

3.5 Energy transfers in and between organisms

3.5.1 Photosynthesis

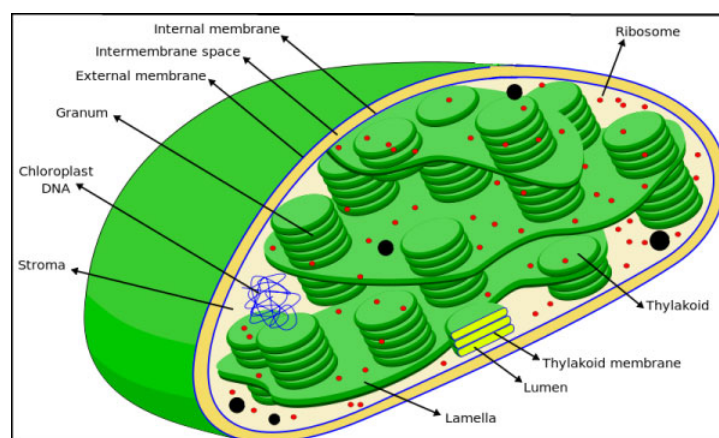
Content

- The light-dependent reaction in such detail as to show that:
 - Chlorophyll absorbs light, leading to photoionisation of chlorophyll
 - Some of the energy from electrons released during photoionisation is conserved in the production of ATP and reduced NADP
 - The production of ATP involves electron transfer associated with the transfer of electrons down the electron transfer chain and passage of protons across chloroplast membranes and is catalysed by ATP synthase embedded in these membranes (chemiosmotic theory)
 - Photolysis of water produces protons, electrons and oxygen.
- The light-independent reaction uses reduced NADP from the light-dependent reaction to form a simple sugar. The hydrolysis of ATP, also from the light-dependent reaction, provides the additional energy for this reaction.
- The light-independent reaction in such detail as to show that:
 - Carbon dioxide reacts with ribulose biphosphate (RuBP) to form two molecules of glycerate 3-phosphate (GP). This reaction is catalysed by the enzyme rubisco
 - ATP and reduced NADP from the light-dependent reaction are used to reduce GP to triose phosphate
 - Some of the triose phosphate is used to regenerate RuBP in the Calvin cycle
 - Some of the triose phosphate is converted to **useful organic substances**.
- Students should be able to:
 - Identify environmental factors that limit the rate of photosynthesis
 - Evaluate data relating to common agricultural practices used to overcome the effect of these limiting factors

Opportunities for Skills Development

- Students could devise and carry out experiments to investigate the effect of named environmental variables on the rate of photosynthesis using aquatic plants, algae or immobilised algal beads.

The Light-Dependent Reaction occurs in the thylakoid space of chloroplasts. The diagram below shows a chloroplast; the **thylakoid space** lies within the thylakoid membrane.



The first stage is for a photon of light to **excite electrons** within the **chlorophyll** molecule held in photosystem II. These excited electrons have enough energy to leave the chlorophyll molecule, and as a result cause the **photoionisation** of chlorophyll (ionisation with light). Some of the energy from electrons released during photoionisation is conserved in the production of **ATP** and **reduced NADP**.

The excited electrons then move across the **electron transfer chain** and provide energy to actively transport protons into the thylakoid space, as it is against the concentration gradient. However, these excited electrons that have been removed from the chlorophyll molecule need to be replaced. They are replaced in a process of splitting up water with light, called **photolysis**. The reaction is as follows:



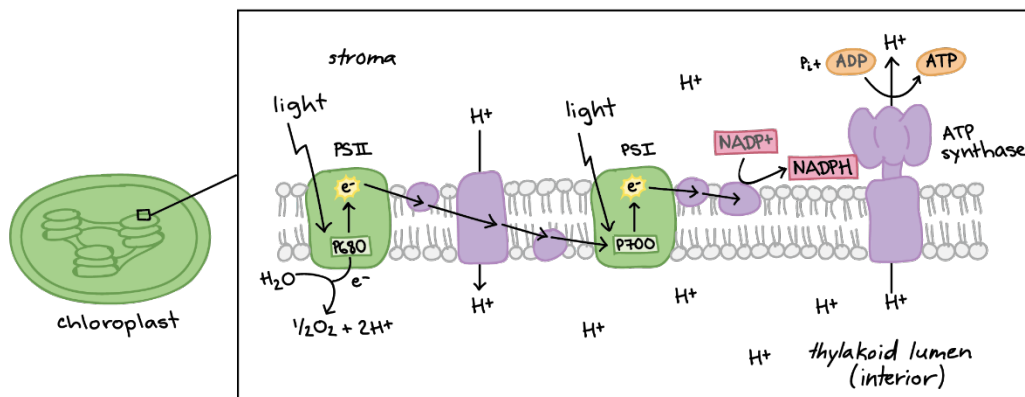
This reaction produces protons, electrons and oxygen. The oxygen is a by-product and diffuses into the atmosphere, the electrons replace those lost in the chlorophyll, and the protons stay in the thylakoid space.

There is now a high concentration of protons in the thylakoid space, and a low concentration in the stroma, so protons move by **facilitated diffusion** through the **ATP synthase channel** to phosphorylate ADP to ATP. This is known as the **chemiosmotic** theory; this theory explains the functioning of electron transport chains. According to this theory, the transfer of electrons down an electron transport system through a series of oxidation-reduction reactions releases energy.

Therefore, from the light-dependent reaction, we have now produced ATP. However, there is another product we still need to make, called reduced NADP. This process of producing reduced NADP also begins with exciting electrons in chlorophyll molecules. This excitation occurs in photosystem I (which also contains chlorophyll), whereas the excitation of electrons for the production of ATP was in photosystem II, however these names of the photosystems

are not required for the specification. These excited electrons are taken up by the NADP, alongside protons, to produce reduced NADP. NADP is sometimes written as $\text{NADPH} + \text{H}^+$, as the NADP has taken electrons and protons in.

The diagram below illustrates the light dependent reaction.



Therefore, the products of the light dependent reaction are **ATP**, **reduced NADP** and oxygen, where oxygen is a by-product, mostly diffusing into the atmosphere. The ATP and reduced NADP move to the light independent reaction, which takes place in the stroma. Their role in this stage is covered in the next part.

Chloroplasts are adapted to carry out the light-dependent stage by;

1. Thylakoid membranes provide a large surface area for the attachment of chlorophyll, electron carriers, and the enzymes that carry out the light dependent stage (ATP synthase)

One thing to remember is that it relies on the products of the light-dependent stage, and so even though its various reactions occur without the need for light, its rate will dramatically decrease in the absence of light. Also, the light-independent stage is sometimes referred to the Calvin Cycle, after the name of the person who worked out the processes involved (Melvin Calvin).

The first step involves carbon dioxide, a 1 carbon molecule reacting with **ribulose biphosphate (RuBP)**, a 5 carbon compound, to form two molecules of **glycerate 3-phosphate**, a three carbon compound. This reaction is catalysed by the enzyme **rubisco**.

The next stage is for the glycerate 3-phosphate (GP), to be reduced to **triose phosphate**. The reduced NADP provides the reducing power for this reaction (electrons and protons), and the ATP provides the energy for the reaction. The ATP and reduced NADP has come from the light dependent reaction.

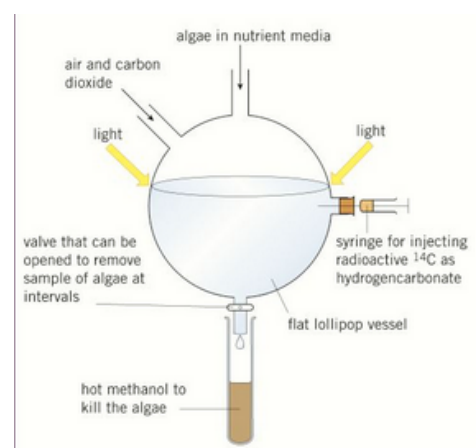
Now you are left with triose phosphate, a three carbon compound. It can either be used to regenerate RuBP by combining with a 2 carbon molecule, or can be converted to useful organic substances like glucose.

Melvin Calvin and his Lollipop Experiment

His experiment involved providing radioactive CO_2 to algae contained within a structure resembling the shape of a lollipop, hence the name of the experiment. Light sources were provided on either side, with heat screens to prevent overheating.

He tracked the radioactive carbon in the cycle. In this way he was able to see what the different stages were. He would drop a section of algae into hot methanol to stop all chemical reactions instantly. This process was repeated at regular intervals to identify the different compounds present at different times, thus the stages of the cycle.

The figure to the right shows the arrangement of his experiment, and the table shows the different products found at each time interval.



Time / s	Substances found to be radioactive
0	carbon dioxide
5	glycerate 3-phosphate
10	glycerate 3-phosphate + triose phosphate
15	glycerate 3-phosphate + triose phosphate + glucose
20	glycerate 3-phosphate + triose phosphate + glucose + ribulose biphosphate

AQA June 2014 Unit 4 Q8a

Question:

During the light-independent reaction of photosynthesis, carbon dioxide is converted into organic substances. Describe how.

Answer:

1. Carbon dioxide combines with ribulose biphosphate/RuBP;
2. Produces two glycerate (3-)phosphate/GP;
3. GP reduced to triose phosphate/TP;
4. Using reduced NADP;
5. Using energy from ATP;
6. Triose phosphate converted to glucose/hexose/RuBP/ ribulose biphosphate/named organic substance;

AQA June 2011 Q8c

Question:

‘During photosynthesis, oil-palm trees convert carbon dioxide into organic substances. Describe how.’

Answer:

- Carbon dioxide combines with ribulose biphosphate/RuBP;
- Produces two molecules of glycerate 3-phosphate/GP;
- Reduced to triose phosphate/TP;
- Using reduced NADP;
- Using energy from ATP;
- Triose phosphate converted to other organic substances/ named organic substances/ribulose biphosphate;
- In light independent reaction/Calvin cycle;

EXAM TIP:

WHEN TALKING ABOUT PHOTOSYNTHESIS REFER TO THE ACTUAL NAMES OF EACH STAGE IE LIGHT INDEPENDENT/DEPENDENT STAGE.

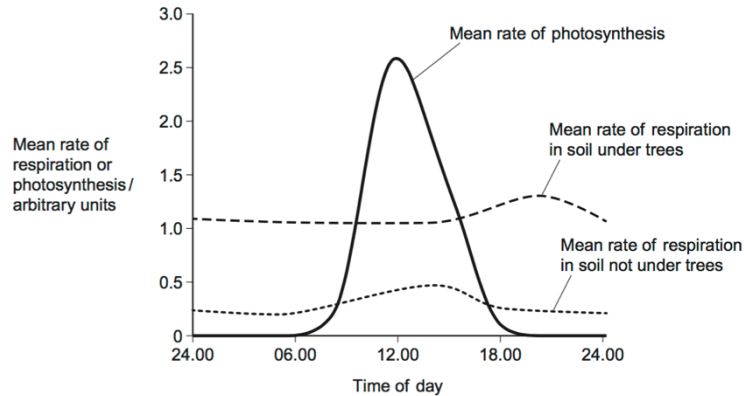
AQA June 2014 Unit 5 Q9eii)fi)ii)

Another group of scientists measured the mean rate of respiration in soil under trees and soil not under trees in the same wood. They also measured the mean rate of photosynthesis in the trees.

They took measurements at different times of day during the summer.

Figure 7 shows the scientists' results.

Figure 7



Question:

Suggest **one** explanation for the differences in the mean rate of respiration in soil under trees and soil not under trees between 06.00 and 12.00.

Answer:

(Between 06.00 and 12.00, (No Mark)

Respiration higher in soil under tree, (No mark)

1. Tree roots carry out (a lot of) respiration;
2. More/there are roots under tree;

OR

3. More food under trees;
4. So more active/greater mass of/more organisms (carrying out respiration);

OR

Soil not under trees respiration increases (No mark)

5. Soil in sunlight gets warmer;
6. Enzymes (of respiration) work faster;

Question:

The scientists suggested that the rise in the mean rate of photosynthesis was the cause of the rise in the mean rate of respiration in soil under trees.

Suggest how the rise in the mean rate of photosynthesis could lead to the rise in the mean rate of respiration in soil under trees.

Answer:

1. Photosynthesis produces sugars;
2. Sugars moved to roots;
3. (Sugars) are used/required for respiration;

Question:

Suggest why there is a delay between the rise in the mean rate of photosynthesis and the rise in the mean rate of respiration.

Answer:

Takes time to move sugars to roots;

AQA June 2013 Unit 5 Q5d

	At 20 °C	In suit at 38 °C	P value
Mean body temperature / °C	36.82	38.62	< 0.001
Mean rate of oxygen consumption / $\text{cm}^3 \text{kg}^{-1} \text{minute}^{-1}$	3.31	4.16	< 0.05
Mean rate of carbon dioxide production / $\text{cm}^3 \text{kg}^{-1} \text{minute}^{-1}$	2.68	3.03	> 0.05

Question

Using information from the table, explain the increase in mean rate of oxygen consumption

Answer:

1. Increased temperature leads to faster enzyme activity;
2. Faster rate of respiration (and oxygen consumption)

**IF QUESTIONS TALK ABOUT
PHOTOSYNTHESIS/RESPIRATION ALWAYS LINK TEMP TO
ENZYMES!!!!!!!!!!!!**

AQA June 2013 Unit 5 Q9abcde

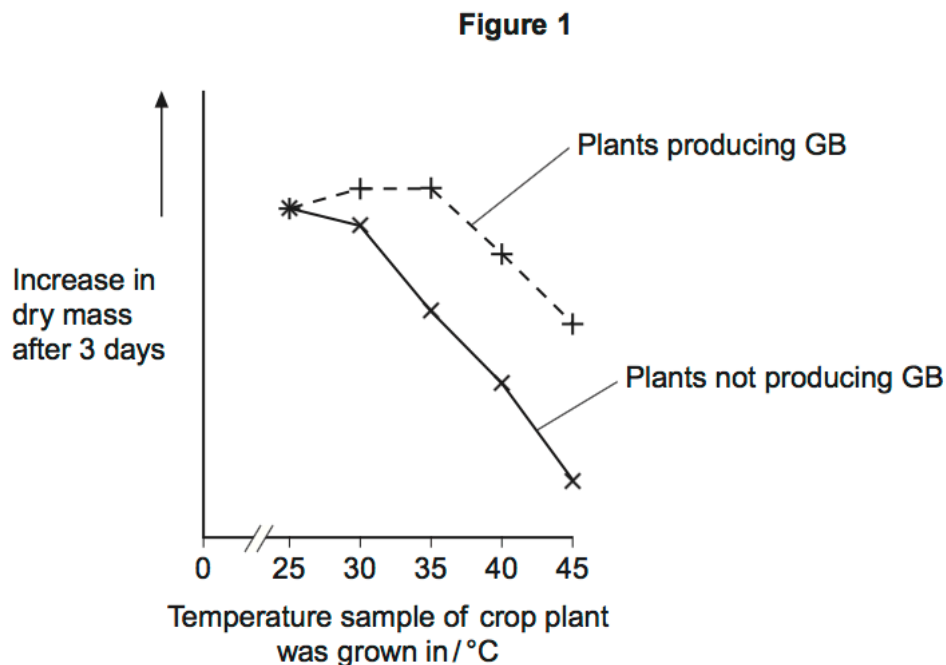
Some species of crop plant produce a substance called glycinebetaine (GB).

Scientists transferred the gene for GB into a species of crop plant that does not normally produce GB. These genetically modified plants then produced GB.

The scientists grew large numbers of the same crop plant with and without the gene at different temperatures. After 3 days, they found the increase in dry mass of the plants.

Figure 1 shows their results.

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Question:

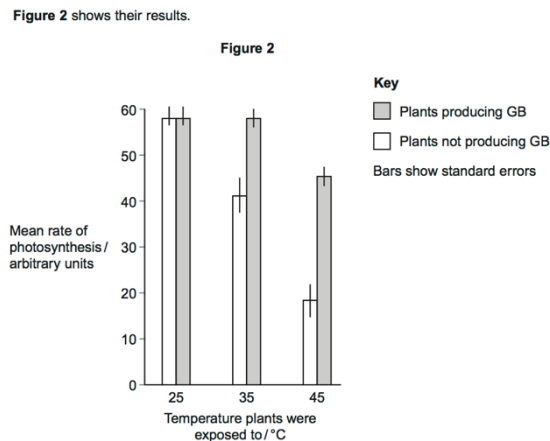
Describe the effect on growth of transferring the gene for GB into this plant.

Answer:

1. No effect at 25°C;
2. Keeps growing at 35°C and 35°C/up to 35°C (more than without GB);
3. Above 35°C, falls but grows more than plant without GB;

The scientists measured the rate of photosynthesis in plants that produce GB and plants that do not produce GB at 25°C, 35°C and 45°C.

Figure 2 shows their results.



Question:

The scientists concluded that the production of GB protects photosynthesis from damage by high temperatures.

Use these data to support this conclusion.

Answer:

Significantly different (because SEs do not overlap)

KEY WORD WHEN TALKING ABOUT STANDARD ERRORS, DEVIATIONS, P VALUES ETC, IS **SIGNIFICANCE**

Question:

Use the data from figure 2 for plants that do not produce GB to explain the effect of temperature on changes in dry mass of the plants shown in figure 1

Answer:

Enzyme activity reduced/(some) enzymes denatured;

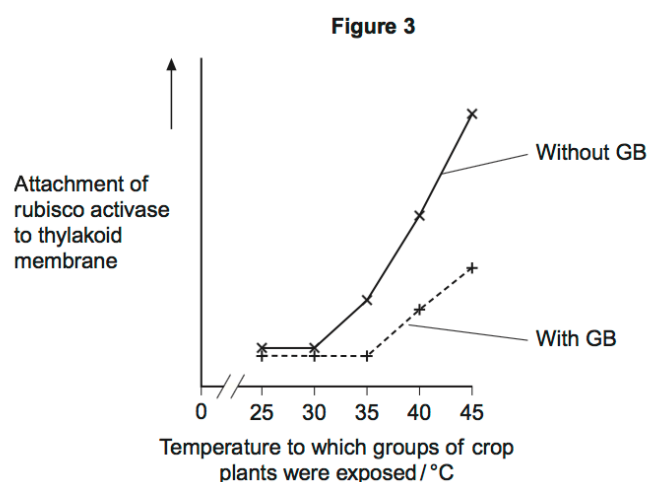
1. Less photosynthesis, so fewer sugars formed;
2. Less (complex) biological molecules/organic substances made (that add to mass);
3. Less respiration;
4. Less energy/ATP for growth;
5. Less energy for named function associated with growth

Question:

The scientists investigated the effect of GB on attachment of rubisco activase to thylakoid membranes at different temperatures.

Figure 3 shows their results.

Figure 3 shows their results.



Use information from **Figure 2** and **Figure 3** to suggest how GB protects the crop plant from high temperatures.

Answer:

1. GB prevents/reduces binding of rubiscoactivase to (thylakoid membrane);
2. (Prevents it) up to 35°C;
3. (So) rubiscoactivase/enzyme remains active;
4. (So) photosynthesis/light- independent stage still happens;
5. Above 35°C, some binding still occurs but less than without GB, so less reduction in growth

Question:

The scientists' hypothesis at the start of the investigation was that crop plants genetically engineered to produce GB would become more resistant to high environmental temperatures. The scientists developed this hypothesis on the basis of previous research on crops that are grown in hot climates.

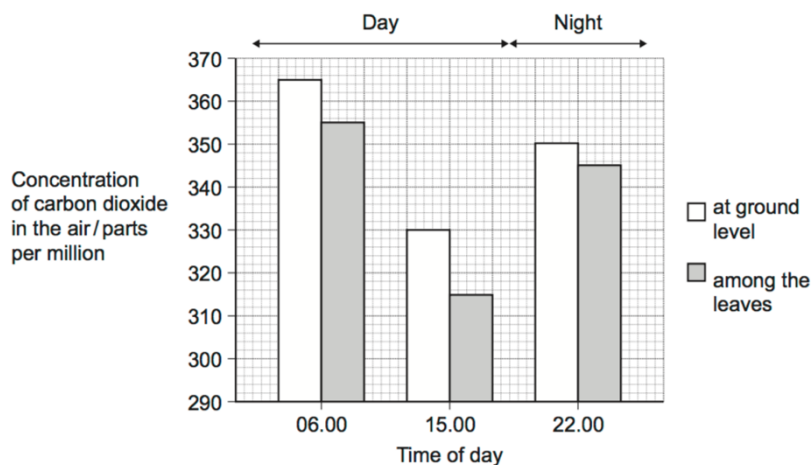
Suggest how the scientists arrived at their hypothesis.

Answer:

1. Looked for information/journals, on crop plants that grow at high temperatures;
2. (Crop plants cited in this research) contain/make GB;
3. So assumed making plants produce GB makes them resistant to high temperatures;

AQA Jan 2012 Unit 4 Q4b

Scientists measured the concentration of carbon dioxide in the air in one part of the forest. They took measurements at different times of day and at two different heights above the ground. Their results are shown in the bar chart.



Question:

Use your knowledge of photosynthesis and respiration to explain the data in the bar chart.

Answer:

1. Correct explanation for differences between day and night e.g. photosynthesis only during the daytime / no photosynthesis/only respiration at night;
2. Net carbon dioxide uptake during the day/in light **OR** No carbon dioxide taken up at night/in dark / carbon dioxide released at night/in dark;
3. At ground level more respiration / in leaves more photosynthesis;
4. Carbon dioxide produced at ground level/carbon dioxide taken up in leaves (because less sunlight passes through).

AQA Jan 2012 Unit 4 Q8a

Question:

ATP is useful in many biological processes. Explain why.

Answer:

1. Releases energy in small / manageable amounts;
2. (Broken down) in a one step / single bond broken;
3. Immediate energy compound/makes energy available rapidly;
4. Phosphorylates/adds phosphate;
5. Makes (phosphorylated substances) more reactive / lowers activation energy;
6. Reformed/made again;

Question:

Describe how ATP is made in mitochondria.

Answer:

1. Substrate level phosphorylation / ATP produced in Krebs cycle;
2. Krebs cycle/link reaction produces reduced coenzyme/reduced NAD/reduced FAD;
3. Electrons released from reduced /coenzymes/ NAD/FAD;
4. (Electrons) pass along carriers/through electron transport chain/through series of redox reactions;
5. Energy released;
6. ADP/ADP + Pi;
7. Protons move into intermembrane space;
8. ATP synthase;

Question:

Plants produce ATP in their chloroplasts during photosynthesis. They also produce ATP during respiration. Explain why it is important for plants to produce ATP during respiration in addition to during photosynthesis.

Answer:

1. In the dark no ATP production in photosynthesis;
2. Some tissues unable to photosynthesise/produce ATP;
3. ATP cannot be moved from cell to cell/stored;
4. Plant uses more ATP than produced in photosynthesis;
5. ATP for active transport;
6. ATP for synthesis (of named substance)

3.5.2 Respiration

Content

- Respiration produces ATP.
- Glycolysis is the first stage of anaerobic and aerobic respiration. It occurs in the cytoplasm and is an anaerobic process.
- Glycolysis involves the following stages
 - Phosphorylation of glucose to glucose phosphate, using ATP
 - Production of triose phosphate
 - Oxidation of triose phosphate to pyruvate with a net gain of ATP and reduced NAD.
- If respiration is only anaerobic, pyruvate can be converted to ethanol or lactate using reduced NAD. The oxidised NAD produced in this way can be used in further glycolysis.
- If respiration is aerobic, pyruvate from glycolysis enters the mitochondrial matrix by active transport.
- Aerobic respiration in such detail as to show that:
 - Pyruvate is oxidised to acetate, **producing** reduced NAD in the process
 - Acetate combines with coenzyme A in the link reaction to produce acetylcoenzyme A
 - Acetylcoenzyme A reacts with a four-carbon molecule, releasing
 - Coenzyme A and producing a six-carbon molecule that enters the Krebs cycle
 - In a series of oxidation-reduction reactions, the Krebs cycle generates reduced coenzymes and ATP by substrate-level phosphorylation, and carbon dioxide is lost
- Synthesis of ATP by oxidative phosphorylation is associated with the transfer of electrons down the electron transfer chain and passage of protons across inner mitochondrial membranes and is catalysed by ATP synthase embedded in these membranes (chemiosmotic theory)
- Other respiratory substrates include the breakdown products of lipids and amino acids, which enter the Krebs cycle.

Opportunities for Skills Development

- Students could use a redox indicator to investigate dehydrogenase activity.

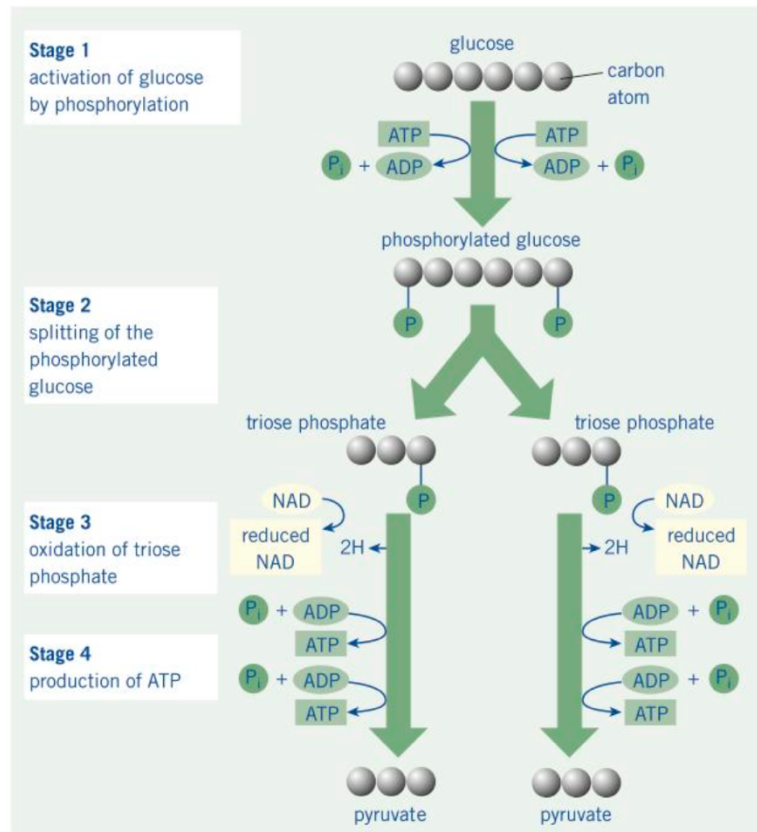
As an overview, respiration is the process by which ATP is produced, using hexose sugars like glucose, or using lipids/proteins.

Glycolysis is the first stage of both anaerobic and aerobic respiration. It occurs in the cytoplasm, and as the name suggests does not require the presence of oxygen.

1. The first stage required glucose to be made more reactive, so by the addition of two phosphates (phosphorylation of glucose). This process required two ATP molecules.
2. Glucose is then split into two molecules of the 3 carbon triose phosphate.
3. Triose phosphate is oxidised to pyruvate. This results in a loss of hydrogen which goes to reduce NAD and form reduced NAD. In this process 4 ATP molecules are

also regenerated, as the phosphates leave the triose phosphate and phosphorylate ADP to ATP.

From Glycolysis, per glucose molecule, you get a net gain of 2 ATP molecules, 2 reduced NAD and two pyruvate molecules.



If respiration is only **anaerobic**, pyruvate can be converted to ethanol or lactate using reduced NAD. The oxidised NAD produced in this way can be used in further glycolysis.

Anaerobic Respiration... occurs in the absence of oxygen. The purpose of anaerobic respiration essentially, is to oxidise the reduced NAD back to NAD, so it can be used again in glycolysis. Without NAD to take up hydrogen, glycolysis would halt. So the products of glycolysis (two molecules of pyruvate) will accept hydrogen from the reduced NAD, and become oxidised. In this way, NAD is recycled and can be used again.

Anaerobic Respiration in **Plants and Microorganisms**:

- Pyruvate + Reduced NAD is converted to Ethanol + Carbon Dioxide + Oxidised NAD.

Anaerobic Respiration in **Animals**:

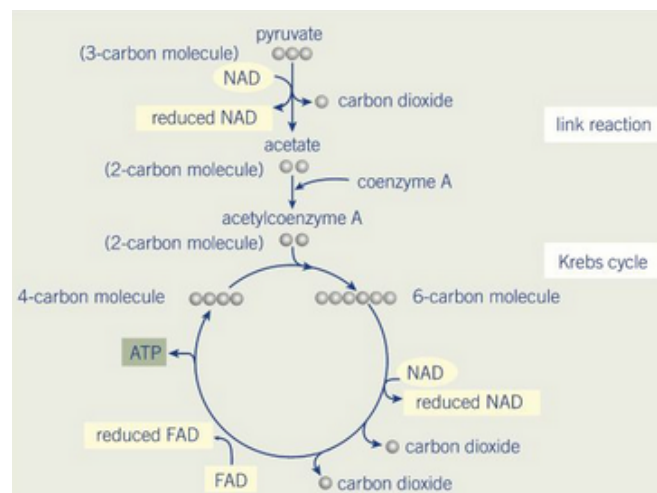
- Pyruvate + Reduced NAD is converted to Lactate + Oxidised NAD.

At some point this lactate is oxidised back to pyruvate, where it can be further oxidised to release energy, or converted to glycogen, once oxygen is available again. Lactate causes cramp and muscle fatigue, and it is also very acidic so causes the enzymes in your body to be affected.

However in the presence of oxygen, **aerobic respiration** will occur. In this process pyruvate is actively transported into the matrix of the mitochondria, the site of aerobic respiration. Aerobic respiration involves three main stages, the **link reaction**, **Krebs cycle** and **oxidative phosphorylation**.

Link Reaction... this involves the oxidation of pyruvate to acetate. This oxidation releases 2 hydrogen atoms that go to form reduced NAD. Also a molecule of CO_2 is lost by the pyruvate molecule. Acetate then combines with coenzyme A to form acetylcoenzyme A. Since pyruvate loses a molecule of CO_2 , the acetylcoenzyme A is a 2 carbon molecule, and this molecule now enters the Krebs cycle.

Krebs Cycle... The 2 carbon acetylcoenzyme A from the link reaction combines with a 4 carbon molecule, this produces a 6 carbon molecule.

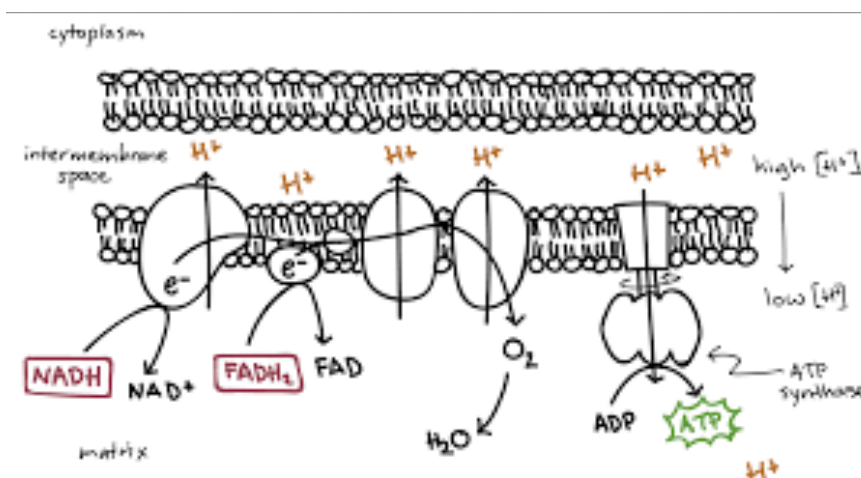


The diagram above illustrates the processes of the link reaction, then how this moves to the Krebs cycle.

The 6 carbon molecule produced loses two molecules of CO_2 , becoming a 4 carbon molecule again. The 6 carbon molecule also loses hydrogen (catalysed by a dehydrogenase enzyme), which reduces the coenzymes NAD and FAD. Furthermore, a molecule of ATP is produced in this cycle, by a process called substrate level phosphorylation. Once this cycle has finished, the end product is two molecules of CO_2 , one molecule of ATP, 3 reduced NAD molecules and one reduced FAD. However, this is only for one molecule of pyruvate that has come from the link reaction, so per glucose molecule these amounts are double, and if you add in the link reaction, you have an extra CO_2 molecule, as well as another reduced NAD. This process occurs in the matrix of the mitochondria, and as a final note, since the Krebs cycle produces a four carbon product at the end, this can then be used to combine with the acetyl CoA to repeat the process.

Oxidative Phosphorylation... ATP is synthesised in this process, and this process involves the transfer of electrons down an electron transfer chain. It also involves the passage of

protons moving across the inner mitochondrial membranes and is catalysed by ATP synthase embedded in these membranes.



Oxidative phosphorylation occurs between the matrix and intermembrane space. This can be seen in the diagram above.

Basically, the reduced coenzymes NAD and FAD donate electrons to the electron transfer chain. These electrons pass along this chain, and in doing so release energy for the active transport of protons into the intermembrane space, through the inner membrane of the mitochondrion. This means that in this space, there is a high concentration of protons, so the protons (like in the light independent stage of photosynthesis) flow down the concentration gradient/electrochemical potential gradient through ATP synthase channels in a process of facilitated diffusion. As they flow down these channels, they cause the phosphorylation of ADP to ATP.

Now you are left with free protons and electrons, so oxygen is oxidised to form H_2O /water by accepting electrons and protons, therefore oxygen is called the final electron acceptor. This is important otherwise it would cause the electron transfer chain to back up, with no place for electrons to go, so would halt the process otherwise. Energy in this process is also released in small amounts each time, as not to lose energy to heat energy, making the process more efficient. This happens because the electrons move down an energy level gradient, so that their energy is released gradually.

Other respiratory substances like the breakdown products of **lipids** and **amino acids** can enter the Krebs cycle.

Lipids are first hydrolysed to glycerol and three fatty acids, glycerol is then phosphorylated and converted to triose phosphate. This triose phosphate can enter the glycolysis pathway, where the triose phosphate is converted to pyruvate. However, the fatty acids can be broken down to 2 carbon fragments, which can be converted to acetylcoenzyme A, where it can then enter the Krebs cycle.

Amino acids first of all have their amino group moved (deamination), and they will join the respiratory pathway at different points depending on the number of carbon atoms present.

AQA June 2015 Unit 4 Q8c

Question:

‘Large areas of tropical forest are still found on some Caribbean islands. The concentration of carbon dioxide in the air of these forests changes over a period of 24 hours and at different heights above ground.

Use your knowledge of photosynthesis and respiration to describe and explain how the concentration of carbon dioxide in the air changes:

- over a period of 24 hours
- different heights above ground’

Answer:

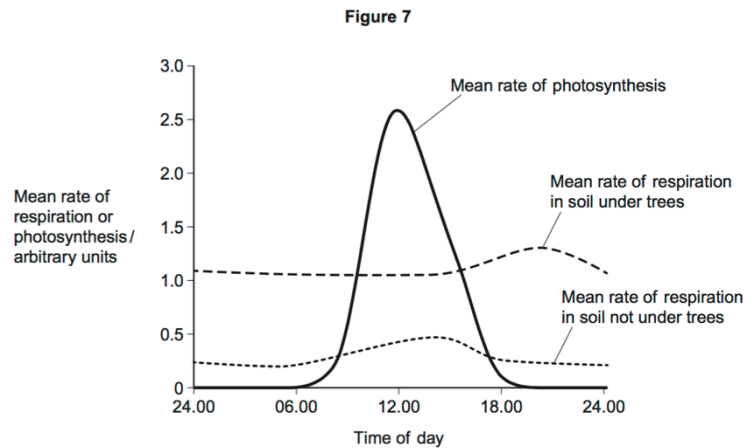
1. High concentration of/increase in carbon dioxide linked with respiration at night/in darkness;
2. No photosynthesis in dark/night / photosynthesis only in light/day;
3. In light net uptake of carbon dioxide / use more carbon dioxide than produced / (rate of) photosynthesis greater than rate of respiration;
4. Decrease in carbon dioxide concentration with height;
5. (At ground level) less photosynthesis / less photosynthesising tissue / more respiration / more micro-organisms / / micro-organisms produce carbon dioxide;

AQA June 2014 Unit 5 Q9eii)fi)ii)

Another group of scientists measured the mean rate of respiration in soil under trees and soil not under trees in the same wood. They also measured the mean rate of photosynthesis in the trees.

They took measurements at different times of day during the summer.

Figure 7 shows the scientists' results.



Question:

Suggest **one** explanation for the differences in the mean rate of respiration in soil under trees and soil not under trees between 06.00 and 12.00.

Answer:

(Between 06.00 and 12.00, (No Mark)

Respiration higher in soil under tree, (No mark)

3. Tree roots carry out (a lot of) respiration;
4. More/there are roots under tree;

OR

5. More food under trees;
6. So more active/greater mass of/more organisms (carrying out respiration);

OR

Soil not under trees respiration increases (No mark)

7. Soil in sunlight gets warmer;
8. Enzymes (of respiration) work faster;

Question:

The scientists suggested that the rise in the mean rate of photosynthesis was the cause of the rise in the mean rate of respiration in soil under trees.

Suggest how the rise in the mean rate of photosynthesis could lead to the rise in the mean rate of respiration in soil under trees.

Answer:

4. Photosynthesis produces sugars;
5. Sugars moved to roots;
6. (Sugars) are used/required for respiration;

Question:

Suggest why there is a delay between the rise in the mean rate of photosynthesis and the rise in the mean rate of respiration.

Answer:

Takes time to move sugars to roots;

AQA June 2013 Unit 5 Q9ab

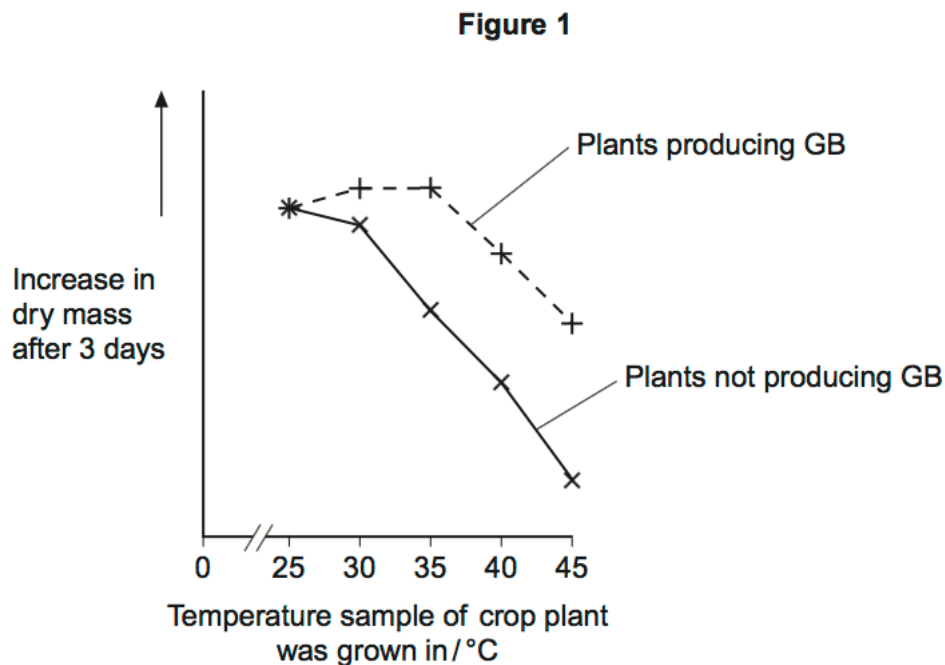
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Scientists transferred the gene for GB into a species of crop plant that does not normally produce GB. These genetically modified plants then produced GB.

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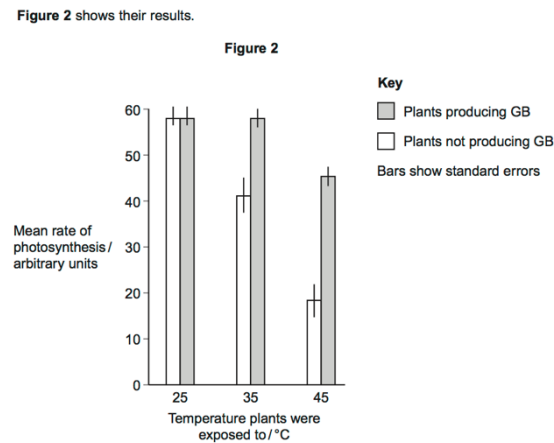
Describe the effect on growth of transferring the gene for GB into this plant.

Answer:

4. No effect at 25°C;
5. Keeps growing at 35°C and 35°C/up to 35°C (more than without GB);
6. Above 35°C, falls but grows more than plant without GB;

The scientists measured the rate of photosynthesis in plants that produce GB and plants that do not produce GB at 25°C, 35°C and 45°C.

Figure 2 shows their results.



Question:

The scientists concluded that the production of GB protects photosynthesis from damage by high temperatures.

Use these data to support this conclusion.

Answer:

Significantly different (because SEs do not overlap)

KEY WORD WHEN TALKING ABOUT STANDARD ERRORS, DEVIATIONS, P VALUES ETC, IS **SIGNIFICANCE**

Question:

Use the data from figure 2 for plants that do not produce GB to explain the effect of temperature on changes in dry mass of the plants shown in figure 1

Answer:

Enzyme activity reduced/(some) enzymes denatured;

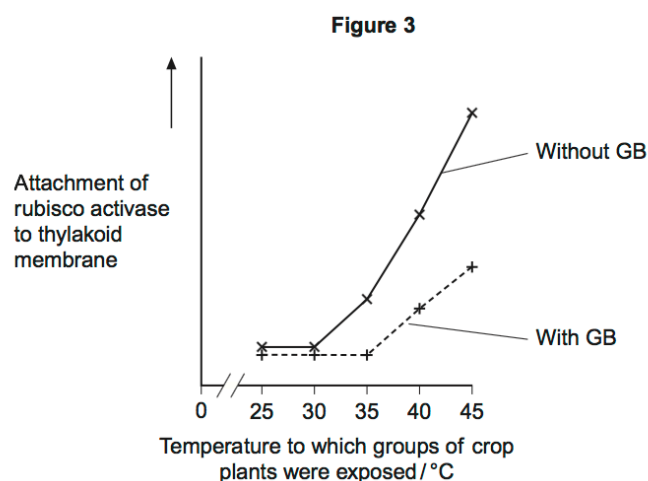
6. Less photosynthesis, so fewer sugars formed;
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8. Less respiration;
9. Less energy/ATP for growth;
10. Less energy for named function associated with growth

Question:

The scientists investigated the effect of GB on attachment of rubisco activase to thylakoid membranes at different temperatures.

Figure 3 shows their results.

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Use information from **Figure 2** and **Figure 3** to suggest how GB protects the crop plant from high temperatures.

Answer:

6. GB prevents/reduces binding of rubiscoactivase to (thylakoid membrane);
7. (Prevents it) up to 35°C;
8. (So) rubiscoactivase/enzyme remains active;
9. (So) photosynthesis/light- independent stage still happens;
10. Above 35°C, some binding still occurs but less than without GB, so less reduction in growth

Question:

The scientists' hypothesis at the start of the investigation was that crop plants genetically engineered to produce GB would become more resistant to high environmental temperatures. The scientists developed this hypothesis on the basis of previous research on crops that are grown in hot climates.

Suggest how the scientists arrived at their hypothesis.

Answer:

1. Looked for information/journals, on crop plants that grow at high temperatures;
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AQA June 2013 Unit 4 Q4a

Question:

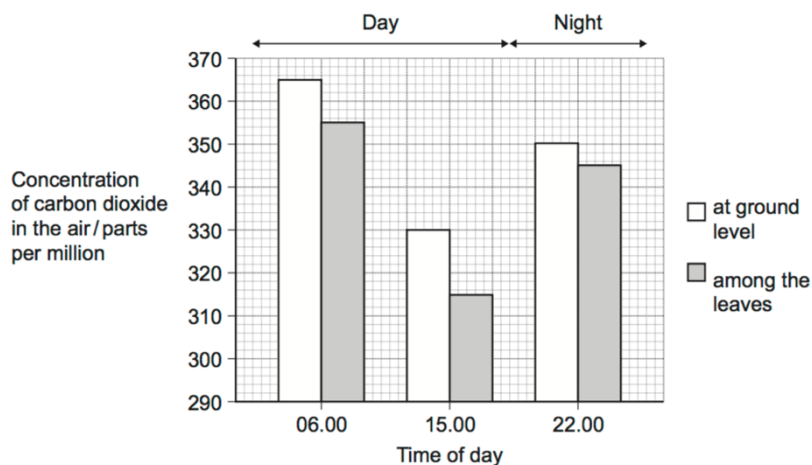
Complete the table.

Answer:

	Glycolysis	Link reaction	Krebs Cycle
Occurs in mitochondria		✓	✓
Carbon dioxide produced		✓	✓
NAD is reduced	✓	✓	✓

AQA Jan 2012 Unit 4 Q4b

Scientists measured the concentration of carbon dioxide in the air in one part of the forest. They took measurements at different times of day and at two different heights above the ground. Their results are shown in the bar chart.



Question:

Use your knowledge of photosynthesis and respiration to explain the data in the bar chart.

Answer:

1. Correct explanation for differences between day and night e.g. photosynthesis only during the daytime / no photosynthesis/only respiration at night;
2. Net carbon dioxide uptake during the day/in light **OR** No carbon dioxide taken up at night/in dark / carbon dioxide released at night/in dark;
3. At ground level more respiration / in leaves more photosynthesis;
4. Carbon dioxide produced at ground level/carbon dioxide taken up in leaves (because less sunlight passes through).

3.5.3 Energy and ecosystems

Content

- In any ecosystem, plants synthesise organic compounds from atmospheric, or aquatic, carbon dioxide.
- Most of the sugars synthesised by plants are used by the plant as respiratory substrates. The rest are used to make other groups of biological molecules. These biological molecules form the biomass of the plants.
- Biomass can be measured in terms of mass of carbon or dry mass of tissue per given area. The chemical energy store in dry biomass can be estimated using calorimetry.
- Gross primary production (*GPP*) is the chemical energy store in plant biomass, in a given area or volume.
- Net primary production (*NPP*) is the chemical energy store in plant biomass after respiratory losses to the environment have been taken into account,
- i.e. $NPP = GPP - R$
- where *GPP* represents gross production and *R* represents respiratory losses to the environment
- This net primary production is available for plant growth and reproduction. It is also available to other trophic levels in the ecosystem, such as herbivores and decomposers.
- The net production of consumers (*N*), such as animals, can be calculated as:
- $N = I - (F + R)$
- Where *I* represents the chemical energy store in ingested food, *F* represents the chemical energy lost to the environment in faeces and urine and *R* represents the respiratory losses to the environment.
- Primary and secondary productivity is the rate of primary or secondary production, respectively. It is measured as biomass in a given area in a given time eg $\text{kJ ha}^{-1}\text{year}^{-1}$.
- **Students should be able to:** appreciate the ways in which production is affected by farming practices designed to increase the efficiency of energy transfer by:
 - Simplifying food webs to reduce energy losses to non-human food chains
 - Reducing respiratory losses within a human food chain.

In any **ecosystem**, plants synthesise organic compounds from atmospheric, or aquatic, carbon dioxide. These organic compounds include sugars, most of which are used by the plant as respiratory substrates. The rest are used to make other biological molecules; these biological molecules form the biomass of the plant.

Organisms living within ecosystems can be divided into three groups, producers, consumer and Saprobionts.

- Producers manufacture their organic substances using light energy, water, carbon dioxide and mineral ions.
- Consumers obtain their energy by feeding on other organisms as opposed to getting it directly from sunlight. Those feeding directly on producers are called primary consumers, then secondary consumers etc.

- Saprobionts are a group of organisms that break down the complex materials in dead organisms into simple ones. They release valuable minerals and elements in a form that can be absorbed by plants and so contribute to recycling. The main organisms in this group are fungi and bacteria.

A **food chain** is made up of different **trophic levels**, and show feeding relationships between consumers and producers. However, in reality most animals do not rely on a single food source, so **food webs** can be used to demonstrate relationships. Although food webs can become complex and it is likely that most food webs are in fact linked.

Biomass is the total mass of living material in a specific area at a given time. The fresh mass is easily assessed, but varying water amounts makes it unreliable. Measuring the mass of carbon or dry mass of tissue per given area overcomes this, but requires the organisms to be killed so only small samples can be used, so it may not be representative. Biomass is measured using dry mass per given area, in a given time, for example gm^{-2} if an area is sampled, or gm^{-3} if it is a volume ie pond.

To estimate the **chemical** energy stored in dry biomass calorimetry can be used. Bomb calorimetry uses a weighed sample of dry material, which is then burnt in pure oxygen within a sealed chamber called a 'bomb', hence the name. The bomb is surrounded by a water bath and the heat of combustion causes a small temperature rise in the water, this can be used to calculate the energy released from the mass of burnt biomass in a unit such as kJkg^{-1}

The sun is the source of energy for all ecosystems. But roughly only 1% of its energy is utilised by green plants, so this small amount then filters down the food chains. Most of the sun's energy is reflected back into space, not all wavelengths of light can be used for photosynthesis, light may not fall on the chlorophyll molecule and other limiting factors may inhibit photosynthesis.

Gross primary production (GPP) is the chemical energy store in plant biomass, in a given area or volume. However most of this energy is used in respiration, so the chemical energy store left is called the **net primary production (NPP)**, and is the chemical energy store in plant biomass after respiratory losses to the environment have been taken into account.

$$\begin{array}{ccccccc} \text{net primary production} & = & \text{gross primary production} & - & \text{respiratory losses} \\ NPP & & GPP & & R \end{array}$$

This **net primary production** is available for plant growth and reproduction. It is also available to other trophic levels in the ecosystem, such as herbivores and decomposers. Usually less than 10% of the NPP can be used by primary consumers for growth, and so the overall amount of energy transferred between each trophic level decreases. Some of the reasons for this are:

- Some of the organism is not consumed
- Some parts are consumed but cannot be digested, therefore lost in faeces
- Some of the energy is lost in excretory materials, such as urine
- Some energy losses occur as heat from respiration and lost to the environment. These losses are high in mammals and birds because of their high body temperature. Much

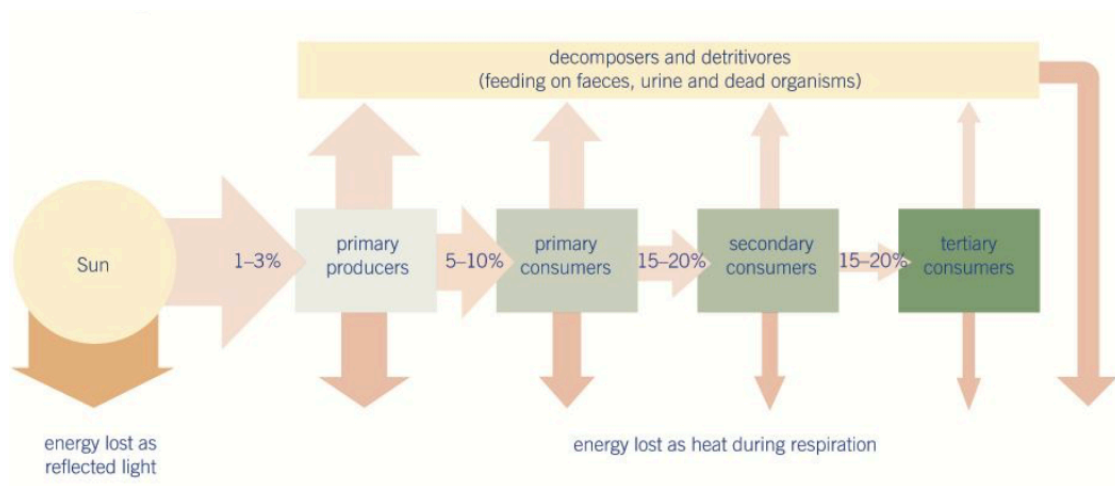
energy is needed to maintain their body temperature when heat is constantly being lost to the environment.

The net production of consumers can be calculated as:

$$N = I - (F + R)$$

N = NPP, I = Chemical energy store of ingested food, F = The energy lost in faeces and urine, R = The energy lost in respiration.

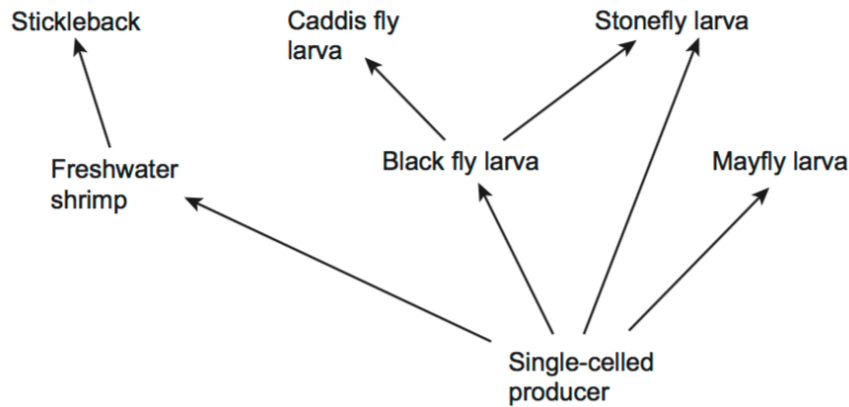
The relative inefficiency of energy transfer through trophic levels explains why most food chains only have four or five trophic levels, as there is not enough energy available to support a large enough breeding population for any higher levels. Also, the total mass of organisms in a particular place is less at higher trophic levels, and the total amount of energy available is less at each level as one moves up the food chain.



Primary and secondary productivity is the rate of primary or secondary production, respectively. It is measured as biomass in a given area in a given time eg $\text{kJ ha}^{-1}\text{year}^{-1}$.

AQA Jan 2012 Unit 4

The diagram shows organisms in a food web



Question:

Name **all** the secondary consumers in this food web

Answer:

Stickleback + caddis fly (larva) + stonefly (larva);

Question:

Use the diagram to explain the likely effect of a sudden decrease in the stickleback population on the population of mayfly larvae

Answer:

1. (With fewer fish) reduced predation / not being eaten results in more freshwater shrimps;
2. Increased competition for food/resources / more producers eaten by shrimps / more shrimps eating producers;
3. Less food/resources for mayfly;

Question:

The average efficiency of energy transfer between producers and primary consumers in pyramids of energy is around 10 %.

Suggest why the efficiency of energy transfer from producers to primary consumers in this food web is higher than 10 %.

Answer:

1. Single-celled producers are more digestible / contain less cellulose (than plants) / less energy lost in faeces;
2. All of producer eaten/parts of plant not eaten;
3. Less heat/energy lost / less respiration;

Question:

Energy from the sun may ultimately end up in dead plant matter. Describe how

Answer:

1. Photosynthesis/light dependent reaction/light independent reaction;
2. Carbon-containing substances;

AQA Jan 2010 Unit 4 Q8b

Question:

Energy is transferred through an ecosystem.

Describe how and explain why the efficiency of energy transfer is different at different stages in the transfer.

Answer:

1	Some light energy fails to strike/is reflected/not of appropriate wavelength;
2	Efficiency of photosynthesis in plants is low/approximately 2% efficient;
3	Respiratory loss / excretion / faeces / not eaten;
4	Loss as heat;
5	Efficiency of transfer to consumers greater than transfer to producers/approximately 10%;
6	Efficiency lower in older animals/herbivores/ primary consumers/warm blooded animals/homoiotherms;
7	Carnivores use more of their food than herbivores;

AQA Jan 2012 Unit 4 Q7cii

Question:

The efficiency of conversion of food to biomass is lower at 0°C than it is at 20°C. Suggest an explanation for the lower efficiency.

Answer:

1. Will lose more heat / not as much energy used to maintain body temperature;
2. Heat resulting from respiration/more respiration;
3. More food used in respiration;

3.5.4 Nutrient cycles

Content

- Nutrients are recycled within natural ecosystems, exemplified by the nitrogen cycle and the phosphorus cycle.
- Microorganisms play a vital role in recycling chemical elements such as phosphorus and nitrogen.
- The role of Saprobionts in decomposition.
- The role of mycorrhizae in facilitating the uptake of water and inorganic ions by plants.
- The role of bacteria in the nitrogen cycle in sufficient detail to illustrate the processes of saprobiotic nutrition, ammonification, nitrification, nitrogen fixation and denitrification.
- (The names of individual species of bacteria are not required)
- The use of natural and artificial fertilisers to replace the nitrates and phosphates lost by harvesting plants and removing livestock.
- The environmental issues arising from the use of fertilisers including leaching and eutrophication

Two main nutrient cycles are the **nitrogen cycle** and **phosphorous cycle**. Another example is the carbon cycle; however, this is not part of the course. Nitrogen is an essential part of every living organism, forming part of all proteins, nucleic acids and their products. Phosphorous on the other hand is also essential to life, part of ATP, nucleic acids and phospholipids. Nitrogen is readily accessible in the atmosphere to the biotic component of an ecosystem, however phosphorous is locked up in sediment and is only made available to organisms by slow physical processes.

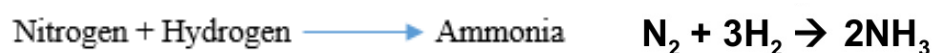
Microorganisms play a vital role in recycling chemical elements such as phosphorous and nitrogen. **Saprobionts** are microorganisms that have this role of decomposition and recycling. They break down the complex molecules in producers and consumers that contain the locked up nutrients.

The Phosphorous Cycle recycles phosphates in ecosystems. The phosphorous cycle, unlike the carbon and nitrogen cycle, lacks a gaseous stage as most phosphorous is locked up in mineral form and dissolved in oceans, lakes and soils. Most sedimentary rock deposits and fossils contain phosphates, originating from the seas. Weathering and erosion of these rocks allows phosphate ions to become dissolved and so available for absorption by plants. These dissolved phosphate ions can also be harvested by manufacturers of fertilisers. The phosphate ions taken up by plants are then passed on to consumer animals. These phosphates in the animals may be excreted out, or upon death of both plants and animals, certain bacteria and fungi decomposers break them down. This releases phosphate ions back into the water and soil. However a lot of the phosphate ions will remain in the bones or shells of animals, and these are very slow to breakdown. Thus the ions will be locked up by fossilisation or locked in sedimentary rocks awaiting erosion and weathering to begin the process again.

Mycorrhizae are associations between certain types of fungi, and the roots of the vast majority of plants. They have a role in facilitating the uptake of water and inorganic ions by plants. Essentially the fungi act like extensions of the plant's root system and increase the total surface area for absorbing water and minerals. The mycorrhizae as a whole act like a sponge, where it holds the minerals and water close to the roots. It enables plants to much more quickly take up inorganic ions and water, so mycorrhizae also play a huge role in increasing uptake of phosphate ions. There is a mutualistic relationship between plants and fungi, as the plant receives better water and inorganic ion uptake, and on the other hand the fungus receives organic compounds like sugars and amino acids from the plant.

The Nitrogen Cycle includes four main stages, ammonification, nitrification, nitrogen fixation and denitrification. Saprobionts also play a big role in the nitrogen cycle.

- **Nitrogen Fixation** involves turning nitrogen to nitrogen containing compounds. Nitrogen makes up around 79% of the atmosphere, however very few organisms are able to use atmospheric nitrogen directly, or nitrogen that is dissolved in water. This is mainly due to nitrogen gas being chemically unreactive. Before plants and animals have access to nitrogen, it must first be converted to absorbable nitrogen containing compounds. This conversion is called nitrogen fixation. Naturally, some nitrogen fixation occurs when lightning strikes, as lightning provides energy to oxidise nitrogen to nitrogen oxides. These gases then dissolve in rain to form dilute nitric acid. However most nitrogen fixation is done by nitrogen-fixing bacteria. These bacteria are either free living, or live mutualistically in root nodules on plants like peas and beans. Nitrogen fixing bacteria contain **nitrogenase**, which is an enzyme that enables them to reduce nitrogen to ammonia or ammonia compounds. The reaction is shown below and is catalysed by nitrogenase. Nitrogen fixation can also be done artificially by industry in the production of nitrogen fertilisers.



- **Ammonification** is the process by which ammonia is produced in ecosystems from nitrogen-containing compounds. These compounds occur in faeces, urea (breakdown of excess amino acids), proteins, nucleic acids, dead organisms etc. The process of ammonification is predominantly carried out by saprobiontic microorganisms, mainly fungi and bacteria. They break down dead organisms, and feed on faeces to release ammonia which forms ammonium ions in the soil. In this process, nitrogen returns to the abiotic component of the ecosystem.
- **Nitrification** is where ammonium ions in the soil are oxidised to nitrites and nitrates by free-living soil microorganisms called nitrifying bacteria. Since oxidation is occurring, the nitrifying bacteria require oxygen, so it happens most rapidly in well aerated soils or well oxygenated bodies of water. The process involved ammonia being oxidised to nitrite (NO_2^-), and then nitrite is oxidised again to nitrate (NO_3^-). Also, since this is an oxidation reaction it will release energy. The nitrate ions produced can be taken up by plants and used to make proteins, consumers will then obtain their nitrogen in the form of proteins when they eat plants or other animals.
- **Denitrification** completes the cycle. Anaerobic denitrifying bacteria live in conditions of low oxygen content so reverse the nitrifying process, converting nitrates

to nitrites, then nitrites to nitrogen gas. This leads to loss of nitrogen from biotic components of an ecosystem. Denitrification occurs in soils that may have become waterlogged, as this causes a low oxygen concentration. This also means there are less aerobic nitrifying and nitrogen-fixing bacteria found.

Fertilisers are used in industry, both natural and artificial, to replace lost nitrates and phosphates in harvesting plants and removing livestock. The vast population is requiring larger crop yields, and more animals to be farmed on very concentrated pieces of land. This intensive food production puts large amounts of stress on the soil, as the large majority of mineral ions are being used by the crops being grown. These ions are then removed, whereas usually these crops and animals would die in the area and return the ions, a deficit now forms. The reduction of mineral ions will become **the limiting factor** for the growth of plants unless they are replaced. They are replaced by using natural fertilisers, consisting of the dead and decaying remains of plants and animals, as well as animal waste such as manure. They can also be replenished using artificial fertilisers, which are mined from rocks and deposits, then converted into an appropriate balance of minerals for a particular crop. Overall a combination of natural and artificial fertilisers seems to give the best long-term productivity. However, there seems to be a point in which further increase in the quantity of fertiliser no longer results in increased productivity.

Fertilisers are essential to plant growth. For example, nitrogen is essential in amino acids, ATP and nucleotides in DNA, which are all required for plant growth. Plants that have access to vast quantities of nitrate ions typically develop earlier, grow taller and have a greater leaf area. This results in an increased rate of photosynthesis, thus crop productivity is improved.

Despite the fact that fertilisers have increased crop productivity tremendously, there are some **environmental issues** that arise from the use of fertilisers like leaching and eutrophication. There are three main issues,

1. Reduced species diversity
2. Leaching
3. Eutrophication

Reduced species diversity is as a result of species like grasses and nettles that favour nitrogen-rich soils have been out-competing many other species that die as a result.

Leaching is where nutrients are removed from the soil, as rainfall will dissolve soluble nutrients like nitrate ions, carrying them into much deeper soil. They will eventually move too deep and out of reach of plants, moving into groundwater stores that will take them to streams and rivers, then possibly ending up in freshwater lakes. These lakes provide a source of drinking water for humans, and **too high nitrate ion concentrations** can prevent efficient oxygen transport in babies, and a link has been found to stomach cancer. This leaching also then causes eutrophication.

Eutrophication occurs where organic material, or inorganic nutrients, especially nitrates or phosphates enter a freshwater habitat. This can be as a result of pollution by sewage or agricultural runoff containing fertiliser. The process is as follows;

1. Usually there will be a low concentration of nitrate and nitrate ions in most lakes and rivers, thus the concentration of nitrates and nitrate ions are a **limiting factor** for plant and algal growth.
2. **Leaching** causes the concentration to increase, so nitrate concentration and ions are no longer the limiting factor for growth of plants and algae.
3. Since most algae grow at the surface, the upper layers of water become densely populated with algae, called an algal bloom.
4. The dense surface layer of algae absorbs the vast majority of light, so preventing light from reaching lower depths.
5. Light is now the **limiting factor** for growth of plants and algae at lower depths, thus they die.
6. The lack of dead plants and algae is now no longer the limiting factor for **saprobiontic bacteria**, so these populations grow as they have a vast food source
7. Saprobiontic bacteria use **oxygen** for respiration, so demand for oxygen increases.
8. The concentration of oxygen decreases, and nitrates are being constantly released from the decaying organisms.
9. Oxygen now becomes the limiting factor for the population of aerobic organisms like fish. These organisms will ultimately die as they lack oxygen.
10. Without the aerobic conditions, there is less competition for the anaerobic organisms, so the populations of these organisms now rises.
11. The anaerobic conditions further decompose dead material, so they release more nitrates and some toxic wastes like hydrogen sulphide. This makes the water putrid.

Leaching of artificial fertilisers is the main cause of eutrophication, however organic manures, animal slurry and human sewage can all contribute.

AQA June 2011 Q8a

‘Much of Indonesia is covered with forest. Large areas of forest have been cleared and planted with oil-palm trees to be used in the production of fuel.

In these forests, nitrogen in dead leaves is made available to growing plants by the action of bacteria. Describe the role of bacteria in making the nitrogen in dead leaves available to growing plants.’

- Saprobiants
- Digest/break down proteins/DNA/nitrogen-containing substances;
- Extracellular digestion/release of enzymes;
- Ammonia/ammonium produced;
- Ammonia converted to nitrite to nitrate/ammonia to nitrate;
- Nitrifying bacteria do this in a process called nitrification;
- Oxidation is the process whereby ammonia is converted to nitrate.

AQA June 2012 Q8abc

a) ‘Explain how farming practices increase the productivity of agricultural crops.’

- Fertilisers/minerals added to soil
- Role of named nutrient or element e.g. nitrate/nitrogen for proteins / phosphate/phosphorus for ATP/DNA;
- Pesticides/biological control prevents damage/consumption of crop;
- Pesticides/weed killers /herbicides/weeding remove competition;
- Selective breeding / genetic modification (of crops);
- Glass/greenhouses enhance temp/CO/ light;
- Ploughing aerates soil/improves drainage;
- Ploughing/aeration allows nitrification/decreases denitrification;
- Benefit of crop rotation in terms of soil nutrients/fertility/pest reduction;
- Irrigation/watering to remove limiting factor;
- Protection of crops from birds/pests/frost by covers/netting etc.;

b) ‘Describe how the action of microorganisms in the soil produces a source of nitrates for crop plants.’

- Protein/amino acids/DNA into ammonium compounds / ammonia;
- By Saprobiants;
- Ammonium/ammonia into nitrite;
- Nitrite into nitrate;
- By nitrifying bacteria/microorganisms;
- Nitrogen to ammonia/ammonium;
- By nitrogen-fixing bacteria/microorganisms in soil;

c) 'Explain how the use of pesticides can result in resistant strains of insect pests.'

- Variation/variety in pest population;
- Due to mutation;
- Allele for resistance;
- Reference to selection;
- Pests with resistance (survive and) breed / differential reproductive success;
- Increase in frequency of allele;

AQA June 2014 Q2aii)b)

Question:

'Describe the role of microorganisms in producing nitrates from the remains of dead organisms'

Answer:

- Saprobiotic (microorganisms/bacteria) break down remains/dead material/protein/DNA into ammonia/ammonium;
- Ammonia/ammonium ions into nitrite and then into nitrate;
- (By) Nitrifying bacteria / nitrification;

Upwelling is a process where water moves from deeper parts of the sea to the surface. This water contains a lot of nutrients from the remains of dead organisms.

Question:

Upwelling often results in high primary productivity in coastal waters. Explain why some of the most productive fishing areas are found in coastal waters.

Answer:

1. Nitrate/phosphate/named ion/nutrients for growth of/absorbed/used by plants/algae/producers;
2. More producers/consumers/food so more fish / fish reproduce more / fish grow more / fish move to area;

AQA June 2013 Unit 4 Q8b

Question:

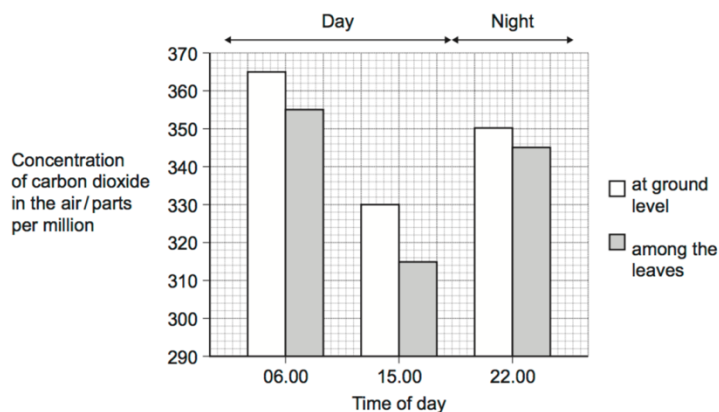
Nitrate from fertiliser applied to crops may enter ponds and lakes. Explain how nitrate may cause the death of fish in fresh water.

Answer:

1. Growth of algae/surface plants/algal bloom blocks light;
2. Reduced/no photosynthesis so (submerged) plants die;
3. Saprobial (microorganisms/bacteria);
4. Aerobically respire / use oxygen in respiration;
5. Less oxygen for fish to respire / aerobic organisms die;

AQA Jan 2012 Unit 4 Q6b

Reeds are plants that grow with their roots under water. A reed bed contains a large number of growing reeds. Reed beds may be used to absorb nitrates produced when bacteria break down human sewage. The diagram shows a reed bed.



Reeds have hollow, air-filled tissue in their stems which supplies oxygen to their roots.

Question:

Explain how this enables the roots to take up nitrogen-containing substances.

Answer:

1. **Uptake** (by roots) involves active transport;
2. Requires ATP/ aerobic respiration;

Question:

There is an optimum rate at which human sewage should flow through the reed bed. If the flow of human sewage is too fast, the nitrate concentration at point A falls. Explain why.

Answer:

1. Not enough time / fast flow washes bacteria away;
2. (Not all/less) ammonia converted to nitrate/less nitrification;

Question:

An increase in nitrate concentration in the water entering the lake could affect algae and fish in the lake. Explain how.

Answer:

1. Algal bloom / increase in algae;
2. Algae block light / plants/algae die;

3. Decomposers/saprobionts/bacteria break down dead plant materials;
4. Bacteria/decomposers/saprobionts use up oxygen in respiration / increase BOD;
5. Fish die due to lack of oxygen