Year 11 Biology

Module 1: Cells as the Basis of Life

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## Teaching the Year 11 Modules

The Biology Stage 6 Syllabus is a sequential development of concepts that lead the student to a deep understanding of life processes, from the molecular level to the ecosystem level. This understanding, together with science inquiry skills, will allow students to apply knowledge from across the modules to

‘take an informed part in science-based decisions and take appropriate actions that affect their own wellbeing and the wellbeing of the society and the environment’. (Harlen, 2010)

Biology can often be best understood through the lens of evolution. Students should develop a deep understanding of the concept that all species are descended from a common ancestor, and patterns can therefore be observed in the living world. This will be essential for students to appreciate heredity and genetic processes, manipulation of genetic material, the concept of biodiversity and the understanding of diseases covered in the Year 12 course.

In Biology, like all science disciplines, new evidence can refine views about concepts. This is illustrated in the development of disciplinary ideas in areas such as evolutionary biology and climate change. New evidence often arises from the development and use of new technologies. Students need a sound understanding of the role of new technologies in improving the understanding of various concepts in the Year 11 course, including ideas around cell and organism structure and function, and evolution.

The understanding of biological processes has been significantly impacted upon by societal, cultural and economic factors. Students should be provided with opportunities to engage in work that allows them to acknowledge these influences.

Students should develop a deep understanding of humans’ impacts on ecosystems and appreciate the importance of sustainability in its various forms. This includes understanding the roles of Aboriginal and Torres Strait Islander Peoples in caring for Country and Place.

During the Year 11 course, it is expected that students will be provided with opportunities to develop all seven of the Working Scientifically skills. Ideally, these would be embedded into the teaching of the Knowledge and Understanding components of the course, allowing students to develop a sound knowledge of the structure and function of living things, from the sub-cellular level through to the ecosystem level.

In preparation for the Year 12 course, students in Year 11 will benefit from work that engages them in the following areas.

* **Propose questions and hypotheses** and **design and conduc**t valid and reliable practical **investigations** that enable data collection and analysis. There are many opportunities to conduct practical investigations beyond where the syllabus explicitly states the need to conduct one.
* **Collect** and **analyse data** from primary and secondary sources, including various formats of tables and graphs, and determine the data’s accuracy, reliability and validity. Many of the investigations will require students to obtain information from the Internet or other sources. Students will benefit from learning how to access and acknowledge valid and reliable sources of information
* **Assess** the uses, benefits and limitations of various types of **scientific models**. Many biological processes occur on a cellular or molecular level (for example movement across a cell membrane) or happen over a long time period (for example natural selection). Models help us to better understand these processes.
* **Construct labelled diagrams, flowcharts** and other methods of communicating information. This skill is important to develop for students to explain processes such as the movement of substances across cell membranes and the relationships in an ecosystem.

This module guide indicates which Working Scientifically skills are developed in each learning activity, for example **BIO 11/12-2**. By embedding the Working Scientifically skills students develop and apply a sound understanding of the role scientific inquiry plays in proposing explanations for biological processes.

Throughout the syllabus content descriptors will have the statement, including but not limited too. This specifically allows for the opportunity to differentiate student activities and extend students’ understanding.

## Course overview

The Year 11 course underpins the Year 12 course. Students are expected to access and apply the concepts developed in Year 11 to Year 12 learning. Students are also expected to draw from knowledge and understanding across modules and apply them to new and unfamiliar situations using their Working Scientifically skills. The modules in Year 11 and Year 12 are not to be seen as standalone entities but rather as inter-related and interdependent. Students are expected to draw from information across the modules to explain phenomena and solve problems.

The major themes or big ideas that weave throughout the Year 11 modules are:

* **Being alive**: Biology is the study of life. Living things have organised structures and coordinated functions to facilitate life.
* **Interactions occur within and between organisms to supply energy and materials necessary for life.**
* **Living things are dynamic and diverse**. Life has not always been, and will not always be, the same.
* **Tools and technologies are used to make observations about living things**. They help us better understand life in the present and the past and to enhance life in the future.

## Module 1 summary

Module 1 explores the following inquiry questions:

* IQ1-1: What distinguishes one cell from another?
* IQ1-2: How do cells coordinate activities within their internal environment and the external environment?

Module 1 is the foundation for every other module in the Stage 6 Syllabus. Students must develop a sound understanding of the key concepts developed here and not just focus on the metalanguage.

For students to see this module’s relevance, it may be best approached by posing questions relating to the big ideas, for example:

* Why are cells considered the units for life?
* If cells are the basis of life, what do they have in common? What are the differences between them, and why?
* How do substances enter and leave the cell to allow it to be alive?
* What chemical processes are essential for life?
* What factors influence the chemical processes occurring in cells?

## Big Ideas

The big ideas that weave through the modules are introduced and established in Module 1.

* **Being alive**: Living things are organised on a cellular basis. All the essential functions of life result from what happens inside the cells that make up the organism. Therefore there are structures and processes common to all living cells.
* **Interactions occur within and between organisms**. Within the cell many molecules interact to supply energy and materials essential for life. Organelles interact with each other to allow life to function optimally.
* **Living things are dynamic and diverse**. There are similarities and differences between cells resulting in diverse cell types. The requirements and activity of cells will change depending on their environments.
* **Tools and technologies are used to make observations about living things**. Microscopy allows us to visualise cell structures and processes.

## Relationship to other modules

Module 1 is the foundation for every other module in the Stage 6 Syllabus. A sound knowledge of cell structure and function will allow students to understand the organisation and functioning of tissues, organs, systems and organisms in Module 2.

The adaptations of organisms studied in Module 3 arise from a need to supply cells with the necessary molecules and environment for life. Evolutionary change is observable with changes at the cellular level.

Evidence for past changes in ecosystems explored in Module 4 is gathered from chemicals produced by, and stored in, prehistoric cells.

As students move to Year 12, they learn that the lives of individuals and the species continue through cell reproduction. Humans can manipulate cell structure and function for agricultural, medical and industrial applications.

Diseases result from changes to cell structure or function or the cellular environment. Agents of infectious disease are classified by cell type. This determines how the disease is transmitted, how the organism responds, how the disease can be treated and how the spread of disease can be controlled.

Cells are responsible for maintaining homeostasis. Homeostasis is essential to keep cells, and hence the organism, functioning optimally.

## Core concepts

* Cells can be classified based on their structure and function.
* Cells contain structures that contribute to cell function. Those contained within a membrane are called organelles.
* Models of the cell membrane and enzymes can be used to demonstrate their function.
* The cell membrane forms the boundary between the cell and its external environment. It functions to regulate the movement of substances into and out of the cell, which is imperative for cell function.
* All living cells require energy. Cellular respiration is an essential biochemical process undertaken by all living cells to produce energy. In this process glucose is broken down to release energy, which is then stored in the energy storage compound, ATP.
* Photosynthesis is a biochemical process undertaken by plants and some other organisms. Light energy is used to build glucose molecules from carbon dioxide and water.
* Enzymes are biological catalysts. They lower the activation energy required for biochemical reactions, allowing them to occur effectively at body temperature.

## Misconceptions

The only membrane is the cell membrane**.**

Students readily understand that cells are surrounded by a cell membrane, however, students often do not understand that in eukaryotic cells organelles are also bound by a membrane. Explicitly teach what is meant by the phrase ‘membrane-bound organelles’ when discussing the differences between prokaryotic and eukaryotic cells. English as an additional language or dialect (EALD) students may find this concept difficult unless they are explicitly told the meaning of the word ‘bound’.

As students move through the module, provide opportunities for students to link their knowledge of photosynthesis and respiration to the movement of nutrients, water and gases across membranes. Students can track the transport of reactants and products across the cell membrane and then across the relevant organelle membranes.

Plants do not respire and do not need oxygen

Students often have a good understanding from Stages 4 and 5 science of plants’ role in producing oxygen as a by-product of photosynthesis. This often leads to the common misconception that plants only photosynthesise and do not undergo cellular respiration. The two processes are seen as being mutually exclusive.

This misconception is best clarified when discussing the difference between plant and animal cells and can be presented to the class in the form of an inquiry-based activity. Provide students with diagrams of plant and animal cells showing the distribution of chloroplasts and mitochondria. Ask students why plant cells have both mitochondria and chloroplasts. By posing questions to students and encouraging them to justify their answers (**BIO11/12-7**), other related misconceptions to be identified and then addressed.

Conceptual difficulties

New vocabulary/metalanguage

One of the most significant challenges in Module 1 is the large number of new terms students are expose to and required to use. Students should be explicitly taught the skills necessary to develop a glossary that can be expanded as required.

* Explore with students the different methods of generating glossaries, for example using physical flash cards or utilising one of the many digital flash card apps available ([Brainscape](https://www.brainscape.com/), [Cram](https://www.cram.com/), [CheggPrep](https://www.chegg.com/flashcards)).
* Model for students how to define terms using their own words.
* Encourage students to use analogies and metaphors when appropriate (see Suggested teaching strategies, IQ1-1 Cell organelles) and include diagrams/images. **BIO11/12-7**
* **Include pictures and diagrams in the glossary. This is especially helpful for EALD students, allowing them to visualise and make connections to the terminology.**
* The Department has resources to support writing in [Stage 6 Science](https://education.nsw.gov.au/teaching-and-learning/curriculum/literacy-and-numeracy/teaching-and-learning-resources/literacy/stage-6-literacy-in-context-writing/science).

#### Scale and measurement

Students often struggle with visualising and converting units of measurement at the microscopic level. Liaise with your mathematics faculty to coordinate your introduction of this concept with their teaching of measurement in Year 11. Students may be confused as mathematics uses the term ‘standard form’ which is interchangeable with ‘scientific notation’.

* Visualising: [Learn Genetics](https://learn.genetics.utah.edu/content/cells/scale/) has an interactive to help students visualise the terms micrometre, nanometre, and picometre. Students can construct their own table (see Appendix 1) with examples of organisms of different sizes. As a guide, eukaryotic cells are between 1 and 100 µm, viruses between 10 and 500 nm and molecules are measured in picometres.  **BIO11/12-4**
* Converting: when converting from smaller units to larger units (for example from nanometres to micrometres) it helps if students think about whether there should be more or less of the larger units. This means that even if they forget the rule to divide as they move to the larger unit (and multiply to move to the smaller) then they can derive the logical answer.

#### The fluid mosaic model is a dynamic structure and is not static.

Students have difficulty visualising the structure of the cell membrane. They may think of it like skin, enclosing the contents and not allowing substances to pass through.

* Reinforce the concept that the cell membrane is a mosaic of embedded proteins and phospholipid molecules by showing and/or building models of the membrane (e.g. [TeachGenetics - Build-A-Membrane](https://teach.genetics.utah.edu/content/cells/files/build-a-membrane.pdf). **BIO11/12-6**
* Show students images of mosaic artwork and ask them to describe the similarities between mosaic art and the mosaic membrane. **BIO11/12-5**
* Have students engage with an online interactive of the cell membrane (for example [BioMan Biology - Cell Defense: The Plasma Membrane](https://biomanbio.com/HTML5GamesandLabs/Cellgames/celldefensehtml5page.html), [Hong Kong City Education - Making a Fluid Mosaic Model](https://cd1.edb.hkedcity.net/cd/science/biology/resources/l%26t2/model_making/model_making_E_1.pdf). **BIO11/12-6**, or watch a video clip (e.g. [TED-Ed Cell membranes are way more complicated than you think - Nazzy Pakpour](https://ed.ted.com/lessons/cell-membranes-are-way-more-complicated-than-you-think-nazzy-pakpour)) that demonstrates the fluid nature of the membrane and shows the movement of individual phospholipids within the bilayer. **BIO11/12-6**

Internal and external environments

The use of the terms ‘internal’ and ‘external’ are relative depending on what is being focused on. For example, what is external to an organelle is internal to a cell. Ensure that students have a solid understanding of the meaning of these terms.

It may be helpful to have students liken a cell to their school environment. Organelles may be likened to classrooms, while the cell may be likened to the school. Have students identify what is internal and external to them in different locations. This analogy can be extended to likening the students and teachers (and insects, cars and delivery vehicles) to molecules who can enter the school and possibly classrooms, staff rooms and store rooms via various channels. Consistently use this terminology with students when discussing cellular transport and the movement of reactants and products in biochemical processes.

Surface area to volume ratio (SA:V)

Students often do not understand what a ratio is and are unable to calculate a ratio. They struggle with the notion that while a smaller object may have a smaller surface area than a larger object, it will have a larger SA:V. Modelling the concept before introducing the mathematics will support students understanding.

Model the concept for students by breaking a large cube apart into smaller cubes. **BIO11/12-6**

* Base Ten Blocks are useful to use as a model. These may be sourced from the Mathematics faculty or have students make their own cubes from paper and combine them as a class to create one large cell and then break them apart into many small cells.
* Demonstrate the concept of increased surface area by dismantling a Rubik’s cube. How many coloured faces on the assembled large cube? 54. How many coloured faces on all the small cubes when the large cube is dismantled? 162.
* How much wrapping paper is needed to wrap a DVD box set compared to wrapping the DVDs individually?

If students struggle with this concept, consider team teaching with a member of your school’s mathematics faculty.

What an enzyme is and how it operates

Students struggle with the concept of the enzyme:

* lowering activation energy
* participating in, but not being used up by, the reaction.

The analogy of a matchmaker is a way for students to understand an enzyme’s role as something that causes a change, but is not changed by the reaction. A matchmaker introduces couples, making it easier for them to get together, but the matchmaker’s status is not changed and they are free to introduce other couples. Conversely, a gossiper may spread vicious rumours and cause couples to break up, but the gossiper is not affected by the process. In each case, the enzyme (the matchmaker or gossiper) has lowered the activation energy, allowing the reaction to proceed when it otherwise would not have.

When moving from the analogy to enzymes students may explore the conditions hypothermia and hyperthermia. Students know that people may die from over-exposure to heat or cold but do not know why. News reports of real incidents, such as those below, can put this in context.

* [Torran Thomas rugby death](https://www.abc.net.au/news/2019-03-05/coroner-calls-better-first-aid-after-torran-thomas-rugby-death/10873662) – hyperthermia
* [Hypothermia can be a deadly condition](https://www.abc.net.au/news/2019-06-11/hypothermias-deadly-consequences-and-why-its-so-hard-to-treat/11196224)
* [Cause of death](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2803%2912423-3/fulltext) among passengers on the Titanic

Discuss what is happening in each situation and why. Students should be able to identify that the human body functions optimally within a specific temperature range. **BIO11/12-4.**

Use this understanding to prompt students to think about enzymes working better at certain temperatures and extend their understanding to other factors such as pH.

## Suggested teaching strategies

### IQ1-1 What distinguishes one cell from another?

#### Activate prior knowledge.

Students will display a wide range of abilities in recalling their knowledge and understanding of cells. It is important to determine the prior knowledge before commencing the material covered in Module 1. Engage students in a brainstorming activity on questions.

* What are cells?
* What would you find inside a cell?
* Why are cells important?
* What do cells do?
* What are some different types of cells?

Have students individually write down brief ideas on sticky notes and, as a class, arrange their notes under broad categories on large sheets of paper or on the whiteboard (Affinity diagram in the Digital Learning Selector or Google Jam Board in the Google Apps for Education in your Staff Portal)

#### Cell Organelles.

The role of cell organelles is often challenging for students to remember if relying on rote learning alone. Have students develop their own metaphors for the function of cell organelles. For example, the cell membrane is a gate.

This activity can be run using stations where students work cooperatively in small groups, moving from station to station around the room creating new metaphors for each cell organelle.

1. Provide students with the image of the organelle and its function and a blank piece of paper on which to write a metaphor.
2. As each group moves from station to station, students must think of a new metaphor that has not been used before to add to the piece of paper.

This activity will increase in difficulty as students move from station to station and they are challenged to provide metaphors that have not been used before. It consolidates the students’ understanding of organelles’ functions and exposes them to other students ideas’.

Students can be placed in mixed ability groupings or in similar ability groupings. When placing in similar ability groups, consider running the station activity with another activity so that lower ability students can create their metaphors before the higher ability students. This will provide a more significant challenge for the higher ability students as the more straightforward metaphors will already be used, requiring them to be more creative. Instead of writing a metaphor this activity could also be differentiated to allow students to draw or find a picture as an example of a metaphor.

#### Cell Membrane

For an activity on the difficult concept of the cell membrane and fluid mosaic model see Conceptual difficulties.

For possible extension activities or depth study see Opportunities for extending concepts.

Comparing prokaryotic and eukaryotic cells, plant and animal cells

Explicitly teach students how to compare and contrast using Venn diagrams. Provide students with images and/or text and have them organise key content into a Venn diagram. **BIO11/12-7**

This activity can also be used in reverse by providing students with the information in a Venn diagram. The students are required to draw a diagram or write a summary. A table is good way for students to present this information.

Make the activity into a competitive game by marking out Venn diagrams on concrete using chalk. Laminate large diagrams or micrographs of cell organelles. Students can compete individually, or as teams, to correctly finish their Venn diagram the fastest.

#### Microscopy

**Practical investigation:** Examine the letter “e” using a light microscope. Use this activity as an opportunity to pre-test students’ skills in correctly handling and focusing a light microscope. Have students identify what happens to the image’s orientation compared to the specimen/object being viewed. Provide an opportunity for higher ability students to explain why a change in orientation occurs and how this may affect observations’ accuracy, particularly for organisms with some asymmetry. **BIO11/12-3**

**Practical investigation:** Prepare a wet mount microscope slide. This is a standard practical detailed in biology textbooks and websites ([Microscope.com](https://www.microscope.com/education-center/how-to-guides/mount-slides/)) that can easily be extended for students to apply their understanding further.

* Students can compare the use of different stains and describe the situations in which certain stains may be more beneficial than others. For information on stains: [Microscope world](https://schoolsnsw.sharepoint.com/sites/Yr11ModuleWriters/Shared%20Documents/BIO/Microscope%20Slide%20Staining%20Information). [Preparing animal and plant slides](https://assist.asta.edu.au/sites/assist.asta.edu.au/files/SOP%20Preparing%20animal%20and%20plant%20cells.pdf) has clear instructions on basic staining of plant and animal tissue. [The American Biology Teacher: Under the Scope: Microscopy Techniques to Visualize Plant Anatomy & Measure Structures](https://online.ucpress.edu/abt/article/82/4/257/107423/Under-the-Scope-Microscopy-Techniques-to-Visualize) has a more advanced procedure for staining cross-sections of stems. **BIO11/12-3, BIO11/12-4**
* Using mini-grids (or graph paper) students can estimate the field of view and then use this information to calculate and compare different cells’ sizes, such as onion cells and red blood cells. Scaffold this activity into step-by-step calculations and place students into mixed ability groupings. **BIO11/12-4**
* Provide students with the definitions of validity, reliability and accuracy (see Appendix 2).
	+ Groups discuss and identify which aspect of their investigation matches each definition.
	+ Students should evaluate the validity, reliability and accuracy of their investigation. **BIO11/12-5**
	+ As a class discuss the reliability of results by comparing one student’s observations with the whole class’s observations (when an average is calculated).
	+ Students conduct their own research to determine if their calculated size matches with previous documented measurements. **BIO11/12-4**
	+ Students can use their calculated cell sizes from the practical activity to draw scaled diagrams. **BIO11/12-7**

Use an interactive, such as [Science Learning Hub – Which Microscope?](https://www.sciencelearn.org.nz/image_maps/100-which-microscope) , to introduce students to the range of other microscopes and how they are used. [Science Learning Hub Which microscope is best?](https://www.sciencelearn.org.nz/resources/523-which-microscope-is-best) has branching key for students to work through to identify the most appropriate microscope to use in different situations, and a table for students to complete allowing a comparison of different microscopes.

The [BioNinja – Cell Micrographs](https://ib.bioninja.com.au/standard-level/topic-1-cell-biology/12-ultrastructure-of-cells/cell-micrographs.html) website allows students to click on cell organelles which are then highlighted in the micrograph, and compares prokaryotic and eukaryotic cells. Images of different electron micrographs and diagrams of cell organelles can be laminated into cards and students can play snap in small groups to consolidate their identification of cell organelles.

#### Scale Diagrams

Remind students of the conventions when drawing biological diagrams.
- use pencil
- continuous lines
- no shading
- large drawings, approximately half-page in size
- lines from labels touch the structure, and without arrow heads
- Include a scale bar

Explicitly teach students how to calculate cell size using the equation:

$$actual size= \frac{image size}{magnification}$$

Provide students with images of a variety of cells and calculate the size of the various cells. Show students how to rearrange the equation to calculate magnification or image size. **BIO11/12-4**

Explicitly teach students how to incorporate a scale bar into their diagrams. See Appendix 1.

### IQ1-2 How do cells coordinate activities within their internal environment and the external environment?

#### Passive Transport - Diffusion and Osmosis

**Practical investigation**: Undertake this initial engagement activity to allow students to explore this concept before explicitly teaching the osmosis and diffusion definitions.

1. Place gummy bears in different concentrations of salt solutions.
2. Students record their observations of the gummy bears over 24 hours.
3. Students propose inferences as to what they think happened to the gummy bears.
4. As a class develop inquiry questions that could be investigated based on their observations and inferences. **BIO11/12-1**

**Most textbooks and many websites have detailed instructions on how to run the following investigations into osmosis and diffusion.** A [predict, observe, explain](https://arbs.nzcer.org.nz/predict-observe-explain-poe#template) activity can be used to turn the standard formulaic diffusion and osmosis experiment into an inquiry led task. **See appendix 1.**

Students should apply their knowledge of diffusion and osmosis to explain the properties of hypertonic, hypotonic and isotonic solutions. To help students remember these terms consider other words where hypo and hyper are used as prefixes. For example, hyperactive means more activity, therefore hypertonic means more concentrated, while hypoactive means not active enough, therefore hypotonic means less concentrated.

Discuss the use of saline solutions in hospital intravenous drips (0.9% sodium chloride which is similar to the sodium concentration in blood and tears) and/or show students examples of sports drinks and ask them why they are designed to be isotonic. Provide stimulus material in the form of diagrams of cells in hypertonic, hypotonic and isotonic solutions. Ask students:

* Which solution would be best for a dehydrated cell? Hypotonic
* If someone was vomiting and/or had diarrhoea what solution would replace the lost fluids? Isotonic
* If someone is sweating excessively and losing salts from their body, which solution would help them to replace these salts or prevent further loss of salts? Hypertonic **BIO11/12-6**

#### Active Transport, Endocytosis and Exocytosis

Based on previous experiments on diffusion and osmosis, ask students how starch would be transported across the cell membrane. Help students to visualise the process by showing them a simulation ([abpischools.org.uk – Active transport across cell membranes](https://www.abpischools.org.uk/topic/cellbiology/6). They must understand how such transport is linked to the structure and function of cell membranes. They should identify that proteins in the cell membrane structure have different roles. Some of these roles are related to transport. For example aquaporins are used for passive transport whereas the sodium potassium pump uses active transport which requires an input of energy.

Discuss examples of where endocytosis and exocytosis occur; for example phagocytes consuming bacteria (this provides background knowledge for Year 12 Module 7 content). Animations of the different types of endocytosis can be viewed at [Oxford Learning Link: Endocytosis and Exocytosis](https://learninglink.oup.com/access/content/life-12e-student-resources/hillis12e-life-chapter-6-animation-3). For a more detailed animation of active transport view [Oxford Learning Link: Active Transport](https://learninglink.oup.com/access/content/life-12e-student-resources/hillis12e-life-chapter-6-animation-2)

#### Surface Area to Volume Ratio

Pose the question, ‘Why are we made of billions of cells rather than just one big cell?’ Brainstorm answers but do not assess whether they are correct.

Follow the activity with the practical investigation that models the efficiency of movement of substances into small cells (large SA:V) compared to large cells (small SA:V). This can be done using phenolphthalein agar cubes placed in sodium hydroxide. This standard experiment is outlined in biology textbooks and online at [Phenolphthalein/NaOH agar cube experiment](https://assist.asta.edu.au/sites/assist.asta.edu.au/files/Laboratory%20notes%20Phenolphthalein-NaOH.pdf). Alternatively cubes of [beetroot](https://www.sciencelessonsthatrock.com/blog/cell-size-lab-examining-surface-area-to-volume-ratios) can be placed in bleach. Students predict the order in which the cubes will become clear/white and justify their prediction. **BIO11/12-1, BIO11/12-3**

After recording the data, and before calculating the SA:V view [TED-Ed – What is the biggest single-celled organism? – Murry Gans](https://ed.ted.com/lessons/what-is-the-biggest-single-celled-organism-murry-gans), which clearly demonstrates the concept of SA:V. Students then analyse their data and propose explanations for their observations. **BIO11/12-4, BIO11/12-5.** Return to the original brainstorm and discuss answers. **BIO11/12-6**

For an activity on the difficult concept of ratio see ‘Conceptual difficulties’.

For possible extension activity or depth study see ‘Opportunities for extending concepts’.

#### Enzymes

It is suggested that enzymes be taught prior to teaching the biochemical processes as these processes rely on enzymes. Refer to Conceptual difficulties to introduce this topic.

Students may be familiar with the disorder lactose intolerance, but may not understand how this occurs. [BioNinja](https://ib.bioninja.com.au/standard-level/topic-2-molecular-biology/25-enzymes/lactose-intolerance.html) has a graphic explaining the condition. Have students research enzymes of the human body, either individually or in small groups, and describe the chemical reactions that they facilitate. For example, students could research the various enzymes involved in digestion. Encourage students to use the word catalyst in their description of the enzyme and its function.

Reinforce with students the fact that all enzymes are proteins but not all proteins are enzymes. This is built on further in Module 5 when exploring protein synthesis.

Explicitly teach the two different enzyme action models, the lock-and-key model and the induced-fit model. Lock-and-key model can be demonstrated to students using laminated paper cut-outs. Students should identify key terminology such as enzyme, active site, substrate, enzyme-substrate complex and products. The induced-fit model can be explained to students as a sock fitting over a foot, where the enzyme is the sock, and it changes the shape of the active site (or conforms) to fit the foot inside.

**Practical Investigation**: Common enzymes that are readily available are:

* rennin (junket tablets) which acts on the substrate milk (use whole fresh, not UHT, milk)
* catalase (found in liver, potatoes and bananas) which acts on the substrate hydrogen peroxide.

The effect of temperature, pH and substrate concentration on enzyme activity are investigations described in many textbooks. Before commencing investigations conduct background research into the enzyme and its action. Using this information, demonstrate to students how background information can be used to formulate an inquiry question, aim and hypothesis.

[Western libraries](https://library.wwu.edu/lit/getting-started/inquiry/developing-an-inquiry-question) has an interactive explaining how to develop a high-quality inquiry question that should be:

**Arguable** - resists simplistic answers.

**Complex** - resists yes/no answers and elicits complex responses.

**Specific in language** - resists vague or undefined words.

**Clear and concise** - resists broad topics that are too big to address within the allocated time.

For example, rennin is an enzyme that is found in the stomach of young calves and acts to coagulate milk protein to aid in nutrient absorption. Generate questions as a class such as

* What is the optimal temperature for rennin to coagulate milk protein?
* What is the optimal pH for rennin coagulate milk protein?

First-hand investigations can be carried out by choosing one factor, e.g. temperature, and modelling the experimental design process for the class using this factor as an example. Students can then design their experiment, either individually or in small groups, based on another factor and enzyme of their choosing. A jigsaw activity can be used after the investigations have concluded. Students share their results with different groups and form conclusions about the effect of different environmental conditions on enzyme activity. **BIO11/12-1, BIO11/12-2, BIO11/12-3, BIO11/12-4, BIO11/12-5**

Graph the results from each investigation and discuss the trend of the data shown in the graph. Students can use their knowledge to then predict optimal conditions for unknown enzymes based on the presented data. **BIO11/12-6**

For possible extension activities or depth study see Opportunities for extending concepts.

#### Photosynthesis

Students need to understand that the photosynthesis equation is not a one stage reaction but summarises many distinct reactions that occur in two stages. The light-dependent stage occurs in the chloroplast grana and the light-independent stage occurs in the stroma. This is an opportunity to link back to IQ1-1 with students explaining chloroplast structure by applying their knowledge of SA:V. Students draw simplified diagrams of the chloroplast showing the movement of the reactants and products across the organelle membrane at each stage of the reactions. **BIO11/12-7**

For possible extension activities or depth study see Opportunities for extending concepts.

#### Cellular Respiration

Before introducing the term cellular respiration, discuss the cells’ need for energy. All cells need to be able to obtain and transport energy to undertake the processes that allow them to live. This can be related to active transport, which requires energy and is introduced when learning about the cell membrane.

Ask students where that energy comes from. From the descriptor about cell requirements, they will know that carbohydrates and lipids can supply energy. They now need to realise that these substances are not directly used by the cell, but need to be converted into a form that is useable – an energy currency. This can be likened to us being required to pay for goods in our currency (Australian dollars), not a foreign currency or using a barter system.

Explicitly teach students that ATP is the chemical, the energy currency, used by cells to provide the energy for the processes and reactions that occur within them. ATP is a molecule that stores energy in its chemical bonds. When these bonds are broken, energy is released. Cellular respiration is a chemical process that produces ATP.

Like photosynthesis, cellular respiration is not a single chemical reaction but a series of reactions, with inputs and outputs, facilitated by enzymes and which occur in different parts of the cell. Also, like photosynthesis, any restriction to the supply of inputs or the removal of outputs will restrict cellular respiration reaction rate and, therefore, the supply of energy. Students may be familiar with cyanide poisoning in movie plots. Use this example to show that by blocking the activity of an enzyme in one of the reactions in cellular respiration, the reaction cannot proceed and the victim dies.

Provide students with micrographs and ask them to relate the mitochondria’s structure to the function of cellular respiration. For example, the highly folded cristae provide a higher SA:V.

Students need to identify that cellular respiration is either aerobic or anaerobic. Most students will readily understand this concept when applied to exercise and lactic acid production, leading to muscle cramps. See Opportunities for extending concepts for the types of anaerobic respiration and the cellular respiration stages.

## Opportunities for extending concepts

### Cell Membrane

Students analyse the data from Gorter’s and Grendel’s experiments ([The Nuffield Foundation - Theoretical Models: Cell membranes](https://www.nuffieldfoundation.org/sites/default/files/files/resources%20part%201_cell%20membranes.pdf)) that led them to propose the current cell membrane model. This data could also be used to explain how hypotheses are tested, and subsequent models accepted or rejected, based on scientific evidence. **BIO11/12-5, BIO11/12-6**

### Surface Area to Volume Ratio

Students repeat the investigation outlined in IQ2 ‘Surface Area to Volume Ratio’ but compare different shapes, for example cube, sphere, cylinder. In multicellular organisms some cells need to be large because of the functions that they perform, for example nerve cells. From their investigation students infer and/or justify the most desirable shape for these cells **BIO11/12-1, BIO11/12-2, BIO11/12-3, BIO11/12-4, BIO11/12-6**

Enzymes

Following an investigation on the effect of pH on enzyme activity, students develop an inquiry question based on the action of digestive enzymes in the human body, making predictions about the optimal pH for enzymes such as pepsin, trypsin and lipase. Students then undertake secondary research to gather evidence that supports or does not support their hypothesis. **BIO11/12-1, BIO11/12-3, BIO11/12-5**

Inhibitors of enzyme function can be explored, such as the role of inhibitors in medicine and agriculture. [BioNinja – Enzyme Inhibition](https://ib.bioninja.com.au/higher-level/topic-8-metabolism-cell/untitled-6/enzyme-inhibition.html) provides a basic overview to introduce the topic and some examples that students could use to conduct their research.

Students interested in nutrition and the role of inorganic minerals and organic substances, such as vitamins and minerals in the body, could develop a secondary research depth study around the role and action of cofactors and coenzymes. **BIO11/12-1, BIO11/12-3, BIO11/12-5, BIO11/12-7**

There are many applications of enzymes in everyday life around the home and in medicine. Students may research an enzyme used in everyday life and/or the development of new enzymes and their possible applications. The TED Talk [Meet the enzymes living in your house](https://www.ted.com/talks/vicky_huang_meet_the_enzymes_living_in_your_house#t-1550) and [How designing brand-new enzymes could change the world](https://www.ted.com/talks/adam_garske_how_designing_brand_new_enzymes_could_change_the_world/footnotes#t-609970) can be used as stimulus material for students to complete a literature review based on an inquiry question that they have developed. **BIO11/12-1, BIO11/12-3, BIO11/12-5, BIO11/12-7** For example:

* How does the knowledge of optimal conditions allow us to design enzymes that will work in a dishwasher?
* If lipase breaks down fats in the human digestive system, will it break down fats in a dishwasher?

### Photosynthesis

Students investigate the conditions required for photosynthesis to occur. For example:

* Is light required for photosynthesis? Compare starch production in leaves exposed to sunlight vs no sunlight.
* Is chlorophyll required for photosynthesis? Compare starch production in variegated vs non-variegated leaves.
* Is carbon dioxide required for photosynthesis? Compare starch production in plants exposed to carbon dioxide vs no carbon dioxide.

These methods are outlined in [Practical Biology - Identifying the conditions needed for photosynthesis](https://practicalbiology.org/energy/photosynthesis/identifying-the-conditions-needed-for-photosynthesis). **BIO11/12-3, BIO11/12-5, BIO11/12-7** Suggestions for running this activity:

* Ensure that non-waxy leaves are used for these experiments. Geraniums and pelargoniums work very well. It is suggested that pots of both green and variegated varieties are maintained for these experiments
* Ensure that the plants have a few hours of exposure to sunlight before undertaking the experiment. For those plants to be not exposed to sunlight, leave them in the dark for at least 24 hours.
* Consider dividing the class into groups and having each group conduct an experiment on one of these factors. Discuss each group’s results as a class.
* This investigation could be used as an inquiry activity where students make their own evidence-based conclusions about the requirements for photosynthesis before being explicitly taught the biochemical process.

An advanced practical that allows a quantitative analysis of the rate of photosynthesis under different light intensities is available at [Science and Plants for Schools](https://www.saps.org.uk/secondary/teaching-resources/1354-a-level-set-practicals-factors-affecting-rates-of-photosynthesis). Alternatively the same site has the investigation [Algal balls: investigating photosynthesis and respiration,](https://www.saps.org.uk/secondary/teaching-resources/235) which uses algal balls as the photosynthetic material. A video is included showing how to make algal balls. Alternatively they can be purchased from biological material suppliers.

For students who may be interested in investigating the source of electrons to reduce carbon dioxide to carbohydrates, [Practical Biology - Investigating the Light Dependent Reaction in Photosynthesis](https://practicalbiology.org/energy/photosynthesis/investigating-the-light-dependent-reaction-in-photosynthesis) outlines the method to detect any reducing agent produced by the chloroplasts. Sample data that can be used as a data analysis task is also provided. The table of results could be provided and students graph the data and analyse the trends. **BIO11/12-3, BIO11/12-4, BIO11/12-5, BIO11/12-7**

### ****Respiration****

Students’ knowledge can be extended by introducing the three stages of cellular respiration in terms of inputs and outputs and where they take place in the cell. ([sumanasinc.com – Cellular Respiration](http://www.sumanasinc.com/webcontent/animations/content/cellularrespiration.html)). Students could design a model to demonstrate these steps. **BIO11/12-6**

Having covered aerobic cellular respiration in class, students could investigate the other methods of obtaining energy in

* Animals
* Yeast
* Prokaryotic cells
	+ Obligate aerobes
	+ Obligate anaerobes
	+ Facultative anaerobes

Students may link to modules 3 and 4 and investigate how the knowledge of organelles and cellular reactions is used in the study of evolution. Scientists propose that glycolysis evolved before cellular respiration because the Krebs cycle and electron transport require oxygen, whereas glycolysis does not. There was no oxygen in the Earth’s atmosphere when life first evolved 3.5-4 billion years ago and these early prokaryotic microbes did not contain mitochondria, despite requiring energy.

## Appendices

### Appendix 1: Measurement and scale diagrams

Students often struggle with visualising and converting units of measurement at the microscopy level. Have students use [learn genetics](https://learn.genetics.utah.edu/content/cells/scale/) to design and complete a table as shown below. **BIO11/12-4**

|  |  |  |  |
| --- | --- | --- | --- |
| Unit of measurement | Symbol | Scientific notation  | Example |
| metre | m |  | Height of a small child |
| centimetre | cm | X 10-2 m | Length of an earthworm |
| millimetre | mm | X 10-3 m | Length of an insect, seed |
| micrometre | µm | X 10-6 m | Diameter of eukaryotic cells |
| nanometre | nm | X 10-9 m | Diameter of viruses, proteins, |
| picometre | pm | X 10-12 m | Diameter of simple molecules |

Explicitly teach students how to incorporate a scale bar into their diagrams. The scale bar represents a specific whole number of µm and is often 1-5cm in length. In order to draw the scale bar, use the following guidelines:

1. Determine the actual length of the object to be drawn
2. Divide the actual length by the length of the drawing or proposed drawing. A whole number should be obtained.

For example: Actual length of cell = 30µm, Length of drawing = 10cm

$$scale=\frac{actual length}{length of drawing}$$

$$scale= \frac{30}{10}= \frac{3}{1}$$

Therefore, a scale bar 1cm in length would represent 3µm or a scale bar 2cm in length would represent 6µm.

Students calculate, using scale bars, the actual size of cells and organelles shown on drawings and micrographs. **BIO11/12-4.** Use the equation:

$$actual size=\left(\frac{length of image (mm)}{length of scale bar (mm}\right)x representative length of scale bar (µm)$$

$$actual size=\left(\frac{100}{20}\right)x 6$$

$$actual size= 30µm$$

Examples with images are available at [Magnification, Size and Scale Bars](http://www.fmfranco.com/Text/ib_biology/mag_size_scale_bars.pdf)

### Appendix 2: Evaluating scientific investigations

Measurements can be precise without being accurate. Some publications use the terms ‘internal reliability’ and ‘precision’ synonymously, while using the term ‘external reliability’ to define the consistency of measurements across experiments. Validity is a holistic evaluation of scientific investigations and relies on all aspects of investigations to be accurate or precise and reliable. An unreliable investigation cannot be valid, but a reliable investigation may be invalid if it does not address the question under investigation. The definitions of accuracy, precision, reliability, and validity described above are consistent in science, engineering, and statistics. However, publications in psychology, education and sociology research use the descriptions in different contexts. For example, ‘accuracy’, ‘precision’ and ‘internal reliability’ are used interchangeably.

The following table references the [Science Year 7-10 Syllabus](https://educationstandards.nsw.edu.au/wps/portal/nesa/k-10/learning-areas/science/science-7-10-2018/%21ut/p/z1/rVPLcoIwFP0WFywzuQmB4BIflVqtVkuVbJwI0eIjIDJq-_WFTtud0I7NKpk5r9ycYIHnWGh5itcyjxMtd8U5EPaC3XsAJtCBY3cYPLUJ6baoNem1GZ59AqhLbOIx8jDqOQTc5xGxaZ_TkW9hUfIJ7RHi0CFwysGdjNvjjndHYWB98eHKcuF3_AqAqM7_ggUWoc7T_BUH6XkRJjpXOjcgzZKNCnN0VksDtDpKA7aIgAE7JTMd6zWSmZJHA45hrHSofjaIFzBEgTildBrGEQ6YbUbLiBLkrJpLxHjTQhIYQTYo6hAZ8bD5PcqKrKJ6UrPSr-Yx6jSCIgO_noHj2SlWZ-zrJNsX9Zj-8YpencOU3uhQI2_dKN-v61PxYeLN4SDcolVllS45nv93rdK97_t7x3xD29Wwa7Kgf3pvPSIRuI3GByoo2EI%21/dz/d5/L2dBISEvZ0FBIS9nQSEh/?urile=wcm%3Apath%3A%2Fpw_content%2Fproject-web%2Fnesa%2Fk-10%2Flearning-areas%2Fscience%2Fscience-7-10-2018) © 2018 NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales.

|  |  |  |  |
| --- | --- | --- | --- |
| Term | Definition | Synonym | Notes |
| Accuracy | The extent to which a measured value agrees with its true value (namely - reference value). | Exact | Requires prior knowledge about the measured variable (that is - reference values) |
| Precision | The extent to which multiple measurements, made under identical or similar conditions, agree with each other (namely - variations within a dataset). | Internal reliabilityDispersionSpread | Measurement precision: applied to repeated measurements in a single experiment.Instrument precision: the precision of measuring devices (analogue and digital) |
| Reliability | The extent to which the findings of repeated experiments, conducted under identical or similar conditions, agree with each other. | ConsistencyRepeatabilityReproducibilityStability  | In some disciplines, the term ‘external reliability’ is used. External reliability, like reliability, refers to the reliability of measurements across multiple experiments |
| Validity | The extent to which an experiment addresses the question under investigation. | Internal validity | Some disciplines use the term ‘external validity’ to refer to the extent to which the study’s results can be generalised (for example, extrapolated). |

### Appendix 3: Osmosis and diffusion

**Most textbooks and many websites have detailed instructions on how to run the following investigations into** [osmosis](https://www.bbc.co.uk/bitesize/guides/zc9tyrd/revision/6#:~:text=The%20sucrose%20solution%20is%20hypertonic,in%20the%20capillary%20tube%20rise.) **and** [diffusion](https://www.evolvingsciences.com/Diffusion%20starch%20and%20iodine.html#:~:text=Iodine%20molecules%20are%20small%20enough,to%20pass%20through%20the%20membrane.&text=Thus%20iodine%20diffused%20into%20the,the%20starch%20a%20darker%20colour.)**.** A [predict, observe, explain](https://arbs.nzcer.org.nz/predict-observe-explain-poe#template) activity can be used to turn this standard formulaic experiment into an inquiry led task.

**The following provides an outline as to how to run the investigations as inquiry activities. BIO11/12-1, BIO11/12-3, BIO11/12-4, BIO11/12-5, BIO11/12-7**

Practical investigation: Osmosis:

1. Demonstrate how to make a dialysis tubing bag. Soaking the dialysis tubing in distilled water for 15 minutes will make it easier to open the ends.
2. Students place sucrose solution into the dialysis tubing and then submerge in a beaker of distilled water. A control (a tube of distilled water placed in distilled water) should also be set up. Students could also prepare investigations with a range of sucrose concentrations
3. Students develop their hypotheses about what will happen to the dialysis tubing bags.
4. Record the changes in the dialysis tubing bags. Accurate quantitative measurements are difficult to obtain. It is sufficient to make qualitative observations of an increase in the volume of the sucrose bags. If a range of concentrations are being investigated the greatest increase in volume will occur in the most concentrated solution.
5. Students explain their observations using their terminology and based on reasoning from their collected data. The increased volume in the dialysis tubing was caused by water moving from the beaker into the tubing. More water moved into the tubing when the solution in the tube was more concentrated (to ‘even out’ or ‘equalise’ the concentrations
6. The teacher will identify the movement of water as **osmosis**, that is, water moving from a dilute solution to a more concentrated solution.
7. Students rephrase their conclusion using the correct terminology.

#### Practical Investigation: Diffusion

1. Students test what happens when iodine is added to the starch solution.
2. Students predict what will happen to the colours of the solutions when a dialysis tube of starch is placed in a beaker of potassium iodide solution and explain why this will happen. (if .. then... because)
3. Students place starch solution into dialysis tubing and then submerge in solution of potassium iodide.
4. Record result. The tube will turn blue-black rapidly. It is suggested not to leave the apparatus over an extended period of time as the dialysis tubing eventually leaks where it is tied off, thereby destroying the desired results.
5. Students discuss their results and propose why they occurred. They should identify that the iodine moved into the bag from an area of high iodine concentration to an area of low iodine concentration, and that the starch has not moved out, however they may not be able to explain why.
6. The teacher explains that the dialysis tubing provides a **semi-permeable** membrane, only allowing smaller molecules to pass through it by **diffusion**. Iodine molecules are small enough to pass freely through the membrane, however starch molecules are complex and too large to pass through the membrane.
7. Students write a conclusion using the correct terminology.
	* Initially, there was a higher concentration of iodine outside the tube than inside it, therefore iodine diffused into the tube containing the starch. This turned the starch in the tube a darker colour.
	* There was no colour change outside the membrane because the starch molecules are too large to pass through the membrane into the iodine solution.