of ATP.
- ATP is made form a molecule of ADP and Pi.
- In order to add phosphate group to a molecule a phosphorlylation must take place.
- Respiration consists of four stages. – Glycolysis – The Link reaction – The Krebs cycle – The electron transport chain
- Glycolysis is the first step. – Glycolysis takes place in the cytoplasm. – Involves splitting glucose into

pyruvate. – This process releases ATP (net gain 2) and reduced NAD (NADH)

- The link reaction follows glycolysis – The link reaction converts pyruvate into Acetyl CoA which enters the mitochondrion to be in the Krebs cycle.
- The Krebs cycle produces ATP and Carbon Dioxide – It is carried out twice for each glucose molecule.
- The Krebs cycle also produces reduced electron carriers – These carriers take electrons to the electron transport chain.
- The electron transport chain uses the energy provided by electrons to pump protons across the membrane of the mitochondrion. – It creates an electrochemical gradient – This allows ATP to be produced by ATP synthase – This is called oxidative phosphorylation
- For each molecule of glucose 37/38 ATP molecules can be produced.
- Anaerobic respiration only produces 2 ATP molecules for each glucose.

BY4 'Essay' Questions

Marking: 1 mark for each bold part or words to that effect up to a maximum of 10 marks.

How is it that nervous impulses are transmitted across a synapse?

- The **action potential travels along the nerve until it arrives at the axon terminal**.
- When the action potential arrives **Calcium (Ca^{2+}) ions are moved into the synaptic knob**.
- **Synaptic vesicles then fuse with the presynaptic membrane**.
- The synaptic vesicles contain **neurotransmitter**, in the case of Humans this is **acetylcholine** which is **released by exocytosis into the synaptic cleft** when the vesicles fuse.
- The **neurotransmitter diffuses across the synaptic cleft and binds to receptors on the postsynaptic membrane**.
- This causes **the opening of protein channels which allow Na (Sodium) ions across the postsynaptic membrane**.
- As the Na enters the postsynaptic membrane it **depolarises it**.

- When the membrane is sufficiently depolarised an **action potential is generated in the postsynaptic neurone**.
- The **acetylcholine is broken down by acetylcholinesterase**.
- Acetylcholine is then **resynthesized and repackaged in a process requiring ATP**.

What are the advantages and disadvantages of possible pest control methods?

- Both methods of control have a advantages and disadvantages.
- The advantages of chemical control include:
  - **It is quick to use**.
  - Relatively **cheap to use**.
  - **Highly effective**.
  - It can be **applied only on a select (small area)** for example only in a greenhouse.
  - **Little skill or training is required to apply the chemicals**.
- The disadvantages of chemical control include:
  - Chemicals are **less specific than biological control methods** so may kill of useful insects e.g. 'farmers friends' - ladybirds etc.
  - If a large amount of chemicals are used for a prolonged period of time the **target organism(s) may develop resistance to the chemical**.

  - Resistance is the ability of an organism to withstand a dose of chemical which would otherwise kill it.
  - **Bioaccumulation** may also occur after prolonged use.
  - This could have a negative impact on organisms further up the food chain.
  - This includes **toxicity to humans**.
- The advantages of biological control include:
  - **Highly specific** in comparison with chemical control - allows the targeting of a specific organism.
  - **Longer lasting** as the target and the control can enter a predator - prey relationship.
  - Although biological control has a high 'start up' cost to carry out research and trials it can be **inexpensive if the solution works long term**.
  - Biological control mechanisms are also **more environmentally friendly** - causing no contamination.
- The disadvantages of biological control include:
  - The method is **not 100% effective**, there will always be some damage to the crop (etc) as the pest will never be fully eradicated.
  - There is a **high initial capital outlay to carry out research and trials** because **detailed knowledge of the target organisms life cycle is required**. This work can only be carried out by **skilled workers**.

  - There are **few successful models/examples** on which to base a new biological control.
  - Less successful examples include those where **the control has itself become a pest**, such as cane toads in Australia.
  - Even though it can have a long term effect there is still a **need to reintroduce the predator at regular intervals in case it struggles to survive in the environment** or leaves. Alternatively the predator can only be used in a closed environment.

How does an organisms environment change both its disposal mechanism for nitrogenous waste and its ability to retain water?

- Different **animals produce different forms of nitrogenous waste**.
- **Aquatic organisms like fish excrete nitrogen as ammonia**.
- Although **ammonia is highly toxic** the fish are surrounded by water and so after excretion the **ammonia is quickly diluted to safe levels**.
- Fish do not have issues with water conservation as they can **easily get water from their surroundings**. This means they have poor water conservation abilities.
- **Birds excrete uric acid**.

- **Uric acid is thick, stick and insoluble** with little water content.
- Uric acid is **not toxic**.
- This is useful because birds may have to **carry the waste for a long time**. The **small amount of water present allows the birds to excrete it but still allows them to fly**.
- Uric acid helps **birds conserve water because less is lost through excretion of nitrogenous waste**.
- Unlike ammonia however **uric acid is a far more complicated molecule so it has a higher energy cost associated with producing it**.
- **Mammals such as ourselves excrete urea**.
- **Urea requires less energy to produce that uric acid because it is less complex**.
- It is however **more toxic than uric acid though less so than ammonia**.
- As a result it **can only be tolerated in the body for a short period of time**.
- Apart from the form of nitrogenous waste excreted some animals have further adaptations which allow them to conserve water.
- The **kangaroo rat and other desert (or dry) dwelling animals for example are adapted to have a longer loop of henle**.
- Having a longer loop of henle **allows more water to be reabsorbed from the collecting duct**.

- This is because it creates a much **higher solute concentration in the medulla** so more water passes out of the collecting duct by osmosis.
- Animals which have this adaptation produce **more concentrated urine** than those who do not.
- Desert animals may also make use of **metabolic water** rather than external water sources to survive in such an environment.
- Animals that do this often **live underground in burrows etc during the day when the sun is hottest to counter water loss through evaporation**.

The nephron has a number of adaptations that ensure waste substances are excreted from the body but not useful ones, what are they?.

- In order to remove waste substances from the blood a **high blood pressure** is created in the glomerulus which forces small molecules through holes in the walls of the glomerulus and across the basement membrane.
- The high blood pressure is caused by the relative sizes of the afferent and efferent arterioles - with the **efferent arteriole having a smaller diameter** (it is adapted to being long and narrow compared with the afferent which is adapted to be wide and short) in order to create the pressure.

- Constant blood flow from the **renal artery**, a branch of the aorta ensures the pressure remains constant.
- The forcing of small molecules across the membrane as described above is called **Ultrafiltration - filtration under high pressure**.
- The molecules pass through three layers of membrane, the first is the **capillary (glomerulus) wall** followed by the **podocytes** and the **basement membrane**.
- Podocytes are **specially adapted epithelial cells** which further filter the blood leaving the glomerulus.
- **All substances** are removed from the blood *with the exception of large plasma proteins.*
- Once the capillaries leave the glomerulus they closely follow the path of the proximal convoluted tubule (they are **associated** with it).
- In the proximal convoluted tubule **selective reabsorption occurs**. This is where the molecules that the body needs are taken back into the blood.
- Selective reabsorption requires **ATP** because it uses *active transport.*
- As a result of using active transport the proximal convoluted tubule is adapted to have a **large number of mitochondria** which provide the ATP for this process.
- The proximal convoluted tubule is also adapted for absorption through its large surface area which is a

result of its **long length** and **microvilli** in the walls of the tubule.
- Selective reabsorption reabsorbs useful molecules like **water (80%), glucose and amino acids**.
- Any waste products like **urea** remain in the filtrate to be excreted *as urine*.

Other valid points e.g. "**Water potential in capillaries now very low due to loss of liquid lowering pressure and plasma proteins keeping solute potential low**"

Describe by way of a comparison the key differences between chemiosmosis in photophosphorylation and oxidative phophorylation.

- **Chemiosmosis is the movement of ions across a selectively permeable membrane**.
- Chemiosmosis is the process by which **ATP is synthesized**.
- In **oxidative photophosphorylation a proton concentration gradient is produced by ion pumps which pump protons across the inner membrane of mitochondria** using the energy from electrons in the electron carriers.
- In photophosphorylation however the **energy comes from the change in energy levels of electrons** in the electron transport chain.

- Once the proton concentration is produced protons move down it from high to low concentration. To do this they pass across the membrane through **ATP synthase**.
- The **motive force of the protons is used by ATP synthase to combine ATP with ADP and Pi** every *3* protons that pass through it.
- In photophosphorylation **the concentration of protons builds up in the thylakoid space** whilst **in oxidative photophosphorylation the protons build up in the inter-membrane space**.
- Oxidative phosphorylation uses **three proton pumps** which are situated in the electron transport chain. On the other hand photophosphorylation uses **only one proton pump** in the light dependant reaction.
- The **final electron acceptor also differs between the two forms of phosphorylation**, photophosphorylation has **NADP as the final electron acceptor** whilst in oxidative phosphorylation **oxygen is the final electron acceptor**.
- The source of the electrons is also different - **glucose is the source of electrons in oxidative phosphorylation** and **photolysis of water is the source in photophosphorylation**.
- Finally, the carriers of theses electrons are also different between the two forms. Oxidative phosphorylation uses **NADP** as the carrier/co-enzyme and photophosphorylation uses **both NAD and FAD** as carriers/co-enzymes.

Describe the growth of a given population of organisms, include how the growth of the population may be limited.

- In general population growth follows the **population growth curve**.
- The population growth curve consists of several stages - **lag, log stationary and death**.
- The first stage is the lag phase. In the lag phase population growth is slow as the organisms **adapt to the new environment** by **synthesising the proteins** they require *and so on.*
- The following phase is the log phase. In this phase the population size grows **exponentially** until such point as a factor acts to limit the growth of the population. The factor could be space or nutrient supply etc.
- Once a factor acts to curb population growth then the population enters the stationary phase. This is where the **birth rate is equal to the death rate** so the population remains at the same size.
- Following the stationary phase is the death phase in which the population size crashes and the death rate far exceeds the birth rate.
- It is **environmental resistance** that limits population growth.
- Environmental resistance can be subdivided into two further categories - **density dependant factors and density independent factors**.

- Density dependant factors include **competition**, **predation**, **toxic waste and disease**.
- **Predation controls the size of the prey population** and vice versa. e.g. if there are too few prey then the predator population will fall whilst is there are too many predators then the prey population will fall.
- Predator and prey populations are linked and roughly follow each other.
- Density dependant factors **increase resistance to growth as the population does increases in size**.
- Density independent factors are **not reliant on the size of the population**.
- Density independent factors include **flood**, **weather and fire**.
- The overall population size is regulated by the **birth and death rate for the population**.
- Along with births and deaths **immigration and emigration** impact population with a net migration causing population size to fall and vice versa.
- Competition both among the same species **(intraspecific)** and among other species in the environment **(interspecific)** impact competition. **Organisms are always in competition for the environments resources** such as space and light.
- **Those organisms which are best adapted to the environment out compete other species and so their population size grows**.
- A stable population will have a size around the **carrying capacity of the environment**.

- **Carrying capacity is the maximum size of a population an environment can sustain without environmental degradation.**

Bacteria are sometimes cultured in a batch culture fermenter, describe and explain the shape of the population growth of such bacteria.

- The **growth curve begins with the lag phase.**
- During the **lag phase the population grows slowly.**
- This is because during the lag phase the **bacteria are adapting to the environment.**
- They do this by carrying **switching on the required genes, synthesising the proteins they require, producing enzymes and substrate breakdown.**
- Following the lag phase is the **log phase.**
- During the log phase **the population of bacteria undergoes exponential growth.**
- This is because during this phase there is an **excess supply of nutrients and no environmental resistance which allows the population to grow rapidly.**
- Bacteria undergo binary fission and the population doubles in unit time.
- As the **bacteria consume more of the nutrients, nutrient supply becomes limiting factor to pop-**

ulation growth along with the **accumulation of waste products**.

- When this happens the bacterial growth curve levels off and enters **the stationary phase**.
- During the stationary phase the **bacteria population remains constant with cell production equalling the number of deaths**.
- The population at this point has reached the **carrying capacity of the fermenter**.
- In this phase **secondary metabolites like penicillin are produced**.
- As space runs out the **death rate begins to exceed the cell production rate so the bacteria enter the death phase**.
- In the death phase the bacteria population plummets until there are no bacteria left.

Note: you must use the term 'cell production' not births in your answer. The latter gains no marks.

Bacteria are important in the maintenance of soil fertility. Discuss.

(a)

Note: this question consists of two parts. The marks are split: 6 for (a) 4 for (b)

- **Bacteria carry out putrefaction (decomposition)**

- This helps **recycle nutrients that are stored in organisms over their lifetime**, like nitrogen back into the environment.
- The bacteria that maintain soil fertility are those that **recycle nitrogen an important nutrient for plants**.
- **Nitrifying bacteria like Nitrosomonas and nitrobacter perform this task**.
- **Nitrosomonas takes ammonium compounds from the soil and converts them to nitrites**.
- **Nitrobacter then converts the nitrites into nitrates which the plant can use**.
- **Plants need nitrogen from the synthesis of proteins and for nucleic acid production**.
- Other bacteria fix nitrogen from the atmosphere to a form the plants can use since they cannot use atmospheric nitrogen directly.
- They convert the **atmospheric nitrogen into organic nitrogen**.
- Theses bacteria include the **free living Azotobacter** and Rhizobium.
- **Rhizobium is a symbiotic bacteria found in the root nodules of legumes**. It **supplies nitrogen to the plant in exchange for protection from oxygen**.

How can farmers encourage the maintenance of soil fertility by these bacteria?

(b)

- **Denitrifying bacteria require anaerobic conditions** to operate.
- **Ploughing and the drainage of waterlogged land create aerobic conditions which stop dentrifiers**.
- **Growing leguminous crops** such as broad beans can encourage nitrification.
- The **addition of waste products containing nitrogen** (in some form) also encourages bacteria activity e.g. use of manure, urea and other organic waste products.

Detail the process of anaerobic respiration.

- Respiration begins with glucose which first goes through **glycolysis in the cytoplasm of the cell**.
- The **glucose is phosphorylated with 2 ATP to form hexose phosphate**.
- The **hexose phosphate is split into two molecules of triose phosphate**.
- The **triose phosphate is converted into pyruvate** in a process that produces **2H and 2 ATP**.
- The **2 H are used to reduce NAD so that 2 molecules of NADH are also produced**.
- In the **absence of oxygen aerobic respiration, the Krebs cycle and electron transport chain cannot occur because oxygen is the final electron acceptor** at the end of the electron transport chain.
- Instead anaerobic respiration takes place.

- The **pyruvate is converted to lactic acid** in humans and animals.
- In the process **hydrogen is transferred to the pyruvate by NADH**.
- This **recycles the NADH for use in glycolysis again**.
- In plants and fungi on the other hand when **decarboxylation occurs and ethanal is produced**.
- The **ethanal is reduced using NADH to form ethanol - again recycling the NADH back into NAD**.
- The amount of **ATP produced by each pass of anaerobic respiration is 2ATP**.
- This is because **a large amount of energy remains stored within either the lactic acid (animals) or the ethanol (plants)**.

Explain and describe the industrial production of penicillin.

- **Penicillin is produced in a batch culture fermenter**.
- To carry out the fermentation **all the materials are added at the start** rather than throughout the process.
- **All the equipment is sterilised before fermentation begins and after each fermentation**.
- A **pure culture of the mould Penicillium Notatum is added to a sterile nutrient medium**.

- The **medium is mixed with a paddle to increase the contact between the organisms and the nutrients**.
- The mixture is also **aerated to ensure the aerobic conditions required for growth are maintained**.
- The **air that is used for aeration is also sterile** to prevent contamination by airborne organisms.
- A **pH buffer may also be added to ensure suitable pH conditions for optimum growth**.
- **A water jacket surrounds the fermenter to remove excess heat produced by respiration and ensure that enzymes do not become denatured by the heat**.
- **Penicillin is not produced until the secondary phase of the mould growth** after nutrients have been depleted in the growth phase.
- This is because **penicillin is a secondary metabolite**.
- The **penicillin is harvested during the stationary phase and filtered and purified** from the culture fluid.
- **Penicillin is produced as secondary metabolite because in nature it may be produced to reduce competition**.

Name the technique that is used to count the number of viable cells in a population.

(a) (1 mark)

- Serial dilution is the technique used to monitor viable cells.

Describe the process, indicating any aseptic techniques you would use.

(b) (9 marks)

- In order to produce an aseptic preparation **the equipment used should be first sterilised**.
- Equipment sterilisation can be carried out with an **autoclave or using radiation**.
- **The working area should also be sterilised with disinfectant** e.g. with Virkon.
- **Flaming the bottleneck of any liquid cultures** and **working near an updraft/ bunsen burner** also ensure that aseptic conditions are maintained.
- **To carry out a serial dilution**:
    1. 9 cm3 of distilled water is placed in series of test tubes with lids.
    2. 1 cm3 bacterial sample is placed in first tube.
    3. The 1cm3 sample is transferred to the second tube and mixed.
    4. Step 3 is repeated for the remaining tubes. [max 2 marks to this point from listing of steps]
    5. Transfer 1.0 cm3 of each sample onto a nutrient agar plate - lifting the lid only slightly to avoid contamination.

6. Step 5 should be repeated twice to give a total of 3 plates per dilution.
7. A sterile spreader should be used to spread the bacteria on the plate.
8. The plates should be taped closed to ensure that no contamination occurs.
9. The plates should then be indicated for 24 hours at 25 degrees. This is lower than the optimum temperature of human pathogenic bacteria (37 degrees).
10. Choose plates which have a number of countable colonies avoiding those with clumping and count the colonies.
11. The number of bacteria that were in the original sample can then be calculated from. 1 / dilution factor * number of colonies where dilution factor is 1/10ˆn n = test tube number.
12. The mean value for the population size should also be found by summing all the calculations and dividing by the number of calculations. [max 6 marks from remaining steps] [a diagram indicating steps 1-4 & 11 (e.g. dilution factor of tube(s) shown) can be used to gain 4 of the 8 marks for listing steps]

- A **problem with this method is that it assumes that each colony arises from only one cell**.

Give an account of the light dependant stage of photosynthesis in plants.

- A **photon of light strikes photosystem II** and the **energy is transferred to a molceule of chloropyll a in the reaction centre**.
- This **excites electrons in chlorophyll a which loses the electron**.
- The **electron passes down a series of electron carriers and as it does so ot loses energy which is used to convert ADP to ATP**.
- For **non-cyclic photophosphorylation** the electron is passed to photosystem I to replace one lost from chlorophyll a there.
- **The electron that is lost from PS I is returned back to PS I in cyclic phosphorylation** after being used to produce an ATP molecule.
- **In non-cyclic photophosphorylation however the electrons are given to Hydrogen ions outside the membrane which reduces NADP to NADPH** which **passes to the light indepndant reaction along with ATP**.
- **Photosystem II is unstable** having lost electrons so these are **replaced by the photolysis of water**.
- **Oxygen and H+ ions are produced also from the photolysis**.

Describe the Krebs cycle

- The **starting point for the Krebs cycle is Acetyl CoA**.
- **Acetyl CoA is converted to a 6C** compound in a **reaction with a 4C compound** and the **CoA is regenerated**.
- The **6C compound is converted to a 5C compound by decarboxylation**. Dehydrogenation also occurs and **2 H ions are also produced** in this step.
- The **carbon from decarboxylation is removed as CO2**.
- The **hydrogen produced in this step and others is used to reduce NAD and FAD into NADH and FADH**.
- The **5C compound becomes a 4C** compound through **producing ATP directly in the cycle** as well as **2H for NAD and CO2**.
- THe **4C compound goes through a series of steps to leave the original 4C compound**.
- The **electrons given to the NAD and FAD are carried to the electron transport chain**.

ATP is formed in the electron transport chain. Describe this process.

- The **NAD and FAD give their electrons to electron acceptors** in the electron transport chain.
- These **high energy electrons pass along the chain passing some of their energy to proton pumps**.
- This fuels the protons pumps which **pump protons across the membrane** into the intermembrane space.
- This sets up an **electrochemical gradient**.
- The protons then pass by **chemiosmosis** through a molecule of **ATP synthetase. (stalked particles)**.
- This **combines ADP and Pi (Inorganic phosphate) to make ATP**.
- **Oxygen is the final electron acceptor** and **forms water by combining the electrons from the transport chain with protons**.

Describe the calvin cycle. Suggest the possible use of the products of this process.

- **ATP and reduced NAD (NADH) are supplied to the light independent phase** from the light dependant phase.

- The light dependant phase **takes place in the stroma of chloroplasts**.
- A **RuBP a 5C acceptor molecule is catalysed by RuBisCO** using ATP to form a 5C molecule.
- The **RuBP is used to fix carbon dioxide and becomes a unstable 6C intermediary which splits apart into 2 molecules of GP**.
- The GP is in turn converted into **3C triose phosphate using reduced for the reduction and ATP** which is broken down into ADP and Pi to supply energy.
- **RuBP is then regenerated from the TP** using Phosphate from ATP.
- **One TP from each cycle is used to make hexose sugars** like glucose.
- Other products that may be produced are **lipids, amino acids, starch, cellulose and other carbohydrates**.
- The **glucose is used as energy** and the **amino acids are later used in protein synthesis**.

Green plants trap energy from the sun. How is this done?

- The **source of energy for green plants is photons of light**.

- The **light strikes photosystems** made of an **antenna complex and a reaction centre** containing **chlorophyll a which absorbs the photon**.
- The **antenna complex consists of a number of different pigments: carotene, xanthophyll, chlorophyll b**.
- Having a **wide range of pigments allows a wide range of wavelengths of light to be absorbed**.
- When the photon strikes the antenna complex pigments they must **transfer the energy to chlorophyll a because they cannot themselves release an electron**.
- The chlorophyll a on the other hand can **release an electron which subsequently passes to an electron acceptor**.
- The **electron then travels down an electron transfer chain between PS II and PS I**.
- **This powers protons pumps which move protons into the stroma**.
- **NADP mops up the protons**.
- **NADP is reduced**.
- The **electrons lost from PS II are replaced when they become available from the photolysis of water**.
- The final **energy is stored as chemical energy** in molecules of ATP.

Describe the final products of photosynthesis and explain their use in the plant or as part of the synthesis of other compounds.

- **Triose phosphate, glucose and oxygen are the final products** of photosynthesis.
- **TP is converted to glucose every two cycles** (of the calvin cycle).
- The **glucose is later used by mitochondria in aerobic respiration**.
- The **glucose may also be used as a respiratory substrate to allow ATP synthesis** in the growing parts of the plant.
- Alternatively it **may be converted into starch and stored as starch grains in the chloroplast** or **in a temporary specialised area** e.g. potatoes.
- **Glucose can also be combined with fructose to form sucrose** which is **used in transport**.
- **Cellulose can also be made from converted glucose** and is **used in the cell wall of plant cells**.
- The plant can also **synthesise amino acids if a source of nitrogen is available**.
- Amino acids can be used to **synthesise proteins**.
- **Lipids may also be synthesised** for the **cell membranes (phospholipid bilayer)**.
- **Chlorophyll can be synthesised provided a magnesium source is present**

- DNA may also be synthesised along with other **nucleic acids** RNA etc.
- All the organic materials in the plant must be **made from the intermediaries and the products of photosynthesis**.

BY5

Effects of Human activity (on the environment)

Keywords

- Warfarin
- Resistance
- Antibiotic
- penicillinase
- conjugation
- Artificial selection
- Inbreeding
- Outbreeding
- Extinction
- Endangered species
- CITES
- conservation
- ecotourism
- monoculture
- deforestation
- regeneration
- erosion
- coppicing

- rotation time
- selective cutting
- biofuel
- trawling
- drift netting
- overfishing
- eutrophication
- global warming
- greenhouse gas
- fertiliser
- nitrates
- phosphates
- algal bloom

Resistance

Resistance is the ability of an organism to survive exposure to harmful chemicals such as poisons which in normal cases would result in the death of the organism. Examples of resistance developing are found among the rat population. Warfarin is an anticoagulant which has in the past been used as a large scale in a bid to keep rats of the species Rattus norvegicus numbers down.

Warfarin resistance is conferred to a rat by the dominant R allele. As well as making the rats resistant to warfarin it also makes the rat need vitamin K. RR (homozygous) rats require a large amount of vitamin K which is difficult for

them to obtain. Rr (heterozygous) rats only have a small vitamin K requirement giving them the advantage over the homozygous rats and homozygous non resistant rats. In the absence of warfarin however RR (homozygous resistant) rats fare worse than non resistant rats (small rr). Because the heterozygous rats have the most advantage all three possible gametes Rr, rr, RR, being produced per generation.

Bacteria are also becoming increasingly resistant. MRSA is a methicillin resistant strain of the Staphylococcus aureus bacteria which is resistant to penicillin's like meticillin which are antibiotics. (meticillin is the British approved name and INN whilst methicillin is the US approved name). Resistance in bacteria arises by mutations occurring randomly in populations of bacteria which provide an advantage if the particular antibiotic is present e.g. in hospitals. Resistance can take a number of forms. The bacteria can produce enzymes which break down the antibiotic such as penicillinase which breaks down penicillin. If penicillin is present in this cases the bacteria which produce the enzyme are favoured so survive to reproduce. This selection pressure is affected by both the quantity and frequency of the penicillin usage. Bacteria have developed a wide range of resistances through repeated exposure to antibiotics with resistant genes being passed on to each subsequent generation.

When bacteria sexually reproduce (conjugation) resistance can be passed between the organisms on plasmids. This can only occur between individuals which are members of the

same species but it does mean that a pathogen can become resistant to a given antibiotic before it is used to fight them.

Resistance development is especially common in agriculture because farm reared animals which are kept indoors commonly spread diseases among them as a result of the confined space. To prevent this broad spectrum antibiotics are added to animal feed to prevent disease but in fact allows resistance to develop.

Artificial Selection

Artificial selection is also known as selective breeding makes use of the natural variations that occur within a population to produce the best organisms possible. Humans often choose animals with the best characteristics to breed from in order to maximise profit etc. This means that instead of the environment dictating the alleles which occur in future generations we do instead. Artificial selection mimics natural selection but happens at an accelerated rate. It can lead to very distinct breeds forming such as in dogs and many plants.

Although artificial selection does occur at an increased rate it can still take many years to produce organisms which have the desired characteristics. These organisms are of the same species as their relatives but are often called breeds in animals and varieties in plants.

Artificial selection can occur in one of two ways. The first

is through inbreeding. Inbreeding occurs when the gametes of close relatives fuse. It has a number of disadvantages which mean that occasionally it becomes necessary to introduce new genes through outbreeding. The disadvantage of inbreeding is called inbreeding depression. Inbreeding depression occurs because inbreeding favours homozygosity. Homozygosity means that the chance of a recessive allele expressing itself through a double recessive individual increases. Outbreeding which is also used to 'undo' some of the damage caused by inbreeding occurs when unrelated varieties or breeds are crossed. Unlike inbreeding outbreeding favours heterozygosity. Hybrid vigour or heterosis in which organisms have improved function in a hybrid offspring is caused by outbreeding. This occurs when new chromosomes are introduced which are complementary in their effects - one example of this is modern wheat development.

Biodiversity

Humans have a large impact in biodiversity both negatively e.g. driving species to extinction and positively e.g. species conservation programs.

Extinction is firstly a natural process. It has taken place since from the very first organisms and continues to the present day. The issue is however that extinctions occur at a much increased rate now in comparison with the background rate which scientists believe is the normal rate

at which extinction would be occurring. The background rate is said to be 1 in every 1 million species per year. It is also estimated that human activity (primarily in the tropics but also through agriculture, forestry, mining and expanding our own population i.e. urban development) has increased this by over 10000 times. Extinction is also not simply confined to terrestrial animals - marine life is also impacted especially by the removal of corral reefs on which a third of marine life depends.

Those organisms which are 'on the brink' of extinction are said to be endangered species. The decline in numbers which leads to a species becoming endangered is often attributed to three main causes. These causes are over hunting or over fishing, habitat loss, competition from other species (especially those which have been introduced). Pollution, deforestation and destruction of wetlands are also attributed as causing a decline in population numbers. By altering ecosystems in this manner not only is the organism or organisms which inhabit the ecosystem affected but also other species which are dependant on those organisms too.

Any organism has the potential to contain useful chemicals or disease fighting genes. As a result it is important to conserve the gene pool of every species on earth as best as possible. This is done through species conservation which is the planned preservation of wildlife.

The animals and plants that we make use of through farming and horticulture are descendants of wild plants and animals. Unlike wild animals and plants they have more

'genetic uniformity' and little to no rare alleles. Even when performing artificial selection some characteristics may be overlooked which could later become more important. For example if you were choosing only the biggest cattle for meat purposes you might not realise that you were also selecting for less hairy cows which might not survive well should it suddenly become cold. To reintroduce this genes wild plants and animals need to be used much like a 'gene bank' would be. It is important to carry out species conservation at the present time rather than later because it may become too late.

Numerous steps have been taken to prevent the loss of genes which may be potentially useful. These steps include: Storage of seeds in seed banks, sperm banks, caring of older breeds through 'rare breed societies', various pieces of legislation such as CITES, reintroduction programmes, breeding programmes, public awareness campaigns.

Legislation like CITES can be used to prevent over-fishing, over-hunting, plant collecting and egg collecting - not just trade (in endangered species) prevention.

Another system that has been developed in order to promote conservation is that of ecotourism. Ecotourism is responsible travel to places which have natural environments that are in need of conservation and which the tourism improves the well being of the local [human] population.

The goals of ecotourism include: contributing to conservation, employing local people, giving back to the community, co-operation with local people and educating the

visitors as well as the local people about the environmental issues involved.

The UK body for promoting nature conservation is the countryside commission. The countryside commission produces a number of publications and creates nature reserves - advising government on the activities that affect the countries wildlife and that wildlife's natural habitat.

Exploitation through farming

Farming is one of the ways in which human beings act to reduce biodiversity. This is because farming is becoming increasingly more advanced (technologically speaking) and efficient in order to keep up with the intense demands of human food consumption. A number of changes which make taken place since the end of world war two have had a large impact on the environment - primarily because mechanisation was introduced but also because fertiliser and pesticide usage also soared.

The impact on the environment from these changes is related to the growing size of fields to accommodate large machinery. To get the machinery into the field hedgerows had to be removed - taking away a vital habitat for many small animals such as mice and birds. Further in the large fields farmers tended to only grow one crop such as wheat or maize. This is known as a monoculture. A monoculture is the growing of a large number of crops which are of a

simpler type as well as age and that are grown simultaneously. Monocultures result in reduced species diversity and in the long term lead to decreased year on year yield. The decline in yield can be attributed to one of two factors. The first of these is mineral depletion in which intensive cultivation of the crop requires an ever increasing amount of nitrate (inorganic) fertilisers. As well as more fertiliser intensive cultivation attracts pests and crop related diseases therefore increasing amounts of pesticide must also be used to kill of the pests which are usually insects.

Farming however is changing. In 1995 with the passing of the Environment act the UK government reversed the removal of hedgerows. Hedgerows are perhaps the most important habitat in a heavily farmed area. This is because hedges act as wildlife corridors which allow animals to move between different areas of woodland which also maintains the woodland biodiversity. Hedges also provide habitats and nesting sites for a wide range or birds and animals which live and feed on the other animals such as insects present in the hedgerow.

In general people have become far more aware and protective of 'their' countryside so farmers have been encouraged to manage their farms to increase biodiversity including grants for giving up land for conservation efforts.

Deforestation

Although around 35% of the earth surface is covered in forest that number is decreasing rapidly - in the last 30 years alone half the worlds forests have been cut down. This is deforestation. Under normal circumstances a forest can regenerate naturally or be replanted artificially to make up for felled trees however tree felling now happens so fast that woodlands are being cut down faster than they can be replaced.

Forests are a very important ecosystem. Because they consist primarily of large plants (trees) they help maintain the balance between carbon dioxide and oxygen in the earths atmosphere. Without forests controlling this balance climate change and further habitat destruction occur. Several factors 'drive' deforestation. The primary factor is human need - these reasons include: Wood for use as fuel (as well as building materials paper and packaging), land clearance for farming and new transport infrastructure e.g. roads.

As a consequence of deforestation other natural habitats are destroyed. 50% of the earths species live in tropical rain forests (though 10% of the earth is covered in them) and removal of these species habitats results in 'incalculable' losses in terms of loss of genes or medicinal properties that have not yet been investigates through extinction. Another consequence of deforestation is soil erosion. Soil erosion is the removal of the topsoil - a layer of soil which contains valuable nutrients. Soil erosion is caused

by loosening of the topsoil as a result of digging and ploughing for agricultural purposes and the removal of vegetation which also impacts local climate. The key effect of vegetation removal on the local climate is reduction in rainfall which speeds up the process of desertification i.e. the formation of a desert from fertile land. Lowland flooding is also a issue caused by soil erosion (and therefore by deforestation) because the removal of vegetation on high slopes on mountains and valleys causes exposed soil to be washed into the flood plains on low ground after heavy rain. If vegetation were present on the flood plain the water would be better absorbed and would subsequently pass quickly into the atmosphere through transpiration. Instead the lack of vegetation means that the water must instead evaporate into the atmosphere - a slower process than transpiration which results in wetter soil conditions and more susceptibility to flooding.

Deforestation also contributes to climate change. This is because carbon dioxide traps heat in the earths atmosphere. When it isn't removed by trees there is a massive increase globally in atmospheric carbon dioxide concentration which adds to increases in earths temperature. The rate at which carbon dioxide is removed from the atmosphere is linked to the rate of photosynthesis.

Deforestation can be reduced through good forest management. Managed forests are sustainable and managed forestry involves the replanting and regeneration of the forest. An example of a forest management technique used

in Britain is coppicing. Coppicing has been used here for over a thousand years and is the cutting down of trees close to the ground before they are left for a number of years to regrow. Coppicing works here because because of our deciduous forests - most deciduous trees grow from the base if their trunks are cut down. Selective cutting is another widely used forest management technique. Selective cutting is felling only some large trees leaving the others in place to provide a habitat and allowing them to continue growing - this maintains the nutrients in the soil and prevents soil from being washed into waterways. Selective cutting is most often used on steep slopes. It has to be used in this case because tree removal leaves the soil open to erosion. After felling part of a forest it is often left before it is re-harvested, this is known as long rotation and it also increases the sustainability of the forest.

Good forest management also improves efficiency with several steps being taken to improve the availability of the forest as a source of timber without damaging the ecosystem. Efficiency can be increased by planting trees at an optimal distance apart from one another because it decreases intra specific competition and allows the trees to grow wide and tall producing quality timber. Efficiency can also be increased by removing a similar amount of trees on a regular cycle. Yearly for example. This maintains the ecosystem because species can exist in their habitat without disturbance even though wood is being extracted. Finally good forest management also requires the careful control of pests and diseases. Free from disease and pests more quality

timber is produced by forests meaning that less trees need to be felled in the first place. Because less trees are felled less land is needed so this control allows us to make the best use of the land available.

In the UK 10% of the country is covered in forest. Only 1% of this 10& or 0.1% of the UK is covered in native or natural woodland. These woodlands in particular must be conserved to maintain as well as increase biodiversity. Currently there are plans and a need to plant more native woodland species to increase the available habitat for the numerous species which inhabit them.

Biofuels

A biofuel is any fuel which has a biological origin. This includes ethanol as well as diesel which has been made from corn, sugarcane and rapeseed along with other crops, wood, wood shavings or clippings, biogas (aka methane from animal excrement) and so on.

Ethanol is a good example of a biofuel because it is made through fermentation in the same way that beer is produced it is though usually mixed with petrol before use - reducing its environmental friendliness. Oilseed rape or Rapeseed (Brassica napus) is a member of the mustard family and is known for its oil rich seeds and is largely the source of the worlds vegetable oil. Biodiesal is an oil substitute made from this plant which can be used on its own or mixed with other chemicals for use as fuel. Biogas

which is primarily methane is often used in small scale power generators rather than directly as fuel.

Biofuels are said to be 'climate friendly' as they are supposed to reduce greenhouse gas emissions in comparison with traditional fossil fuels which; when burnt produce carbon dioxide which traps heat in the atmosphere thereby contributing to global warming. The primary way that they work to reduce emissions are through reduction in carbon dioxide emissions but also through the growing of the crops which are used to produce the fuels in the first place which take some of the carbon dioxide n out of the air through photosynthesis. Biofuels however are not entirely biologically friendly because they require farming, processing and other treatment which can make them as polluting as their petroleum based counterparts.

Currently the country that produces and uses the largest amount of biofuel is brazil. The sugarcane industry is big in the country - producing 16 billion litres of ethanol per year. Most new cars in the country now run on an 85% ethanol mix. There is a problem with biodiversity in countries which depend on and produce large amounts of biofuel. Like much of the UK and other western countries farmland, to produce large amounts of biofuel fields of monocultures are used which can reduce the habitat available to native plant and animal species e.g. in some Asian countries it has been considered that rainforests be chopped down to make way for palm oil plantations. Crops such as corn or soy being used in biofuel can increase the cost to consumers

buying the crop for eating thereby reducing food supply to less prosperous regions.

There are barriers to biofuel production however. Current engines can cope with the new fuels generally speaking - plant production is a limiting factor. This is because only a small part of the plant can be used. Plants have cellulose cell walls which have to be broken down before fermentation (in the case of ethanol production). Work is currently being done to create 'second generation' biofuels which will make use of or process the cellulose making production more efficient and allowing a wider range of plants and plant waste to be used.

Because of current problems with biofuel production opposers to biofuel often cast doubt on the climate benefit of biofuels. Instead they say that priority should be given to cutting energy use rather than run financial initiatives for biofuel producers - the farmers.

Overfishing

In recent times there has been a significant increase in the intensity of fishing. As a result commercial fishing has caused overfishing around the world. Overfishing can be loosely defined as the rate of fishing exceeding the rate at which fish breed.

Commercial fishing takes a number of different forms. Drift netting for example is used to catch pelagic fish which

inhabit the upper parts of the water. The size of the fish caught by this method is dependant on the size of the mesh of the net that is used. In some cases the fish caught are too small to sell but are dead before they are thrown back.

To catch mid and bottom feeder fish a different technique is used. This is called trawling. Unlike drift nets which are suspended between floats and boats trawl nets are dragged through the water. This has the unfortunate effect of 'catching' everything in the nets path. As with drift netting the mesh size of the trawl net is important and in most places closely regulated so as to prevent fishermen from catching younger fish which have not yet matured enough to reproduce and so maintain fish stocks.

Maintaining fish stocks isn't just important for sustaining aquatic ecosystems it is also important in maintaining the fishermen's livelihoods. With no fish to catch there wouldn't be any fishermen. To ensure that both are kept in balance i.e. there are enough fish to make a living with but also enough to replenish stocks a number of measures have been taken. These measures include restricting mesh size (as mentioned earlier) to reduce accidental catches, international agreements which place quotas on the size of catches as well as local quotas on catches based on the size of the current fish stock as estimated by scientists. exclusion zones and closed/open seasons. All of these methods require an amount of enforcement to be effective which can be costly.

Overfishing has effects on entire food chains if a particu-

lar species is overfished. Overfishing of organisms lower in the food chain reduces the population size of those further up. Krill (a small shrimp) are an example of this because they are positioned low in the food chain - feeding on phytoplankton. They convert the energy from these animals into a form suitable for other animals such as whales (whose diet consists primarily of krill), squid, seals, penguin and other fish. Krill are especially overfished in the Antarctic where they can be found in swarms which are miles across. From the 1980's onwards Russia, South Korea, Poland, Ukraine, Chile, and Japan (6 countries) have been harvesting tons of krill impacting the whale population which has already been overexploited.

Rather than fishing in open waters some fish have become farmed. Perhaps surprisingly fish can grow very well in warm waters discharged from factories as well as in ponds, lakes and estuaries in which they live in enclosures. These enclosures are managed and have predators removed along with their food supplies maintained at an optimum level through the addition of artificial fertilisers which aid phytoplankton growth. These phytoplankton are later eaten by the fish which are being farmed.

Fish farming poses a number of problems. Most of these problems arise as a result of the way the fish stock are kept. Fish are often in cramped conditions very close together in order to make the most profit from as little space. This means that disease can easily spread between the fish and into wild fish populations. For this reason large amounts

of antibiotics are added to the 'farm' to keep the fish healthy. Along with these pesticides are used (as with a conventional farm) to kill of fish parasites. Like the diseases these pesticides can spread from the farm and harm marine invertebrates. Fish excreta can also spread out into the surroundings from the warm and cause eutrophication. Eutrophication is the sudden growth of algae/cyanobacteria due to excessive richness of nutrients in the body of water.

On occasion the fish themselves may also escape from the farm. If this happens and the escaped fish breed with the wild stock the wild fish population can be weakened. Further in order to farm the fish (especially carnivorous fish like salmon) you have to have more fish in the first place - salmon eat 3 times their own weight in fish food. Since the fish food consists mainly of other fish this is not a good use of the environment. Today about half of the salmon sold worldwide comes from fish farms. Salmon however have a problem (both types, wild and farmed) they contain PCB's or polychlorinated biphenyls and high levels of dioxins. PCB's often come from the fish feed and are a persistent organic pollutant which has been shown to cause cancer and other illnesses in both other animals and humans. These chemicals build up in salmon because they are high in the food chain and also because they accumulate in fat. Seals are another marine animal effected by these chemicals.

Carbon cycle

Human activity also impacts the carbon cycle. In recent years (the last century) there has been a dramatic rise in atmospheric carbon dioxide levels. This increase has been largely attributed to fossil fuel combustion. In all this accounts for 70% of the carbon dioxide increase in the last 50 years with 76% of the carbon dioxide from industrial countries. Deforestation accounts for the remaining 30% increase in carbon dioxide levels. 50% of the worlds forest have been removed in under 30 years. Forests are important because they maintain the carbon dioxide levels in the atmosphere by using it in photosynthesis, replacing it with oxygen. It is important that carbon dioxide and oxygen levels in the atmosphere are balanced because carbon dioxide is a greenhouse gas. Like the other greenhouse gases: methane and CFC's it absorbs heat reflected from the earths surface and prevents it from escaping into space thereby raising the temperature of the earth at the surface. This is the cause of global warming.

Global warming leads to changes in climate including changes in patterns of rainfall and rises in the level of seas. See level rises are caused by the melting of polar icecaps which can lead to increased flooding in coastal or low lying areas. Forest fires, cyclones (and tropical cyclones aka hurricanes) as well as prolonged drought can also be caused by climate changes resulting from global warming. In terms of drought in same places around the world deserts may form due to the decreased water availability. It is

possible to refer to the increased crop yields as an upside to global warming but scientists have suggested that this may increase insect pest populations as well. Crop yields will also fall elsewhere. Grain crops in north america and some asian countries would be reduced with economic consequences.

In a bid to fight global warming ongoing genetic engineering research is being carried out to develop drought resistant crops. Already this research has determined the gene which controls water efficiency in plants but it will require many more years of research before the ideas are developed enough that drought resistant crops become a reality.

Fertilisers

Fertiliser use in farming also has an impact on the environment. Developed agriculture is intensive, producing more and more crops from smaller areas of land. To achieve this fertilisers containing nitrate are used. These fertilisers have a detrimental affect on both terrestrial and aquatic organisms.

The effects of the fertiliser use are due to excess nitrate in the soil. The excess fertiliser is used by plants such as grasses and nettles which grow taller and faster covering smaller plants so that they do not receive enough sunlight, In the long term this reduces species diversity. The excess nitrates can also run off into water bodies nearby or slowly

leach into rivers along with phosphates. This causes a build up of salts in bodies of water until an equilibrium is reached. At this point the salts are removed at the same rate as they are added. Because sewage works and fertilisers carry large amounts of these salts (nitrates and phosphates) leaching results in eutrophication of lakes and rivers. It is easy for nitrates to enter water because they are highly soluble. Their build up causes algal blooms because of the excessive nutrients in the water. If this happens the water becomes densely populated with species of algae turning the surface green, preventing any light from penetrating deep into the water. This means that the plants in deeper water cannot photosynthesise and die out. This has a knock on effect in reducing the number of animal species because they rely in these plants for food and shelter. Algae however are short lived and die very quickly. They are decomposed by saprobiotic bacteria in a process that requires lots of oxygen. This biochemical oxygen demand (sometimes written BOD) causes the water to become deoxygenated except very near to the surface. This results in fish and other animals which rely on the oxygen to die out also. More bacteria may reduce the nitrate to nitrite in the water during the final stages of eutrophication. Because both of these chemicals are toxic there is an EU wide limit of 11.3 parts per million of nitrogen in water which is suitable for humans to drink. Unfortunately this amount has been exceeded in the UK in some places.

There is further strict legislation aimed at stopping the high nitrite level problem. This includes forcing farmers to

restrict the amount of fertiliser they use and the time when they use it so that it is only used when the crops are actively growing. Legislation also adds 10 metre clear strips by any watercourse and drainage ditches.

Energy and Ecosystems

Keywords

- Habitat
- Ecosystem
- Community
- Detritivores
- Decomposers
- producers
- Herbivores
- primary consumers
- trophic level
- excretion
- respiration
- food chain
- carnivore
- Gross primary productivity
- net primary productivity
- Secondary productivity
- biomass
- Succession
- Climax community
- quantitative
- environment

Flow of Energy

The energy flow through an ecosystem begins with producers. These are green plants which take the energy from the sun (through photosynthesis) and build sugars using that energy. The source of all the energy in the system is the sun, the energy is simply passed up trophic levels through the ecosystem.

Primary consumers are those which feed on the producers, these are Herbivores since they are animals that feed on plants. Secondary and tertiary consumers (and higher) are Carnivores, eating the animals below them in the chain. These groups are referred to as trophic levels as biological material is eaten the energy contained therein is passed on the the consumer. To get out of the system the energy must leave as heat. This happens at each trophic level where a large loss in energy occurs. The energy is primarily lost through respiration and through the excretion of various unneeded waste products e.g. Urea. Since energy is lost at each level the ultimate length of the food chain is limited. Usually the food chain is limited to around 4 levels, Producer -> Primary Consumer -> Secondary Consumer -> Tertiary Consumer.

Each level involves the 'building in' of some of the energy into the organic molecules of the organism at that level. On death these organic molecules still remain in the organism along with the energy they contain. To release this energy decomposers are detritivores which behave as saprobionts

recycle the nutrients and release the energy into the environment.

Decomposers are microbes such as fungi which take their nutrients for faeces and dead organisms e.g. Trees. Before decomposers can work on decomposition, larger organisms like earthworms feed on detritus (they are Detritivores) to decompose it. This detritus is made up of abiotic (non-living) material like faeces, dead organisms and the fallen leaves from trees.

Diagrams can be used to represent this flow of energy through the ecosystem. There are several types of diagram (pyramids of biomass etc) - primarily however pyramids of energy are used. A pyramid of energy is a diagram which shows the amount of energy which is transferred between each trophic level, travelling up the pyramid. The energy transferred is given as per metre squared per unit time as such it represents the total energy requirement of the next trophic level in the chain.

The pyramid is formed from the size of the bars decreases at each level due to energy loss the pyramid can never be 'upside down' because energy is only lost at each level not added. When comparing communities energy pyramids can also prove useful to compare how efficiently energy is transferred between the different communities in the ecosystem.

Flow (Producers)

The energy that is provided by producers to animals higher up in the food chain comes from the photons of light from the sun. Producers cannot absorb all of the suns energy however and a large amount is unabsorbed either because it is reflected or because it misses chlorophyll or just doesn't hit the plants leaves at all.

The energy that the producer does capture from the sun is called the gross primary productivity. This GPP refers to the rate at which the products from photosynthesis are formed. A significant amount of gross production is used up. Such as glucose in respiration. What is left over after this is referred to as net primary productivity. Primary consumers can obtain the energy that is represented by the NPP. Consumers also have a name for the rate at which their cels and tissues 'build up' energy - it is called Secondary productivity.

Flow (Consumers)

Herbivores such as sheep and other grazing animals eat a large amount of plant material i.e. producers but not all of it. For example the sheep may eat a lot of grass but will not eat the roots of the grasses. Some of this material is eaten by other herbivores but often it 'goes to waste'. As a result consumers have a efficiency of approximately 10% - eating 10 grams of food nets them a mere gram. This coupled

with the fact that some herbivores like cows are unable to digest cellulose (they lack the correct enzymes) effectively this means that only some of the net primary productivity is in fact transferred to primary consumers. However the energy from undigested cellulose is not lost since it is made available to decomposers through the faeces of the animal. In all herbivores are less efficient than carnivores. This is because carnivores lose only 20% of their energy intake through excretion. Carnivores also have a higher Secondary productivity due to their easily digestible diet which is rich in protein. This means that 2 times the amount of energy per unit mass of food is taken in by carnivores compared with herbivores.

Succession

A succession is the change that occurs in a community in terms of its composition and structure over time. If a habitat has not previously supported a community before then the first succession refers to when the different species that make up the community are introduced or begin to colonise the area. An example of this would be grass seeds after a volcanic eruption. Secondary successions on the other hand are where organisms are reintroduced into an area which has previously supported a community.

Over time species diversity in the community gradually increases until such time as a table state is reached. This stable state is known as a climax community e.g. (in the

UK) an Oak woodland.

Communities

A Community is the different populations of species which can be found living in a habitat. Since Ecosystems are dynamic they don't remain the same indefinitely. When the environment changes it has a direct impact on the organisms which inhabit it. Likewise, if an organism changes it too impacts on the environment.

When a group of organisms colonise a new environment they are referred to as a pioneer community. The pioneer community (in fact any community) can consist of both animals as well as plants. These first plants and animals are pioneer species lay the groundwork for further successions, that is changes in the structure and composition of the community as time goes on. Eventually a climax community is formed. A climax community is one which has reached an equilibrium point in relation to its environment. There are no further changes in a climax community so the community is said to be stable. For this reason the community usually consists of long lived plants and animals.

During the development of the climax community Human activity may have a direct or indirect impact on the succession which can in some cases prevent the natural development of the climax community. e.g. Controlled burning, Farming, Soil erosion & deforestation.

Genetic Code and Cells

Keywords

- DNA
- template
- chromosomes
- genes
- protein synthesis
- transcription
- translation
- RNA
- codon
- mRNA
- tRNA
- meiosis
- homologous
- ribosome
- genotype
- phenotype
- crossing over
- independent assortment

Genetic Code

A DNA molecule can be further subdivided into genes. A gene consists of a certain length of DNA on a chromosome which codes for the production of a particular polypeptide in the process of protein synthesis. These genes make up the genetic code of a cell. These are carried in DNA across generations of the same cell. This code determines what reactions can take place in the cell and therefore in the entire organism. Genes code of polypeptides which are built into proteins like enzymes. These enzymes determine the characteristics of an organism. These characteristics are the phenotype of the organism. Each polypeptide code is a 'triplet code'. That is each polypeptide is coded for by 3 bases on a DNA strand. A DNA molecule has four different nitrogenous bases. These are: adenine, guanine, cytosine and thymine. If only one base was used per amino acid there would only be 4 (one for each base), if two were used there would be 16 amino acids in total. However there are over 20 amino acids coded for by the triplet code. Some of the codes however are actually STOP and START codons which signal to the ribosome when to stop building a protein. A codon is a set of three bases. Each codon is always read separately and do not overlap. These codons are not just the ones used in humans, they are exactly the same in every single living organism.

Replication

When a cell divides it is important that the offspring have an exact copy of the genetic material in the parent cell. This means that Chromosomes in the parent cell must make exact copies of themselves - this takes place during interphase. To carry out DNA replication the hydrogen bonds holding together the nitrogenous base 'steps' of the DNA break. Once this has occurred to two separate parts of the DNA molecule separate further. As this separation happens the DNA unwinds. Each strand of the DNA is a template (like an engineers blueprint for making an exact copy) for its complementary strand i.e. its opposite. Free nucleotides from the cytoplasm are added to these exposed strands in a reaction that is catalysed by DNA polymerase. This forms two DNA molecules each with a fresh chain of nucleotides but also with a strand of the original DNA molecule. Because of this mixture between new and old parts of DNA this process is referred to as 'semi conservative replication'. The semi conservative replication hypothesis was confirmed using an experiment which used E. Coli bacteria and different isotopes of the element nitrogen. The bacteria E. Coli was first cultured over many generations in a nutrient media containing the heavy isotope of nitrogen N15 within the supplied amino acids. This N15 was then incorporated into the bacteria DNA through its nucleotides. After a number of generations all the DNA contained the heavier N15 isotope. To confirm this the bacteria had their DNA extracted and ran through an ultra-centrifuge. An ultra-

centrifuge rotates centrifuge tubes containing suspensions at high speed causing denser particles to separate out of the tube at a lower point. In this case the heavy N15 caused the DNA to settle at a low point in the tube. The bacteria were then transferred to another medium this one containing the isotope of nitrogen N14 which is lighter than the N15 form. The bacteria were also allowed to divide in this medium. These bacteria also had their DNA extracted after the first and second generations. The first generation of bacteria cultured on the N14 medium had mid density DNA due to the heavy N15 strand and the new lighter N14 strand. The second generation of bacteria on the other hand had low density DNA which settled at the top of the suspension after passing through the centrifuge. This was because the new DNA strands were made from the light N14 isotope. This difference in the density of each DNA molecule is the evidence for the semi conservative hypothesis.

Protein synthesis and amino acids

DNA is the fundamental start of protein synthesis; acting as a template to create a protein out of its constituent amino acids. Whilst the DNA molecule never leaves the nucleus itself one strand is used to form mRNA (messenger RNA) in transcription. It is this molecule which leaves the nucleus through the nuclear pores and enters the cytoplasm where it is used by a number of ribosomes to build proteins. This build process is translation and uses complementary (to the

mRNA strand) tRNA (transfer RNA) molecules to chain together linked amino acids into a polypeptide chain. After translation has occurred this tRNA is released from its bound amino acid (which is now in the polypeptide chain) and can collect more amino acids from the cells amino acid 'pool'. This collection of amino acids is called activation and requires ATP to provide the energy the allows the amino acid to be attached to the tRNA.

Transcription

Transcription is the first step in protein synthesis and is the process of building the mRNA strand which will eventually leave the nucleus and enter the cytoplasm (the location of protein synthesis). First the enzyme helicase acts on a particular part of the DNA called the cistron. In doing so the helicase breaks the hydrogen bonds between the nitrogenous bases and causes the newly separated DNA to move apart. This make the bases in that section of DNA available to another enzyme - RNA polymerase. The RNA polymerase binds to the exposed template strand of the DNA at the start point of the to be copied sequence. Free RNA nucleotides then align themselves with the template strand. The free RNA nucleotides align to complement the DNA strand e.g. cytosine -> guanine, thymine -> adenine and adenine which in RNA binds with uracil which is not present in DNA. RNA polymerase then travels down the DNA strand bonding together the RNA nucleotides

into a molecule of mRNA. Just behind the travelling RNA polymerase molecule the DNA winds back up again. Once the mRNA has been synthesised it then leaves the nucleus through a nuclear pore to the cytoplasm and attaches to one or more ribosomes which consist of rRNA (ribosomal RNA) and protein.

Translation

The ribosome which the mRNA molecule reaches is formed from two smaller sub units. A small sub unit which has two sites for attachment of tRNA (so only two molecules of tRNA can be associated with a ribosome at any one time) and a large sub unit. The ribosome first attaches to the start codon on the mRNA molecule which is denoted by the codon AUG. Reading this codon causes a tRNA molecule with a complementary anticodon to become attached to the ribosome. It also causes another tRNA molecule with the complementary anticodon for the next triplet code in the mRNA to become attached to the ribosome. This brings the two amino acids on the tRNA molecules into a close enough proximity that a peptide bond can form between them (a ribosomal enzyme catalyses this bond formation). The first of the tRNA molecules then leaves the ribosome leaving a free attachment site for another tRNA molecule. As this happens the ribosome moves along the mRNA strand one codon. The above process then repeats until a STOP codon is reached. Translation therefore allows amino acids to be

built into polypeptides as specified in the DNA that is found in the nucleus of that cell. Each time a single ribosome moves along a mRNA molecule one polypeptide is produced but usually a number of ribosomes can be found on the same mRNA molecule resulting in many polypeptides being formed. This is called a polysome system. These polypeptides may need more 'work' to become proteins for that reason they often travel to the Golgi body where they are formed into the other levels of protein structure (secondary, tertiary etc).

Meiosis

Meiosis is the form of cell division which takes place in the reproductive organs of animals and plants. The resulting gametes produced in this process are haploid unlike mitosis which produces diploid cells. This is important in sexual reproduction because it allows for genetic variation to occur. The first step in the meiosis process is called Meiosis 1. In meiosis 1 a pair of chromosomes (maternal and paternal) which have identical gene locations (loci) i.e. a homologous pair which code for the same features of an organism pair up. After they have paired up the chromatids of each chromosome wrap around each other and exchange in a process known as crossing over. After crossing over has occurred one chromosome from each pair is made into one daughter cell. Because of this step of 'halving' the daughter cells have only half the required genetic material and so

are haploid. These newly produced haploid nuclei divide again in meiosis two which is a process identical to mitosis. After this step there is a total of four haploid nuclei which each have a differing genetic composition. Once the cell has stopped dividing it is in interphase and the DNA present in the cell doubles in quantity and new organelles are formed.

Both meiosis one and two can be further split into phases. These phases are Prophase 1 & 2, Metaphase 1 & 2, Anaphase 1 & 2 and Telophase 1 & 2. The 1 phases occur during meiosis 1 and the 2 phases occur in meiosis 2.

Prophase 1 is where the chromosomes become shorter as well as thicker. They also split into two chromatids. If centrioles are also present in the cell they move to the poles of the cell at this point. Microtubules then extend from the centrioles forming asters which make up the spindle. Once prophase has completed the nuclear membrane breaks down and the nucleolus completely disappears. The following phase is Metaphase 1. In this stage the pairs of homologous chromosomes are lined up on the equator of the spindle in a random manner. This random alignment produces an independent assortment of chromosomes which in turn creates brand new genetic combinations. After Metaphase 1 is Anaphase 1. Here the chromosomes which make up each bivalent separate and one of each pair is pulled to a separate pole whilst its sister chromosome is pulled in the opposite direction. Because of the pairs being pulled in opposite directions and their random arrangement during metaphase each pole gets just one of

the pair. The result of this phase is a mixture of maternal and paternal chromosomes and is called independent assortment. At completion of anaphase the chromosomes have reached opposite poles and the nuclear envelope as reformed around the chromosome groups. The final phase of meiosis 1 is Telophase 1. More often than not the chromosomes remain condensed and meiosis 2 occurs straight after completion of meiosis 1 as in plants where it occurs with no re-formation of the spindle. Unlike plants animal cells undergo cytokinesis at this point - the division of the cytoplasm to form two haploid cells.

Meiosis 2 has the same processes as meiosis 1. In prophase 2 the new spindle develops at a right angle to the previous (now old) spindle. Metaphase 2 sees the chromosomes line up separately on the equator of this new spindle each chromosome attached to a spindle by its centromere. During anaphase 2 these centromeres divide pulling the chromatids to opposite ends of the cell. The final step of the entire process is telophase 2. This occurs when the chromatids reach the poles. Here they lengthen and the spindle disappears as the nuclear membrane is re-formed. Cytokinesis then occurs to end the process producing four haploid daughter cells each with a different genetic code.

Importance of meiosis

Meiosis is important for sexual reproduction because it produces variation but also haploid cells. Having haploid

cells is important because it means that when two gametes fuse at fertilisation the resulting cell (the zygote) is diploid and so has the correct number of chromosomes. Genetic variation is equally important. The two events responsible for introducing variation during meiosis are crossing over between the chromatids of homologous pairs of chromosomes and independent assortment. Fertilisation also introduces variation due to the random fusing of gametes. All of these sources of variation aid in a species survival and providing the ability of a species to colonise a new environment. The variety is produced many different ways. The first is that the chromosomes making up a homologous pair carry different genetic material so that during sexual reproduction when the haploid gametes fuse the genotype (genetic code) of the mother and father mix. Arrangement along the spindle in metaphase 1 also adds variation when they separate independently producing daughter cells with a different combination of maternal and paternal chromosomes. The final way that variation can be introduced is crossing over in chiasmata formation (prophase 1) this allows equivalent genes on homologous pairs to be exchanged to make new combinations as well as separate genes that may be linked. This final method is called recombination.

Crossing over

Crossing over in meiosis is a key feature which makes it different from mitosis. Homologous chromosomes form pairs called bivalents. A bivalent consists of four strands made up of two chromosomes. These split into two chromatids which wrap around and then partially repel each other - remaining joined only at the chiasmata. At these chiasmata chromatids can break and later recombine with different but still equivalent chromatids.

Inheritance

Keywords

- Monohybrid
- Dihybrid
- backcross
- Chi-squared
- Mutation
- Mutagen
- Sickle cell anaemia
- substitution
- Haemoglobin S
- Non-disjunction
- disjunction
- trisomy 21
- tetraploid
- tetraploidy
- Polyploidy
- carcinogen
- Oncogenes
- suppressor cells

Genes and alleles

All living organisms have genotype which describes the genetics of that particular organism including the alleles or alternative gene forms that it contains. Linked to the genotype of an organism is the phenotype of that organism. The phenotype is the set of observable characteristics an organisms possesses as a result of its genotype. Genes are sections of DNA which code for a particular polypeptide to be used in protein synthesis. Genes are located on chromosomes. Homologous chromosomes are chromosomes which share the same length, centromere position and other properties. Alleles have similar gene loci on these homologous pairs. Genes are inherited and can determine particular characteristics. For a given chromosome locus there are a possible 3 allele combinations for a specific characteristic. The first is heterozygous, having two different alleles for a gene - one dominant and one recessive. In this case each allele will be present on a different chromosome of the homologous pair. Homozygous dominant is the second allele combination. In this case the organism will have the same two dominant alleles present which express the dominant characteristic in the individual. The 'opposite' of this is the homozygous recessive combination whereby the organism has two recessive alleles for the same gene which cause the recessive characteristic to be expressed in the individual.

If an particular characteristic is controlled by a single gene then the organism will express the dominant characteristic

unless they are homozygous recessive in which case the organism will express the recessive characteristic.

Monohybrid inheritance

Monohybrid inheritance is the inheritance of a single pair of characteristics which contrast each other. Gregor Mendel was the first person who worked out how genes are inherited. As a result of his experiments he formulated two laws. These two laws form the basis of genetics. Mendel's first law is known as the law of segregation and it states:

"Every individual possesses a pair of alleles (assuming diploidy) for any particular trait and that each parent passes a randomly selected copy (allele) of only one of these to its offspring."

Dihybrid inheritance

Dihybrid inheritance is where two separate genes are inherited. These are crosses between individuals with two contrasting traits of interest e.g. a white and large rat with a brown and small rat. In offspring there are four possible characteristics, in this case Brown small, Brown Large, White Large & White Small. These characteristics express themselves in a 9:3:3:1 ratio. This ratio is known as the dihybrid ratio.

Using the evidence from his pea experiments and this ration Mendel proposed his second law that "Each member of a pair of alleles can combine in a random manner with either of another pair." This law is also referred to as the law of independent assortment.

Codominance

codominance occurs when both alleles are dominant rather than one being recessive whilst the other is dominant. Because the alleles are both dominant they are both expressed in the phenotype of the individual. In most cases the expression of both alleles results in a phenotype that is midway between the two possible characteristics.

Examples of codominance include the roan colour in cattle which is a combination of the dominant red and white alleles and the pink snapdragon flower which is also a combination of the red and white dominant alleles.

Linkage

There are two key forms of allele linkage. The first is Sex linkage. Sex linked alleles are carried on the X chromosome. Sex linked alleles are not carried on the Y chromosome because it is significantly smaller than the X chromosome and as a direct result has very few genes. This means that recessive alleles on the X chromosome will always

be expressed in the phenotype of a male because they are unmatched with an equivalent dominant form because one is not carried on the Y chromosome. Recessive genes on the X chromosome cannot be passed from father to son because for they son must receive the fathers Y chromosome. Daughters however must receive the recessive allele on the X chromosome. If the female only receives one copy of the recessive allele then they are a heterozygous carrier, if they have two copies however they express the characteristic in their phenotype. Female carriers have a 50% chance of passing on the allele to their son(s).

Haemophilia is an example of a sex linked condition. Haemophilia means that an individual cannot produce a clotting factor thereby preventing their blood from clotting and causing slow, persistent bleeding. The recessive allele codes for factor 8 (VIII) a protein which is takes part in the clotting process.

Whilst the symptoms of haemophilia can be minimised using the clotting factor from blood donations the chance that it may be passed on to offspring will always remain.

```
|   XhY
|------------
XH-XHXh--XHY-
|-----------
XH-XHXh--XHY-
|------------
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XH = Haemophilia Xh = Normal

Linkage can also occur on other genes. Linked genes which are present on the same chromosome pass into the offspring remaining linked. Linked genes do not result in Mendelian ratios unless recombination occurs. Recombination is where alleles are exchanged between homologous chromosomes through the crossing over step process in meiosis. Since crossing over only happens in up-to 10% of cells undergoing meiosis that changes are the very few gametes will have recombinant genes and so practically nil offspring will have the recombinant genes. However the distance between each gene determines the chance of crossing over taking place with longer distances increasing the chance.

Sex determination

The final pair of human chromosomes - pair 23 determines sex in humans. Males have two different sex chromosomes one X and one Y. Females on the other hand have two similar X chromosomes XX. Because females are homozygous in terms of sex chromosomes their eggs only contain the X chromosome. For male sperm cells however because of the presence of both X and Y chromosomes in the parent the sperm cells contain 50% of Y chromosome and 50% of the X chromosome.

Drawing out a genetic cross for sex chromosomes shows that there is an equal (50%) chance of being either a boy or a girl.

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-----X----Y-----
|---------------
X---XX----XY----
|---------------
X---XX----XY----
|---------------
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Anaemia

The gene that codes for Haemoglobin can undergo a point mutation in the form of a substitution which results in the formed Haemoglobin being Haemoglobin S rather than standard haemoglobin. Haemoglobin S is the form of Haemoglobin responsible for sickle cell anaemia. Haemoglobin S has the wrong amino acid in two of its polypeptide chains which causes the cell to become sickle shaped. Sickle cells struggle to carry oxygen so cause anaemia.

The gene which mutates is co-dominant. For a homozygous individual the individual will suffer from the disease. Heterozygous individuals however are carriers and have only 30/40% sickle cells with the remaining 70/60% of their blood cells having normal haemoglobin. This heterozygous condition is also referred to as the sickle cell trait.

Statistical Methods

The Chi-squared statistical test can be used to determine if observed results are close to those which are expected or if something is happening to affect the results other than chance.

The Chi-squared test is carried out as follows:

- Calculate the set of expected values (E)
- Calculate the set of differences between the observed (O) and expected (E) results. This is done with the formula Sum (Sigma) ((O-E)ˆ2) / E
- Calculate the 'degrees of freedom'. The degrees of freedom are a measure of the spread of the data equal to the number of classes of data minus one.
- Using a Chi-Squared table the significance of the deviation can be determined. If the deviation is less than 5% then it is significant and an unknown factor is affecting the results.

Mutations

Any change to an organisms DNA is a mutation. Mutations may be localised to one gene or may effect many genes, even the whole chromosome. Mutations are very rare because they occur randomly and in a spontaneous manner which results in a low mutation rate in a population. Whilst

the variation caused by mutation can impact evolution because it provides characteristics on which natural selection pressures can act they do not have as much impact as other variation sources such as independent assortment.

The organisms which are most affected by mutations are those which have relatively brief lives. This is because as a species/population they undergo meiosis much more frequently than long lived organisms increasing both the chance that mutations occur and the overall mutation rate.

Mutations occur of their own accord but the mutation rate can be increased by exposure to mutagens. These are agents which cause mutations. Examples of mutagens include Ionising radiation (X-rays, UV, gamma), Viruses such as HPV, Chemicals such as tar in cigarettes. As well as these mutagens some mutations are linked to hereditary predisposition in which an organism inherits the tendency to have a particular mutation occur.

Some mutations can cause cancer, in this case they are called carcinogens. All carcinogens are mutagens but not all mutagens are carcinogens. Mutations occur in one of two ways: Incorrect copying of DNA and Chromosome damage. If DNA is not correctly replicated before cell division it can result in new faulty chromosomes. These mutations are often confined to one gene so are known as point mutations (sometimes as gene mutations). Note though that only mutations like these that occur in gamete formation have the chance to be inherited by offspring. Chromosome damage is usually reversible, the DNA that is

broken will rejoin should the chromosome break. On occasion however the chromosomes may not repair themselves correctly - this is a cause of chromosome mutation and has serious consequences because it affects a large number of genes.

Point mutations can cause changes in the phenotype of an organism. When a point mutation occurs a different allele is produced. The point mutation can take the form of an addition, deletion, duplication, inversion or substitution. All of these mutations change the polypeptide produced in protein synthesis by changing the primary structure of the protein because if the modified amino acid which is built into the chain.

As well as gene mutations there are also chromosome mutations. Chromosome mutations are responsible for variation in the number of chromosomes found in cells as well as their structure. Chromosome mutations are most likely to occur during meiosis.

Changes in the structure of the chromosome that occur during prophase one are such an example. When the homologous chromosomes pair up and crossing over occurs they exchange in material may result in the wrong pieces being rejoined - this causes a completely different gene sequence and prevents pairing up from occurring in meiosis again. As well as changes in the structure of the chromosome they can also vary in number. Non-disjunction is an example of this. Non-disjunction is a process in which the chromosomes do not separate resulting in one daughter cell

with no copies of that pair and one with two copies of the homologous pair.

Down syndrome is an example of chromosome mutation. Trisomy 21 is the most common form of Down's syndrome and is caused by non disjunction of chromosome 21.

Sometimes more than one chromosome is affected. Mutations in entire sets of chromosomes is known as polyploidy. If a diploid gamete (produced by meiotic error) is fertilised by a haploid gamete then the resulting zygote is triploid (it has three sets of chromosomes). If both gametes are diploid then a tetraploid is produced. Polyploidy like this is common in flowering plants (angiosperms like tomatoes and wheat) because it has some benefits for the plant but it can also be caused in animals when during mitosis the two chromosome sets (one from each haploid gamete) duplicate but are not then separated. When triploids are produced they are usually sterile because their chromosomes cannot match up into homologous pairs.

Although the term mutations has negative connotations they can in fact be beneficial. Beneficial mutations however are very rare. When they do occur though they provide a selective advantage to the organism increasing the amount of discontinuous variation in the population. Mutated genes however are often recessive alleles. As a result of this they have to be replicated in the gene pool a significant number of times over many generations so that the chance of an offspring having both recessive alleles and expressing the characteristics is large enough that it occurs

with relative frequency.

Carcinogens

If a mutagen causes cancer it is called a carcinogen. Like other mutagens carcinogens affect the DNA in cells through mutations. Mutations in somatic (body) cells more often than not have no effect on the body because they are dispatched by the immune system. It is important to note that not all mutagens are carcinogens but all carcinogens are mutagens.

It is thought that the formation of a tumour begins with mutations in the genes which regulate cell division. These genes are proto-oncogenes and the point mutations that occur within them are sometimes unnoticed by the immune system leading to uncontrolled mitosis. Eventually the unchecked cell division forms a ball of cells which is called a tumour. Often tumours are benign, that is they are harmless and do not move from their site of formation. On the other hand some tumours are dangerous - these are malignant tumours. Malignant tumours spread through the blood and lymph as a result of cells 'breaking off' from the main tumour body. These cells can invade other tissue leading to secondary growths. This is called metastasis and the diseases that result are called cancers.

Tobacco smoke is a good example of a carcinogen though it is the chemicals found within the smoke that are in fact carcinogenic. Nicotine and Carbon monoxide are amongst

the harmful chemicals present. Tar which solidifies in the lungs contains many carcinogens which affect the DNA of cells in the alveoli. Oncognes (mutated genes which cause cancer) and bad suppressor genes cab both lead to lung cancer. This means tar causes 25% of all cancer deaths in developed countries.

Reproduction

Plants (Reproduction)

Keywords

- flower
- petal
- stigma
- anther
- stamen
- sepal
- style
- ovule
- embryo sac
- receptacle
- angiosperms
- pollination
- desiccation
- generative nucleus
- tube nucleus
- dehiscence
- triploid endosperm nucleus
- integuments
- dicotyledon

- monocotyledon
- germination
- apices
- amylase
- plumule
- radicle

Flower structure

Flowering plants are referred to as angiosperms. Angiosperms are the most successful of all terrestrial plants. Flowers consist of petals which are brightly coloured so that the attract insects, a sepal which protects the flower in bud and so often remains under the flower once it has blossomed. The flower also has both male and female reproductive organs. The female reproductive system further consists of the style which supports the stigma - the receptive surface for pollen. The flower also contains the embryo sac, ovule and ovary which are situated just above the receptacle.

The male parts of the flower are the filament and stamen which it supports. The actual pollen grain producing part of the flower is the anther which is also said to be male.

Pollination

The transferral of pollen from one flower to another is called pollination. Pollination generally occurs to the stigma of a flower that is of the same species. Pollination allows

fertilisation to occur since it brings the male and female gametes together.

Some species of flower may self-pollinate. This is where the pollen from the anthers of a flower are only transferred to the stigma of that flower or one that is present on the same plant. Cross-pollination on the other hand occurs is the majority of known plant species and involves the transfer between flowers of different plants of the same species.

Genetic Implications of Pollination

Self-pollination is analogous to in-breeding. As such it shared many of the same disadvantages. These disadvantages include reduction in variation and the size of the gene pool for a given species. Another more serious disadvantage is that two undesirable recessive alleles have greater chance of being paired in fertilisation if self-pollination occurs.

Conversely however self-pollination can help to preserve good genomes so is possibly more suitable if the environment that the plant currently inhabits is a stable one.

Flowers are adapted to cross pollinate through one of two methods. These methods are: insect pollination or wind pollination. Insect pollinated flowers often have colourful petals with scent to attract insects. Such flowers may also produce nectar from their nectaries in order to attract insects such as bees which feed upon it. Bees feed on sugary nectar and are adapted to do so - having long tongues

so that they can reach the base of the flower where the nectar is located. When a bee enters the flower it also comes into contact with the male part. The anthers which brush against the bee leaving pollen behind - this pollen is the brushed off against a stigma of another flower when the bee enters it. The other method of cross pollination is wind pollination. Wind pollinated flowers have anthers that hang outside the flower as opposed to inside so that the wind can carry the pollen away. Wind pollinated flowers produce (large quantities) pollen adapted for this purpose - the pollen is smooth and light so that it is easily picked up by the wind. The anthers of wind pollinated plants can also be found outside of the flower. The stigmas are feathery so that they have a large surface area for 'catching' the pollen grains that are inevitably blown into them.

Each type of pollination leads to an equivalent fertilisation i.e. self/cross pollinated ⇒ self/cross fertilised.

Though self pollinated species display less variation than cross pollinated species variation does still occur. This variations arises from the random assortment as well as 'crossing over' processes that occur during meiosis. Mutation may also add variation to a self fertilised species of plants. Together this means that out-breeding becomes of greater evolutionary importance as some genomes will be successful whilst others will not.

Flower sex cells

The sex cells of a flower develop in both the anther (for male sex cells) and ovary (for female sex cells). Initially there are diploid cells in the anther which undergo meiosis into haploid cells which later become pollen grains. These pollen grains are surrounded by tough walls which are resistant to desiccation. Resistance to desiccation is what allows the pollen grain to be transported from flower to flower without it drying out.

Further mitosis occurs in the pollen grain - dividing the nucleus to produced two nuclei. One of these nuclei will be the tube nucleus and the other the generative nucleus which itself will go on to generate two more nuclei which take part in double fertilisation. The pollen grains are not released until after this division and they have matured. When the pollen grain is sufficiently matured the anther becomes dried out (tensions are produced in grooves) and dehiscence occurs. This is the curling of the pollen sacs to reveal the pollen grains.

The female gamete (egg nucleus) on the other hand develops inside the ovule which is produced in the ovary of the flower. Inside the ovule a mother cell undergoes meiosis forming an embryo sac which is haploid. Inside the embryo sac eight nuclei form through mitosis - two of these are polar nuclei and one is the egg nucleus.

Flower fertilisation

Fertilisation is the point at which the male and female gametes fuse together and produce a zygote. For plants to undergo fertilisation a number of steps must happen. This is because the ovule - that is the female gamete is protected by the ovary which means that the male gamete can only come into contact with the female nucleus through a pollen tube. The male gamete is the nucleus that is present inside the pollen grain.

Fertilisation begins with a pollen grain landing on the stigma. The pollen grain has to be 'compatible' with the plant for fertilisation to occur. This prevents plant hybrids from being produced. Once the pollen has landed on the stigma it germinates in a sugary solution that has been produced by the stigma. When the pollen grain germinates it produces a pollen tube which grows downwards as a result of chemotropism. Chemotropism is the growth of organisms dictated by a chemical stimulus. In the case of the pollen tube the response is positive because the pollen tube grows towards the stimulus - in this case the ovary. As the pollen tube grows down it releases enzymes which digest the style allowing the pollen tube to pass through whilst also providing it with some nutrients.

At the tip of the pollen tube is the pollen tube nucleus followed by the male nuclei (of which there are two). The pollen tube eventually reaches the integuments and grows through a gap in them called the micropyle. At this point the pollen tube comes into contact with the embryo sac so

the pollen tube nucleus disintegrates. The two male nuclei are then released into the embryo sac. Because there are two male nuclei a double fertilisation occurs. One male nucleus fuses with the female nucleus forming the zygote whilst the other fuses with the polar nuclei to form the endosperm nucleus which is triploid.

Double fertilisation is a unique process that only occurs in flowering plants.

Seed structure

Seeds can be broadly classified into two groups. Dicotyledons which have two seed leaves (cotyledons) and monocotyledons which have only one seed leaf or cotyledon. The broad bean is an example of a dicotlydon whilst the maize plant is a monocotyledon example.

The broad been (Vicia faba) seed food store is absorbed into the cotyledons. Maize however often have endosperm consisting of cereal grain which surround the cotyledons. In fact the monocotyledon group includes cereals. The arrangement of food storage in the maize plant actually makes the maize a fruit rather than a seed which is the hard part within the maize (think sweetcorn).

Germination

Plant seeds such as those of the broad bean (Vicia faba) can lie dormant for prolonged periods of time. Plants which

lie dormant do not germinate until such point as environmental conditions become favourable for the survival of the plant. The primary requirements for a successful germination are Water, Oxygen and an appropriate temperature. Water is required so that enzymes can be mobilised and other nutrients can be transported as well as for vacuolation of cells. Vacuolation is the process by which plant cells become filled with vacuoles. The Oxygen is important because it is sued in respiration the product of which (ATP) is used as the energy supply for growth and other metabolic reactions. Appropriate temperatures for germination varies between different plant species but is always optimal when it matches the optimum temperature of the enzymes that take part in germination.

During germination the seeds food sources are mobilised but they cannot be transported in the seedling because they are insoluble in water. As a result of this the plant food sources are first broken down into simple but soluble substances which can be transported to the growing apices of the plumule (young shoot) and radicle (young root) through a water medium. Because of this vast requirement for water the seed takes water up very quickly in the first steps of germination. This results in the plant tissues swelling. The radicle and plumule of the plant grow in opposite directions, the radicle beginning its growth first and forcing its way through the seed coat which ruptures to allow it through.

Though there are a large number of enzymes which are

used in germination amylase an enzyme also found in human saliva plays a key role. That role is the hydrolysis of starch to form maltose which can be transported to the apices (growing points) of the young plant. This is an important supply of 'food' whilst the plant remains underground - for the broad bean the cotyledons remain underground through germination. The plant can only begin to make its own food when the plumule emerges from the soil and unfurls (the plumule is originally bent over to protect it from soil abrasion) to gather light for photosynthesis, by this time the food source that originally was stored in the cotyledons will have been depleted.

Fruit development

Shortly ofter fertilisation of the plant fruit development takes place. This occurs alongside the development of the seed. The seed itself develops out of the ovule and consists of both the embryo of the plant and a food store. These seperate components are formed from the double fertilisation that occurs in flowering plants though the embryo is developed from the zygote. To form the embryo the diploid zygote divides by mitosis. This forms an embryo that is made up of several components. These components are the plumule, radicle and cotyledons. These can also be referred to as the developing shoot, developing root and seed leaves respectively. There can also be only one seed leaf instead of two.

The food store part of the seed is developed from the

triploid endosperm nucleus and provides a reserve nutrient supply for the developing embryo. Surrounding the entire seed however is the seed coat, referred to as the testa which is formed from the integuments.

Generalising these developments it can be said that the ovule becomes the seed whilst the ovary becomes the fruit.

Humans (Reproduction)

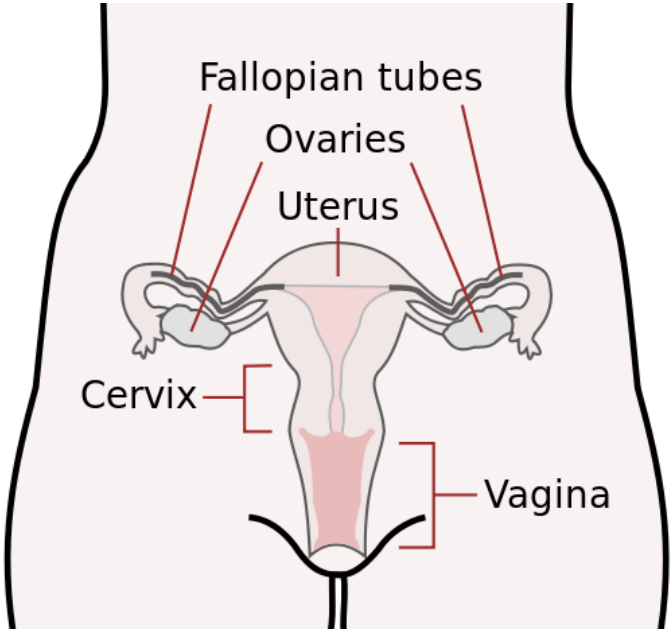
Keywords

- Ova
- Ovaries
- embryo
- Gamete
- Spermatogenesis
- Oogenesis
- diploid
- haploid
- spermatocyte
- oocyte
- acrosome
- blastocyst
- trophoblast
- amnion
- chorion
- hCG

- corpus luteum
- monoclonal antibodies

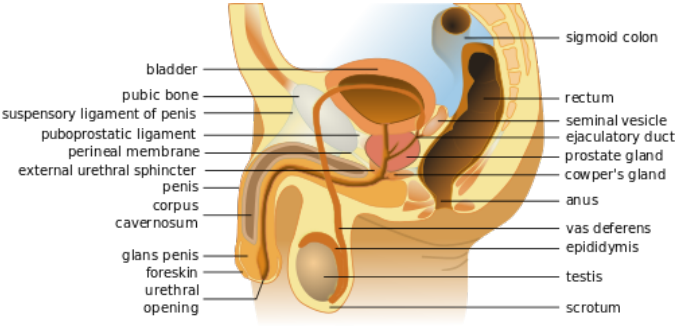
Female Reproductive System

A key part of the female reproductive system are the ovaries of which there are two. The ovaries produce the ova (eggs). Specifically ova are produced in the germinal epithelium where they become follicles, these follicles mature and the ova is shed. The ova then pass from the ovaries into the fallopian tube (also known as the oviduct) which carries the ova to the uterus. The uterus has muscular walls with a mucus membrane (the endometrium) and a large blood supply. Once the ova reaches here it implants if fertilised or is shed through menstruation. The uterus is connected to the vagina by the cervix - a ring of muscular tissue.



Female reproductive system

Male Reproductive System



Male reproductive system

Oogenesis

Oogenesis is the process by which the female gamete is formed. The female gamete is the ova which is produced in the two ovaries of the female reproductive system. In the developing female foetus Oogonia are formed which undergo meiosis to form around 2 million primary oocytes before birth. These primary oocytes also start division by meiosis but stop at the prophase one stage, they stop maturing until just before ovulation. Around this point the germinal epithelium also divides to form follicle cells. These cells then surround the primary oocytes to make primary follicles.

When puberty is reached hormones stimulate the follicles and cause them to develop further. This happens monthly and only one of the follicles fully matures into a Graafian

follicle. The development at this stage consists of the primary oocyte completing the first meiotic division and so forming a haploid secondary oocyte as well as a polar body (the first of many polar bodies to be produced). The now matured graafian follicle migrates to the surface of the ovary where it causes the ovary to rupture, releasing the secondary oocyte in the process which is known as ovulation.

Spermatogenesis

Spermatozoa (mature sperm cells) are produced in the process of spermatogenesis. Spermatogenesis takes place in the germinal epithelium of the seminiferous tubule - a part of the male reproductive system. The germinal epithelium cells divide into spermatogonia which themselves undergo division many times through mitosis to produce primary spermatocytes. The primary spermatocytes become secondary spermatocytes which are haploid cells through one meiotic division. Secondary spermatocytes undergo one further meiotic division to become spermatids which later differentiate into spermatozoa.

The seminiferous tubule where this process occurs has sertoli cells within its walls. These cells secrete a fluid which provides nutrients for the developing sperm cells (spermatids) and protects them from the bodies immune system which would otherwise attack them. The male sex hormones (androgens) are also secreted here.

Sperm

Sperm consist of a head piece, middle piece and tail. The head of the sperm contains the nucleus in front of which is the acrosome which contains enzymes for breaking down the walls of the egg cell during fertilisation. Behind the head is the neck and the middle piece. The middle piece contains a large number of mitochondria which provide energy in the form of ATP which is used in the tail to propel the sperm along.

Gametogenesis

Gametes are haploid male or female sperm cells which are produced in the gonads. The process by which gametes are formed is known as gametogenesis. Gametogenesis can be further divided into two separate processes, one for sperm and one for eggs. Spermatogenesis is the process which produces sperm in the testes whilst Oogenesis is the formation of ova (eggs) in the ovary.

The germinal epithelium of the tests and of the ovaries go through a series of meiotic and meiotic divisions to form haploid gametes. The gametes must be at haploid so that when the zygote is formed it has a diploid number of chromosomes.

Sex

To allow fertilisation to take place the sperm must travel from the seminiferous tubules where it is produced to the oviduct (fallopian tube) in the female. The sperm travels in a fluid called semen. Semen consists of sperm along with secretions from the seminal vesicles, prostate gland and Cowper's glands.

Semen is ejaculated from the penis into the vagina, the force of the ejaculation is large enough that it will propel some sperm through the cervix and directly into the uterus. The sperm make lashing movements with their tails to propel themselves into the oviducts. It is however only a small number of sperm which make it this far and only one that fertilises the egg.

Fertilisation

Fertilisation in a large number of animals is internal. This ensures that the sperm are correctly deposited in the females reproductive tract. Human sperm remain are only viable for 48 hours. This means that the sperm have to reach the oviducts as fast as possible. The sperm will meet a secondary oocyte in the oviduct as the oocyte makes it's way from the ovaries to the uterus provided that ovulation has occurred recently. Eggs also 'expire' and the oocyte will die 24 hours after release if it remains unfertilised.

Several thousand sperm cells will surround the secondary

oocyte but only one will penetrate through the follicle cells and the clear outer membrane known as the zona pelluda. For sperm to fertilise the egg they must first go through capacitation. Capacitation is a process which changes the membrane covering the acrosome and can take many hours.

Once the sperm comes into contact with the secondary oocyte and comes into contact with the zona pelucida the acrosome membrane is ruptured and enzymes are released. These enzymes act to soften the cells around the oocyte. When the acrosome becomes inverted it becomes needle thin. This allows the sperm to penetrate the now softened cells. This entire process is known as the acrosome reaction.

As the sperm penetrates the egg reactions are triggered in the oocyte that cause the formation of the fertilisation membrane. It is this membrane which prevents further entry by other sperm cells. The oocyte (nucleus) also completes its second meiotic division at this point. The two nuclei then fuse to form the diploid nucleus of the zygote.

The newly formed zygote divides by mitosis until it is a hollow ball of cells called the blastocyst. Travelling down the fallopian tube the zygote is continuously developing - after three days it reaches the nucleus and embeds itself in the endometrium. This point is called implantation.

The blastocyst which is now implanted in the endometrium of the nucleus consists of an outer layer called the trophoblast. The trophoblast will eventually develop into the chorion and amnion, two further membranes. The chorion

will grow chorionic villi which allow for more absorption of nutrients from the wall of the uterus as a result of the increased surface area. hCG is also secreted by the chorion. Human chorionic gonadotrophin prevents the degeneration of the corpus luteum. The corpus luteum itself is formed from the Graffian follicle after the ovum has been released. Detecting this hormone is the basis for pregnancy tests. The chorionic villi also later become attached to the developing foetus through its umbilical cord as the placenta.

Pregnancy Testing

Pregnancy tests use antibodies to test for the presence of human chorionic gonadotrophin. hCG is secreted by the chorion (which later becomes the placenta) during pregnancy to maintain he corpus luteum and can be found in the urine of pregnant women. The antibodies used in pregnancy tests are monoclonal. Monoclonal antibodies respond to only one foreign antigen this makes them very specific. In this case the antibodies are specific to hCG.

hCG is produced during the early stage of pregnancy. The test requires that a reaction between the antibodies and hCG occurs to cause changes on a coloured latex to which the antibodies are attached.

Sub-fertility

One in six people in the United Kingdom seek medical assistance because they have difficultly conceiving. Difficulty in conceiving naturally for any reason affecting either the man or the woman is known as sub-fertility.

Infertility on the other hand is the inability to conceive a child at all. Infertility unlike sub-fertility is a rare condition.

Infertility has two primary causes. The first of these is blockage of the fallopian tubes. This can be caused by infection but can be treated. For example by microsurgery. Any blockage of the fallopian tubes prevents the passage of the ovum to the point where it is fertilised making it impossible to conceive.

The second (primary) cause of infertility is failure to ovulate. Persons suffering from this tend to also have abnormal menstrual cycles. Treatment often takes the form of the drug clomifene which inhibits oestrogen receptors in the hypothalamus.

Variation and Evolution

Keywords

- Continuous variation
- Discontinuous variation
- heritable
- Non-heritable
- ABO
- phenotypic variation
- Selection pressure
- Predation
- gene pool
- population
- genetic drift
- natural selection
- Speciation
- Geographical isolation
- Reproductive isolation
- Behavioural isolation
- Mechanical isolation
- Gametic isolation
- hybrid
- hybrid unviability
- hybrid sterility

Variation

There are two types of variation. Discontinuous variation and continuous variation. Both types of variation can be caused in one of two ways depending on the manner in which the organism reproduces. Organisms which reproduce asexually such as bacteria, some plants and fungi can only gain variety in their population through mutations. Sexually reproducing organisms however gain variation through meiosis and fusion of gametes alongside mutations.

Continuous variation is where the variation occurs over a range of values. Examples of continuous variation include height or shoe size. Discontinuous variation on the other hand is variation in characteristics which are clear cut and controlled by a single gene. e.g. blood group (the ABO system) and other genes in which there are more than two alleles.

Variation also arises in two ways. Heritable variation is variation that arises from genetic changes. This variation is produced through three processes.

- Cross fertilisation: when two parental genotypes are mixed.
- Crossing over: The exchange of genes between homologous chromosomes during prophase one of meiosis.

- Random distribution: the random manner in which chromosomes are distributed through metaphase one of meiosis.

Most often the changes that occur through these processes create a new combination of alleles in only a single generation. This is in contrast to mutations which often create long lasting variations. The problem with mutations is that the majority of mutations that occur are not useful.

This is also true for Non-heritable variation which is variation arising from environmental factors. An organisms environment dictates things like diet, light sources and availability of nutrients. These determine the phenotypic variation of the organism. That is the characteristics are shown in the organism. Consider that you inherit a number of genes from your parents which determine how tall you'll grow. You may not reach that height if you do not get appropriate nutrients. This is variation caused by your environment and is primarily the cause of continuous variation in a population.

Competition

Population sizes are limited by the environment of the organism. As a population grows in size environmental factors act to keep the size of the population relatively small. This is a factor in the fact that often organisms do

not reproduce to grow their population size even through the have the (reproductive) potential to do so.

There are only finite resources in an environment so organisms have to compete both among their species and with other species for resources. These resources include food, shelter, mates, light, space etc. Competition that occurs between members of the same species is intra specific competition, it is this competition that is the foundation of speciation through natural selection. Inter specific competition on the other hand is competition that occurs between individuals in different species. For example a predator - prey relationship.

Competition is a form of selection pressure. In predator - prey relationships for example predation causes an increase in the fitness (as in 'survival of the fittest') of the prey by changing the frequency of alleles in a population.

Organisms which are better adapted to their surroundings and environment survive to breed. This means that they pass their alleles on to the next generation. Less well adapted individuals are 'eliminated from the gene pool' because their characteristics are not passed on to the next generation. The gene pool is the number of alleles present in a population at a given time and is determined by selection pressures exerted by the environment.

For a population that reproduces sexually the gene pool is large because of the large amount of variation present. To determine the proportion of occurrences of different genotypes in a population and so the proportions of alleles

(allele frequency) population genetics is used.

The gene pool of a population is constantly changing. Some alleles grow to be more frequent whilst others less so. In some cases one or more alleles may be completely removed from the population. A gene pool is only as stable as the environment. A stable environment creates a stable gene pool but variations in the environment favour different alleles in different ways creating changes in the frequency of alleles in a population and so also in the gene pool.

A stable gene pool is known as 'genetic equilibrium'. Genetic drift, natural selection and mutations are factors which act on the genetic equilibrium and alter the gene pool.

Of these factors genetic drift is perhaps the most important for all populations though it has greater importance in populations that are small in size or are isolated. Genetic drift is most important in small populations because the smaller the population the smaller number of individuals that may be carrying the allele and so the greater chance of those individuals not mating and passing the allele on to the next generation - possibly causing it to be lost from the gene pool. Genetic drift is also important in the formation of new species. When some individuals of a population become isolated the small population undergoes genetic drift which can make it greatly different in comparison with the original species (the parental population). This effect is known as the founder effect and is best demonstrated by Darwin's finches.

Selection

The theory of natural selection is credited to Charles Darwin (1809-1882) who proposed the theory after visiting the Galapagos Islands in 1832 as part of a scientific survey. The islands were particularly good for observing variation in populations because they were originally volcanic. Because of this when they formed there was no life present on them. This meant Darwin could conclude that all the plants and animals that were living on the island at the time must have flown or arrived by see from the mainland (the Galapagos are situated 600 miles off Ecuador, South America).

The theory of natural selection proposed that organisms which are adapted better to their environment relative to other members are more likely to survive long enough to produce offspring the are successful. The theory is based on observations that Darwin made, variation occurs in any population and individuals in a population can produce large numbers of offspring yet population size remains roughly constant. Based on this it can be suggested that 'there is competition for resources', 'only the fittest members of a population survive' and 'individuals which survive have a selective advantage (they have the characteristics that allow them to succeed)'.

Natural selection is a continuous process in that as environmental conditions vary the characteristics needed to survive also change.

Speciation

Over time individuals the were originally members of the same species can become part of two completely distinct species. The formation of a new species is called speciation.

In a single species population there exist further sub groups called demes. Demes are interbreeding sub units which tend to breed among themselves more often than they breed outside their deme. A new species is formed when there is a 'reproductive barrier' that prevents reproduction from occurring between demes. This prevents the 'flow' of genetic material between demes and in the long term causes the two groups to be sufficiently different that a new species with its own gene pool incapable of breeding with the parent species is formed. The 'reproductive barriers' which cause this are known as isolation mechanisms. The entire process is called speciation.

Isolation

There are two main forms of isolating mechanism that lead to the formation of new species (speciation).

The first of these is geographical isolation. Geographical isolation occurs through the physical separation of one or more demes. This separation can take the form of a river forming or an earthquake - any physical feature that would prevents members of the same species from interbreeding.

This form of speciation is known as allopatric speciation and is very likely to give rise to a new species. A new species is said to have formed if the two populations have established a separate gene pool and can no longer interbred.

The second form of isolating mechanism is reproductive isolation. Reproductive isolation itself can be further broken down into further more specific mechanisms: behavioural, mechanical, gametic, unviability and sterility. Reproductive isolation is caused when organisms which are inhabiting the same environment become seperated into two groups even though there are no physical barriers to their reproduction. This form of species formation is known as sympatric speciation and occurs between demes in the same geographic area.

Behavioural isolation is the mechanism that occurs in animals with elaborate mating rituals or courtship behaviour. The isolation occurs because the steps in one subspecies ritual fails to elicit and required response in a member of the other subspecies who is the potential partner.

Gametic isolation occurs in flowering plants and animals. In plants it is where pollination is prevented from occurring because the pollen grain does not germinate on the stigma. In animals sperm may fail to survive long enough for fertilisation to occur.

Mechanical isolation is simple that the genitalia of two subspecies is incompatible.

Unviability and sterility refer to properties of Hybrids. Hybrids are animals like the 'liger' or the 'zebronky'. Hybrid unviability occurs when even though fertilisation has taken place the embryo does not develop. Often hybrid unviability occurs because chromosomes no longer match each other for example having some chromosomes with different sizes or gene loci. This is the case in polyploidy.

Sterility on the other hand is caused because the sets of chromosomes in the offspring of the inter-species breeding can not pair up during meiosis because the sets of chromosomes from each parent are different. It results in offspring which cannot produce gametes - making the individual sterile.

Using Genetics

Keywords

- clone
- Embryo cloning
- nuclear transplant
- donor
- recipient
- mutation
- Progeny
- Stem cell
- In vitro
- Differentiate
- Tissue culture
- Tissue engineering
- embryonic
- Micropropagation
- totipotent
- meristems
- callus
- propagation
- Human Genome Project
- Gene probes
- Pre-symptomatic

- Pre-natal
- Huntington's
- Alzheimer's
- autosomal
- Cystic fibrosis
- liposomes
- pancreatic duct
- CFTR
- Plasmid
- DNA ligases
- Recombinant DNA
- Restriction enzymes
- Sticky ends
- Reverse transcriptase
- Transgenic
- GM/GMO
- Electrophoresis
- Gel Electrophoresis
- Polymerase
- Peptide

Cloning

There are a number of ways in which animals can be cloned. Of these methods - Embryo cloning is perhaps the simplest. Embryo cloning has been used to produce organisms which are genetically identical and allow farmers to

increase the numbers of their animals. It is carried out by taking eggs from the animal with the desired quality for example cows which produce the most milk. The eggs are then fertilised in vitro with the sperm of the best male animal. The newly fertilised egg subsequently divides into a ball of cells. When this ball consists of 16 cells it is split up into smaller bundles which each develop into more genetically identical clones. These clones are identical to each other not to the parent similar to identical twins which form in the same way. The embryos are transplanted into surrogates to complete gestation before they are born.

The 16 cell limit is important because at this point the cells are totipotent, they can divide into a number of different types of cell such as the complete organism but after this stage the cells differentiate and can no longer be used to produce complete organisms.

Another commonly used but more complex cloning method is cloning by nuclear transplant. Unlike the embryo cloning method which produces genetically identical offspring a la twins this method produces individuals that are genetically identical to the organism that you want to clone. The technique involves transplanting a nucleus from a somatic cell (a body cell) into a 'blank' egg which is an egg with the nucleus removed. Dolly the sheep is an example of an animal cloned in this manner.

Dolly was cloned in the following way, similar steps apply to other animals. Cells were taken from the udder of the sheep (the donor that you want to clone). Another sheep

who is 'the recipient' has their eggs taken and the nucleus removed leaving other cell organelles intact. Removing the nucleus still leaves mitochondrial DNA in the cell. The donor nucleus and this cell are fused in vitro using a gentle electric pulse which stimulates some of the reactions which occur in fertilisation. This forms a ball of cels which is the developing embryo and is transplanted into a surrogate or 'the host' to complete gestation. When the lamb is born it is genetically identical to the donor sheep though it has mitochondrial DNA from the recipient. This cloning technique is not as useful as ebmryo cloning because it does not allow a large quantity of animal copies to be produced. Instead this technique is used to preserve desirable qualities for future generations. For example in castrated race horses who cannot produce sperm (obviously) in order to maintain their genetic material they have to be cloned. Cloning is used when artificial selection would be too slow or would cause a loss of the characteristic. Cloning has many applications and is not limited to big organisms like animals, cancer cells can be cloned for medical research or for cloning antibodies that are used on pregnancy tests. The overall goal of cloning is to maintain a line of cells with desirable characteristics for as long as required to maintain genetic stock and biodiversity.

There are a few disadvantages to cloning in animals. The most obvious of these is expense, cloning requires lab time and labour which is very costly considering how unreliable the entire procedure is. Further without closely analysing the genetics of the animal that is being cloned

scientists may select for bad alleles by accident. The final disadvantage that may have been shown in dolly the sheep is premature ageing, Dolly's telomeres were short on examination a usual result of the ageing process although Dolly was young, only 6 when she died. Along with this other unforeseen and long term effects may develop in progeny of cloning.

Micropropagation

Micropropagation is also called plant tissue culture and is a technique used in the cloning of plants. Micropropagation is based on the fact that differentiated plant cells can give rise to all the different plant cells that would normally be found in the adult plant. Under the correct conditions plant cells can develop into any other cell because they are totipotent, that is capable of differentiation.

Micropropagation is also sometimes called test-tube plant culture and is a relatively recent development in comparison with conventional plant propagation methods such as taking cuttings.

To carry out micropropagation the plants meristems are are exposed and cells removed from the meristem to be placed in the correct conditions. The meristem is a growing point of a plant where the cells are rapidly deriding through meiosis. The tissue here is called meristematic tissue and can be used to develop new genetically identical crops from a single parent of which they are clones.

Generally micropropagation takes place in the following steps.

- A plant is selected to be cloned, this is often the one with the most desirable characteristics.
- A scalpel is used to separate the root and the meristem in aseptic conditions.
- The meristem is cut into small tooth sized pieces called explants.
- The explants are placed on sterile medium such as agar jelly which is aerated and provides the plants with all the nutrients and chemicals it needs.
- The exoplant cells divide by mitosis.
- The exoplant becomes a mass of undifferentiated cells called a callus.
- The callus is cut down into a number of pieces which are encouraged to develop (differentiate) into a plantlet.
- Plantlet's are transplanted into sterile soil at the appropriate time.

There are wide ranging reasons for micropropagation to be carried out. It is a process which has a number of advantages. The most obvious of these advantages is that large number of the plants can be grown in sterile conditions. This sterile environment free from harmful bacteria and other parasites means that the cloned plants have a greater chance of surviving than if seeds were simply planted

outside. Resistance to disease or high yield can also be selected for in the parent of the clones making sure that good quality stock are eventually produced.

Having desirable characteristics has commercial value as does the uniformity of the crop if crops are propagated. Micropropagation can also be used to preserve unique genotypes and in general micropropagation requires little space both for storage and for transport thereby reducing heating, lighting and transport costs.

Naturally there are also disadvantages to micropropagation. The primary disadvantage is the lab time required. Sterile conditions have to be maintained until the plants are ready to be planted out otherwise some of the plants are likely to die from fungi or bacterial contamination. The resulting plants from the process are also genetically unstable. This is because of an increased mutation rate in the cells that are grown in the nutrient medium that causes abnormalities in the resulting plantlets. To 'nip' the mutated plants in the bud requires workers to regularly inspect the plants and remove defective individuals pushing up costs further.

Tissue_culture

The technique by which cells are grown in laboratory conditions are called tissue culture. Tissue culture is carried out in vitro and allows cells from young animals or cancer cells to divide under observation. These cells are used

instead of adult cells because most (though not all) adult cells retain the ability to differentiate since they are already differentiated (specialised for a specific purpose such as sweeping dust from our airways).

To grow cells in vitro the conditions have to be exactly right and correctly controlled. Controlled conditions range from osmotic potential to temperature and pH. Cells grown in tissue culture are able to become mature cells of the same type from which the culture was made whilst staying genetically identical to the parent cell. Tissue engineering is a slight tweak to this concept in which the cells are induced to grow in a synthetic mesh like framework which nudges the cells into growing the correct way for example the cells might need to be grown spread in a thin layer for later use as skin. Artificial skin produced in this way is used in place of skin grafts in some cases.

Tissue engineering can also be used to repair other organs but relies on stem cells. The source of these cells, or rather the best source is very early stage embryos though they can also be taken from the bone marrow of adults. It is the source of these cells that raises ethical concerns despite the massive potential for the technology e.g. generating organs that wound be rejected by the recipients immune system. Stems cells are made to differentiate into the required cells by adding the appropriate growth factors or hormones to the culture of cells. The cells are initially taken from the patient and have their nucleus removed, this nucleus is inserted into a human ovum which has also had its nucleus

removed - though as with other animal cloning other cell organelles remain. This ovum is the cell that divides to form the ball of stem cells which can then be used for any number of purposes.

GMOs

GMO is an abbreviation for genetically modified organisms and includes GM crops as well as animals and microorganisms. GM crops are perhaps the most common GMOs because of the relative lack of ethical issues surrounding their use in experiments. On the whole the GM crops have a 'bad name' which has resulted in many retailers banning GM ingredients from their products, you would find it difficult to find GM ingredients in UK supermarkets and indeed in the EU. As mentioned elsewhere low public confidence in GM has lead to the EU being one of the toughest places to produce GM crops. In fact only one crop MON 810, a maize plant, is licensed for human consumption in the EU currently. The only other to receive licence was Amflora, a potato that failed due to lack of demand.

Outside the EU however there are a wide range of genetically modified or transgenic crops. Transgenic means that the organism contains genes from another species. Soy beans are one example. In many countries the soya bean (of soy sauce fame) is of extreme importance as a food source. In some countries around 60% or more of foods are soy based e.g. soy milk, bread, biscuits etc. Some soya bean

comes from GM soya crops which have been modified to be resistant to weed killer. This allows the soy crop to survive in situations where weed killer is relied on to kill weeds that would otherwise reduce crop yield. The weed killer ends up as broken down compounds in the soil.

Tomatoes are another plant which have been genetically modified, the 'Flavr Savr' strain of tomatoes has been modified to keep them firm for display in supermarkets after long distance travel. These tomatoes also have a longer shelf life and notably better taste. 'Flavr Savr' tomatoes have a gene whose base pairs are complementary to the enzyme that ripens tomatoes through breakdown of pectin in their cell walls. The enzyme is not produced because when the mRNA for both genes is produced they combine to form a double strand which cannot be translated and so the polypeptide and later protein cannot be made.

The process by which GM crops are produced is relatively 'natural' taking advantage of a naturally occurring bacteria which contains a plasmid that it copies into trees to cause tumours (crown gall disease). This natural ability to copy its own DNA into that of the tree has been exploited by scientists who want to insert their own plasmids into plants. The species most used for this task is Agrobacterium tumefaciens which is now called Rhizobium radiobacter.

GM crops and GMOs in general have massive potential in terms of solving food shortages, improving food quality and flavour, reducing the environmental impact of farming and disease resistance. There are several reasons though

why one would be opposed to GM crops including concerns that organic crops will be contaminated with GM pollen, GM pollen transfer to wild plants (although some biotech companies have planned to and patented forcing sterility in GM crops) and antibiotic or herbicide resistance developing in unwanted organisms. The sterile seed idea was not fully developed because of anti-GM backlash from concerns that it means that farmers would have to buy new seeds each year. Giving a monopoly on plant breeding to biotech companies and reducing crop diversity.

Genetic Engineering

Genetic engineering is deliberately modifying an organism by manipulating its genetic material to produce the required characteristics. This can range from modifying bacteria to produce drugs to 'building' pest resistant crops. Genetic engineering is carried out through recombinant DNA technology. Human insulin production by the bacteria E.coli or yeast is an example of large scale genetic engineering.

To begin the process of genetically engineered molecule production the gene which codes for that molecule to be produced has to be isolated from the donor DNA molecule. This is done using a gene probe. In some cases it is the mRNA that is isolated from the cells. In this case DNA is made from the mRNA template using reverse transcriptase and enzyme taken from viruses. After this both methods

continue in the same manner. The DNA is cut into segments using restriction enzymes (restriction endonuclease) which 'cut' the DNA at recognised base pairings. At the end of the new DNA strand are sticky ends which are unpaired bases later used to join the DNA to the vector.

Reverse transcriptase is made from a group of viruses called retroviruses and the copy of DNA the produce from mRNA is referred to as cDNA or copy-DNA. The cDNA has to be made into a double strand, this is done with the addition of DNA polymerase. Reverse transcriptase is often used instead of the gene probe method when functional mRNA is present in large quantities in the cell, such as in the pancreas. This is often the case when the cell synthesises and secretes the molecule. It is easier than isolating the DNA because there are only two DNA copies whilst there can be significant amounts of mRNA.

Once the DNA has been isolated it has to be inserted into a vector for delivery into the bacteria. The vector used most commonly is a plasmid. Plasmids are small circular pieces of DNA which are found in bacteria. The plasmids first have to be taken from other bacteria by dissolving the cell wall and taking the plasmid. This plasmid is then cut open using the same restriction enzyme that is used in the cutting of the human or animal gene which codes for the molecule we want to make. This ensures that the bases on the sticky ends are complimentary so that when mixed the plasmid and the gene recombine. DNA ligases are the enzymes used to join the donor DNA and vector DNA (the

plasmid) together through creating phosphodiester bonds in the sugar phosphate backbone of the DNA. Hydrogen bonds form naturally between the complementary bases on the sticky ends. The DNA produced as a result of these steps is called recombinant DNA.

Once scientists have obtained the plasmid it can be reinserted into the bacteria to produce more copies of the plasmid. These bacteria are then commercially cultured for example in a batch culture (or otherwise) fermenter. The molecule that was aimed to be produce is then collected and purified from the fermenter. This is relatively cheap and quick in comparison with other methods such as producing insulin from cows.

Only 1% of the bacteria however take up the plasmid to it becomes difficult to identify which bacteria need to be used in the fermentation process. To solve this problem marker genes are used. Marker genes used in this way are to identify genetically engineered bacteria using antibiotic resistance. Marker genes can however be used to identify labelled genes to show they have been incorporated into the host cell. This is often done by making the marker radioactive. When genetically engineered cells are grown in the lab they are grown on plates laced with ampicillin, a largely useless antibiotic. Because the bacteria that have the donor DNA have also had the marker gene - in this case resistance to the ampicillin also inserted they survive on the plates whilst the others to not. This allows scientists to easily see which bacteria have the plasmid and can be

cultured for fermenting.

Concerns about Genetic Engineering

Whilst there are numerous advantages to genetic engineering including the medcinal benefits, high yield crop production (possibly preventing famine) and producing increasingly needed polypeptides (incl. proteins) the could not be made with any other means at our disposal there are also some concerns which offset the benefits. These concerns range from privacy issues to general hazards associated with the procedures carried out as part of genetic engineering.

As sceintists gather ever increasing amounts of data epecially related to genetic fingerprinting concerns are being reaise over how safe the data is. Apart from normal scientific use cases, forensics, paternaty studies etc the data could be obtained by insurance companies to determine the premiums they charge. This could for some people make getting life insurance impossible. For this reason its important that the data collected through sceintific studies is appropriately regulated and controlled.

Genetic engineering provides other possibilities for either things to go wrong or for people use the tools in the wrong way. Germ-line (i.e. modification of the egg cell) therapy is very controversial for example. This is because genes that

appear to have no effect other than switching on or off other genes on the same chromosome that are tampered with could cause unpredictable problems in future generations. There are other problems associated with the fact that it is very difficult to predict the outcome of genetically engineered solutions. For example a new gene might cause a harmless organism to become pathogenic, if such as organism found its way into the environment it could have disastrous consequences. Likewise because bacteria can freely exchange genetic material the recombinant DNA used may become transferred into other organisms including the antibiotic resistant marker genes. If this genetic material were to make it into pathogens it could be 'bad news'. Ampicillin resistance is used as a genetic marker because it is not nearly the most dangerous resistance that could 'escape' into the environment. Despite this the gene usage in the EU is heavily regulated along with others. The EU has very tough GMO regulations in comparison with the U.S.

Ethics

Ethics can be loosely defined as either "Moral principles that govern a person's or group's behaviour" or "The moral correctness of specified conduct". The definition depends on the context.

Tissue culture is an example of a scientific research area that causes a fair share of controversy. The main cause

for concern is over the use of stem cells. This is because the best source of stem cells is very early embryos. These embryos are sourced from fertility treatment patients because there are excess embryos that are not implanted into the uterus during the treatment. These embryos can have their stem cells removed for research purposes after which they are destroyed. Opponents of stem cell therapy consider in unacceptable that the embryos are used in this manner despite the fact that the embryos would never have developed regardless of their use in research. They (the opponents) say that the technology which allows use to do this are a slippery slope to reproductive cloning and the devaluation of 'life'. There are often religious reasons for this - e.g. 'playing God'. However the stem cells can be used to treat a wide spectrum of diseases from Alzheimer's to multiple sclerosis as well as more common diseases like heart disease. Even cancers have the potential to be treated in this manner. Many would argue that this outweighs an ethical concerns that arise.

Human Genome Project

The human genome project started in 1990 as a worldwide initiative. It aimed to determine the sequence of the four bases (A: Adenine, G: Guanine, C: Cytosine, T: Thymine) in all of human DNA. Once this was determined the project aimed to identify the genes that are produced by all the bases. These genes then had to be located on the human

chromosome. Subsequently all this data had to be stored in databases designed for the task. Along the way the researchers had to consider the ethical, social and legal issues that they met collecting the data on the human genome.

The information from the human genome project has numerous beneficial applications. The information tells scientists which sections of DNA on each of the 23 chromosomes are responsible for inherited diseases. Thereby allowing scientists to replace bad genes with normal functioning copies which are also known.

The human genome project was a long task - identifying the 25,000 genes alone took 13 years and finished in 2003. The remaining tasks involve analysing the data collected.

Cystic fibrosis

5 in 1000 people in the U.K. alone will suffer from Cystic fibrosis as a result of a defective autosomal allele. Since the allele is recessive it requires two carriers to cause expression of the condition in offspring. This is hard to test which is why genetic screening is sometimes used. Sufferers produce a thick mucus from the epithelial cells of a number of passageways including the lungs and pancreas. The mucus arises because the CTFR protein (cystic fibrosis transmembrane regulator) in sufferers does not transport chloride ions out of the cell. This is because of a three base deletion on chromosome 7 that leads to a missing amino

acid. In normal circumstances the transport of chloride ions draw water out of the cell by osmosis into the layer of dust and so on which forms the mucus. This makes the mucus watery so it can be easily brushed away by cilia on the cell surface. When chloride ions are not transported, as in sufferers the mucus dries out and can not be moved by the cilia - this makes the individual prone to infection which is especially serious in the lungs. Many suffers do not live past their late 20s.

In order to relieve the symptoms of respiratory distress a frequent physiotherapy is required to keep the airways open. Because the condition also affects the pancreas sufferers can digest less, as a result children have large appetites to compensate. Research being carried out currently is looking at ways that gene therapy can be used to alleviate or stop symptoms. The CTFR gene has been isolated and clones multiple times. Currently the gene therapy uses liposomes - small spheres of lipid molecules as a vector to transfer the correct gene to the affected cells. This is not the best method as liposomes have a low chance of being taken in and the DNA being combined with the cell. They are however easy to administer, inhalers can be used to deliver the liposomes to the lungs. In the future viruses from the adeno-associated group may be improved (they have been trialled before) to be used in gene therapy, currently as with the adenovirus they have a low success rate.

Gene testing

In order to test for gene mutations scientists obtain DNA samples from a number of patient or patients and scan the sample for mutated genes. A gene probe (a short section of DNA whose sequence is the complement of the strand that is to be looked for) is used for this because they seek their complement from the three billion pairs that make up an individuals genome. Should the mutation be found the probe binds to it and 'flags' the mutation to scientists.

There is another method that can be used for DNA testing. It involves comparing the DNA sequence from the patient to a known normal version of the gene. Because these tests can take time and labour that varies with the size of the genes and the number of mutations which have to be tested against these tests are often expensive.

Genetic testing is used in a wide variety of scenarios.

- Pre-natal diagnostics and newborn baby testing (e.g. Hereditary conditions)
- Carrier screening
- Pre-symptomatic testing for adult onset diseases (e.g. Huntington's) and predicting risk of onset (e.g. Alzheimer's)
- Forensic testing (e.g. Identity, paternity etc)

Knowing the results of a genetic test can have wide reaching consequences on the way an individual chooses to live their life. For example if you have been been tested as a

carrier for cystic fibrosis and the test comes back positive you might choose not to have children in case they become a sufferer. Alternatively you might choose to abort a child if an antenatal test showed it could suffer from a disease like this.

There are both pros and cons to gene testing. The pros are that it can be used to clarify doctors diagnosis and so allow for better targeted treatment of symptoms. Gene tests have been commercialised such as those for adult onset disorders like Alzheimer's and some cancers. These tests are targeted at health people before the express the symptoms of the illness (pre-symptomatic) if they have the disease at all. They are most likely tested because they have been marked as high risk as a result of their family medical history. Most of the debate over gene testing is over these kinds of test. This is in part because the tests only give a probability that the individual might develop the disorder. In some cases a positively tested individual may never develop the illness making it hard to interpret a positive result. Scientists use information like this to determine the likelihood of someone developing the condition and also to make deductions about the condition. For example scientists now think that some disease causing mutations only express the disease in combination with other mutations and environmental factors.

The 'cons' of testing include the limitations of lab testing during which mistakes can occur. Laboratory errors might occur due to mislabelling samples chemical contamination

or a number of other reasons. Further the uncertainty in the test result interpretation and lack of available medical options means that the tests often provoke anxiety or cause distress for a number of individuals as well as social stigmatisation and discrimination that can occur after testing.

Along with these there are a number of social concerns that include: who gets access to the personal genetic information and who gets to use it. For example there are concerns around insurance companies getting hold of genetic information because it could affect their decision to ensure you for e.g. in life insurance or medical insurance (for countries like the US where medical care is not provided by the state). There are also questions about wether parents have the right to get their child tested for diseases that may affect them in their adult lives and who owns genetic information.

The biggest question of them all though - will we one day produce human clones??

Gene therapy

There are many diseases which are caused by problems with genes or alleles. There is research into ways that these can be treated. The topic is called gene therapy. The aim of which is to replace the defective genes in the patients body with copies taken from healthy individuals. Currently some methods of gene therapy have been approved - primarily

targeting cancer (60%+) whilst the remainder treat genetic disorders.

The hurdle that gene therapy has to overcome in order to be successful is development of a gene delivery system. Such a system must have a way of inserting normal genes into a patients cells and then ensure that these genes function correctly. Currently viruses are used as the primary vector for carrying the new DNA to the correct cells. The viruses (or a different vector) then inject the naked plasma DNA or make use of liposomes to insert the DNA into the cell.

Generally speaking gene therapies can be broadly categorised into two groups, germ line and somatic cell therapy. Both forms of therapy simply introduce the new DNA to the cell rather than remove the defective genes. This means that both correct and bad polypeptides are produced at the same time. Germ line therapy concerns 'germ line' cells. These are the cells that form the egg and as a result the genetic changes made will be inheritable. Somatic cell therapy on the other hand targets the cells in the affected tissue so the changes are not heritable. Sometimes stem cells are used instead of mature somatic cells which can have longer lasting therapeutic results but is also non heritable.

Genetic 'Advice'

Couples whose families have a history of genetic defects may consult a genetic counsellor for advice on the risk

that any child they bear will suffer from the defect even if they themselves are unaffected. The risk of bearing a child which has the genetic defect is based on the family history along with other factors like how closely the parents are related and the general occurrence of the gene in the population - locally and globally.

If the risk is sufficiently large the couple may choose not to have a child themselves (opting instead for adoption etc). However some couples may still choose to conceive despite the risk. Couples which do this can still choose to have an abortion subject to legal requirements if the condition is discovered in the unborn child. This is called genetic screening and involves several methods which can be used to test for a genetic defect. Not all are 100% accurate which raises some ethical issues. The methods that might be employed include blood tests such as the one for cystic fibrosis. There are other tests which are more invasive, time consuming and labour intensive. These include Chorionic villus sampling which can only be carried out between 8 and 10 weeks into the pregnancy. Chorionic villus sampling requires taking foetal tissue from the uterus to be cultured so that they can later be examined under a microscope to look for defects. Ammiocentis is another more involved procedure - it involves withdrawing some amniotic fluid. The withdrawn fluid contains cells which have 'floated' from the surface of the embryo. As with chrionic villus sampling these cells can be taken from the fluid and examined under a microscope.

Though the advantages of gene therapy, counselling and screening are large, giving a child a chance to lead a normal life for example there are people who are against the notion of using genetic screening and so on. People for example feel that genetic screening is an invasion of privacy despite the fact that it can only be carried out with consent. Further it puts a large amount of pressure on couples who discover they are 'high risk' and so must decide if they can raise a child with a genetic disease. Some are scared that scarce regulation will lead to companies modifying the genetics of the child before it is born. But is this a bad thing?

Fingerprinting

Everyones DNA is unique - excluding clones, identical twins and people who against almost unbeatable odds have ended up with the same DNA has another human being. This means that we can inspect a persons DNA to identify them, an individuals DNA profile used in this way is a genetic fingerprint and the process of obtaining such a fingerprint is genetic fingerprinting. Genetic fingerprinting is used in a number of scenarios including paternity cases and in other forensic tasks aka tasks relating to the investigation of crime or of interest to a court of law.

90% of our entire genome has no known function though different people still have different sequences of 'useless' DNA. The non coding sequences in DNA are often repeated many times consisting of up-to 40 base pairs and usually

more than 20. These lengths of DNA are called HVRs or hyper-variable regions or even STRs, short tandem repeats. Like the rest of DNA they are passed on from parent to offspring and the number of repeats in the lengths of the non coding DNA can be used to identify and individual.

To produce a genetic fingerprint a technique called gel electrophoresis is used (sometimes simply referred to as electrophoresis). Electrophoresis is exposing DNA to an electric current in a gel medium through which different fragments of the DNA travel depending on their size. The process is analogous to chromatography. The DNA has to first be extracted from the individual and cut into smaller fragments, this is done with an enzyme called restriction endonuclease. The fragments are then transferred to the gel and the current switched on. Because the DNA fragments are negatively charged they move towards the positive end of the gel with smaller fragments moving further to the positive end. This produces a series of bands which are positioned according to the size of the fragments. The gel trough is then covered with e nylon membrane onto with the fragments are transferred whilst they maintain their position. The process by which the fragments are transferred is known as Southern blotting. Southern blotting is named after Sir Edwin Mellor Southern a british biologist who invented the technique relatively recently in a 5 November 1975 paper entitled "Detection of specific sequences among DNA fragments separated by gel electrophoresis". Chemiluminescent probes or (though now rarely used) radioactive probes are attached to the

nylon and to specific parts of the fragments. Any fragments which remain unbound after this process are simply washed away. The nylon is them placed in chemicals which trigger chemiluminescence or in the case of radioactive probes under X-RAY film causing the probes to expose the film. The pattern (or autoradiograph) captured from this is a pattern of dark and light bands which are unique to that individual. This is the genetic fingerprint of that person.

Because the band pattern is inherited from both parents it is used in paternity cases by taking DNA from the white blood cells of the mother, (possible) father and child. Removing the mother bands from the child pattern leaves the pattern that should be in the fathers fingerprint. These are compared to determine if the individual concerned is actually the father. This is a favourite technique of ITV's The Jeremy Kyle show and causes much controversy.

In vitro

In vitro is latin for in glass and refers to experiments especially in biology which occur in petri dishes or test tubes which are often made of glass.

In vitro also refers to the fertilisation technique used to assist couples who want children but are 'infertile' here the definition of infertile is unable to conceive a child after 12 months of trying. It doesn't meant that it would be impossible for the couple to conceive a child but in some cases that may be the case. In the UK 50% of fertility issued

are related to the female reproductive system and only 35% of the issues are linked to the male reproductive system. The remaining issues are unattributable. The number of couples seeking fertility treatment has seen a sharp uptake in the last 30 years.

In general IVF (in vitro fertilisation) is carried out as follows. In order to stimulate ovulation the female is injected with hormones of a specifically calculated dosage that aims to cause multiple follicles to develop. The oocytes that develop are collected from the female via a tube that is inserted into the oviducts, this operation is often carried out with the aid of an ultrasound. Male semen is also collected at the same time and stored in a liquid with nutrients to keep the sperm nourished. The oocytes are then separated, one per dish onto a number of petri dishes. Once in place on the dish the sperm can either be injected directly into the egg - a difficult task or the sperm can be added to the dish also in the hundreds of thousands in the hope that one sperm will fertilise the egg as under normal fertilisation conditions.

The eggs are checked frequently and three days after fertilisation is supposed to have occurred those which have successfully fertilised are filtered to find the two best eggs which are selected for the best chance of implantation and inserted into the uterus using a tube. This is why IVF patients often give birth to twins.

Polymerase reaction

The polymerase chain reaction is the semi conservative replication of DNA that takes place in a test tube. To carry out the reaction the DNA is added to a buffer (pH controlling) and enzyme (DNA polymerase) solution. To this solution nucleotides are added for building the new DNA strand along with short pieces of DNA called primers. These primers trigger the DNA polymerase to start the replication process. The reaction is used to produce large quantities of DNA - this involves repeating the following steps many time with each pass doubling the quantity of DNA.

To begin the target DNA is first denatured by heating it to 95 degrees C, this is important because it causes the DNA to separate into two strands. The two strands form because the hydrogen bonds between the base pairs break under the energy they have. The enzyme, buffers and so on are then added as the solution is cooled to 55 degrees C. This causes the complimentary base pairs to join with the primers, this in turn triggers the DNA polymerase to cary out the replication of each strand. The solution then has to be heated to 70 degrees C to catalyse the synthesis of a complementary strand for the currently single strands, this produces two identical DNA strands. The enzyme DNA polymerase is unaffected by the heat so this process is repeated to increase the DNA by a factor of 2 each time.

Recap

Effects of Human activities (Recap)

- Mankind has a significant impact on the environment.
- If pesticides are over used organisms can become resistant.
- Artificial selection is where animals or plants are cross bred to produce offspring with useful characteristics.
- Human activity is a major contributing factor to species extinction.
- Conservation preserves gene pools which are already in existence.
- There are conflicts that occur between farming and conservation.
- Deforestation causes a loss of habitats.
- Deforestation can cause soil erosion and a change in atmospheric gas concentrations.
- Growing levels of Carbon Dioxide are the cause of the greenhouse effect. This possibly impacts global warming.
- Use of fertilisers results in water pollution and cause eutrophication.

- Eutrophication is excessive richness of nutrients in a lake or other body of water.
- Increases in commercial fishing has resulted in overfishing in many locations.
- Biofuels have the potential to reduce greenhouse gas emissions.
- Adoption of biofuels may result in reduction of habitats for both plants and animals.

Energy and Ecosystems (Recap)

- An ecosystem consists of the living/biotic and nonliving/abiotic inhabitants of an area and their interactions.
- Ecological energetics is the study of energy flow through different ecosystems.
- Energy passes between trophic levels, moving higher up the energy pyramid each time.
- The energy passing results in energy loss as a result of excretion and respiration.
- Photosynthesis has a low efficiency.
- Energy pyramids are one of the diagrams (and the most accurate) used in representing food chains/feeding relationships.
- Succession is the change of a community over time in terms of its composition and structure.

Genetic Code and Cells (Recap)

- DNA can be copied through a process known as semi-conservative replication.
- Meiosis is the process of cell division in sex cells.
- Meiosis results in the formation of haploid gametes.
- Meiosis produced gametes which are genetically different.
- Meiosis has two divisions.
- Crossing over and random segregation results in variation.
- DNA also acts as a template strand for mRNA.
- mRNA is messenger RNA and is used for protein synthesis.
- mRNA carries information from the DNA in the nucleus to the ribosome in the cytoplasm.
- Ribosomes are where proteins are synthesised.

Inheritance (Recap)

- A monohybrid cross is the study of the inheritance of one single gene.
- Dihybrid crosses show inheritance of two separate genes.
- In meiosis only one of a pair of alleles enters a gamete.

- dihybrid inheritance involves a either of a pair of alleles combining randomly with either of another pair.
- Codomminance is where heterozygote individuals have a phenotype that is intermediate between two homozygous parents.
- Genes that are present on the same chromosome are linked and inherited together.
- Genes carried out the same sex chromosome are sex linked.

Sexual Reproduction (Recap)

- In sexual reproduction haploid gametes fuse to produce a diploid zygote.
- For humans spermatozoa are produced in the testes. (Male)
- For humans ova are produced in the ovaries. (Female)
- Spermatogenesis is the process that produces sperm.
- Oogenisis is the production of the secondary oocyte.
- Fertilisation can only occur after capacitation.
- Two main methods of pollination for flowering plants, wind or insect.
- Cross-pollination allows for far greater genetic variation in a population of plants.
- Self-pollination results in little genetic variation.

- Flowering plants carry out double fertilisation, they are unique in this aspect.
- The seed produced by flowering plants is enclosed within the ovary.
- The seed contains the zygote.
- The seed develops into the embryo and food store.
- The food store contained within the seed is known as the endosperm.

Variation and Evolution (Recap)

- Variation occurs as a result of environmental factors and genetic changes.
- A genetic mutation occurs when a change in the DNA base sequence is made.
- A mutation is unpredictable.
- A chromosome mutation occurs because of modifications in chromosome structure.
- Chromosome mutations can also occur because of changes in the number of individual or whole sets of chromosomes.
- Natural selection suggests that organisms which are best adapted to survive reproduce to pass on their genes.
- The genes passed on by successful organisms contain beneficial characteristics for the next generation.
- Organisms which reproduce through sexual reproduction have lots of genetic variation.

- The amount of genetic variation in a group of organisms is known as the gene pool.
- If two populations become split and isolated from each other a new species may be formed.
- Isolation can occur because of geographical mechanisms or reproductive mechanisms.

Applications of Genetics and Reproduction (Recap)

- Cloning can be used to produce genetically identical organisms.
- Cloning can produce large numbers of organisms, quickly.
- Micropropagation provides a rapid method for producing lots of genetically identical plants.
- Artificial clones can be formed in animals by separating embryos.
- Growing cells in a lab is known as tissue culture.
- Stem cells are important in tissue engineering.
- Therapeutic stem cell cloning has large medical potential.
- Stem cells raise ethical issues.
- The human genome project has determined the order of the bases in the human genome.
- The human genome project has also identified, sequenced and mapped all the bases in the human genome.

- Genetic engineering takes genes from one organism and transfers them into another host organism.
- Recombinant DNA technology involves the introduction of DNA from various organisms into bacteria.
- Bacteria can be used in genetic engineering to produce a desired product.
- A transgenic/genetically modified organism has its genotype altered.
- A transgenic or GM organism produces a new strain of organism.
- GM Organisms have lots of potential in agriculture (crops) and health.
- Gene therapy aims to treat genetic diseases.
- Gene therapy replaces defective genes in a patients body with those which function correctly.
- A reaction called the polymerase chain reaction can produce large amounts of identical DNA from a small sample.
- A persons genetic fingerprint (DNA profile) is unique to them.
- DNA fingerprinting can be used as forensic evidence.
- DNA fingerprinting can also determine parents in paternity cases.

BY5 'Essay' Questions

Marking: 1 mark for each bold part or words to that effect up to a maximum of 10 marks.

Describe flow of energy through an ecosystem. Ensure that you explain how energy is lost in the system and its inefficiencies.

- The flow of energy through an ecosystem is the **passage of energy as organic molecules between increasing trophic levels**.
- **Energy enters the process through photosynthesis**.
- Photosynthetic organisms **convert light energy, usually from the sun into chemical energy**.
- Photosynthesis is not 100% efficient. **Not all wavelengths of light are absorbed by the plant and some simply gets reflected** from the leaf surface for example.
- **Energy is used by the plant and lost through respiration**.
- The energy that the plant captures and stores is **GPP (gross primary productivity)** whilst **the energy available to the next trophic level is NPP (net primary productivity)**

- **NPP = GPP - Energy lost in respiration** (by plants)
- This **energy passes to the next trophic level when the plant is eaten by primary consumers** (herbivores).
- **Not all of the energy is transferred** because not all of the plant is eaten. As a result some enters the **decomposition pathway**.
- More energy is lost from respiration by consumers. For example to **power active transport and temperature maintenance**.
- This **energy is lost as heat**.
- Excretion by consumers loses energy to the decomposition pathway again.
- Some **parts of the plant that are consumed can not be used**.
- Cellulose for example can not be broken down without special enzymes, **this energy is lost through egestion**.
- **Higher consumers i.e. secondary and tertiary consumers are more efficient** than primary consumers.
- Increased egestion in primary consumers is one reason for this.

Highlight the main steps in pollination and fertilisation along with the development of the seed and fruit.

- **Pollination is the transfer of pollen from anther to stigma.**

- There are **two primary pollination mechanisms**, wind and insect.
- In both cases the pollen is transferred to the stigma.
- Once on the stigma the **pollen grain absorbs water and sucrose form a solution present there**.
- With these nutrients **the pollen grain forms a pollen tube**.
- The pollen tube contains the **tube nucleus which controls growth as well as the male gamete**.
- The **tube (directed by the tube nucleus) grows through the style and ovary wall by releasing enzymes which digest the style and ovary wall cells**.
- The pollen tube eventually **passes through the micropyle**.
- At this point the **male gamete fuses with the egg cell**.
- This is a **double fertilisation** which is unique to flowering plants.
- A **zygote is formed by fertilisation and develops into the embryo plant**.
- The embryo plant components include the **plumule (embryo shoot) and radicle (embryo root) along with the Cotyledon (embryonic leaves) and food store**.
- The fertilised **ovule of the flower becomes the seed**.
- The fertilised **ovary becomes the fruit**.

What problems does deforestation cause and how can they be reduced?

- The primary consequence of deforestation is that **less CO2 is removed from the atmosphere**.
- This is important because **CO2 is a greenhouse gas**.
- CO2 in the atmosphere reflects heat that would usually escape into space back to earth causing **global warming**.
- Global warming can cause **flooding in low lying areas and unpredictable weather conditions elsewhere**.
- Deforestation also causes a **loss of habitats for plant and animal species, reducing biodiversity**.
- This can **cause some species to become extinct**.
- This is a problem because many **plants could have medicinal properties that have as yet remained uninvestigated**. This is an incalculable loss.
- Some **species may have had alleles which could have been introduced to a similar species** to improve its chances of survival.
- Removing trees also removes their roots which can lead to **soil erosion** and increases **desertification** because the soil is no longer held by the roots so is dried out by the wind.
- This **impacts the local climate**.
- To reduce the impacts of deforestation there are a number of steps that can be carried out:
  - **Replanting**

- **Controlling pests or diseases** which may impact the forest further.
- Allowing **natural regeneration** e.g. through **coppicing** or **selective cutting**
- **Planting endemic species**
- Correctly **spacing out replanted trees** to ensure **efficient forestry**

Explain the process of genetic engineering that allows commercial synthesis of human insulin.

- To produce bacteria which synthesise human insulin the gene for **human insulin is first located**.
- The **gene is found in cells of the Islets of Langerhans**.
- The islets of Langerhans are **regions of the pancreas containing endocrine cells**.
- This task is performed with the use of a **gene probe**.
- The gene probe is complementary to the DNA base sequence that is being looked for and **marks the gene when it binds to the DNA either through radiation or fluorescence**.
- It is easier to **obtain mRNA from these cells because they are constantly producing insulin this results in large quantities of mRNA in the cytoplasm of the cell**.
- **Reverse transcriptase is used to make DNA from the RNA template**.

- **DNA polymerase is then used to make double stranded DNA**.
- The **gene is then cut from the DNA with restriction endonuclease**.
- Cutting the gene leaves **sticky ends** which allow it to be inserted into a plasmid later in the process.
- The **plasmid(s) are taken from bacterium**, most often it is E. coli that is the source of plasmids.
- The **plasmid is then also cut using exactly the same restriction endonuclease as used to cut the DNA**.
- This leaves **complementary (to the DNA) sticky ends**.
- The **gene is then joined into the plasmid using DNA ligase**.
- This leaves the **recombinant DNA plasmid which is inserted back into the bacterium**.
- Sometimes along with the gene for the desired product which here is insulin, **a marker gene is also inserted into the plasmid. Marker genes confer antibiotic resistance to the bacteria which allows scientists to identify the bacteria that have taken up the plasmid by growing them on plates laced with antibiotic**.

State the meaning of conservation and extinction.

- **Conservation is the planned preservation of wildlife**.

- **Extinction is the loss of species**.

Why is conservation important and how is it carried out?

- **Conservation is carried out to preserve existing gene pools**.
- It is important to **ensure the survival of the species**.
- As well as ensuring species survival maintaining the gene pool **conserves potentially useful genes like disease for future generations**.
- For example the **conservation of plants which have or may have medicinal properties**.
- **Genes can be preserved using a gene bank**.
- **Sperm or seed banks** can also be used for this purpose.
- Conservation can also entail the **planned preservation of habitats** like hedgerows.
- **Reintroduction programs** are also run for species like the Red-kite in a bid to increase the number of breeding pairs.
- Many zoos also have **captive breeding programs** both nationally and internationally.
- Conservation can also involve the **formation of rare breeds societies** such as for cattle and the like which have little commercial value.
- **Trade restrictions in endangered species** are also a form of conservation.

- One such piece of legislation that creates trade restrictions is CITES.
- Other legislation also tackles conservation including **enforcing quotes for fishing, egg collecting and so on**.
- **Ecotourism** is another conservation method.
- In the UK the **countryside commission** is responsible for conserving the countryside and associated wildlife which it does through public awareness campaigns etc.
- Other **NGOs worldwide like the WWF also have a public awareness role**.

Provide an account of the principles and steps involved in the cloning of mammals.

- Mammals can be cloned through a process called **embryo cloning**.
- In embryo cloning **the egg is removed from the donor and allowed to divide by mitosis to form a ball of cells**.
- The **ball of cells is then split into an number of separate embryos**.
- This **must be done before differentiation occurs** which is around the 8 cell stage.
- Another method by which mammals can be cloned is the **nuclear transplant**.
- In this process **the nucleus is removed from diploid somatic or egg cell provided by the donor**.

- An **egg cell is also taken and blanked**, that is its nucleus is removed.
- The **donor nucleus fused into the blank egg cell** with a gentle electric current.
- The **egg is allowed to divide into an embryo**.
- This **embryo is then implanted into and continues to develop in a surrogate**.
- The **surrogate later gives birth to an animal which is genetically identical to the donor** (that provides the nucleus)
- This method works because the egg cell is **totipotent** and can differentiate to give rise to all the cells in an organism.
- Totipotent cells include **stem cells from bone marrow**, **the testes and embryonic stem cells**.

State any possible objections to the use of stem cells.

- The fundamental issue with stem cells, particularly those sourced from embryos is that the **embryos must be destroyed to provide stem cells**.
- People are concerned about this because of **Pro-life issues**, namely that the **embryo has the potential to be a human life**. Though this is not necessarily true as **IVF embryos would be destroyed regardless**.
- Also it is felt that currently **little is known about the long term side effects of stem cell usage**.

- There are some **concerns about the genetic modification of humans for non medical reasons** particularly **eugenics** which is improving a human population by controlled breeding to increase the occurrence of desirable heritable characteristics.

Glossary/Key terms

BY4

homeostasis *Adjustment of an organisms internal environment to allow it to maintain a stable equilibrium.*

negative feedback *As a mechanism for maintaining homeostasis it is where the action of effectors counteract changes in order to maintain a stable state.*

thermoregulation *The ability of an organism to keep its body temperature within certain boundaries.*

osmoregulation *The maintenance of constant osmotic pressure through variations in water/salt concentration.*

nitrogenous *Containing nitrogen.*

urea *Water soluble and nitrogenous product produced as a result of protein metabolism (mammals).*

ultrafiltration *Filtration under high hydrostatic pressure which retains large molecules.*

selective reabsorption *The process by which substances that are required by the body (e.g. glucose) that have previously been removed from the blood (via ultrafilration) are reabsorbed. It occurs in the proximal convoluted tubule.*

ADH *Abbreviation for Antidiuretic hormone. ADH is secreted by the posterior pituitary gland and changes the permeability of the collecting duct wall.*

pituitary gland *A gland which is located at the base of the brain and is the 'master gland' of the endocrine system.*

metabolic water *Water created by a living organism through metabolism.*

Bowman's capsule *The sac which surrounds the glomerulus at the start of the nephron. It is where ultrafiltration occurs.*

basement membrane *A thin membrane of fibrous protein that separates an epithelium from underlying tissue.*

Nitrogen *Chemical element with atomic number 7 - key component of amino acids, DNA, RNA etc.*

Carbon *Chemical element with atomic number 6 - key component of carbohydrates, lipids, DNA etc. Also used by plants in photosynthesis.*

saprobionts *Organisms that digest their food externally before absorbing the products.*

nucleic acid *A molecule which is made of a number of nucleotides linked together to form a chain. Examples include DNA + RNA.*

putrefaction *The decay of a body or other organic matter.*

nitrification *Oxidisation of ammonia into nitrate or nitrite.*

Denitrification *The reduction of nitrate into nitrogen.*

ATP *Abbreviation for Adenosine triphosphate. ATP is the 'universal energy currency' it provides energy for biochemical reactions in a number of organisms.*

activation energy *The energy required for a reaction/process to commence.*

ADP *Abbreviation of Adenosine diphosphate. ADP is ATP less a phosphate group. Removing the phosphate group from ATP releases 30 KJ/mol of energy.*

phosphorylation *The process of adding a inorganic phosphate group to a molecule.*

enzyme *A protein which works as a catalyst for a biochemical reaction.*

substrate *The substance on which an enzyme acts.*

glucose *A monosaccharide sugar. It has several forms, alpha + beta..*

Bacillus *A rod-shaped bacterium.*

Cocci *A spherical bacterium.*

Spirillum *A bacterium with a rigid spiral structure oft found in stagnant water.*

Gram-negative *Not retaining the violet stain used in Gram's method which shows that the bacterium has very little peptidoglycan in its cell wall; though the bacteria will have an outer membrane of polysaccharides and proteins.*

Gram-positive *Retaining the violet stain used in Gram's method which shows the bacteria has a cell wall primarily*

made of peptidoglycan but lacking the outer membrane of gram negative bacteria. (also often less toxic)

peptidoglycan *Peptidoglycan, also known as murein, is a polymer consisting of sugars and amino acids that forms a mesh-like cell wall.*

lysozyme *An enzyme that catalyses the destruction of the cell walls of gram positive bacteria (by removing a the peptidoglycan and causing lysis) that is found in tears.*

lipopolysaccharide *Large molecules made of a lipid and polysaccharide joined by a covalent bond that are found in the outer membrane of Gram-negative bacteria.*

aseptic *(referring to technique) Techniques that aim to ensure the complete exclusion of harmful micro-organisms.*

Colony *A group of bacteria grown from a single cell on a culture medium.*

Pathogen *A microorganism that can cause disease.*

Culture *Cultivation of microorganisms in an artificial medium containing nutrients.*

Ferment *To undergo the chemical breakdown of a substance by microorganisms e.g bacteria, yeast.*

Penicillin *An antibiotic group produced naturally by some blue moulds.*

Secondary metabolite *Organic compound that is not directly involved in the normal growth and development of an organism.*

stimuli *Things that causes a physiological response.*

CNS *Central Nervous System*

effector *A cell/s that acts in response to a stimulus.*

receptor *A cell capable of responding to stimulus and transmitting a signal to a sensory nerve.*

reflex *An action that is performed without conscious thought.*

hydra *A tiny aquatic invertebrate with a stalk-like tubular body and a ring of tentacles around the mouth. (of same phyla as jellyfish)*

sensory neuron *A neuron which is responsible for converting external stimuli into corresponding internal stimuli.*

motor neuron *A neuron which carries signals from the spinal cord to the muscles in order to produce movement.*

relay neuron *A neuron that forms a connection between other neurons.*

action potential *A short-lasting event in which the electrical membrane potential of a cell rapidly rises and falls.*

depolarised *To have lost polarity.*

synapse *A junction between two nerve cells with a minute gap across which impulses pass by diffusion of a neurotransmitter. In humans this neurotransmitter is acetylcholine.*

photoperiodism *Response of an organism to changes in the relative length of light and dark periods (day length).*

photoperiod *The time each day during which an organism receives light. (equal to day length)*

phytochrome *A pigment that plants use to detect light. It is sensitive to light in the red and far-red region of the visible spectrum.*

Pr *The ground state of phytochrome in which red light is strongly absorbed.*

Pfr *State of phytochrome in which far-red (fr) light is absorbed in preference to red light.*

short day plants *Plants which flower when the day lengths are less than their critical photoperiod.*

long day plants *Plants which flower when the day length exceeds their critical photoperiod.*

day neutral plants *Plants which do not initiate flowering based on photoperiodism at all.*

photosynthesis *A process used by plants and other autotrophic organisms to convert light energy into chemical energy in the form of ATP.*

light-dependent phase *The first stage of photosynthesis by which plants capture and store energy from sunlight. In this process, light energy is transferred to energy-carrying molecules ATP and NADPH.*

light-independent phase *The part of photosynthesis referred to as the calvin cycle which occurs in the stroma through which carbon dioxide (or alternatives) is converted to glucose.*

Engelmann *Theodor Engelmann carried out an 1882 experiment measured the effects of different colours of light on photosynthetic activity and showed that the conversion of light energy to chemical energy took place in the chloroplast.*

action spectra *(in terms of photosynthesis) The action spectrum shows the rate of photosynthesis at different wavelengths.*

absorbance spectra *(in terms of photosynthesis) The absorption spectrum shows how strongly the pigments absorb at different wavelengths.*

pigments *Chemical compounds which reflect only certain wavelengths of visible light.*

chlorophylls *Greenish pigments which contain a porphyrin ring.*

carotenoids *Red, orange, or yellow pigments, and include the familiar compound carotene. They are accessory pigments because they must pass their absorbed energy to chlorophyll.*

carotene *A carotenoid pigment that gives carrots their colour.*

Xanthophylls *Yellow pigments that form one of two major divisions of the carotenoid group.*

accessory pigments *Accessory pigments are light-absorbing compounds that transfer energy to/work with chlorophyll a and have different absorption spectra.*

photophosphorylation *The production of ATP using the energy of sunlight.*

immigrate *The movement of organisms into a region to which they are not native.*

emigrate *The movement of organisms from a region to which they are native.*

lag phase *The first stage of bacterial growth in which adapt themselves to growth conditions.*

exponential phase *The second stage of bacterial growth in which the number of new bacteria appearing per unit time is proportional to the present population.*

stationary phase *Third phase of bacterial growth in which growth rate and death rate are equal.*

death phase *Final phase of bacterial growth in which bacteria run out of nutrients and die.*

density dependant *A factor affecting a population which has a varying affect based on the population size e.g. water supply*

density independent *A factor affecting the size of population which does not have a varying affect based on the population size e.g. weather, natural disaster.*

pesticides *A substance or substances used for destroying organisms which are harmful to crops or animals.*

resistance *The ability not to be affected by something in an adverse manner.*

Glycolysis *The first step in respiration which produces two 3C pyruvate molecules through the removal of phosphate groups from glucose. This step reduces 2 NAD and produces 2 ATP.*

the link reaction *The second step in respiration in which pyruvate is converted to acetyl-CoA producing C02 and a molecule of NADH.*

the Krebs cycle *The sequence of reactions by which most living cells generate energy during the process of aerobic respiration. Produces 3NADH, 1FADH and 1 ATP (double for each glucose).*

Electron transport chain *Respiration step in which electrons are passed along a chain through a series of redox reactions in which they lose energy to produce a concentration gradient.*

decarboxylation *The removal of a carboxyl group which releases carbon dioxide.*

dehydrogenation *The removal of hydrogen from a molecule as H2.*

ATP *Adenosine triphosphate. The universal energy currency.*

ADP *Adenosine diphosphate. Can be made into ATP though the addition of a phosphate group (phosphorylation) and when ATP loses a phosphate group to form ADP 30.5 kJ/mol of energy is released.*

NAD *An electron acceptor and carrier that is reduced to*

NADH an gives up its electrons to the electron transport chain.

FAD *An electron carrier in respiration which is reduced to FADH2 it only contributes to 2 ATP as it has less energy, passing its electrons to a later point in the electron transport chain.*

pyruvate *An organic acid produced in glycolysis which is decarboxylated by Acetyl-CoA so the carbon can be used in the Krebs cycle. Can also ferment to produce lactic acid when oxygen is not available.*

acetyl CoA *acetyl coenzyme A. The main function of A-CoA is to convey the carbon atoms within the acetyl group to the citric acid cycle (Krebs cycle) to be oxidised for energy production.*

final electron acceptor *Oxygen is the final electron acceptor in respiration.*

chemiosmotic *The movement of ions across a selectively permeable membrane.*

concentration gradient *A difference in concentration of solutes between two regions.*

BY5

Habitat *The sort of environment in which an organism normally lives and grows.*

Ecosystem *The living organisms in a particular place, together with their physical environment.*

Community *All of the groups of animals or plants living together in a environment interacting with one another.*

Detritivores *Organisms that obtain nutrients by consuming decomposing plant and animal parts as well as organic fecal matter.*

Decomposers *(An) organism(s) that decomposes organic material.*

producers *The first level in a food pyramid; consist of organisms that generate the food used by all other organisms. Includes plants (photosynthesis).*

Herbivores *An animal that feeds primarily on plants.*

primary consumers *Animals that are adapted to eat plants.*

trophic level *A energy level within an ecosystem that consists of organisms that share the same function in the food chain.*

excretion *The process of eliminating or expelling waste matter.*

respiration *The metabolic processes allowing organisms to obtain energy from organic molecules.*

food chain *A 'chain' of organisms which are dependant on the previous member as a food source.*

carnivore *An animal which feed primarily on other animals.*

Gross primary productivity *The rate at which the producers of an ecosystem capture and store energy as biomass.*

net primary productivity *Net primary productivity is gross primary productivity less the amount of energy lost in respiration. It is the energy passed to the next trophic level.*

Seconday productivity *The rate of generation of biomass in an ecosystem by the primary consumers (herbivores).*

biomass *The weight of dried organisms (water removed) in a given area.*

Succession *The process by which a community gives way to another.*

Climax community *A stable community formed as a result of successful adaptation to the environment.*

quantitative *Measurement based on numbers as opposed to a quality.*

environment *The conditions and surroundings which an organisms inhabits.*

DNA *The carrier of genetic information in (most) organisms. Abbreviation of Deoxyribonucleic acid.*

template strand *The strand of DNA which is used to determine the sequence of nucleotides in RNA after transcription.*

chromosomes *Twisted and compact structure of DNA and protein which carries genes.*

genes *A distinct sequence of nucleotides forming part of a chromosome which dictates which polypeptide should be synthesised in protein synthesis.*

protein synthesis *Process in which cells build proteins at ribosomes using tRNA and mRNA with amino acids.*

transcription *The process in which DNA is transcribed into an mRNA molecule for protein synthesis.*

translation *Performed at the ribosomes translation takes nucleotide triplets on mRNA and builds a sequence of amino acids as part of protein synthesis.*

RNA *Abbreviation of Ribonucleic acid. Carries instructions from DNA in most organisms by can be the carrier of genetic information (instead of DNA) in some viruses.*

codon *Sequence of three nucleotides which together indicate an amino acid which should be built into a polypeptide chain.*

mRNA *Messenger RNA is a template for protein synthesis. It is made from transcription before mRNA leaves the nucleus through nuclear pores and travels to ribosome(s) where it is read to synthesis proteins.*

tRNA *Transfer RNA is a small RNA molecule that joins an amino acid to a polypeptide chain as part of protein synthesis.*

meiosis *Cell division which produces four haploid daughter cells.*

homologous *Chromosomes which have the same structural features and gene loci which pair up during meiosis.*

ribosome *A cell organelle found in the cytoplasm consisting of a large and small sub unit which reads mRNA and produces polypeptide chains.*

genotype *The alleles at the same loci of each chromosome of an organism.*

phenotype *The observable characteristics of an individual produced by its genes.*

crossing over *Occurring during meiosis it is the exchange of genes between homologous chromosomes.*

independent assortment *The random manner in which chromosomes are distributed to each gamete produced in meiosis.*

Ova *The mature female reproductive cell.*

Ovaries *The female reproductive organ in females in which ova (eggs) are produced.*

embryo *An animal organism in the early stages of growth and differentiation.*

Gamete *A male of female mature germ cell which when meeting with each other form a zygote.*

Spermatogenesis *The production and subsequent development of mature spermatozoa.*

Oogenesis *The production and subsequent development of an ovum.*

diploid *Having two sets of chromosomes, one maternal and one paternal.*

haploid *Having a single set of chromosomes.*

spermatocyte *The cell formed from spermatogonium in the second stage of spermatozoa formation. Spermatocytes later divide into spermatids through meiosis.*

oocyte *The name given to the immature female reproductive cell before it is fertilised.*

acrosome *The acrosome is an organelle that develops over the anterior half of the head in the spermatozoa (sperm cells) it contains enzymes which break down the outer membrane of the ovum.*

blastocyst *A hollow structure in early embryonic development that contains a cluster of cells which give rise to the embryo.*

trophoblasts *Cells forming the outer layer of a blastocyst which provide nutrients to the developing embryo and eventually form the placenta.*

amnion *A membrane that surrounds and protects an embryo.*

chorion *The outermost membrane surrounding an embryo.*

hCG *Abbreviation for human chorionic gonadotropin. hCG is a hormone produced in pregnancy which acts to maintain the corpus luteum.*

corpus luteum *Literally 'yellow body' the corpus luteum*

develops from the ovarian follicle and produces progesterone. This is the hormone which thickens the uterus lining for implantation.

monoclonal antibodies *Highly specific antibodies which are clones of a single parent cell.*

flower *The part of the plant that contains the reproductive organs which is often surrounded with petals.*

petal *A segment of the corolla of the flower.*

stigma *Part of the female reproductive organs of a flower that receive the pollen.*

anther *The part of the stamen that contains the pollen.*

stamen *The male reproductive organ of a flower. Consists of anther and filament.*

sepal *Forms a protective layer around the bud but becomes leaf like structures at the base of the flower.*

style *An elongated extension of the ovary which supports the stigma.*

ovule *The part of the ovary (seed plants) that contains the female germ cell. Later becomes the seed.*

embryo sac *A cell within the ovule where fertilisation occurs. Contains the endosperm nucleus and (fertilised ovum) the developing embryo.*

receptacle *Large area at the end of the stem which the flower is inserted into.*

angiosperms *A group of flowers that have flowers and produced seeds (in a carpel).*

pollination *The depositing of pollen on the stigma so that fertilisation can occur.*

desiccation *Have the moisture removed.*

generative nucleus *The nucleus of the pollen grain which divides to form the sperm nuclei.*

tube nucleus *A cell in the male gametophyte in plants that grows into the ovule.*

dehiscence *The 'bursting' open of a seed vessel.*

triploid endosperm nucleus *Produced by the fusion of one male gamete with two polar bodies which forms the endosperm which provides nutrition (in the form of starch) to the embryo.*

integuments *Tough outer protective layers.*

dicotyledon *A flowering plant whose embryo produces two seed leaves (cotyledons)*

monocotyledon *A flowering plant whose embryo produces one seed leaf (cotyledon)*

germination *The process of growing/shoot formation that occurs after a period of dormancy in plants.*

apices *Plural of apex, the top of something.*

amylase *An enzyme which converts starch as well as glycogen into monosaccharides (simple sugars).*

plumule *The young shoot or stem of a plant embryo.*

radicle *The young (primary) root of a plant embryo.*

Warfarin *A water soluble anticoagulant that is used as a rat poison.*

Resistance *The ability to not be adversely affected by something.*

Antibiotic *A medicine which prevents the growth of of kills microorganisms. e.g. Penicillin.*

penicillinase *An enzyme produced by some bacteria which are resistant to antibiotics like penicillin. (Actually a form of Beta-Lactamase)*

conjugation *Temporary fusion of bacteria to exchange genetic material.*

Artificial selection *(Selective breeding) Intentional breeding for certain traits.*

Inbreeding *To breed from a closely related group.*

Outbreeding *To breed from group which is not closely related.*

Extinction *To have no living members of a species.*

Endangered species *A species of organisms at high risk of extinction.*

CITES *The Convention on International Trade in Endangered Species which aims aim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species.*

conservation *The protection and restoration of wildlife and/or the environment.*

ecotourism *Tourism with the intent of supporting conservation efforts.*

monoculture *The cultivation of just one crop in a given area.*

deforestation *The clearing of areas of forests.*

regeneration *Allowing a damaged area to recover.*

erosion *Gradual destruction.*

coppicing *The periodic cutting back of trees/shrubs in order to stimulate growth.*

rotation time *The time between crop rotations.*

selective cutting *The cutting out of trees that are mature or defective.*

biofuel *A fuel produced from living material.*

trawling *Fishing by dragging a large net along the bottom a body of water.*

drift netting *Using a large net which is kept upright by floats and weights which drifts with the tide or currents to catch fish e.g. herring.*

overfishing *Depleting the stock of fish in a body of water through excessive fishing.*

eutrophication *Excessive nutrients in a body of water caused by (agricultural) run off. Often causes dense plant*

growth on the water e.g. algae.

global warming *The gradual increase in the temperature of our atmosphere.*

greenhouse gas *A gas which contributes to the greenhouse effect through absorption of infrared radiation e.g. C02 + CFC's.*

fertiliser *A substance that is added to soil to increase crop production/growth of plant life.*

nitrates *Salts of nitric acid which contain the NO3 group.*

phosphates *Salts of phosphoric acid.*

algal bloom *Sudden growth of cyanobacteria on a body of water.*

Continuous variation *Variation which is distributed in a continuous way such as a range of heights.*

Discontinuous variation *Variation which can be split into distinct groups such as eye colour.*

heritable *A characteristic which can be passed from parent to offspring.*

Non-heritable *A characteristic which can not be passed from parent to offspring*

ABO *A blood classification system for human blood which consists of four types A, B, O + AB*

phenotypic variation *Variation in the observable characteristics of an individual.*

Selection pressure *An agent which makes a population change genetically.*

Predation *Preying on animals.*

gene pool *The variety of different genes in a population.*

population *A community of animals and plants.*

genetic drift *Variation in the occurrences of different genotypes as a result of reproduction.*

natural selection *The tendency of better adapted organisms to survive and produce more offspring.*

Speciation *The formation of distinct species through evolution.*

Geographical isolation *The speciation which occurs when a population becomes seperated as a result of geographical factors such as mountains.*

Reproductive isolation *The speciation which occurs when a population is prevented from interbreeding.*

Behavioural isolation *A form of reproductive isolation in which animals which have complex mating rituals cannot elicit the necessary response in a potential partner.*

Mechanical isolation *A form of reproductive isolation in which the genitalia of two subspecies or groups is incompatible.*

Gametic isolation *A form of reproductive isolation in which the sperm fails to survive in the oviduct or pollen fails to germinate on the stigma.*

hybrid *Offspring of plants or animals of different species.*

hybrid unviability *Failure of the embryo to develop in hybrids as a result of chromosomes no longer matching.*

hybrid sterility *The fact that hybrids are sterile as a result of the inability for the chromosomes from each parent to pair in meiosis preventing gamete production.*

clone *An organism that is produced asexually from a parent to which it is genetically identical.*

Embryo cloning *The creation of identical copies of an embryo by embryo splitting.*

nuclear transplant *A form of cloning in which the DNA from an oocyte (unfertilised egg) is replaced by injecting the nucleus which contains the DNA to be cloned.*

mutation *A change in the coding of a gene which can be passed on to future generations.*

Progeny *A descendant of an organism.*

Stem cell *An undifferentiated which can produce other types of cell through differentiation.*

In vitro *Lietrally 'In glass' e.g. a test tube or petri dish.*

Differentiate *Become different through growth/development.*

Tissue culture *Growing cells from living tissue in an artificial medium.*

Tissue engineering *Using the principles of tissue growth to produce functional replacement tissue for clinical use.*

embryonic *Relating to the embryo.*

Micropropagation *Propagation of plants through growth in tissue culture and then planting them out.*

totipotent *Capable of giving rise to any cell type.*

meristems *Plant tissue at the tip of the root and shoot which forms new tissue.*

callus *Hard formation of tissue.*

propagation *Breed an organism through natural processes from parent stock.*

Human Genome Project *International project to chart the entire genetic material of a human being. Completed 2000.*

Gene probes *Fragment of DNA or RNA that is used to detect the presence of complimentary nucleotide sequences.*

Pre-symptomatic *Before symptoms are exhibited.*

Pre-natal *Before birth.*

Huntington's *A neurodegenerative genetic disorder that affects muscle coordination and leads to cognitive decline. It is more common in Western Europeans and is caused by dominant mutation of the Huntington gene.*

Alzheimer's *The most common form of dementia. Loss of cognitive ability.*

autosomal *Chromosome that is not a sex chromosome.*

Cystic fibrosis *An autosomal (non sex linked) recessive genetic disorder that affects the lungs and other organs*

causing thick, viscous secretions as a result of abnormal chloride (ion) transport.

liposomes *Sphere of phospholipids which surround a water molecule.*

pancreatic duct *A duct joining the pancreas to the common bile duct to supply pancreatic juices which aid in digestion.*

CFTR *Cystic fibrosis transmembrane conductance regulator a protein ion channel which transports chloride which is also coded by the CFTR gene.*

Plasmid *A small DNA molecule that is separate from, and replicates independently of chromosomal DNA.*

DNA ligases *A ligase that catalyses the bonding of free ends of double-stranded DNA with a phosphodiester bond.*

Recombinant DNA *DNA sequences that result from the use of laboratory methods to bring together genetic material from multiple sources.*

Restriction enzymes *Enzymes which can cut DNA at or near a specific sequence of bases.*

Sticky ends *The ends of a DNA double helix where one strand is longer than the other.*

Reverse transcriptase *An enzyme that catalyses the formation of DNA from an RNA template.*

Transgenic *An organism that contains genetic material from another organism (that has been inserted artificially).*

GM/GMO *Genetically modified/Genetically modified organism.*

Electrophoresis *The movement of charged particles in a fluid or gel under the influence of an electric field.*

Gel Electrophoresis *A technique used for the separation of DNA, RNA as well as protein molecules.*

Polymerase *An enzyme that catalyses polymer formation.*

Peptide *Compound consisting of two or more amino acids linked in a chain.*

Genotype *The genetic 'make up' of an organism.*

Mutation *A change in the base sequences of DNA that can be inherited by future generations.*

Genes *Sections of DNA.*

Alleles *Alternative forms of the same gene. There are usually two for each gene.*

Codomminance *Where both alleles are expressed in the characteristics of an organism.*

Dominant allele *Allele which expresses itself even when present with the recessive allele.*

Recessive allele *Allele which expresses itself only if present with another recessive allele.*

Homozygous recessive *Having both alleles recessive (one from the mother and one from the father).*

Homozygous dominant *Having both alleles dominant (one from the mother and one from the father).*

Heterozygous *Having one dominant and one recessive allele (one from the mother and one from the father).*

Phenotype *The characteristics expressed in the organism as a result of its genotype.*

Monohybrid *A cross resulting in a hybrid which is heterozygous for a specific gene.*

Dihybrid *A cross resulting in a hybrid which is heterozygous for alleles of two different genes.*

backcross *A cross involving an organism with the same genetics as a parent of that organism.*

Chi-squared *A statistical test which determines the fit between observed values and those expected.*

Mutation *A modification to the structure of a gene that can be passed on to later generations.*

Mutagen *An agent which causes genetic mutation. e.g. a chemical*

Sickle cell anaemia *Hereditary form of anaemia where a mutated form of haemoglobin distorts the red blood cells into a crescent shape at low oxygen levels. (Common in Africa/those of African descent)*

substitution *A gene mutation in which a substitution occurs.*

Haemoglobin S *The form of haemoglobin found in people with sickle cell anaemia.*

Non-disjunction *The failing of homologous chromosomes or sister chromatids to separate normally.*

disjunction *Seperation of homologous chromosomes or sister chromatids.*

trisomy 21 *An extra copy of chromosome 21 (trisomy is an extra chromosome), Trisomy 21 is the most common form of Down's syndrome.*

tetraploid *Having four homologous sets of chromosomes.*

tetraploidy *Having tetraploid cells.*

Polyploidy *Containing more than two homologous sets of chromosomes.*

carcinogen *Substance that can cause cancer in living tissue.*

Oncogenes *A gene that can cause cancer (turn a cell into a tumour cell).*

suppressor cells *T cells which suppress the immune response of B cells and/or other T cells*