TOPIC 3: CELL STRUCTURE AND FUNCTION

The basic structure of a cell is introduced for the first time in Topic 1 along with the fact that living things are either unicellular or multicellular. The relative size of cells, how to use a light microscope to view cells and how to prepare a wet mount slide to observe them first hand is detailed in Topic 2. The way materials enter and leave cells and how they divide is discussed in Topics 4 and 5.

RESOURCES

•  [www.cellsalive.com](http://www.cellsalive.com)  
  > Cell Biology > Cell Models > Bacterial Cell  
  Shows a labelled diagram of a bacterium that includes pili and flagella. Click on the internal and external structures to learn about them. A good way to introduce general prokaryote cell structure.

•  [www.bbc.co.uk/schools/gcse bitesize/science](http://www.bbc.co.uk/schools/gcse bitesize/science)  
  > Additional Science (AQA) > Biology: Cells > Revise  
  Page 1 is a straight-forward comparison of the structure of animal and plant cells which provides an opportunity to look at basic similarities and differences between them before looking at them in greater detail.  
  Page 2 shows a leaf cell, root hair cell, a sperm, and a red blood cell. A table links the structure of the cells to their particular function. Illustrates the concept of cell specialisation reasonably well.

•  [www.wise-online.com](http://www.wise-online.com)  
  > Learning objects > General education > Anatomy and Physiology I > A typical animal cell  
  Rolling on the names the animal cell’s parts points out their location. A brief description of each part’s function also appears. More detail than needed at Stage 1 but still useful if used selectively.

ACTIVITY: Information and suggestions

This activity is an excellent opportunity to learn how to make wet mount slides and to consolidate how to use a light microscope effectively.

Part A: Viewing onion cells

•  Keep the onion in the fridge prior to the Activity to reduce the volatility of the irritants it contains.
•  If it is difficult to get one layer of onion tissue, put a drop of water on the slide and use the brush to roll the specimen off it and onto the slide.
•  Make the onion cells more visible by staining them; for example add a drop of iodine solution instead of a drop of water.
•  One ‘less mess’ method for iodine-staining involves putting a drop of iodine solution on the slide next to the coverslip instead of on the specimen. If a piece of tissue is put on the opposite side of the coverslip, the tissue will draw the iodine stain under the coverslip and across the specimen.

Part B: Viewing human cheek cells

•  To reduce clumping of cheek cells, smear the cotton bud onto the slide and then use a tooth-pick to stir the cheek cells in a drop of (methylene blue) stain.
•  Use a 0.1-0.01% solution of methylene blue stain; for example a 0.1% solution which is prepared using 0.1 g of methylene blue powder in 100ml of distilled or de-ionised water.
•  Reduce methylene blue staining of the skin by instructing students to hold the slide with a peg or by wearing disposable gloves.

After the Activity has been completed laboratory staff should use gloves to handle and the wash slides to protect against body fluids and staining of the skin by methylene blue (and iodine if it is used).

Slides/cover slips can be cleaned using an acid/alcohol solution; for example to 100 ml of 70% ethanol add 1 ml of 1% hydrochloric acid. Soak them in this for an hour then rinse in water.
Discussion questions

1. Onion and cheek cells are eukaryote cells because they carry a variety of membrane-enclosed organelles, including a nucleus.
2. Observed structures onion and cheek cells share include a cell membrane, cytoplasm, a nucleus and a nuclear membrane.
3. Chloroplasts are organelles that absorb light for photosynthesis. An onion is a plant organ that grows underground where there is no light. Thus onion cells have no need for chloroplasts.
4. The function of starch granules in the plant cell cytoplasm includes provision of a short-term energy reserve.

ICT opportunity

An excellent interactive animation for students to use to revise animal and plant cell structure in detail.

EVIDENCE OF LEARNING: Sample responses and background

Knowledge and understanding

1. A bacterium is an example of a prokaryote cell.
2. One function of the cell membrane is to control the exchange of materials between a cell and its external environment.
3. Two differences between prokaryote and eukaryote cells include that prokaryote cells lack membrane-enclosed organelles and they only have one circular chromosome instead of many linear ones.
4. Different types of cells are structured differently to permit them to perform specific or specialised functions.

Application

5. a. The organelles which are also found in animal cells are organelle 1 (a mitochondrion), organelle 4 (a nucleus) and organelle 5 (the rough endoplasmic reticulum).
   b. Aerobic cell respiration is performed in organelles represented here by organelle 1, which is a mitochondrion.
   c. Organelle 3 is an example of a chloroplast. Its function therefore is to perform photosynthesis.

Analysis and evaluation

6. A ribosome is an organelle but not a membrane-enclosed one. The cell membrane is not considered to be an organelle because it is not a structure found within cells.
7. The structure-function pairs that include a vacuole and a cell wall are incorrect. Vacuoles store water and ions not the cell wall. The cell wall strengthens the cell not its vacuoles.
8. The cell in the diagram is a eukaryote cell. This is because a nucleus that is enclosed by a nuclear membrane can be clearly seen within it. Other membrane-enclosed organelles, however, are not visible.
9. The cell is likely to be found in leaves. This is because it contains chloroplasts which are organelles that perform photosynthesis. Leaves are the main site of photosynthesis in plants.

Investigation

10. Prokaryotes first appeared at least 3.5 billion years ago. Evidence that supports this includes the fossilised prokaryotes that have been found in rocks this old in Western Australia.

   ‘Hostile to life’ environments in which prokaryotes live include near boiling water in hot springs, very salty water in the Dead Sea, very cold and UV-rich air in the upper stratosphere, water-containing rocks beneath the ocean floor and in the radioactive Chernobyl accident area.
TOPIC 9: Enzymes

Topic 8 introduces enzymes as proteins that catalyse reactions. The role enzymes play in metabolic pathways is developed in Topic 10 and their role in chemical digestion is discussed in Topic 13.

RESOURCES

• Google: Lew Port’s Enzyme Animations
  > Enzyme Activity > All about Enzymes
  Click Next several times to read some fundamental points about enzymes.

• Select from the Enzyme Menu after reading through All About Enzymes above
  > Specificness
  An animation that illustrates how different substrates are complementary to different enzymes.

• Google: Student website for Discover Biology
  > Discover Biology 3ed. > Animations > Tutorial 7.1: Enzyme Catalysis
  Excellent narrated animation that includes all enzyme concepts including activation energy.

• www.kscience.co.uk
  > Animations > Enzyme Kinetics
  Great for demonstrating the kinetic model of matter and for using it to explain why changes in substrate concentration and temperature cause the changes in enzyme activity they do.

• Google: Lew Port’s Enzyme Animations
  > Enzyme Activity > All about Enzymes > Enzyme Menu > Denaturing
  A simple but effective way to illustrate the concept of enzyme denaturation at high temperature.

ACTIVITY: Information and suggestions

This activity gives students the opportunity to discover how the use of the enzyme pectinase increases the yield of juice extracted from chopped apple, thus simulating its industrial application.

Part A: Prepare the apple tissue

• The enzyme pectinase can be obtained as a liquid solution or a powder.
• A source of pectinase solution is Southern Biological (www.southernbiological.com). It is best to use the enzyme at the concentration supplied. Although the activity of the pectinase solution can be maintained for several days by storing it in the fridge, it will nonetheless degrade over time.
• A source of pectinase in powdered form is Brewcraft SA (www.brewcraftsa.com.au). The powder can be used to make a 1% w/v pectinase solution (1g of powder in 100 ml of distilled water). Note that the powdered form of the enzyme will probably maintain its activity for longer during storage.
• The pie apple is chopped into pieces to increase the surface area for pectinase to act. What is needed quickly is lots of pieces of apple about 5mm x 5mm x 5mm. They do not have to be exactly this size.
• Make sure the water level in the water bath is not too high otherwise the beakers will start to float and tip over. Remember too that for every beaker added the water level will rise ever so slightly.
• If a water bath is not available it is possible to make a working version of one by pouring water into a large container or saucepan and putting it onto a large hotplate (or 2 or 3 smaller ones). The temperature can be monitored using a long-stem thermometer.

Part B: Collect the extracted apple juice

• The volume of juice collected from the apple without pectinase may be less than 1 ml in which case its actual volume will have to be estimated if a standard 25 ml measuring cylinder is used.

The activity makes possible a number of extensions. These include investigating the effect of varying the temperature on the activity of pectinase, and finding out what effect the concentration of the pectinase enzyme has on the yield of apple juice collected.
Discussion questions

1. The yield of apple juice extracted with the enzyme pectinase was much higher than that collected if pectinase was not used.
2. Pectinase breaks down pectin, a polysaccharide ‘cement’ found between plant cell walls. It is used to help separate cells in apple tissue which increases the volume of fluid obtained from it.
3. One explanation is lemon juice reduces the pH which denatures the enzyme that catalyses the ‘browning reaction’. Thus chefs do this to stop apple tissue from going brown and therefore looking unpleasant to eat.

ICT Opportunity

For a very comprehensive database that covers all aspects of pectinases and their applications see http://pec.biodbs.info > Applications

EVIDENCE OF LEARNING: Sample responses and background

Knowledge and understanding

1. The molecule that undergoes a chemical reaction catalysed by an enzyme is called a substrate.
2. Three factors that may alter the activity of an enzyme include the concentration of its substrate, and the temperature and pH of the enzyme’s environment.
3. Figure 9.2 page 55 or something similar can be used to describe the lock and key model. The active site can be labelled as the lock and the substrate as the key.
4. Substrate binding at the active site places stress on the substrate’s bonds which lowers activation energy.

Application

5. a. The activity of the enzyme shows a slow linear increase from point A to 20°C.
   Between 20°C and point B enzyme activity increases exponentially.
   b. The optimum temperature is about 40°C.
   c. The water temperature thermophilic bacteria live in is as high as 80°C. The optimum temperature of enzymes in such bacteria is in this range, well above that of human enzymes.

Analysis and evaluation

6. The incorrect statement is ‘Enzymes alter the amount of products that form from a substrate’.
7. A cofactor is an inorganic substance that binds to an enzyme and takes part in the reaction it catalyses, e.g. a metal ion. A coenzyme is an organic molecule that does this, e.g. a vitamin.
8. The enzymes have different pH optima; one ‘peak’ is much lower than the other. Also they function over different pH ranges; one at approx pH 0.5-4.5, the other at approx pH 4-10.5.
9. The graph shows amylase’s optimum temperature to be just under 30°C because at this temperature starch-break-down time is smallest (which indicates maximum enzyme activity). It shows the progressive denaturation of amylase between approx 30 and 40°C because over those temperatures starch-break-down time increases (due to less and less enzyme activity).

Investigation

10. An elegant procedure to test the effect of the concentration of hydrogen peroxide on the activity of catalase is detailed in A Portfolio of Investigations by John Gibson and David Greig.

   If something similar is presented in very general terms students can formulate a hypothesis and then design an experiment to test it without being given all the step-by-step directions. The independent variable is hydrogen peroxide concentration, the dependent variable the rate of activity of catalase (as indicated by the rate of production of ‘foam’) and relevant controlled variables include the volume of liver, hydrogen peroxide and detergent, and temperature.

   The experiment may be used to illustrate how keeping the controlled variables constant makes a method valid and how replication of measurements of a dependent variable improves the reliability of the data.
TOPIC 14: The Circulatory System

Transport of materials is identified as a life process in Topic 1 and the circulatory system is listed as an organ system in the body in Topic 12. The circulatory system’s role in absorbing products of digestion, gas exchange, kidney excretion, hormonal communication and defence are detailed in Topics 13, 15, 16, 18 and 20.

RESOURCES

• www.youtube.com
  > Types of blood vessels
  This is an introduction to the arteries, capillaries and veins which despite the absence of structural details is a good starting point to discuss the functions of them. It also paves the way for Figure 14.1 page 89.

• Google: Student website for Discover Biology
  > Discover Biology 3ed. > Animations > Tutorial 22.3: Haemoglobin picks up and delivers oxygen
  This is good to use to link gas exchange (to come in Topic 15) with the general circulatory system and the exchange of materials in tissues (see Figure 14.2 page 89). No reference to glucose though.

• www.kscience.co.uk
  > Animations > Circulation
  This is a useful way to reinforce the path taken by blood around the circulatory system. Links well with Figure 14.3 page 90. Good for comparing the pulmonary and systemic circulations.

• www.wisconline.com
  > Learning objects > General education > Anatomy and Physiology I > The Anatomy of the Heart
  An excellent animation to use to look at the heart’s structure and function. Links very well with the heart dissection detailed in Activity 14 page 92.

ACTIVITY: Information and suggestions

This activity gives student’s a comprehensive first hand-look at the structure and function of the mammalian heart; in this case, the heart of a sheep.

Part A: Viewing the external structure of the heart

• Finding a supplier of organs for dissection is becoming increasingly difficult. In general, supermarkets are not a good option for hearts as the uppermost section has been cut through to remove all or most of the blood vessels.
• If you discuss your requirements, the local butcher shop may be able to access hearts with more structural detail intact, particularly if it still processes its own meat.
• Order more hearts than you need to give you the option to select the ones most suitable for dissection.
• It can be useful to obtain a cow’s heart so that students can see that heart size varies among mammals.
• If possible order a ‘pluck’, which consists of the heart, a pair of lungs and the trachea, and sometimes the liver as well. This presents an ideal opportunity to illustrate what organs really look like ‘in situ’.
• Consider placing large laminated copies of Figure 14.4 next to each dissection board.
• Large ‘textured’ tiles laid on newspaper make good dissection boards – they stop a heart from ‘slipping’ and are easily cleaned. Ask at tile outlets for oddments that sell cheaply or are given away.

Part B: Viewing the internal structure of the heart

• It is a good idea to demonstrate the main steps of the dissection before students start it and / or view a video of a sheep heart dissection; for example, see the ICT opportunity.
• Consider making available large laminated copies of Figure 14.5 as well.

After the Activity has been completed teaching staff should ensure that all scalps, scissors, blades and other dissection equipment is collected and counted. All heart tissue, gloves and soiled newspaper should be disposed of via a separate plastic bag.

To clean the dissection boards spray with an approved disinfectant then wash with hot soapy water.
EVIDENCE OF LEARNING: Sample responses and background

Knowledge and understanding

1. The term for blood with a high oxygen concentration is oxygenated.
2. Five parts of blood are plasma, plasma proteins, red and white blood cells and platelets.
3. An artery has a tough elastic outer wall, a thick muscular inner wall and, relative to its overall diameter, a narrow lumen.
4. The pumping action of cardiac muscle is an example of an energy-requiring process which means cardiac muscle cells must continuously be able to carry out aerobic cell respiration to make energy available. Thus cardiac muscle needs a continuous supply of oxygenated blood so it can receive the oxygen needed to perform aerobic cell respiration.

Application

5. a. In the arteriole there is a high oxygen concentration and a low carbon dioxide concentration.
   b. As blood flows through the capillary network oxygen and glucose diffuses out of it and into nearby cells. As a result, there is less of them in blood that drains into the venule at point X.
   c. A capillary wall is well-suited for the exchange of materials by being very thin which reduces the distance for diffusion of molecules across it.

Analysis and evaluation

6. One way to distinguish the pulmonary and systemic circulation is the pulmonary circulation is blood flow from the heart out to the lungs and back to the heart whereas the systemic circulation is blood flow from the heart to all body tissues and back to the heart.
7. The blood flow from small intestine to aorta is: small intestine > hepatic portal vein > liver > hepatic vein > one of the veins cavae > right atrium > right ventricle > both of the pulmonary arteries > lungs > both pulmonary veins > left atrium > left ventricle > aorta.
8. The statement is incorrect. All arteries except the pulmonary arteries carry oxygenated blood. The pulmonary arteries transport blood that has been deoxygenated by the body’s tissues.

Investigation

9. The inventor was Paul Winchell, though he did not actually construct an implantable device. The credit for this is mostly attributed to Robert Jarvik. Like Winchell’s invention, the Jarvik heart had two chambers. Each chamber had a disc that pumped blood from an inlet valve to an outlet valve. The two pumps were powered by compressed air that was supplied to them by a system of air hoses that extended from the patient’s chest to an electric compressor unit.

The invention meant that for the first time someone with heart failure could be kept alive until a suitable heart could be obtained to use in a heart transplant operation. It was also the first step towards a permanent artificial heart, still one of the ‘holy grails’ of modern medicine.
TOPIC 21: From DNA to proteins

The role of chromosomes in prokaryote and eukaryote cells is mentioned for the first time in Topic 3. The distribution of chromosomes into daughter cells during mitotic division is considered in detail in Topic 5. The structure of DNA and the structure and function of proteins are both presented in Topic 8.

RESOURCES

- [http://learn.genetics.utah.edu](http://learn.genetics.utah.edu)
  - Tour the Basics > what is a chromosome?
    - This is a very good narrated animation about the general structure of a eukaryote chromosome.
  - Hereditary & Traits > Making a karyotype
    - In this excellent interactive students can click and drag chromosome photos to make a karyotype.
  - Tour the Basics > what is a gene?
    - This narrated animation illustrates clearly the location, general structure and function of genes.

- [http://croptechnology.unl.edu/download.cgi](http://croptechnology.unl.edu/download.cgi)
  - Protein synthesis: A general overview
    - This excellent click-through animation outlines the concepts of transcription and translation so clearly that they should be well within the reach of most Stage 1 students.

ACTIVITY: Information and suggestions

This activity is another opportunity to illustrate the importance of the use of models in biology.

Part A: Design the model

- DNA structure can be quickly revised by showing the following animation from Topic 8:
  - [http://learn.genetics.utah.edu](http://learn.genetics.utah.edu)
  - Tour the Basics > what is DNA?
- Materials to use to construct the model can be purchased from a local ‘$2.00’ shop or Environmental Recycling shops like Cheap as Chips, Ned’s, Le Cheap and That’s Not Garbage.

Part B: Construct the model

- A sample model is shown below. In it, a chromosome is represented using two drinking straws, histones using polystyrene balls, DNA using steel wire and organic bases using pipe-cleaners.
Discussion questions
1. Using the model photographed, examples include DNA is shown wrapped around histones, DNA is double-stranded and base-pairing between organic bases on each strand can be seen.
2. Again, using the photograph, examples include the structure of the whole chromosome is not shown, the model is much larger than a real chromosome and the fact that the histones are grouped into bunches of eight about which DNA is wrapped twice.
3. The chromosomes in a eukaryote cell are located in the nucleus.
4. DNA extraction involves the use of a protein-digesting chemical to break down the histone proteins. This ‘releases’ the DNA and thus increases the purity of the DNA sample.
5. Unwrapped human DNA from a human cell may be as long as three metres.

ICT opportunity
Access http://learn.genetics.utah.edu > Tour the Basics > what is a chromosome?
If not used already this animation is an effective way to consolidate work undertaken in Activity 21.

EVIDENCE OF LEARNING: Sample responses and background
Knowledge and understanding
1. The protein molecule DNA is wrapped around is called a histone.
2. A gene functions to store the genetic instructions a cell needs to make a polypeptide.
3. The human male karyotype consists of 22 pairs of homologous chromosomes and a pair of sex chromosomes. One of the sex chromosomes is called X and the other one is called Y.
4. The ‘one gene one polypeptide’ rule refers to the fact that, as a general rule, a gene carries instructions that are only used to make a specific polypeptide.

Application
5. a. The karyotype is of a human diploid cell because the full set of chromosomes typical for a human is shown; in others words, there are 23 pairs of chromosomes.
   b. The individual is female because the karyotype includes two X chromosomes.
   c. The abnormality concerns chromosome 21. Instead of there being two sets of chromosome 21, there are three; the karyotype in this case is a female with Down syndrome.

Analysis and evaluation
6. A polypeptide is a long chain of amino acids. A protein is made up of two or more polypeptides that are linked together to form a precise 3D structure.
7. No. The number of genes per chromosome on average would be about 538.
   \[
   \text{Genes per chromosome} = \frac{\text{number of genes}}{\text{number of chromosomes}} = \frac{24551}{46} = \text{approx 538}
   \]

Investigation
8. DNA fingerprinting is used to identify individuals. It is based on the fact that DNA consists of genes and non-coding DNA sequences called satellite DNA that vary considerably between individuals. This means if someone’s satellite DNA is cut by enzymes into fragments which are then sorted by a technique called gel electrophoresis, a unique DNA pattern or ‘fingerprint’ will be produced.
For a great overview of this see http://learn.genetics.utah.edu > Virtual labs > Gel electrophoresis.
DNA fingerprinting is used to help identify people who commit crimes like rape and murder, settle paternity disputes, identify disaster victims, and to free innocent prisoners from jail. Although humans share 99.9% the same DNA sequences, the variability in satellite DNA allows a court of law to consider a DNA fingerprint to have a reliability of about one in a million.

In Australia DNA fingerprinting information is only available to Police via the National Criminal Investigation DNA Database (NCIDD). Data stored by the NCIDD is protected by state and federal laws and does not include details about age, ethnicity, appearance or medical conditions; for more detail about this see: www.crimtrac.gov.au > NCIDD – Protection of Privacy.