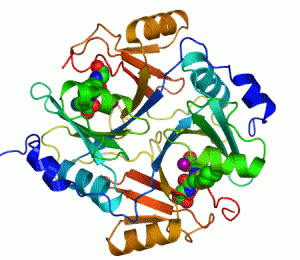
**CfE Higher Biology**

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**Unit 2**

**Metabolism and Survival**

**Pupil Notes**

**Name Teacher Copy**

**Section 2.1 – Metabolic pathways and their control**

**2.1(a) Metabolic Pathways**

Metabolism is the sum of all the **chemical reactions** that take place in a cell. The majority of these reactions happen in connected and integrated pathways and are catalysed by **enzymes**.

Metabolic pathways can have **reversible** and **irreversible** steps and there may be alternative routes that can bypass certain steps.

enzyme 1

Intermediate 2

enzyme 3

enzyme 2

Intermediate 3

original substrate

alternative intermediate

alternative route

(bypassing other steps)

Several enzyme-controlled steps

irreversible step

reversible step

Many enzyme-controlled steps

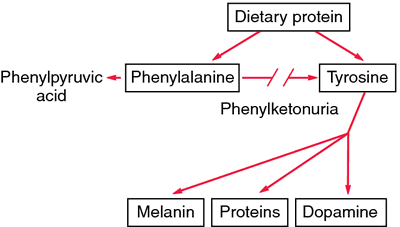
Final Product

Intermediate 1

**ACTIVITY 1**

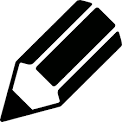
Research the condition Phenylketonuria (PKU). Try to find out about the metabolic pathway affected by this condition and draw it below. Identify how the mutation disrupts the pathway.





There are two types of metabolic pathways that occur in cells.

* Reactions that build up large molecules from small molecules = **anabolic** and so **require** energy (ATP).
* Reactions that break down large molecules into smaller molecules = **catabolic** and so **release** energy (ATP).

 **ACTIVITY 2**

Complete the diagram below to show examples of each type of pathway

Glucose + oxygen

CO2 + H20

Proteins / polypeptides

Amino acids

**ENERGY**

**CATABOLIC PATHWAY**

**ANABOLIC PATHWAY**

Can you give other examples of these reactions?

Anabolic

the growth and mineralization of bone and increases in muscle mass.

Catabolic *the breakdown of fat in adipose tissue to fatty acids*

**2.1(b)Membranes**

REMEMBER

NATIONAL 5 UNIT 1.2 TRANSPORT

The **cell membrane** controls the entry and exit of materials. It consists of **phospholipid** and protein molecules. Its structure is described as **fluid mosaic** as the phospholipids form a bilayer which are in constant motion with embedded **proteins** which are scattered in a patchy mosaic pattern.

The proteins in the membrane can be described as:

* **Pores** – Channel forming proteins which are involved in the passive diffusion of certain small molecules and make the membrane selectively permeable.
* **Pumps** – Proteins involved in active transport which is an ATP requiring process where ions and other large molecules are moved from a low to a high concentration e.g. the sodium, potassium pump.
* **Enzymes** – Enzymes can be embedded in the membrane and catalyse the steps in a metabolic process e.g. ATP synthase.

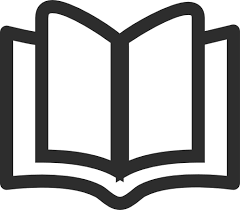
**ACTIVITY 3**

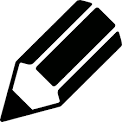
Find out more about the sodium potassium pump (try Torrance p119)

It transports three Na+ ions to the outside of the cell and transports two K+ ions to the inside.

This creates a concentration gradient and an unbalanced charge across the membrane.

The **sodium**-**potassium pump** contributes to action potential produced by nerve cells which allows nerve impulses to travel along neurones.

* 

 **ACTIVITY 4**

Complete the diagram below by filling in the boxes to show each type of membrane

component.

Label the phospholipid bilayer, protein pore, protein pump and embedded enzyme.

Glucose low concentration

Glucose high concentration

Sodium high concentration

Active site

Sodium low concentration

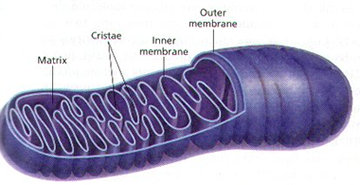
embedded enzyme

protein pore

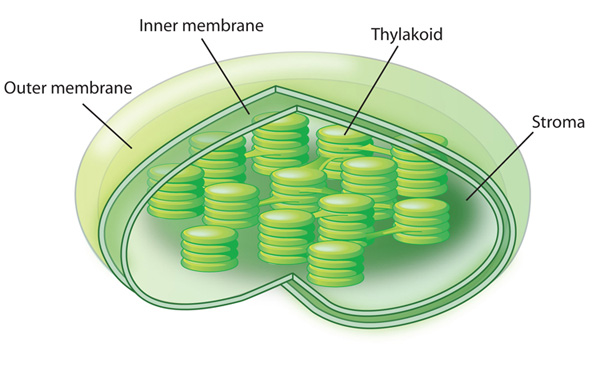
phospholipid bilayer

protein pump

Membranes can form the surface of a cell and also the surface of an **organelle** within a cell. They can also form **folds** within organelle e.g. inside chloroplast and mitochondria.



**Mitochondrion**



**Chloroplast**

**2.1(c) Control of metabolic pathways - Enzymes**

A metabolic pathway is a series of reactions. Metabolic pathways are controlled by the

1. presence or **absence** of **particular** enzymes and
2. regulation of the **rate of reaction** of **key** enzymes.

Specific **enzymes** control each step in a metabolic pathway. Each enzyme is coded for by certain **genes**.

Metabolite A

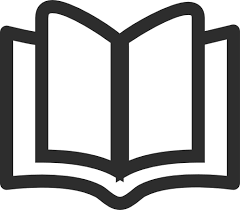
Metabolite B

Metabolite C

Gene 1 codes for enzyme 1

Gene 2 codes for enzyme 2

The regulation of lactose metabolism in *E. coli* is an example of this.



**ACTIVITY 5**

Find out more about the Lac Operon (try Torrance p128)

* The *lac* operon of *E. coli* contains genes involved in lactose metabolism. It's expressed only when lactose is present. A regulator gene turns the operon "on" and "off" in response to lactose levels.
* The ***lac* repressor** acts as a lactose sensor. It normally blocks transcription of the operon, but stops acting as a repressor when lactose is present.

**Enzymes**

REMEMBER

NATIONAL 5 UNIT 1.5 ENZYMES

Enzymes are biological catalysts which **speed up** the rate of chemical reactions and are **unchanged** in the process. They do this by **lowering** the activation energy.

Activation energy is the energy required to **initiate** a reaction. The substrate must receive a certain amount of energy before it can turn into the **products**

**Induced Fit**

Potential energy

Progress of reaction

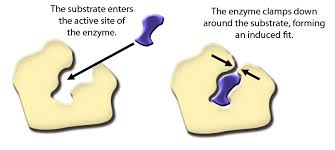
SUBSTRATES

PRODUCTS

Higher activation energy (EA) required without enzyme

Lower EA required with enzyme

Enzymes are large complex proteins folded into a particular shape so they can fit a specific **substrate**. Enzymes are flexible and dynamic and their activity depends on this. The basic theory is referred to as lock and key. There is an area on the enzymes surface called the **active site**. This is a groove or hollow with a particular shape determined by the chemical structure of the protein. The enzymes **substrate** molecule exactly fits the active site and have a chemical attraction (affinity) for it.

A more precise mechanism is described by the model of **Induced fit**. The active site is not a rigid structure, it is flexible and dynamic. As the substrate starts to bind, the active site changes **shape** to better fit the substrate more closely. This **increases** the rate of reaction as the substrate is orientated to fit the active site perfectly.

Once the reaction has taken place products are formed. The products have a **low** affinity for the active site and so are released from the enzyme.

**ACTIVITY 6**

Watch the animation on induced fit:

<http://www.boardworks.co.uk/media/797600dd/AP%20Biology%20Sample/3_2_induced_fit_animation.swf>



**Reaction rate**

The substrate molecule(s) have a **high** affinity for the active site and the subsequent **products** have a low affinity, allowing them to **leave** the active site.

* Some metabolic reactions are **reversible** and the presence of a **substrate** or the removal of a **product** will drive a sequence of reactions in a particular direction.

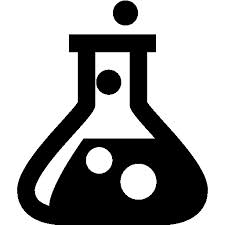
As a consequence the substrate and product concentration affects the direction and rate of reaction.

* Substrate and Enzyme concentration – Increasing the number of molecules of substrate or enzyme **increases** the number of substrate–enzyme complexes and so **increases** the rate of reaction and drives the reaction in the direction of the end point.
* End product concentration – Many metabolic reactions are **reversible** so increasing the end product concentration would increase the amount of product being turned back into substrate until a balance was restored.

**ACTIVITY 7**

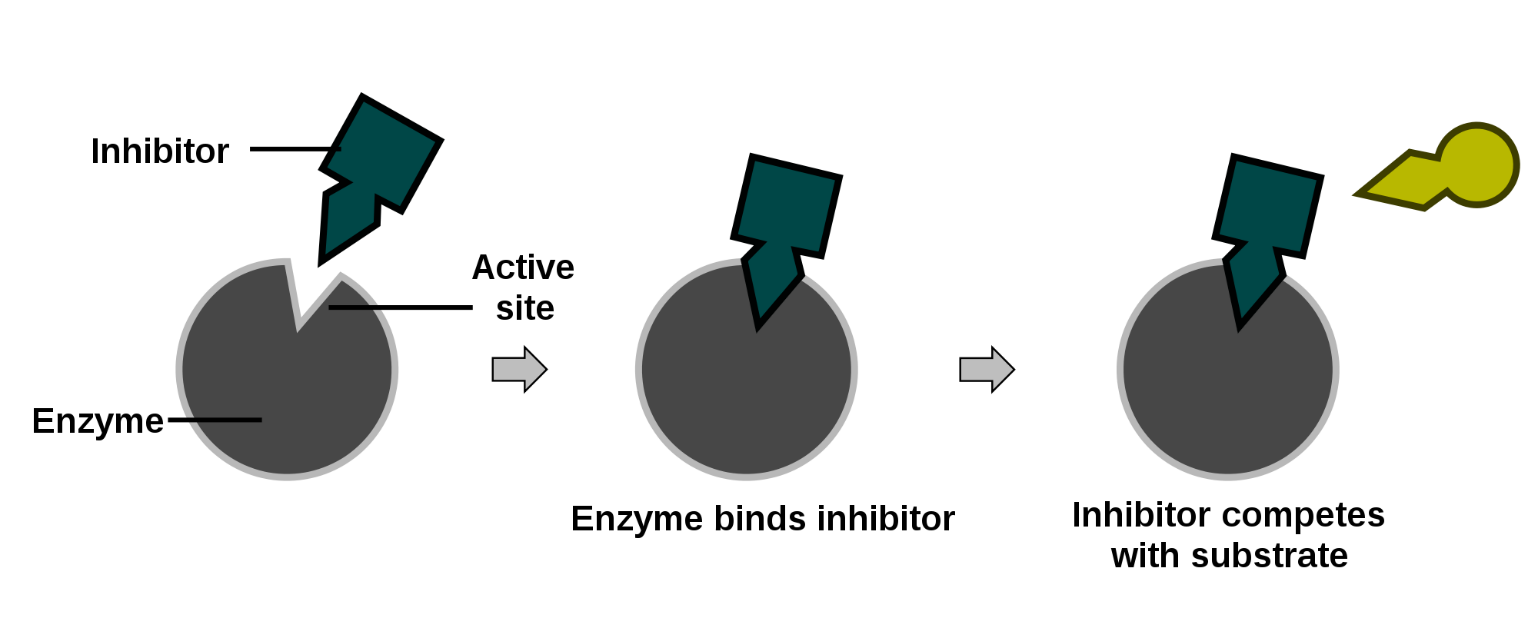
You are going to do an experiment about the effect of substrate concentration on catalase activity.

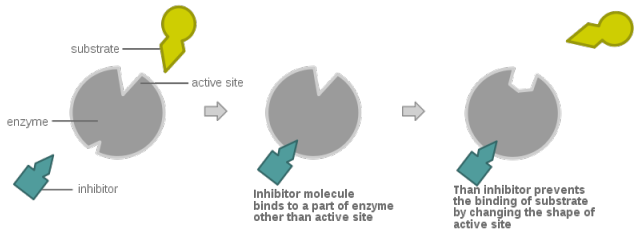
Collect a protocol card and your teacher will guide you through the investigation.

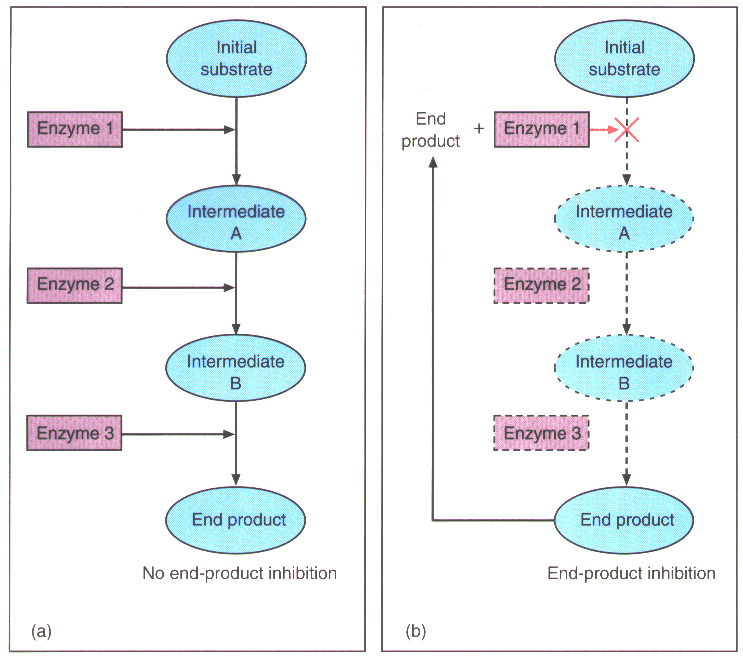


**Control of metabolic pathways – Inhibition of Enzymes**

Many metabolic pathways need to operate continuously to sustain life (e.g. **respiration**). The genes for their enzymes are always on and so the enzymes are always present. These pathways can be controlled by using **inhibitors**. An inhibitor is a substance that **reduces** the rate of an enzyme reaction. There are two main types of inhibitor:

* Competitive – A competitive inhibitor has a **similar structure** to the enzymes substrate and so fits into the enzymes **active site**. They compete with the substrate as they block the active site. If the substrate concentration is increased then it increases the chance of the substrate binding the active site and so the reaction rate returns to normal.
* Non-competitive – A non-competitive inhibitor does not bind to the enzymes active site but bind to another part of the enzyme. This changes the shape of the **active site** and so the substrate can no longer bind to the enzyme. This means that the amount of active enzyme is reduced and the effect is **irreversible** and so is unaffected by substrate concentration.



Feedback Inhibition

Feedback inhibition is another way in which metabolic pathways can be **regulated**. It occurs when the end-product in the metabolic pathway reaches a critical concentration.

The end product inhibits the activity of an earlier enzyme in the pathway. The pathway is then blocked preventing further synthesis of the end product.

In the example the end product blocks enzyme 1. This means there is **less** intermediate A produced and so **less** end product produced. As the end product concentration **falls** so enzyme 1 concentration **rises** and the pathway pathway proceeds as normal. Negative feedback control keeps the pathway regulated.

**ACTIVITY 8**

Watch the animation on enzyme activity:

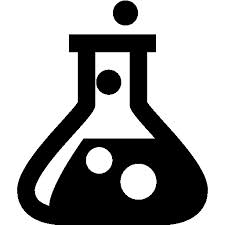
<https://www.youtube.com/watch?v=8woEVmLWTbk>



**ACTIVITY 9**

You are going to do an experiment about the effect of end product concentration on enzyme activity.

Collect a protocol card and your teacher will guide you through the investigation.



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**ACTIVITY 10 - ESSAY Revised Higher 2013 SECTION C Q2B**

Give an account of enzyme action and enzyme inhibition



**ANSWERS**

1. activity depends on flexible / dynamic shape of enzyme molecules 1
2. (there is an) affinity of the substrate for active site 1
3. induced fit described - As the substrate starts to bind, the active site changes **shape** to better fit the substrate more closely 1
4. activation energy lowered by enzyme 1
5. products have low affinity for active site allowing them to **leave** the active site.1
6. substrate and product concentration affects direction and rate of reactions

**OR**

describe the effects of increasing substrate concentration as increasing/speeding up/driving forward the rate of the reaction

OR

Some metabolic reactions are reversible and the presence of a substrate or the removal of a product will drive a sequence of reactions in a particular direction

**Max 5 (from 6)**

|  |
| --- |
| 1. Competitive inhibitors bind at the active site preventing the substrate from binding. 1 |
| 1. Competitive inhibition can be reversed by increasing substrate concentration. 1 |

|  |
| --- |
| 9. Non-competitive inhibitors bind away from the active site but change the shape of the active site preventing the substrate from binding |

10 Non-competitive inhibition cannot be reversed by increasing substrate concentration

11. end product inhibition / feedback inhibition

|  |
| --- |
| 12. Feedback inhibition occurs when the end-product in the metabolic pathway reaches a critical concentration. The end-product then inhibits an earlier enzyme, blocking the pathway, and so prevents further synthesis of the end-product. 1 |

**Max 3 (from 6)**

**Section 2.2 – Cellular Respiration**

**2.2(a) Metabolic Pathways of Cellular Respiration**

Cellular respiration pathways are found in all cells and are of central importance. They release energy from **food** and result in the regeneration of **ATP**. Respiration pathways are connected to many other pathways.

Many enzymes are involved in respiration, for example dehydrogenases remove electrons and hydrogen ions.

Cellular respiration is the process by which energy is released from the food we eat and used to generate **ATP** the energy carrying molecule.

REMEMBER

N5 UNIT 1.8 RESPIRATION

There are three main stages:

* **Glycolysis**
* Citric Acid Cycle
* **Electron** Transport Chain

**ACTIVITY 11**

Watch the animation on the main stages of respiration:

<http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html>



**Glycolysis**

This takes place in the **cytoplasm** and involves a molecule of **glucose** being split to form **pyruvate**.

It happens in a series of **enzyme** controlled steps and happens in two stages; an energy investment stage that requires **2ATP** molecules are used and an energy payoff stage where **4ATP** are produced (per molecule of glucose). It is known as the payoff stage as more ATP is produced than is used earlier.

ATP is involved in **phosphorylation** of glucose and intermediate 1 to **energise** them and allow them to be broken down. As 4 ATP are produced and 2 are made there is a net gain of 2 ATP molecules.

In glycolysis **hydrogen** ions are released from the substrate by a dehydrogenase enzyme. These hydrogens are picked up by a coenzyme molecule called NAD (nicotinamide adenine dinucleotide) forming **NADH**.

Glucose

Intermediate 1

Intermediate 2

Pyruvate

Other metabolic pathways

ATP

ADP

ATP

ADP

4 ATP

4 ADP + Pi

2 NAD

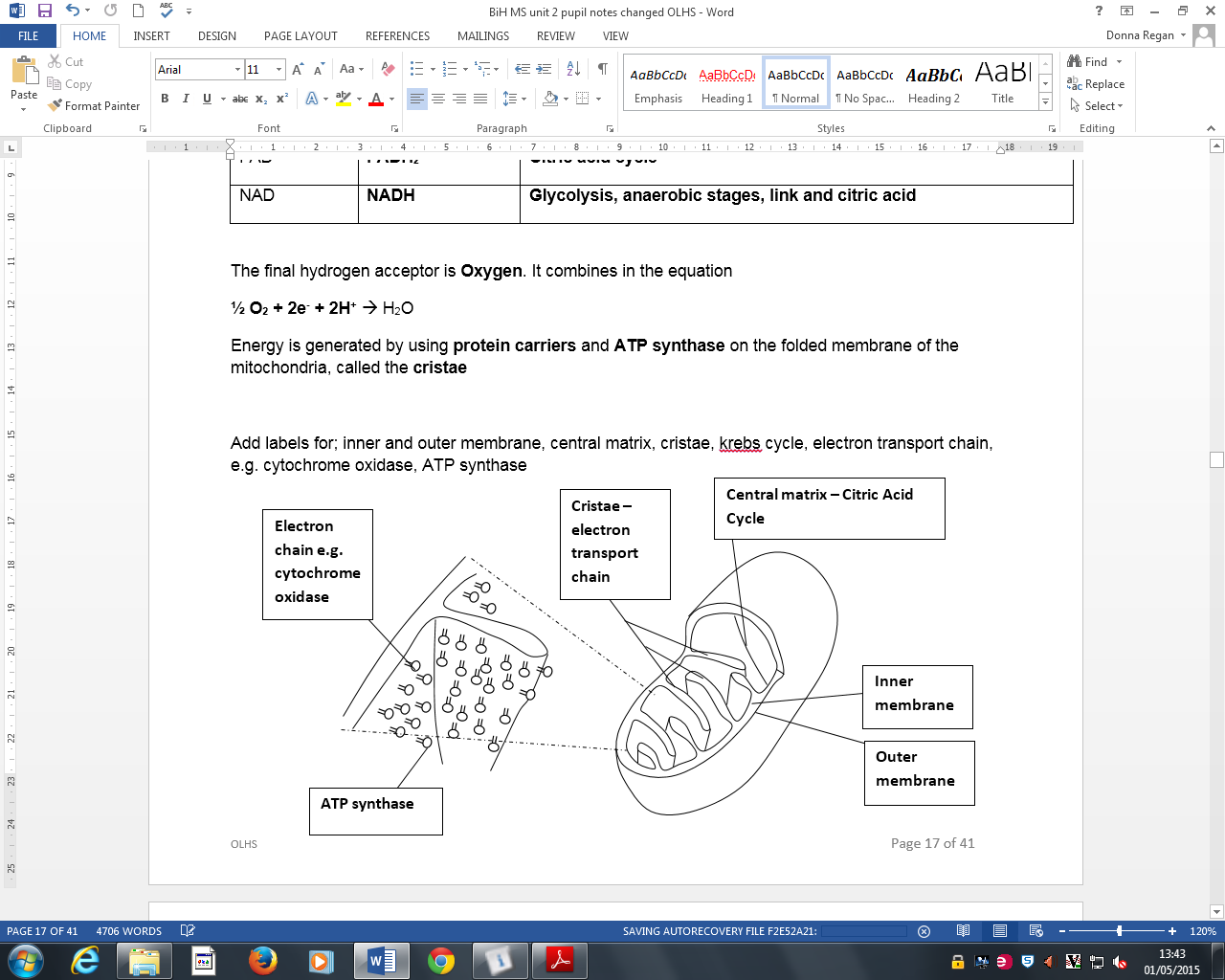
2 NADH

**ENERGY INVESTMENT**

**ENERGY PAYOFF**

1. If **oxygen** is present then aerobic respiration proceeds. Pyruvate is broken down by enzymes to an **acetyl group** and **carbon** **dioxide**.
2. The acetyl group then binds with **co-enzyme A** to be transferred to the citric acid cycle as **acetyl co-enzyme A**.

The citric acid cycle takes place in the **central matrix of the mitochondria**.



In the citric acid cycle

1. **The acetyl group** from the Acetyl CoA combines with **oxaloacetate** to form citrate (citric acid), (co-enzyme A is free to transfer another acetyl group).
2. A **series** of **enzyme controlled** steps follows and citrate is gradually converted back into oxaloacetate.
3. This results in the generation of ATP and release of carbon dioxide
4. During the cycle **dehydrogenase** enzymes remove hydrogen ions (H+) and high energy electrons and pass them to the coenzyme NAD, forming NADH.

Remember this also occurs in glycolysis as well as the citric acid cycle.

1. The hydrogen ions and electrons from NADH are passed to the **electron** transport chain on the inner mitochondrial membrane.

**2.2(b) ATP synthesis**

**Electron Transport Chain**

This is composed of a series of carrier proteins attached to the inner **mitochondrial** membrane. The electrons from NADH are passed along the electron transfer chain on the inner **mitochondrial** membrane resulting in the **release** of energy.

**ATP synthesis**

This energy allows Hydrogen ions to be pumped **across** the inner mitochondrial membrane. The flow of these ions back through the membrane protein, ATP synthase, results in the production of ATP.

Finally H ions and electrons combine with **Oxygen** to form **water**.

pyruvate

acetyl coenzyme A

coenzyme A

citrate

oxaloacetate

2CO2

NAD

NADH

ADP + Pi

ATP

**CITRIC ACID CYCLE**

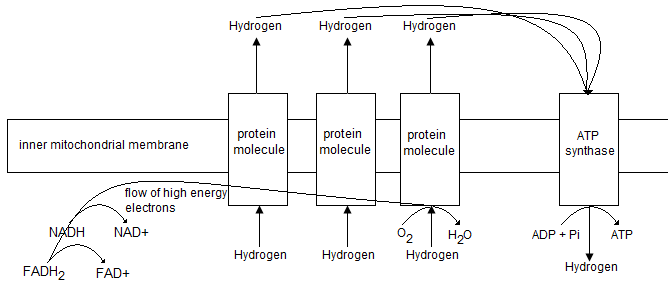
NAD

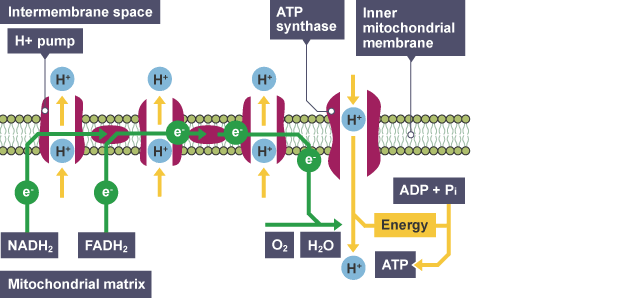
NADH

Acetyl coenzyme A

**ELECTRON TRANSPORT CHAIN**

**(on inner membrane of mitochondrion)**





The diagram shows ATP synthase and the process of regenerating ATP.

|  |  |
| --- | --- |
| H+  H+  3  H+  H+  1  H+  H+  2  H+  H+  H+  H+  H+  H+ | 1. A flow of high energy electrons from **NADH** are passed along the electron transport chain releasing energy which is used to pump **hydrogen** ions across the inner mitochondrial membrane. 2. These hydrogen ions back through the membrane protein enzyme ATP **synthase** 3. This catalyses the synthesis of **ATP** from ADP and Pi. |

**ACTIVITY 12**

Watch the animation on ATP synthase activity: <https://www.nclor.org/nclorprod/items/5333bbfc-2f64-0ea4-39f0-7fe5c9c6a039/1/ATPGradientAdvancedMovHQ.flv?.vi=flvViewer>



**2.2(c) Fermentation**

In the absence of oxygen, fermentation takes place in the cytoplasm.

In animal cells, pyruvate is converted to lactate. This reaction is reversible.

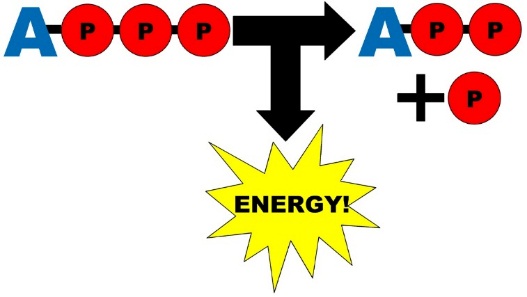
In plants and yeast cells, pyruvate is converted to **ethanol** and CO2. This reaction is irreversible.

The process of fermentation produces much less ATP than aerobic respiration.

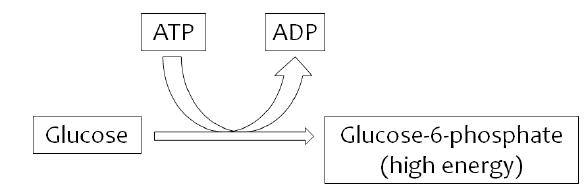
**2.2(d) ATP**

ATP (adenosine triphosphate) is a small molecule that holds the energy released form glucose in respiration. The main role of ATP is to transfer **energy** between **catabolic** and **anabolic** reactions.

A molecule of ATP is made of one adenosine molecule joined with three phosphate molecules. Energy is released when the bond attaching the last phosphate is broken by enzyme action. This forms **ADP** (adenosine diphosphate) and inorganic phosphate.



ADP and phosphate can be converted back to **ATP** using **energy**.



Intermediate 1

Intermediate 2

Pyruvate

Other metabolic pathways

ATP

ADP

ATP

ADP

4 ATP

4 ADP + Pi

2 NAD

2 NADH

**ENERGY INVESTMENT**

**ENERGY PAYOFF**

2 NADH

**GLYCOLYSIS**

**(in cytoplasm)**

Glucose

acetyl coenzyme A

coenzyme A

citrate

2CO2

NAD

NADH

ADP + Pi

ATP

**CITRIC ACID CYCLE**

NAD

NADH

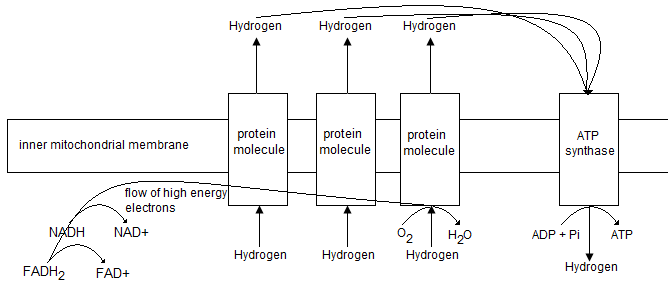
acetyl

oxaloacetate

CO2

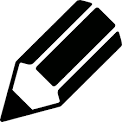
**CITRIC ACID CYCLE**

**(in matrix of mitochondrion)**

****

**ELECTRON TRANSPORT CHAIN**

**(on cristae of mitochondrion)**

****

**ACTIVITY 13**

You are going to work in groups to try and reproduce the respiration diagram.

Your teacher will organise you into groups of 4. Each team member will be given a different coloured pen.

Each member of your team has 3 minutes to try and remember as much of the diagram as possible. One at a time your teacher will call you up to draw as much of the diagram as you can on your team’s paper. You have 30 seconds. Each team member will add to the diagram. At the end you should have a complete diagram contributed to by everyone in your team.

**GOOD LUCK!**

**ACTIVTY 14 ESSAY**

**Revised Higher 2015 SECTION C Q2A**

Give an account of the structure of the inner membranes of mitochondria and the function of the electron transport chain in cellular respiration.



**ESSAY ANSWER**

|  |  |  |
| --- | --- | --- |
| 1 | inner membrane has large surface area | **1** |
| 2 | membranes have protein and phospholipid | **1** |
| 3 | proteins act as pumps/ pores/ enzymes **any 2 = 1 all 3 =2** |
| **Any 3 Max 4** | | |
| 5  6 | dehydrogenase enzymes remove hydrogen ions **AND** electrons electrons and pass them to the coenzyme NAD, forming NADH.  The hydrogen ions and electrons from NADH are passed to the electron transport chain on the inner mitochondrial membrane. | **1**  **1** |
| 7 | electrons are passed along the electron transport chain releasing energy | **1** |
| 8 | This energy allows hydrogen ions to be pumped across the inner mitochondrial membrane. | **1** |
| 9 | The flow of these ions back through the membrane protein ATP synthase results in the production of ATP. | **1** |
| 10 | ATP produced by ATP synthase | **1** |
| 11 | hydrogen ions and electrons combine with oxygen to form water. | **1** |
| **Any 5 Max 7** | | |

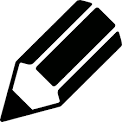
**Section 2.3 – Metabolic Rate**

**2.3(a) Measurement**

The **metabolic rate** of an organism is the **amount of energy used per unit of time**.

As energy is linked to respiration metabolic rate can be measured in terms of:

* Oxygen used using a respirometer or oxygen probe.
* Carbon dioxide produced using a carbon dioxide probe.
* Heat produced using a calorimeter.

****The table below shows a comparison of the metabolic rates of different organisms at rest.

**ACTIVITY 15**

Here are a few Problem Solving Questions to try:

1. *Calculate the volume of oxygen consumed by…*
   1. *A 22g frog in 1 hour.*
   2. *A 2g hummingbird in 4 hours.*
2. *Calculate the difference in the volume of oxygen consumed by a 3.6kg eel and a 5kg octopus in 3 hours.*

|  |  |
| --- | --- |
| Animal | Volume of oxygen consumed (mm3g-1 body mass h-1) |
| Sea anemone | 13 |
| Octopus | 80 |
| Eel | 128 |
| Frog | 150 |
| Human | 200 |
| Mouse | 1500 |
| Hummingbird | 3500 |

**ANSWERS**

1. a. Frog rate = 150 mm3g-1 body mass h-1

work out rate for 22g frog in 1 hour

so 150 x 22g = 3300 mm3

answer = 3300 mm3

1. b. Humming bird rate = 3500 mm3g-1 body mass h-1

work out rate for 2g bee hummingbird in 4 hours

so 3500 x 2g = 7000 mm3

7000 x 4 hours = 28000

answer = 28000 mm3

1. Eel rate128 mm3g-1 body mass h-1

work out rate for 3.6kg eel in 3 hours

so 128 x 3600g = 460,800 mm3

460,800 x 3 hours = 1,382,400 mm3

Octopus 80 mm3g-1 body mass h-1

work out rate for 5kg octopus in 3 hours

so 80 x 5000g = 400,000 mm3

400,000 x 3 hours = 1,200,000 mm3

Work out the difference - 1,382,400 - 1,200,000 = 182,400

answer = 182,400 mm3

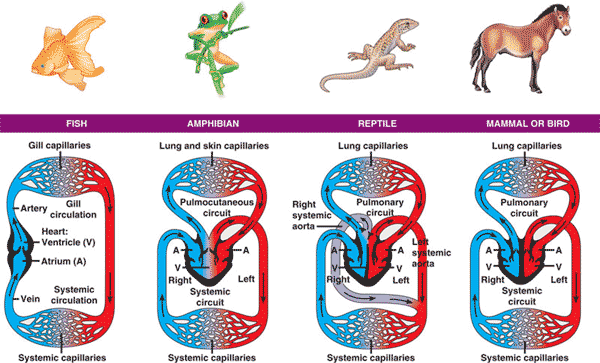
**2.3(b) Comparative Anatomy**

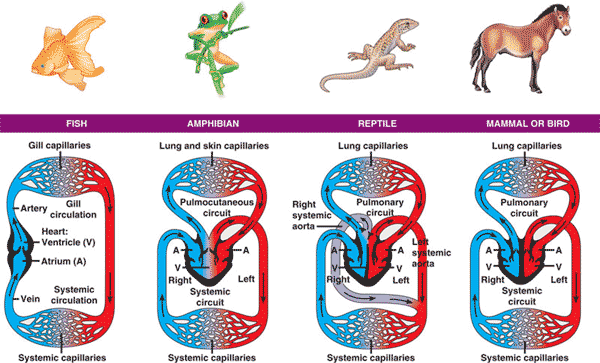
Organisms with high metabolic rates need respiratory and circulatory systems that can meet their demands. There has to be efficient delivery of **oxygen** to cells.

Birds and Mammals have higher metabolic rates than reptiles and amphibians, which in turn have higher metabolic rates than fish.

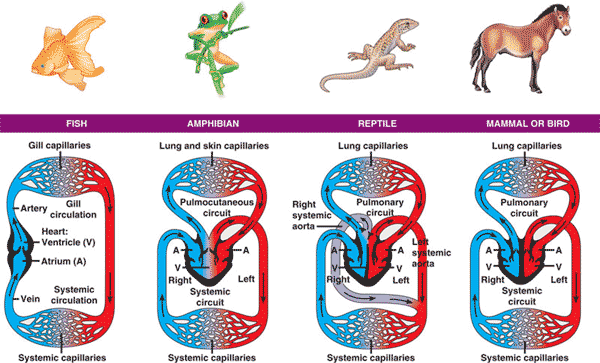
Amphibians, reptiles, mammals, birds and fish have different anatomy and physiology to meet their demands.

**Single circulatory system**

Fish have a single circulatory system. The blood only passes through the heart **once** in each complete circuit. The heart has **two** chambers, an atrium and a ventricle. When blood passes through the capillaries in the body, the blood pressure drops so blood is delivered to body tissues at low pressure. This method of circulation is **inefficient**.

**Incomplete Double circulatory system**

Amphibians and most reptiles have an incomplete double circulatory system. The blood passes through the heart **twice** in each circuit but there are not two distinct circuits. Their hearts have 3 chambers, two **atria** and one **ventricle**. Oxygenated blood from the **lungs** enters the left atrium, deoxygenated blood from the capillaries in the body enters the **right atrium**. The blood from both atria enters the **ventricle** and is pumped to the body tissues and the **lungs**. This method of circulation is more efficient than a single respiratory system but still quite inefficient as oxygenated and deoxygenated blood is mixed.

****

**Complete Double circulatory system**

Mammals and birds have a complete double respiratory system as the blood passes through the heart **twice** on each circuit and there are two separate circuits for the blood. The heart has **four** chambers (2 atria and 2 ventricles) and there are two complete circuits, one for oxygenated blood and one for deoxygenated blood. This is the most **efficient** method of circulation.

There is no mixing of oxygenated and deoxygenated blood and the oxygenated blood can be pumped out at higher pressure. This enables more efficient oxygen delivery to cells.

The table below compares the various methods of circulation

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Vertebrate Groups** | | |
| **Fish** | **Amphibians and reptiles** | **Birds and mammals** |
| *Type of Circulation* | single | incomplete double | complete double |
| *Heart* | 2 chambers  1 atrium, 1 ventricle | 3 chambers  2 atria, 1 ventricle | 4 chambers  2 atria, 2 ventricles |
| *Features* | Problems with loss of pressure | No problems with pressure. Tissues are supplied with mixed oxygenated and deoxygenated blood | Pressure is maintained and tissues are supplied with oxygenated blood. No mixing of oxygenated and deoxygenated blood |
| *Efficiency* | low |  | high |
| *Speed of metabolic rate and level of demand for oxygen* | low |  | high |

**Section 2.4 – Metabolism in Conformers and Regulators**

**2.4(a) Maintaining Metabolic Rate**

Abiotic factors such as temperature, pH and salinity (salt concentration of water) can affect the ability of an organism to maintain its metabolic rate.

**2.4(b) Conformers**

A conformer is an organism that **cannot** maintain its metabolic rate by internal physiological mechanisms. Their internal environment is dependent on the **external environmental** conditions. They tend to live in stable environments such as the ocean floor. Conformers use behaviour to maintain the optimum **metabolic** rate.

* Advantage – They have **low** metabolic costs as they do not use energy on complex metabolic processes.
* Disadvantages – They have a narrow ecological **niche** and cannot tolerate environmental change.
* Example – Lizards and **snakes** cannot maintain their temperature by physiological means but instead have a behavioural adaptations such as basking in the sunshine.

**2.4(c) Regulators**

Regulators use metabolism to control their internal environment regardless of the external environmental conditions. As they are less reliant on their environment for regulation the range of possible ecological niches is increased. Regulation requires **energy** to achieve homeostasis and so has **higher** metabolic costs.

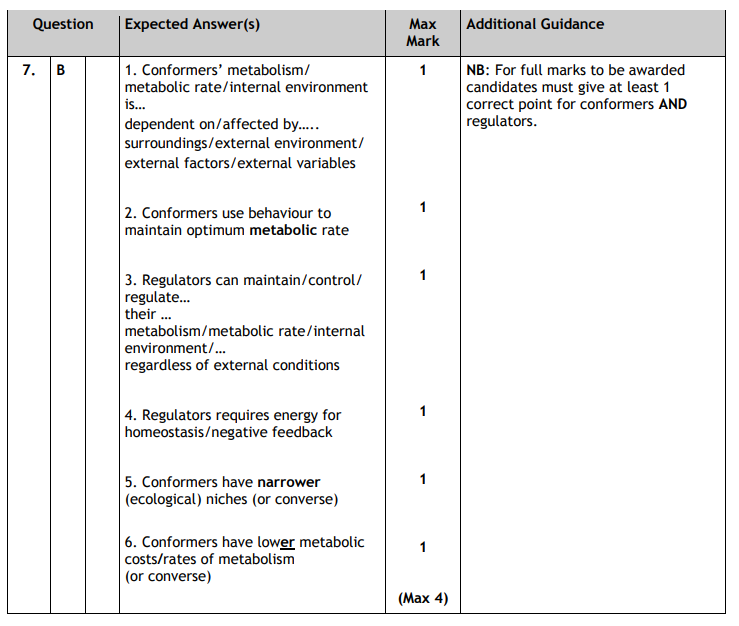
**ACTIVTY 16 SHORT ESSAY**

**Revised Higher 2016 SECTION B Q7B**

Describe and compare metabolism in conformers and regulators. (4 marks)



**ANSWERS**



**2.4(d) Negative Feedback Control**

Homeostasis is maintained by negative feedback control. Negative feedback maintains **constant** internal conditions in the body;

1. A change from the normal optimum level is detected by **receptor cells**.
2. A corrective mechanism is switched on
3. Nervous or **hormonal** messages are sent to the effectors.
4. The **effectors** respond to correct the change.
5. When condition returns to its optimum, the corrective mechanism is switched **off**.

**Thermoregulation**

The regulation of body temperature is called **thermoregulation** and is an example of negative feedback control.

Mammals can maintain their internal body temperature and are called endotherms. Endotherms are **regulators**.

Reptiles are reliant on the external environment and bask in the sun to increase body temperature. They are known as ectotherms and are **conformers**.

The process of thermoregulation is shown below:

Thermoreceptors in the Hypothalamus detect changes in temperature

sweat glands

skin arterioles

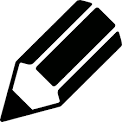
Hair erector muscles

skeletal muscles

Change in temperature of blood

Nerve impulses from skin thermoreceptors

Nerve impulses are sent to effectors



**ACTIVITY 17**

Answer the questions on thermoregulation using the diagram above:

1. What is the temperature monitoring centre? hypothalamus
2. How is information communicated to the effectors? By nerve impulses along neurones.

The table below shows the responses of the effectors to increase and decrease in temperature.

|  |  |  |
| --- | --- | --- |
|  | **Temperature Increase** | **Temperature Decrease** |
| *Sweat glands* | Produce more sweat which evaporates using **heat** energy from the body so cooling the skin. | Less sweat produced |
| *Skin arterioles* | Vasodilation occurs – blood vessels **widen** to bring more blood to the surface of the skin to lose heat by **radiation**. | Vasoconstriction occurs – blood vessels **narrow** to decrease the flow of blood to the surface of the skin to prevent heat loss by radiation. |
| *Hair erector muscles* | Relax to keep hair **flat** against the skin | Contract to **raise** hair, trapping a layer of air to act as **insulation.** |
| *Skeletal muscles* | No effect | Contract and relax rapidly causing shivering to generate heat from metabolic processes. |
| ***Metabolic Rate*** | **Decreased so that less heat is produced** | **Increased to generate more heat** |

**2.4(e) Importance of Regulation**

Enzymes are involved in many metabolic pathways and enzymes activity is affected by temperature. It is important that temperature in an organism is regulated to achieve optimal **enzyme** controlled reaction rates and high **diffusion** rates to maintain metabolism.

**Section 2.5 - Metabolism and adverse conditions**

**2.5(a) Surviving adverse conditions**

Some environments have extreme conditions such as very high temperatures or very little water. In these environments normal homeostatic mechanisms would break down as these conditions are beyond the **tolerable** limits of an organisms normal metabolic rate. Organisms can survive major changes in their environmental conditions through **dormancy** and **migration**.

**Dormancy**

Dormancy is a stage in the lifecycle or an organism where metabolic rate is reduced. Heart rate, breathing rate and body temperature is also reduced.

There are two types of dormancy:

* **Predictive** – Organisms enter into a dormant stage before environmental conditions become too harsh. E.g. chipmunks hibernate before the onset of winter.
* **Consequential** – Organisms enter into a dormant stage after a significant disadvantageous change to environmental conditions.

Examples of dormancy include hibernation and aestivation.

* **Hibernation** allows animals to survive in **cold winter conditions**. The organism’s body temperature, oxygen consumption, heart and breathing rates **decrease** and this lowers metabolic rate. This means that body fat reserves are used up **slowly** in a period where food is scarce. Bats, hedgehogs and dormouse are the only native British animals that hibernate.

Bears do not truly hibernate as their metabolic rate does not decrease significantly. They are also easy to rouse and sometimes wake up to hunt.

* **Aestivation** is similar to hibernation but it takes place in summer during periods of **very high temperature or drought**. The animals often stay in underground burrows where it is moist and temperatures are lower. It does not need as much **energy** as hibernation to maintain temperature so the animal does not need a large store of body **fat**. Examples of animals that use aestivation are snails, earthworms and some tropical butterflies.

**Daily Torpor**

Animals with high metabolic rates such as hummingbirds undergo daily torpor. During torpor body temperature, heart and breathing rates and oxygen consumption are **lowered**. This helps to conserve **energy** during feeding bouts or can occur at night.

**2.5(b) Avoiding adverse conditions**

Animals can avoid adverse conditions by migrating. During migration animals relocate to a more suitable environment. The organism uses energy but avoids the unfavourable conditions.

Migration can be influenced by both innate and learned behaviour:

* Innate – This is **inherited** and carried out by all members of a species. It can be triggered by **day length** or temperature changes. It is inflexible.
* Learned – It develops as a result of experience by watching other individuals or by trial and error. It is flexible.

The timing and direction of migration is thought to be innate but the stopover feeding sites on the route and alterations to the route is thought to be learned.

Migration can be tracked by using various methods:

|  |  |
| --- | --- |
| Radio transmitters | Can be attached to very small animals as well as large e.g. butterfly to polar bear.  Some can gather biological information as well.  Invertebrates can have it attached to shell – can be issue when they shed  Requires a tracking radio signal. |
| Satellite Tracking | Can use different satellite images to track movements of large groups of animals e.g. herd movements of gazelle  Can also use satellite positioning from tags which have satellite signal/locators e.g. osprey tracking  Very accurate and a lot of data can be gathered but expensive |
| Ultrasound transmitters | Transmitter attached to animals – used under water e.g. fish/ seals/whales  Allows tracking in areas that radio does not carry well  Can cause problems with some animals that use ultrasound themselves |
| Ringing | A physical tag e.g. birds  Involves a capture and release and either recapture or observation  Capture can be difficult and distressing (if not handled carefully), identification require careful observers. Long term can build up very detailed information. |

**Section 2.6 – Environmental Control of Metabolism**

Micro-organism means very, very small organism, usually microscopic.There is an enormous variety on earth organised into three main groups:

archaea, bacteria and some species of eukaryotes.

|  |  |  |
| --- | --- | --- |
| Bacteria (Prokaryotes)  **e.g….**  **E.coli,**  **Staphylococcus Aureus** | Archae (Prokaryotes)  Look similar to bacteria but have different DNA to allow them to survive in **extreme** conditions.  **e.g. …**  **Methanogens, thermophiles…** | Eukaryotes  **e.g. …**  **Algae –** can photosynthesise.  **Fungi** – don’t **photosynthesise** and absorb nutrients from their environment  **Protozoa** – don’t photosynthesize but are motile and catch and absorb other microorganisms. |

Microorganisms are highly adaptable and can use a wide variety of substrates for respiration and produce a range of products from their metabolism. They also reproduce **quickly** and can be easily grown in a lab. Scientists can manipulate their metabolisms and so can ensure optimum yield of useful products. These facts make them useful to humans in biotechnology.

**2.6(a) Growth Media and Environmental Factors**

Microorganisms require an energy source (either chemical or light) and raw materials from simple chemical compounds for biosynthesis.

Biosynthesis is another term for **anabolism**; the building up of substrates into more complex molecules during metabolic reactions. These complex molecules include **proteins** and nucleic acids.

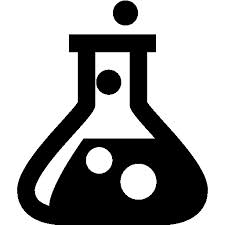
Many micro-organisms can produce all the chemicals needed for biosynthesis from simple compounds found in growth media. Others need more complex chemical substrates such as vitamins or **minerals** and can contain substances such as beef extract.

Only **algae** are able to use light as an energy source and carry out photosynthesis. The majority of microorganisms need to be provided with a chemical substrate. These substances are provided in the form of growth media that can be in liquid form (broth) or solid form (agar jelly).

There are variations in growth media. Many micro-organisms can produce all the chemicals needed for biosynthesis e.g. amino acids, vitamins and fatty acids. Other micro-organisms require these to be supplied in the growth media. e.g. substances such as beef extract.

It is important to maintain the correct culture conditions to ensure optimal growth of the microorganism:

1. **Sterility** – to reduce competition with undesirable microorganisms for nutrients and to reduce the risk of spoilage.
2. Temperature and **pH** levels - to maintain optimum conditions for the bacteria’s metabolism
3. **Oxygen** levels – to ensure plenty of availability for respiration.



**ACTIVITY 17**

You are going to do an experiment to grow some bacterial cells

Collect the protocol card and your teacher will guide you through the practical activity.

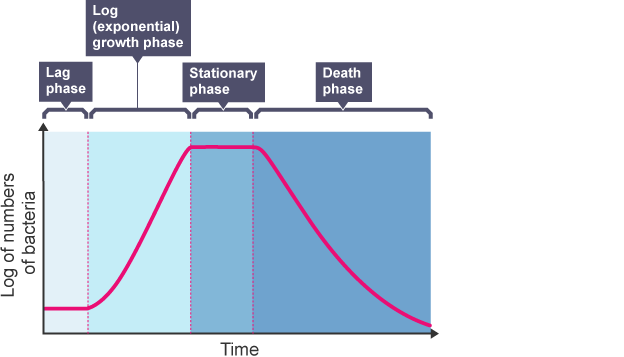
**2.6(b) Growth**

Growth is defined as the **irreversible** increase in the **dry** biomass mass of an organism. In microorganisms growth is recorded by measuring the increase in **cell number** and it happens as a result of each cell dividing into two. The time it takes for a unicellular organism to divide into two is called the **doubling** or **mean generation time**. This is dependent on the species of microbe and the environmental conditions.

When microorganisms grow in a liquid medium they use up substrates and nutrients and release the products of metabolism back into the medium. These changes result in four main phases of growth.

The graph shows the size of the viable cell numbers over time and the four phases.

Phases:

* **Lag** – The cells adjust to the growth medium and **induce the production of enzymes** needed to metabolise the substrates in the medium. There is **little or no** growth.
* **Log/Exponential** – There is a high availability of food and oxygen so conditions are **optimal**. The cells double in number at regular intervals and there is exponential growth.
* **Stationary** – Nutrients and oxygen begin to run out and there is **competition**. Growth rate has decreased to zero as many cells have stopped dividing. The cells produce secondary metabolites. These are chemicals that are not required for growth but may give an ecological advantage such as **antibiotics**.
* **Death** – Lack of **substrate** and toxic accumulation of metabolites causes am increase in the death rate over time.



**ACTIVITY 18** Try to answer the following brain busting questions:

1. Why is dry biomass used as an indicator of growth as opposed to fresh mass?

As fresh biomass includes water which can vary

1. Why would the production of antibiotics as a secondary metabolite give a microorganism an ecological advantage?

As it would kill other competing microorganisms.

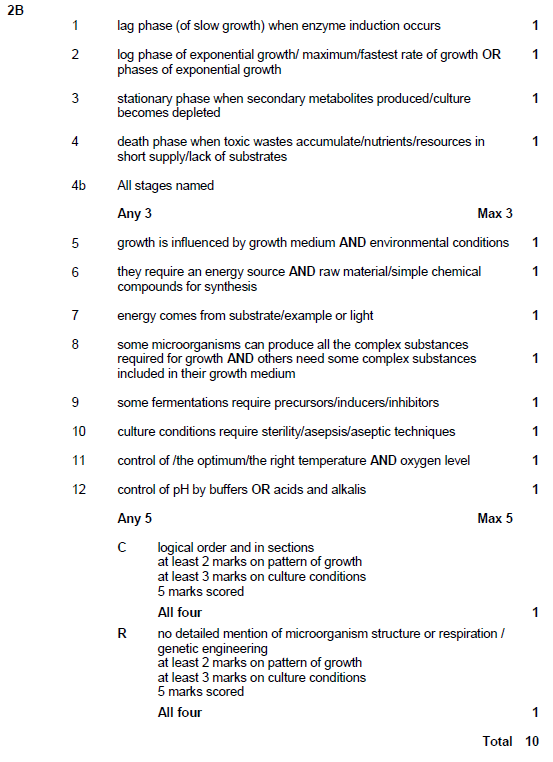
**ACTIVTY 19 ESSAY**

**Revised Higher 2015 SECTION C Q2B**

Give an account of the general pattern of growth of microorganisms and the conditions needed for their culture.

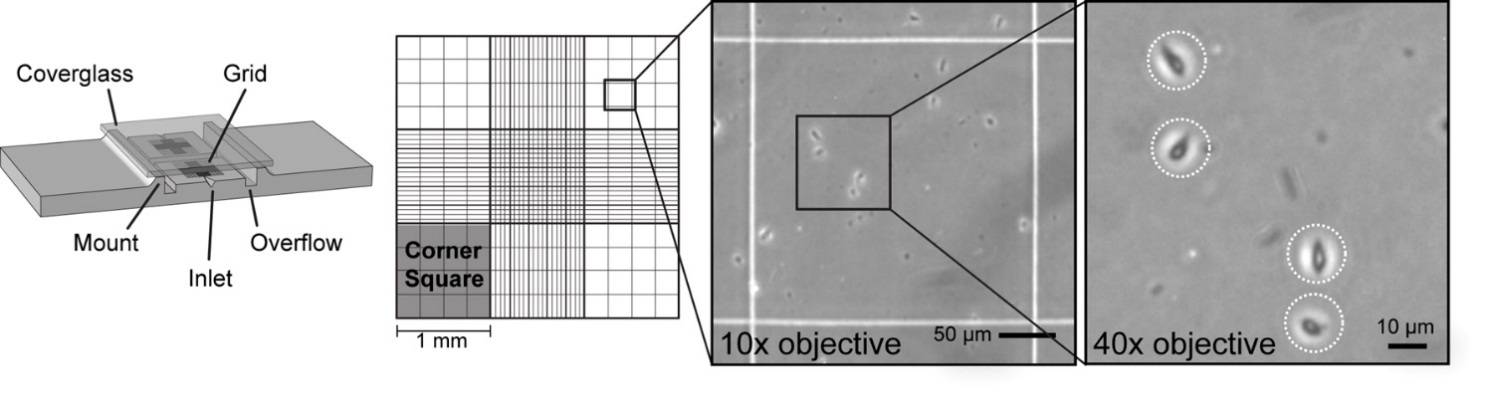


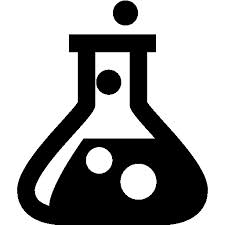
**ESSAY ANSWER**



The density of cells in a culture can be calculated by taking a drop of suspension of known volume and placing it in a piece of apparatus called a haemocytometer as shown in the picture below. A tally counter is then used to count the number of cells. There are two ways to record the cells:

* **Total** cell count – counting all cell present whether living or dead.
* **Viable** cell count – counting only the cells that are alive and able to grow as dead cells are marked by the use of trypan blue, a dye that only stains dead cells. Only viable cell counts show a death phase where cell numbers are decreasing.





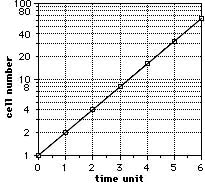
**ACTIVITY 20**

Your teacher will give you a demonstration of the haemocytometer using the digital microscope

During the log phase cell growth is very rapid as it is exponential and can be difficult to plot as a normal graph. An alternative method of plotting is to use a semi-logarithmic scale. The y axis scale is not linear but divided into a repeating cycle of numbers where the numbers are 10 times bigger in each cycle. This makes it easier to read when the number of cells gets very large

Semi-logarithmic plot – The scale on the y axis is logarithmic and the plot takes the form of a straight line.

Normal plot – The y axis is linear and the plot takes the form of a curve.



**ACTIVITY 21**

Want to know more about log graphs? Here’s a link:

<http://study.com/academy/lesson/logarithmic-scale-definition-lesson-quiz.html>



**Section 2.7 – Genetic Control of Metabolism**

**2.7(a) Mutation and Mutagenesis**

Wild strains of microorganisms which show potential for biotechnology can be improved by processes such as **mutagenesis** or recombinant DNA technology.

**Mutagenesis**

Mutagenesis is the process of inducing mutations. Spontaneous mutations are random and rare and so mutagens can be used to increase the rate of mutation.

Some examples of mutagens are:

* **Ultraviolet light**
* Other forms of radiation
* Mutagenic chemicals

Some of the mutations that arise from mutagenesis might result in an improved strain that produces a greater **yield** or lacks undesirable characteristics.

Mutant strains are often genetically **unstable**. They sometimes undergo a reverse mutation and revert to the wild type in continuous culture. They have to be checked regularly to ensure that it is still in a mutated state before use in biotechnological processes.

**7(b) Recombinant DNA Technology**

REMEMBER

N5 UNIT 1.6 GENETIC ENGINEERING

Recombinant DNA technology involves the joining together of DNA molecules from two different species.

Microorganisms can be transformed by transferring animal or plant **gene** sequences into them. This can produce new genetic combinations that are of value to science, medicine, agriculture and industry.

Genes can be introduced:

* to be expressed to produce specific **proteins** useful in medicine or science.
* to remove inhibitory controls or amplify specific metabolic steps in a pathway to increase yield.

In addition genes are added to prevent the survival of the microorganism in the external environment. This prevents contamination with wild crops.

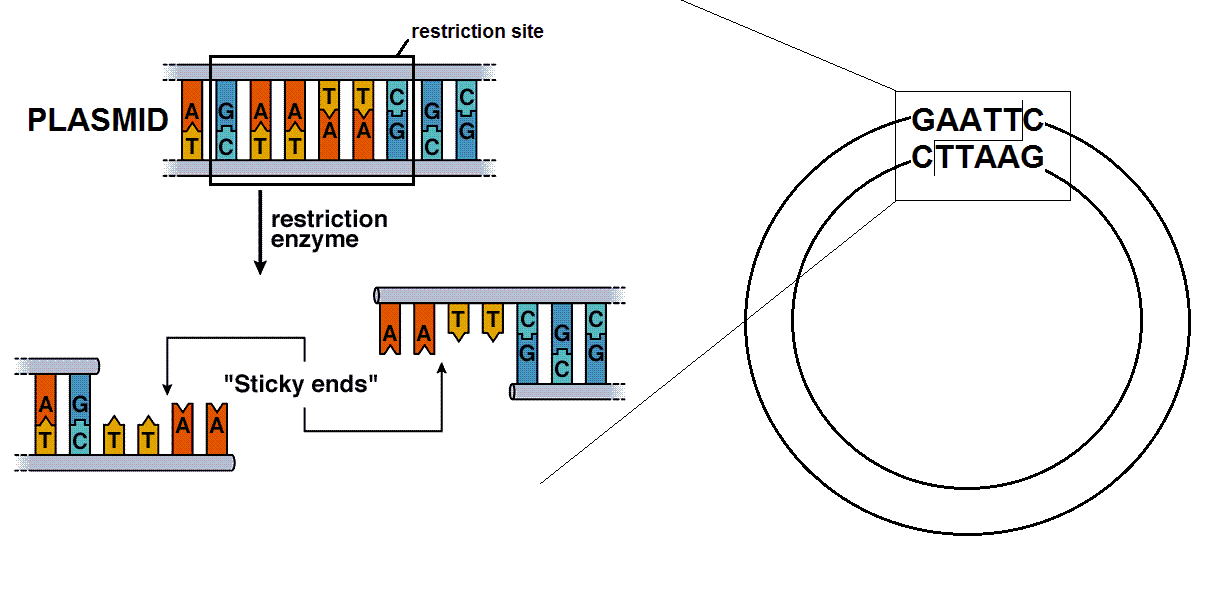
This can be done using plasmids or by producing artificial chromosomes.

These are called vectors as they carry the foreign DNA from the donor organism into a host cell.

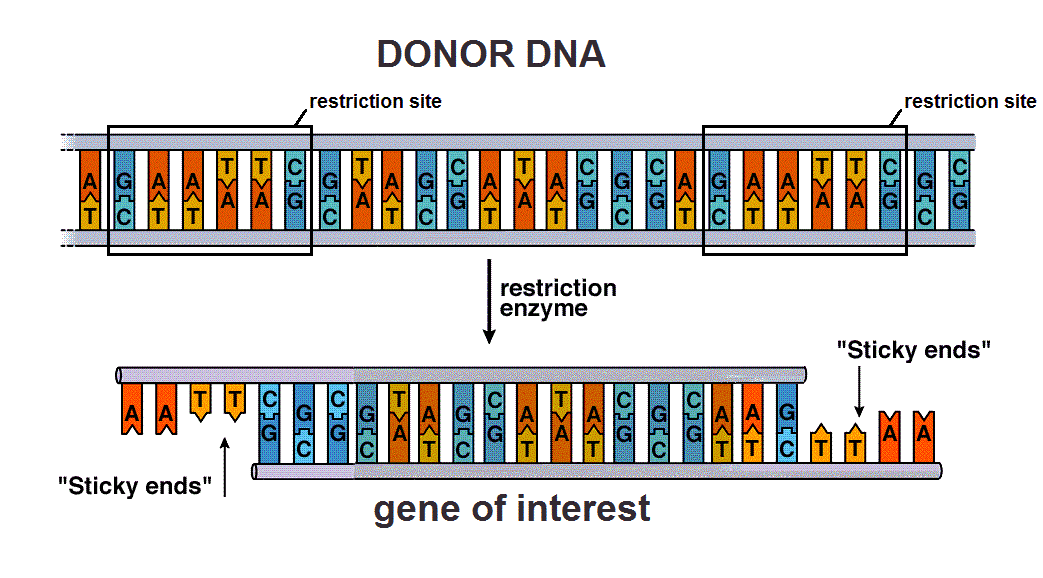
When there are large fragments of foreign DNA to be transferred then artificial chromosomes are preferable.

To be an effective vector the plasmid must contain:

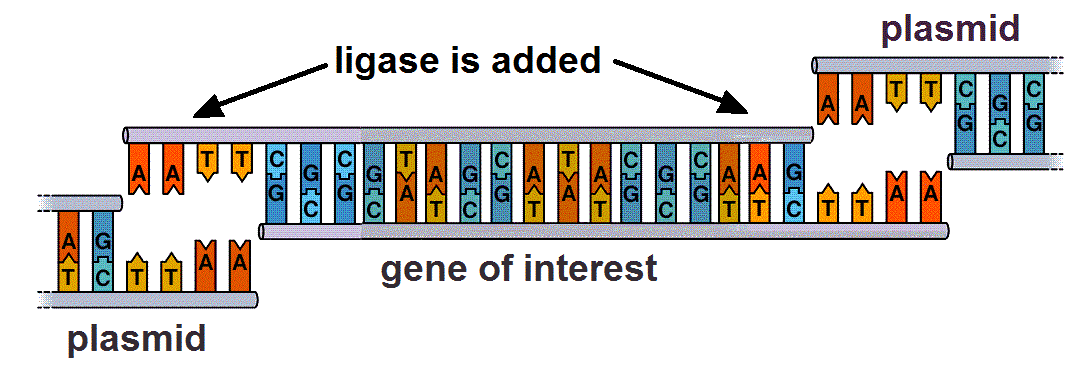
* **Restriction sites** – These are specific base sequences that are recognised by enzymes called **endonucleases**. Different endonucleases cut DNA at different target sequences leaving exposed single stranded ends called **sticky ends** (as they readily form H-bonds with a complementary end). When the donor DNA and the plasmid are cut with the same endonuclease it produces complementary sticky ends. These are combined with **ligase** enzyme to seal the donor DNA into the plasmid.

****

+



=



* **Marker genes** – These are genes that are transferred along with the gene of interest. A marker gene is easily recognised and is used to distinguish the cells that gave been successfully altered by the vector plasmid. Examples of marker genes are genes that give **antibiotic** resistance and genes that make a green fluorescent protein.
* Origin of **replication** – This area contains genes that allow the plasmid to self-replicate. It also contains regulatory sequences to allow the control of gene expression. This is essential to allow the engineered cell to replicate the plasmid and pass it to daughter cells. When many copies of the plasmid are produced, more product can be made by fewer cells.

**ACTIVITY 22**

Try to answer the following brain busting questions:

How would an antibiotic resistance gene act as a marker to show that a modified plasmid had been taken up?

*Grow/culture (on media) with / expose to / treat with / add…*

*ampicillin/antibiotic (1)*

*Only cells containing the plasmid / that gene / transformed cells / modified cells /can grow/survive/thrive (1)*

When culturing the engineered bacteria why is it important to maintain sterile conditions?

*Eliminates/kills…*

*other/contaminating/unwanted... microorganisms/bacteria*

*OR*

*Eliminates competition from… other/unwanted...*

*microorganisms/bacteria*

*OR*

*Prevents/eliminates…*

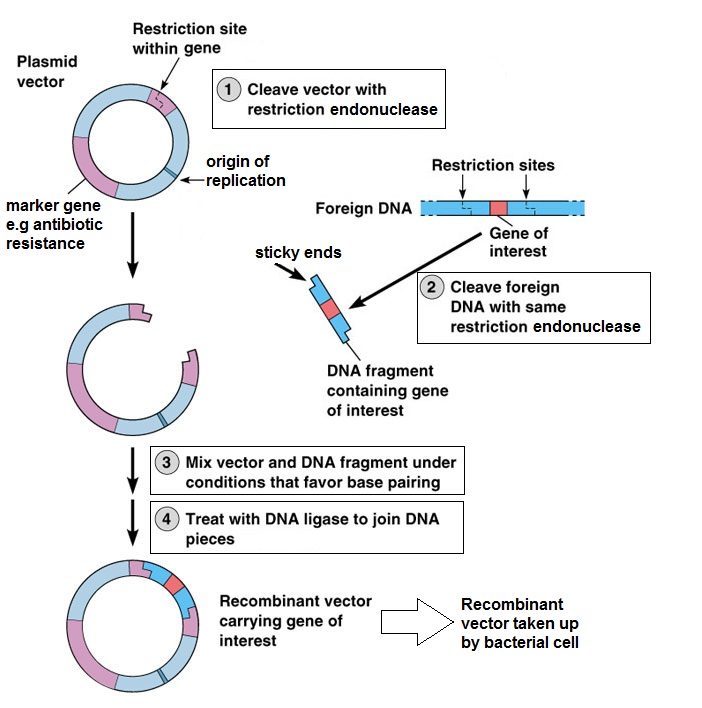
*contamination by microorganisms*

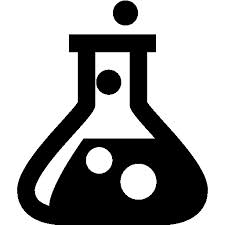
*OR*

*So only insulin-producing bacteria can grow*



The next diagram shows the steps in the production of a recombinant plasmid.





**ACTIVITY 23**

You are going to do an experiment to transform some bacterial cells with an interesting plasmid containing a marker gene that glows!

Collect the protocol card and your teacher will guide you through the practical activity.

Problems with Bacteria

REMEMBER

HIGHER UNIT 1.3 GENE EXPRESSION

Bacteria are **prokaryotic** and so have many differences to human cells. Bacterial DNA has exons but no introns and so bacterial cells do not carry out **alternative splicing**.

This means that human polypeptides made by bacterial cells may be **inactive** as they are folded incorrectly.

To get over these issues yeast cells can be used as they are eukaryotic. However, they are more sensitive than bacterial cells and have more complex needs to grow successfully. The protein can also be chemically modified in the lab.

**ACTIVITY 24**

**Work with a partner to research the development of a microbiological product from discovery to market.**

**Produce a poster to present your information and prepare a short presentation**.

You may wish to consider the following products:

Antibiotics <http://www.nature.com/ja/journal/v62/n1/full/ja200816a.html>

Food crops <http://www.monsanto.com/products/pages/corn-pipeline.aspx>

Overview of drug development

<http://www.eolss.net/sample-chapters/c17/E6-58-04-04.pdf>

