Sub-Topics Include:

2.1 Cell structure
2.2 Transport across cell membranes
2.3 Producing new cells
2.4 DNA and the production of proteins
2.5 Proteins and enzymes
2.6 Genetic Engineering
2.7 Respiration
2.8 Photosynthesis
UNIT 2  TOPIC 1

1. Cell Structure

1. Types of organism

Animals and plants are made up of many cells and so are described as multicellular organisms. Similar cells doing the same job are grouped together to form tissues. Animals and plants have systems made up of a number of organs, each doing a particular job. For example, the circulatory system is made up of the heart, blood and vessels such as arteries, veins and capillaries.

Some fungi such as yeast are single celled while others such as mushrooms and moulds are larger.

Cells of animals, plants and fungi have contain a number of specialised structures inside their cells. These specialised structures are called organelles.

Bacteria are unicellular (exist as single cells) and do not have organelles in the same way as other cells.

2. Looking at Organelles

Some organelles can be observed by staining cells and viewing them using a light microscope. Other organelles are so small that they cannot be seen using a light microscope. Instead, they are viewed using an electron microscope, which provides a far higher magnification than a light microscope.

Most organelles inside cells are surrounded by a membrane which is similar in composition (make-up) to the cell membrane.
3. **A Typical Cell**

![Cell diagram]

4. **Functions of Organelles**

   **Nucleus:**

   The nucleus is surrounded by a nuclear membrane. The nucleus of a cell contains the genetic material, DNA, in structures called chromosomes.

   The nucleus controls cell activities because the chromosomes contain the genetic code which determines the features of the cell.

   **Cell membrane**

   The cell membrane surrounds the cytoplasm of cells. It controls what enters and leaves the cell. It is described as a “selectively permeable” membrane. This means that it only allows certain substances to pass through.
**Mitochondria**

Mitochondria (singular mitochondrion) are involved in the production of energy within the cell as they are the site of aerobic respiration.

Mitochondria are surrounded by a double membrane. They have a central, fluid filled, matrix and finger like projections called cristae.

**Chloroplasts**

Chloroplasts are found only in green plant cells and some algae. They are the site of photosynthesis, the process by which sugar is made using light as a source of energy.

Chlorophyll is the green chemical found in the chloroplast which traps light energy for photosynthesis.

**Cell Walls**

All plant cells have a cell wall, as do fungi and bacteria. A plant cell wall is made of cellulose fibres. The cell wall protects the plant cell and maintains its shape. The cell wall also prevents the plant cell from bursting if it takes in a lot of water.

The structure of the cell wall of a fungal and bacterial cell wall is different from the structure of a plant cell wall.

**Vacuoles**

Vacuoles are sacs within the cell which are surrounded by a membrane. Plant cells have a large, permanent vacuole filled with water and solutes (cell sap), which is responsible for water balance in a plant cell.
**Ribosomes**

Ribosomes are the sites of protein synthesis in the cell. Ribosomes build amino acids into the correct sequence in a protein by following instructions from the genetic code on chromosomes.

Ribosomes are found floating freely in the cell cytoplasm or attached to rough endoplasmic reticulum (you don’t need to know or be able to identify the rough endoplasmic reticulum). Ribosomes do not have membranes.

5. **Bacteria**

Bacteria are single celled micro-organisms.

They have a cell wall and ribosomes, but lack other organelles. They have a circular chromosome which contains all the genetic information needed to control all the activities of a bacterial cell.

Plasmids are small, circular pieces of DNA. They are extra pieces of DNA found in bacterial cells in addition to the normal chromosomal material.
Plasmids are not found in all bacteria. Plasmids can be transferred from one bacterial cell to another. They give bacteria extra properties such as the ability to resist antibiotics.

6. **Fungi**

Fungi are surrounded by a cell wall which has a different structure to that of a plant cell. Fungi have chromosomes contained in a nucleus surrounded by a membrane. They also have the other organelles found in plant and animal cells. Some fungi such as yeast are simple, unicellular organisms.

Here is a table showing the presence or absence of various organelles and structures in different types of cells:

<table>
<thead>
<tr>
<th>Organelle or Structure</th>
<th>Type of cell</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Animal</td>
</tr>
<tr>
<td>Ribosome</td>
<td>Present</td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>Present</td>
</tr>
<tr>
<td>Circular chromosome</td>
<td>Absent</td>
</tr>
<tr>
<td>Permanent vacuole</td>
<td>Absent</td>
</tr>
<tr>
<td>Nucleus</td>
<td>Present</td>
</tr>
<tr>
<td>Chloroplasts</td>
<td>Absent</td>
</tr>
<tr>
<td>Plasmids</td>
<td>Absent</td>
</tr>
</tbody>
</table>

**Unit 2**

**Topic 2**

**Transport across cell membranes**

7. **Function of the cell membrane**

The function of the cell membrane is to allow the transport of materials in and out the cell.
8. **Structure of the cell membrane - Fluid Mosaic Model**

The structure of the cell membrane allows this transport to occur.

The cell membrane is composed of a phospholipid bilayer and protein molecules.

![Diagram of cell membrane with phospholipid bilayer and proteins]

The design of the phospholipid bilayer allows the protein molecules to move freely through the membrane making the membrane fluid.

9. **Selectively permeable**

The protein in the cell membrane are involved the transport of molecules across the membrane.

![Diagram showing spanning proteins]

Some proteins span the entire membrane and act as carriers to actively transport molecules.
10. **Diffusion**

Diffusion is an example of passive transport and involves the movement of molecules from a region of high concentration to a region of low concentration down a concentration gradient and does not require energy.

11. **Concentration gradients**

A concentration gradient is the difference in concentration between the regions of high concentration and low concentration.

12. **Passive Transport**

Passive transport involves the movement of molecules across a cell membrane without using any energy.
13. **Importance of Diffusion**

Diffusion is a vital process in the survival of living organisms. In multicellular organisms it allows the movement of molecules like oxygen from the lungs into the blood, it also moves oxygen and glucose into cells for respiration and allows waste products such as carbon dioxide to be excreted from the body. In a unicellular organism diffusion is the means by which it obtains the resources it requires to survive, such as oxygen, from its surrounding environment.

14. **Osmosis**

Osmosis is the movement of water molecules from a region of high concentration to a lower water concentration through a selectively permeable membrane.

15. **Different types of solution.**

In terms of osmosis there are 3 types of solution

1. Hypotonic - This solution has a higher water concentration and loses water to any cell placed in it.
2. Isotonic - This has an equal water concentration to the cells placed in it; as such there will be no overall movement of water.
3. Hypertonic - This solution has a lower water concentration and gains water from any cell placed in it.

You may have learned this information in class, you will definitely need to know what happens to both plant and animals cells when they are placed in different solutions, however, you will not need to know the names "hypotonic, isotonic and hypertonic".

16. **Effects of osmosis on animal cells.**

1. Animals cells placed in hypotonic solution will gain water and burst.
2. Animal cells placed in isotonic solution will have no overall change in appearance.
3. Animals cells placed in hypertonic solution will lose water and shrink.
17. Effects of osmosis on plant cells

1. Plant cells in hypotonic solution will gain water and become turgid. **Note that the cell wall prevents the cell from bursting.**

2. Plant cells placed in isotonic solution will have no overall change in appearance.

3. Plant cells placed in a hypertonic solution will lose water and become plasmolysed.

18. Active Transport

Active transport is movement of molecules from a region of low concentration to a region of high concentration against a concentration gradient. As this process moves against the concentration gradient it requires energy in the form ATP.
19. Haploid and Diploid Cells

Somatic cells are normal body cells (not sex cells) for example cheek cells, heart cells and leaf cells. Somatic cells in humans contain 46 chromosomes, which is 23 pairs of chromosomes. In other words normal body cells contain a double set of chromosomes. Any cell that contains a double set of chromosomes is said to be diploid \((2n)\).

Normal sex cells contain only half the genetic information. For instance in humans, sex cells contain 23 chromosomes, which is 23 individual chromosomes. In other words normal sex cells contain a single set of chromosomes. Any cell that contains a single set of chromosomes is said to be haploid \((n)\).

<table>
<thead>
<tr>
<th>Sets of chromosomes</th>
<th>Haploid Cell ((n))</th>
<th>Diploid Cell ((2n))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example of Animal Cell</td>
<td>Sperm Cell</td>
<td>Cheek Cell</td>
</tr>
<tr>
<td>Example of Plant Cell</td>
<td>Pollen</td>
<td>Ovule</td>
</tr>
</tbody>
</table>
Examples of chromosome numbers in a variety of species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of Chromosomes in a diploid cell (2n)</th>
<th>Number of Chromosomes in a haploid cell (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homo sapiens (human)</td>
<td>46</td>
<td>23</td>
</tr>
<tr>
<td>Chicken</td>
<td>78</td>
<td>39</td>
</tr>
<tr>
<td>Camel</td>
<td>70</td>
<td>35</td>
</tr>
<tr>
<td>Bat</td>
<td>44</td>
<td>22</td>
</tr>
<tr>
<td>Fly</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Rice</td>
<td>24</td>
<td>12</td>
</tr>
</tbody>
</table>
Mitosis is the natural process that takes place in all cells except sex cells (gametes). Mitosis increases the number of cells but maintains the diploid chromosome number in somatic cells. The process of mitosis involves the division of the nucleus into 2 new identical daughter nuclei and therefore cells. Each of the new daughter cells will contain exactly the same number and type of chromosomes as the original mother cell. Mitosis is required for normal growth and repair of the organism.

### 21. Importance of Mitosis

All species have their own unique diploid number of chromosomes. This unique number is known as their chromosome complement. For example, a horse’s chromosome complement is 66 whereas an onion’s chromosome complement is 16. Mitosis is important as it allows each species somatic cells to maintain their chromosome complement. This is essential so that organisms can grow in size, repair or replace cells. Mitosis is also important as it ensures that each and every cell has all the genetic information required to develop and function.

<table>
<thead>
<tr>
<th>Importance of Mitosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Maintains chromosome complement.</td>
</tr>
<tr>
<td><strong>2</strong></td>
</tr>
<tr>
<td>All organisms to grow in size, repair or replace cells.</td>
</tr>
<tr>
<td><strong>3</strong></td>
</tr>
<tr>
<td>Ensures all cells have all the genetic information for normal growth and development.</td>
</tr>
</tbody>
</table>
22. Mitosis - The Stages

During early mitosis chromosomes make an extra copy of themselves called chromatids, which are held together by the centromere.
23. Tissue Culture

When a supply of a certain type of cell is needed (such as yeast, bacteria or human stem cells), tissue culture can be used as an artificial way of producing new cells.

Tissue culturing must be carried out under sterile conditions using aseptic techniques in order to prevent contamination.

24. Aseptic Techniques

When working in the laboratory, whether that is with micro-organisms or cell cultures, it is very important to take precautions. These precautions help to prevent contamination or avoid the escape of harmful micro-organisms.

Some of the main precautions include:

- Work surface should be cleaned with a disinfectant before use, and should be made of something like glass or plastic which is hard and non-absorbent.

- All equipment should be sterilised using a special piece of equipment called an autoclave. When it is sealed an autoclave can be heated to temperatures as high as 121ºC, normally for 20 minutes, to make sure all micro-organisms have been killed.

- Micro-organisms are often cultured (grown) in special dishes called a Petri dish. Glass dishes can be sterilised using an autoclave, plastic dishes would be sterilised when they were made.

- The micro-biologist must make sure they wash their hands, they should wear lab coats and gloves if necessary and any open wounds should be covered by a waterproof dressing. There should be no eating or drinking in the lab.
If working with petri dishes or plates then they must be clearly labelled on the bottom with the date and information of what is contained within. They are then sealed securely with tape which must not be removed. All plates and petri dishes will be disposed of by technicians.

25. Growth Mediums

1. **Agar jelly** is a growth medium that can support the growth of cells or micro-organisms. The medium contains nutrients and agar jelly that allows growth on the surface of the medium.
   - Agar powder (which makes it "jelly-like") and nutrients are mixed with distilled water.
   - The bottles and their contents are then sterilised in an autoclave.

![](image)

2. **Nutrient broth** is also a growth medium that can support the growth of cells or micro-organisms. This growth medium contains nutrients but no agar.

26. Culturing the micro-organism

An instrument called an "innoculating loop" is used to transfer a sample of the micro-organisms from the bottle which contains the pure culture, to the now sterile Petri dish containing the nutrient agar.

The wire part of the loop is sterilised by heating it until it burns red, using a Bunsen burner, to kill any microbes.

The loop is then allowed to cool for a few seconds before use.
The microbes are then streaked on the agar plate, opening the lid as little as possible, and working close to the Bunsen flame, to ensure no contaminants are allowed to enter the plate.

27. Cell culture requirements

When cells are being cultured they require:

1. A sterile environment.
2. An appropriate growth medium (containing all essential nutrients and an energy source such as glucose).
3. A controlled environment (with optimum pH, temperature and levels of oxygen).

28. Importance of Tissue Culturing

Producing new cells in this way allows mass production from a very small number of cells. For example, in the production of large quantities of a desired plant.
UNIT 2 TOPIC 4

DNA and the Production of Proteins

29. DNA
The features of all cells are determined by genetic information carried on chromosomal material. The chromosomes consist mainly of a material called deoxyribonucleic acid (DNA). Deoxyribonucleic acid (DNA) carries the genetic information for making proteins.

All cell functions depend upon proteins, so all cells need DNA to determine their features and behaviour. Even viruses, which are not considered to be living organisms, contain DNA (or another nucleic acid).

30. DNA Structure
DNA is made up of four different bases. The bases are called adenine (A), cytosine (C), guanine (G), and thymine (T). The bases are linked together to form strands.

A DNA molecule is described as double stranded because each molecule is made of two strands. The two strands are held together by complementary base pairs.

- Adenine (A) in one strand can only pair with thymine (T) in the other strand.
- Guanine (G) can only pair with cytosine (C).

This means that if we know the sequence of bases in one strand of a DNA molecule, we can work out the sequence of bases in the complementary strand.

The double stranded DNA molecule is then twisted to form a coiled shape described as a double helix.
31. DNA and Proteins

The four bases A, T, G and C make up the genetic code. The base sequence of the DNA in a gene determines the amino acid sequence in a protein.

Proteins play a variety of roles inside and outside living cells. They act as enzymes, hormones, receptors and antibodies and are essential structural components of membranes and tissues such as skin and muscle.

Proteins are large molecules made up of many amino acids. The correct functioning of the protein depends upon the order of its amino acids.

Sections of DNA known as genes determine the amino acid sequence of proteins. Arranging the bases in different orders allows the production of millions of different proteins, each with a different amino acid sequence.

32. The Production of Proteins

Proteins are built up from amino acids by organelles called ribosomes. The ribosomes are found in the cell cytoplasm.

The genetic code which decides the order of amino acids in the protein is held on chromosomes in the nucleus of cells. The instructions in the genetic code must be passed from the nucleus to the ribosome to allow the correct protein to be produced. The section of code in the gene is copied to make a molecule called messenger RNA (mRNA). The mRNA molecule carries the instructions in the code to the ribosome where the protein is assembled.
UNIT 2  TOPIC 5

Proteins and Enzymes

33. Proteins

Proteins are organic compounds which contain the chemical elements carbon (C), hydrogen (H), oxygen (O) and nitrogen (N).

Each protein is built up from a large number of subunits called amino acids. There are about twenty different types of amino acids. Hundreds of amino acid molecules are joined together into chains, called polypeptides, by strong peptide bonds.

During the process of protein synthesis, a polypeptide is built up from a particular genetically-determined sequence of amino acids. This sequence of amino acids determines the protein's shape and function.

34. Variety and Functions of Proteins

An enormous number of different proteins are found in living things. A human possesses over 10,000 different proteins. Some examples are:

- Proteins found within the membranes of all cells which provide a vital structural role.
- Hormones are proteins that act as chemical messengers and are transported in an animal's blood to 'target' tissues where they carry out a regulatory effect on growth and metabolism.
- Antibodies are proteins made by white blood cells called lymphocytes. They are made to defend the body against antigens.
- Biochemical processes in living things, such as photosynthesis or respiration, are controlled by enzymes. Every enzyme is made of protein. Each enzyme is made of several polypeptide chains folded together in a roughly spherical shape like a tangled ball of string. This folded structure contains the active site it needs to function as a biological catalyst.
35. Enzymes

Enzymes function as biological catalysts because they speed up the rate of all biochemical reactions, allowing them to proceed rapidly at the relatively low temperatures (e.g. 5 - 40°C). In the absence of enzymes, these reactions would proceed so slowly that life as we know it would cease to exist.

Enzymes are made by all living cells. Enzymes take part in a reaction but remain unchanged at the end of it.

Each enzyme is able to act on only one type of substance (its substrate) since this is the only substance whose molecules exactly fit the enzyme’s active site. The enzyme is said to be specific to its substrate and the substrate’s molecular shape is said to be complementary to the enzyme’s active site. (A table showing some examples of enzymes, substrates and products can be found on page 29).

The substrate combines with the enzyme at its active site in a precise way forming an enzyme-substrate complex. At this point the reaction between them occurs. The end products formed then detach from the active site, leave the enzyme unchanged and free to combine with another molecule of substrate.
The enzyme and substrate fit together like a lock and a key. Just as a key will fit only one lock, so an enzyme can only fit with one substrate.

**Lock and key mechanism of enzyme action (degradation/breakdown of a complex substrate)**

![Diagram of enzyme action](image1)

**Lock and key mechanism of enzyme action (synthesis/build up of a complex product)**

![Diagram of enzyme action](image2)
36. Factors Affecting Enzyme Activity : Temperature

At very low temperatures, enzyme molecules are inactive but undamaged. The enzyme and substrate molecules move around slowly and meet only rarely. Therefore, the rate of enzyme activity remains low.

As the temperature increases, the enzyme and substrate molecules move around at a faster rate, more molecular collisions occur and more enzyme-substrate complexes are formed. So the rate of reaction increases.

The temperature at which the enzyme works at its fastest rate is called the optimum temperature. The optimum temperature for most human body enzymes is 37°C.

Enzymes are proteins and the structure of proteins is easily changed by heating, e.g. as seen when boiling an egg. This results in a change in their shape. This effect is permanent. The protein is said to be denatured, and this is irreversible.

Beyond the optimum temperature, as more and more enzyme molecules become denatured, the rate of reaction decreases rapidly. At temperatures of 50-60°C enzyme activity is found to be zero. This is because all of the enzyme molecules have become denatured.
37. Factors Affecting Enzyme Activity: pH

pH is used to describe whether a solution is acid, alkaline or neutral. The pH scale can be used to show the pH number of any solution which is an acid, an alkali or neutral.

The pH scale

Enzymes work within a range of pH values. Each enzyme works best at its optimum pH. Many enzymes function between a working range of pH 5 - pH 9, with an optimum of pH 7. However, there are many exceptions, e.g. the enzyme pepsin produced by the stomach in humans shown in the graph below.

The shape of an enzyme, or protein, can be changed by changes in the pH of the solution it is in. This will affect the rate of reaction between the enzyme and substrate and may result in the enzyme becoming denatured.
38. Enzyme summary table

<table>
<thead>
<tr>
<th>Name of enzyme</th>
<th>Substrate</th>
<th>Products</th>
<th>Type of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalase</td>
<td>Hydrogen peroxide</td>
<td>Oxygen and Water</td>
<td>Degradation</td>
</tr>
<tr>
<td>Amylase</td>
<td>Starch</td>
<td>Maltose</td>
<td>Degradation</td>
</tr>
<tr>
<td>Pepsin</td>
<td>Protein</td>
<td>Polypeptides</td>
<td>Degradation</td>
</tr>
<tr>
<td>Phosphorylase</td>
<td>Glucose-1-Phosphate</td>
<td>Starch</td>
<td>Synthesis</td>
</tr>
</tbody>
</table>
UNIT 2  TOPIC 6

Genetic Engineering

39. Natural transfer of genetic information

Genetic information can be transferred naturally between cells. This 'gene transfer' can occur between bacterial cells and often involves the bacterial plasmids. Gene transfer is known to be responsible for antibiotic resistance in one species of bacteria being transferred to another species of bacteria.

This is presenting the medical profession with a challenge to deal with. It is the reason why antibiotics must not be given to patients, without being prescribed by a doctor. If there was less control over the use of antibiotics then there is more of a chance of bacteria becoming resistant to those antibiotics most commonly used.

Viruses are also known to transfer their genes between bacterial cells, which can make the symptoms of bacterial infections more acute. This is known to happen to the bacteria which cause the disease called diphtheria.

Genetic information can also be transferred artificially between cells by using genetic engineering.

40. Artificial transfer of genetic information by genetic engineering.

The first organisms to be genetically engineered were bacteria in 1973. Any organism produced by genetic engineering processes can be called a genetically modified (GM) organism, or GMO.

In genetic engineering, a piece of chromosome containing a desired gene from the cell of one organism (e.g. a human) can be transferred into a bacterial cell. The bacterial cell may then produce a substance normally made by the other organism.

Genetic engineering is of medical value because useful substances which can be produced include: human insulin used by people suffering from diabetes to control their blood sugar levels, and human growth hormone.
The stages in genetic engineering are shown below:
Human insulin was first produced by this method in 1982.

There are three advantages to insulin's production by genetic engineering. Firstly, diabetics no longer need to use animal insulin to inject themselves as they had done previously. Many people did not like the idea of introducing animal insulin into their body and some suffered side effects. Secondly, as the population continues to grow, there are a greater number of diabetics. Thirdly, improving medical care increases the life expectancy of diabetics, and so the demand for insulin continually grows.

Other advantages include, given suitable conditions, the bacteria used for genetic engineering can be grown quickly, the product can be produced relatively cheaply and large quantities of product can be manufactured.

Genetically modified food has been sold since 1994. Examples of genetically modified foods developed include tomatoes which have a longer shelf life and potatoes that can resist the potato blight fungus. Golden rice was developed as a fortified food to be grown in areas of the world where there is a shortage of dietary vitamin A, and where people may develop sight problems. Golden rice, however, has met with significant opposition from environmental organisations, as have GM foods generally.

Future development includes the investigating the use of multi-cellular organisms as vectors for other organism's genes in genetic engineering. This would include more research into the use of animals and to developing crop plants which are more resistant to pests and diseases, do not need much fertiliser, can grow in marginal environments, are drought tolerant and produce a higher yield of food.
Unit 2  Topic 7

Photosynthesis

41. Photosynthesis
Photosynthesis is the conversion of light energy into chemical energy (which is stored in sugar) by green plants.

42. Word equation for photosynthesis

\[
\text{Light} \\
\text{Carbon Dioxide} + \text{Water} \rightarrow \text{Sugar} + \text{Oxygen} \\
\text{Chlorophyll}
\]

43. Light stage
This is the first stage of photosynthesis and involves the splitting of water into oxygen and hydrogen using energy captured from sunlight by chlorophyll. This reaction also produces ATP.

Due to requirement of light energy to break apart water molecules this reaction is classified as light dependent, meaning it will only occur in the presence of light.
44. Carbon Fixation

This is the second stage of photosynthesis. It involves a series of enzyme controlled reactions joining together carbon dioxide and hydrogen to form sugar. This reaction requires ATP and hydrogen, passed on from the light stage, and cannot occur without these.

45. Fates of Sugar

The sugar produced during photosynthesis can be used in various ways by the plant cell

1. Used immediately for energy to power cell process, such as mitosis or protein synthesis.
2. It can be converted to starch for long term storage.
3. It can be converted to cellulose and used to create cell walls
46. Limiting Factors

A limiting factor is a factor that by its presence or absence controls the rate at which a reaction happens.

For photosynthesis there are various factors that can affect the rate of photosynthesis:

1. Light Intensity
2. Temperature
3. Carbon dioxide concentration

Increasing light intensity or carbon dioxide concentration should increase the rate of photosynthesis, until the plant is receiving as much as it can utilise at which point they cease being a limiting factor.
At the point labelled Y the limiting factor is the light intensity as the rate of photosynthesis increases as the light intensity increases.

At the points labelled X the rate of photosynthesis shows no further increase even if the light intensity is increased, therefore another factor such as carbon dioxide concentration must be limiting the rate of photosynthesis.

47. Temperature as a limiting factor

Temperature usually works in the same way. Remember, however, that above a certain temperature the enzymes controlling photosynthesis will become denatured and the rate of photosynthesis will actually start decreasing. This is shown on the following graph.
Respiration

48. Respiration
Respiration is a series of enzyme controlled reactions by which energy from food is released and used to power cellular processes. It can be summarised by the following word equation:

\[ \text{Glucose} + \text{Oxygen} \rightarrow \text{Carbon Dioxide} + \text{Water} \]

49. ATP generation & energy storage
The energy released from food is stored in a molecule called ATP (Adenosine Triphosphate). ATP is produced when a molecule of ADP (Adenosine Diphosphate) is joined to a molecule of Pi (inorganic phosphate). When the energy is required for a cellular process, such as muscular contraction or protein synthesis, the ATP is broken down to for ADP and Pi releasing the stored energy.
50. Glycolysis (you do not need to know the name of this first stage)
This is the first stage of respiration and occurs in the cytoplasm of the cell. It involves the breakdown of glucose to form two molecules of pyruvate. Two molecules of ATP are also produced at the same time.

51. Aerobic Respiration
This is the second stage of respiration and requires oxygen. It takes place in the mitochondria, a structure specifically designed for ATP production through respiration. Aerobic respiration occurs in all living cells both plant and animal. It involves the release of hydrogen from pyruvate, this process also forms carbon dioxide as a byproduct. The hydrogen produced is captured by a hydrogen carrier and joined to oxygen to form water. This releases energy which is used to generate ATP molecules. The breakdown of each pyruvate molecule creates 18 ATP molecules.

In total the process of aerobic respiration produces 38 ATP molecules (2 x 18 from the breakdown of pyruvic acid & 2 from glycolysis).
52. Fermentation

Fermentation is the release of energy from food in the absence of oxygen occurring in the cytoplasm only.

53. Fermentation - In Animals

In animals continued periods of fermentation, usually occurring during periods of heavy exercise, will cause muscular fatigue. Muscular fatigue causes the muscle to ache and work at reduced efficiency. This is caused due to a build up of lactic acid, created from the conversion of pyruvate. This is a reversible process and the lactic acid formed can be converted back into pyruvate.

Only 2 ATP molecules are produced in total during fermentation in animals.
54. Oxygen Debt

As lactic acid forms during fermentation an oxygen debt is created. This is the volume of oxygen that is required to convert lactic acid back into pyruvate.

55. Fermentation - In Plants

Plants have a different fermentation pathway to animals. During fermentation in plants pyruvate is converted into ethanol and carbon dioxide. The carbon dioxide is lost to the surrounding atmosphere making this process irreversible. The ethanol produced is also toxic meaning that the plant will die if continues to ferment for too long.

Pyruvate $\rightarrow$ Ethanol + Carbon Dioxide

Only 2 ATP molecules in total are produced during fermentation in plants.
56. **Comparison of Aerobic Respiration and Fermentation.**

<table>
<thead>
<tr>
<th>Type of Respiration</th>
<th>Aerobic Respiration</th>
<th>Fermentation in Animals</th>
<th>Fermentation in Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location(s)</td>
<td>Cytoplasm and Mitochondria</td>
<td>Cytoplasm</td>
<td>Cytoplasm</td>
</tr>
<tr>
<td>Final Products</td>
<td>Carbon Dioxide and Water</td>
<td>Lactic Acid</td>
<td>Ethanol and Carbon Dioxide</td>
</tr>
<tr>
<td>ATP Yield</td>
<td>38 molecules</td>
<td>2 molecules</td>
<td>2 molecules</td>
</tr>
</tbody>
</table>

57. **Biotechnology**

Biotechnology is the use of micro-organisms, such as yeast and bacteria, or biological substances, such as enzymes, to perform specific industrial or manufacturing processes. (You will have examples of this in your notes, however, it is all national 4 level outcomes).

58. **Respirometers**

- Respirometers measure respiration as oxygen uptake/minute
- Carbon dioxide released is absorbed by sodium hydroxide
- Cold blooded animals are used as heat released by warm blooded animals affects volume of gas in test tube
- Temperature must be kept at a constant during experiment by placing in water bath
- Control tube contains glass beads or non respiring (dead) organism

*Top Tip*

*Peas are often used – be careful not to assume they are photosynthesising*
A model respirometer

- **Respiring material**: e.g. germinating sunflower seeds
- **Filter paper**
- **Sodium Hydroxide Solution**
- **Coloured dye**
- **Scale**
- **Respiratory Chamber**

**Diagram Details**:
- Tap
- Respiratory Chamber
- Sodium Hydroxide

**Explanation**:
Respirometers are used to measure the amount of gases produced or consumed during cellular respiration. In this model, the respirometer contains germinating sunflower seeds as the respiring material. Filter paper and sodium hydroxide solution are used to absorb excess moisture and react with respiratory gases respectively. Coloured dye and a scale are used to monitor and measure the changes in volume, indicating the respiratory rate.