

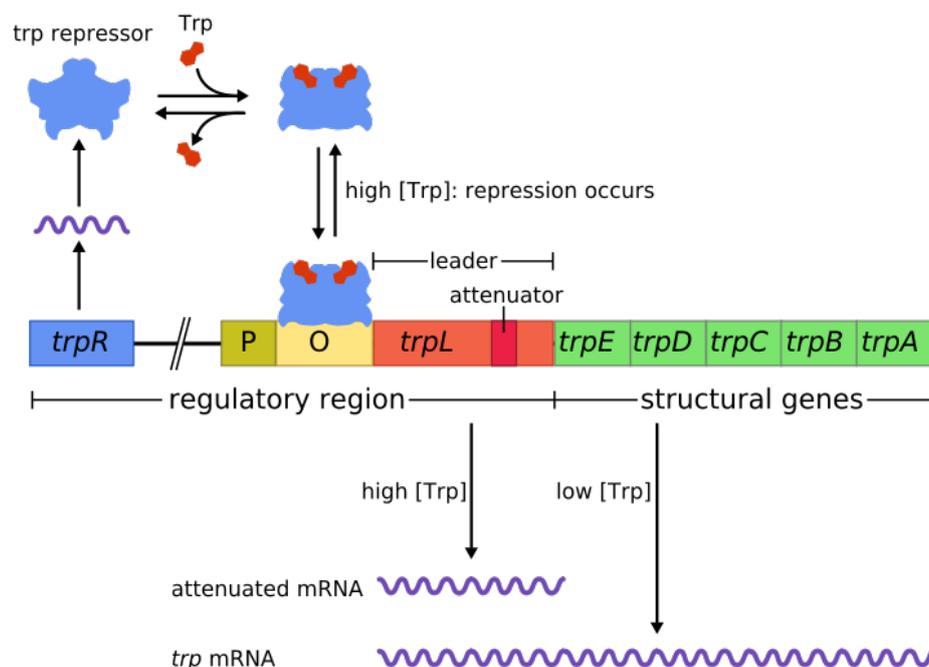
# VCE Biology 2022–2026 – Frequently asked questions

## Are students required to know the names of specific regulatory proteins and regulatory genes in the *trp* operon in Unit 3?

No, students are not required to recall the names of specific regulatory proteins (transcription factors) and regulatory genes. Students are expected to understand the roles of the following in the regulatory function in prokaryotes: operon, regulatory gene, repressor protein, promoter region, operator region and leader region.

## Are students required to know about both repression and attenuation in relation to regulation of the *trp* operon in Unit 3?

Yes, students should understand that in some prokaryote cells, such as *E. coli*, there are two mechanisms that regulate the expression of the structural genes of the *trp* operon when the level of tryptophan in the cell is high: first, repression, which involves the *trp* repressor protein, expressed by the regulatory gene, in its active form (bound to two tryptophans) binding to the operator sequence and blocking the initiation of transcription; and second, attenuation, which prevents the completion of transcription. Students should understand that there is a low basal rate of transcription of the *trp* operon because the *trp* repressor periodically stops binding to the operator region. The second mechanism, attenuation, allows the cell to terminate transcription of the *trp* operon when the level of tryptophan in the cell is high without the repressor protein binding to the operator region.



Source: Trp operon <https://en.wikipedia.org/wiki/File:Trpoperon.svg> licensed [CC-BY SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

## Do students need to know how the hairpin loops form as part of regulation of the *trp* operon?

Students should understand that within the *trp* operon, and before the five structural genes, there is a segment called the leader segment. This segment features two adjacent *trp* codons, and when transcribed has regions that undergo base pairing to form hairpin loops. Students should understand that when the level of tryptophan is low (where the cell requires more tryptophan to be synthesised), the ribosome pauses at the two adjacent *trp* codons and waits for the arrival of tRNA carrying tryptophan. The stalled ribosome causes a hairpin loop to form that does not stop transcription, and the five structural genes are expressed. When the levels of tryptophan are high and the repressor protein is not bound to the operator region, the ribosome does not pause at the two adjacent *trp* codons and a different hairpin loop forms, causing transcription to be terminated. Students do not need to know which specific segments of the leader region are paired to allow each hairpin loop to form.

## To what depth do students need to understand attenuation?

In relation to attenuation, students should understand that when the level of tryptophan is high (and the cell does not need to synthesise more tryptophan), the ribosome does not pause at the two adjacent *trp* codons, allowing a hairpin loop to form that acts as the transcription termination signal. The consequence is that the ribosome detaches from the short (attenuated) mRNA transcript strand, transcription stops prematurely and the five structural genes are not expressed. Students do not need to know how attenuation occurs when the level of tryptophan in the cell is low. Students should also understand that attenuation of the *trp* operon is made possible in prokaryotes because transcription and translation in prokaryotes take place very close to each other in the cytoplasm, as the two processes are not separated by a nuclear membrane.

## Are students required to know the chemical structures of any molecules in Unit 3?

Some basic structural information is required in order to understand how protein polymers are formed from amino acid monomers. Students should understand that all amino acids feature the same functional groups – an amino group and an acid group. Each amino acid also has an R group that varies in its composition. They should also know that the bond formed between amino acid monomers is called a peptide bond. For nucleotides, students should know the arrangement of the three chemical parts of a nucleotide and recognise that the bond between adjacent nucleotides is called a phosphodiester bond. They should be able to apply structural information regarding the formation of polypeptides, DNA and RNA to unfamiliar situations and contexts. Students are not expected to know chemical structures of specific amino acids and they are not expected to understand condensation polymerisation, nor be able to draw the dipeptide that results from the condensation reaction that occurs when amino acids are joined, as these are studied in VCE Chemistry. Students should know that the polypeptide chain undergoes changes to form functional proteins and they should be able to apply hierarchical levels of protein structure to different functional proteins, such as recognising that Rubisco and both DNA and RNA polymerases are proteins that have a quaternary structure.

## Are students required to know specific types of proteins that make up an organism's proteome in Unit 3?

Students should understand that an organism's proteome consists of a large group of diverse proteins with different structures and functions, in the context of the key knowledge in the study design. They do not need to be able to specifically identify protein classes (i.e. fibrous or globular proteins). However, they should be able to identify the functions of specific types of proteins that are included in the study design, such as

enzymes and antibodies, as well as be able to apply their understanding of protein structure and function to unfamiliar situations and contexts.

## Do students need to know about exocytosis as part of the export of proteins from a cell via the protein secretory pathway in Unit 3?

Yes, students should understand that exocytosis is the process that enables the secretion of proteins out of the cell as the final step in the protein secretory pathway. They do not need to understand the fluid mosaic model in relation to the plasma membrane, nor that exocytosis is a form of active transport that requires energy. However, students should understand, as part of the protein secretory pathway that includes exocytosis, that intracellular membranes are fluid and bud off to form vesicles that fuse with the plasma membrane and release their contents into the extracellular environment.

## Are students expected to know specific processes involved in DNA profiling in Unit 3?

Students should be able to apply their understanding of the amplification of DNA using polymerase chain reaction (PCR) and the use of gel electrophoresis in sorting DNA fragments for DNA profiling. They should also understand that DNA profiling involves the use of short tandem repeats (STRs). Students do not need to recall knowledge of other processes involved in DNA profiling.

## Is the production of human insulin the only example of recombinant plasmids that students need to know in Unit 3?

The production of human insulin is the specific example that teachers should use to demonstrate the use of recombinant plasmids as vectors to transform bacterial cells. Students should also be able to apply their understanding of recombinant plasmids to other areas of the study design, such as the production of genetically modified organisms, and other unfamiliar situations and contexts.

## To what depth do students need to understand the methods involved in the production of human insulin in Unit 3?

Students should understand that one of the main methods for the commercial production of human insulin involves the insertion of genes for two different insulin polypeptides into two different plasmids in two separate bacteria. The insulin genes are inserted next to a gene for  $\beta$ -galactosidase protein, which allows for detection of successful gene insertion. Expression of each gene from the two bacteria allows a functional fusion protein to be produced. Students should understand that introns need to be removed prior to inserting the relevant insulin gene. Once the genes are expressed and the fusion proteins are produced by each bacteria, these fusion proteins are then purified, and the insulin polypeptides are removed and then combined together to produce functional insulin.

## To what depth do students need to understand the use of genetically modified and transgenic organisms in Unit 3?

Students should recognise that the production of genetically modified organisms may involve the use of recombinant DNA technologies and they should understand the differences between genetically modified and transgenic organisms. Students should also consider the use of such organisms for specific applications in agriculture, including applications that increase crop yield and disease resistance. Students should also expect to apply their understanding of genetically modified organisms to other areas of the study design,

such as the use of CRISPR-Cas9 to edit an organism's genome. Students do not need to know specific processes of how genes are transferred into eukaryotic cells.

## To what depth do students need to understand the biochemical pathways involved in photosynthesis and cellular respiration in Unit 3?

Students should understand that a biochemical pathway is a series of steps (which may occur at different locations within a cell or, in the case of eukaryotic organisms, in different cells) from initial reactants to a final product and that each step is facilitated by enzymes and coenzymes. Students should understand the inputs, outputs and cellular locations of the light dependent and light independent stages of photosynthesis within chloroplasts in  $C_3$  plants. They should also understand the main inputs, outputs and cellular location of glycolysis and the main inputs, outputs and cellular locations of the Krebs Cycle and the electron transport chain within mitochondria. Students should understand also the location, inputs and difference in outputs from anaerobic fermentation in animals and yeasts. They do not need to understand the specific details of the mechanisms that underpin biochemical pathways involved in photosynthesis and cellular respiration.

## To what depth do students need to understand the role of Rubisco in photosynthesis in Unit 3?

Students should be able to apply their understanding of the function of the enzyme Rubisco and its involvement in carbon fixation as part of the Calvin Cycle in photosynthesis. They should be able to explain how different types of plants have adapted to maximise the efficiency of photosynthesis in various environmental conditions. They should understand that both carbon dioxide ( $CO_2$ ) and oxygen ( $O_2$ ) can bind to Rubisco's active site, but at low temperatures,  $CO_2$  is more likely than  $O_2$  to bind to Rubisco. The binding of oxygen to Rubisco is called photorespiration (this is not related to cellular respiration). At low temperatures, the rate of photorespiration in  $C_3$  plants is low and the rate of photosynthesis is high. However, as the temperature increases, more  $O_2$  and less  $CO_2$  binds to Rubisco and thus the rate of photorespiration will increase and the rate of photosynthesis will decrease. Students should understand that  $C_4$  and CAM plants have adapted through evolution and have very low photorespiration rates. This has been achieved by limiting the exposure of Rubisco to  $O_2$  and therefore maximising  $CO_2$  concentration and increasing photosynthetic efficiency.

## To what depth do students need to understand adaptations of $C_4$ and CAM plants in Unit 3?

Students should understand that  $C_4$  plants are usually tropical plants and in these plants  $CO_2$  is first fixed into an additional biochemical pathway by an enzyme that has a high affinity for  $CO_2$  and does not bind with  $O_2$ .  $C_4$  plants have uniquely specialised cells that later release the fixed  $CO_2$  to enter the Calvin Cycle with negligible competition from  $O_2$ . CAM plants have their stomata closed during the day, hence  $CO_2$  cannot enter. During the night the stomata are open, allowing  $CO_2$  to enter and be fixed in other compounds.  $CO_2$  is released during the daytime and enters the Calvin Cycle. Students are not required to know any specific details of the additional biochemical pathway that fixes  $CO_2$  in  $C_4$  and CAM plants.

## Do students need to know the products of carbon fixation as part of the Calvin Cycle in photosynthesis in Unit 3?

No, students do not need to know the direct products that result from the action of Rubisco as part of the Calvin Cycle; however, they should know that a simple sugar is produced from the Calvin Cycle.

## Do students need to be able to write balanced equations for photosynthesis and cellular respiration in Unit 3?

No, students do not need to be able to write balanced equations for photosynthesis and cellular respiration.

## Do students need to learn the different amounts of ATP produced at each stage in aerobic cellular respiration and anaerobic fermentation (anaerobic cellular respiration) in Unit 3?

Yes. Students are expected to understand the net yields of ATP for aerobic cellular respiration and anaerobic fermentation (as shown in the table below). Students should also recognise that there is variation between theoretical and actual yields of ATP.

Process	ATP yield		
	glycolysis	Krebs Cycle	electron transport chain
aerobic cellular respiration	2 ATP	2 ATP	variable (26 or 28 ATP)
anaerobic fermentation	2 ATP		

Note: The ATP yield for the electron transport chain has been revised from the previous study design, based on the most current research and real-life efficiencies.

## To what depth should enzymes and coenzymes be studied in Unit 3?

Students should consider the role of enzymes as protein catalysts (catalytic proteins) in photosynthesis and cellular respiration. They should understand how enzyme action can be inhibited either reversibly or irreversibly by direct competition from other substrates or by modification (change in shape) of the active site by non-competitive inhibitors that bind elsewhere on the enzyme (allosteric sites). The use of the lock-and-key and/or induced fit model of enzyme action is sufficient to explain this concept. Students should understand that any changes to the active site will affect the enzyme's capacity to bind to a substrate and that the reaction rate can differ when a substrate is in the presence of a competitive inhibitor and/or non-competitive inhibitor. They should understand that changes in temperature and pH affect the rate of reaction and may lead to enzyme denaturation. Students should be familiar with how enzyme activity is affected by varying either enzyme or substrate concentrations. When considering the roles of coenzymes in photosynthesis and cellular respiration, students should understand that coenzymes (ATP, NADH, NADPH) are non-protein organic molecules that facilitate reactions by cycling as loaded or unloaded forms moving energy, protons and electrons between reactions in the cell.

## To what depth should factors affecting enzyme function and factors affecting reaction rates be studied in Unit 3?

The consideration of reaction rate is specific to photosynthesis and cellular respiration. Students should explore the factors that determine the rates of reaction for both photosynthesis and cellular respiration, including the following:

- the concentration of limiting reagents (this is different from the total quantity of a limiting reagent, which determines the maximum theoretical amount of product that can be produced for a given amount of reactant[s])
- coloured light and increasing light intensity to a maximum rate for photosynthesis
- enzymes that operate within defined pH and temperature levels

- the denaturation of enzymes with increasing temperatures and the decrease in reaction rate with lowering temperatures.

Students should understand that enzymes function by reducing the amount of activation energy required for a reaction to proceed. Students do not need to understand the distinction between anabolic and catabolic, or endergonic and exergonic, reactions. No reference to energy profile diagrams is required. Students are expected to be able to interpret experimental data related to photosynthesis and cellular respiration.

## Which anaerobic processes for breaking down glucose should be studied in Unit 3?

Fermentation is the only anaerobic process specified in the study design. Both lactic acid fermentation and alcoholic fermentation pathways should be compared in terms of cellular location, inputs, outputs and net ATP yield.

## To what depth do students need to understand the use of anaerobic fermentation in the production of biofuels in Unit 3?

Students should be able to apply their knowledge of anaerobic fermentation to consider possible types of biomass as an input and possible uses of the output bioethanol. They should also consider how such an output could be used as an input source for other biofuels, such as for biodiesel. Students should understand that enzymes are used in the production of biofuels via anaerobic fermentation. Specific details of biofuels and their synthesis are not required. Students should also be able to apply their understanding of the fermentation of biomass for biofuel production to unfamiliar situations and contexts.

## To what depth do students need to understand the uses and applications of CRISPR-Cas9 technologies in Unit 3?

Students should understand that CRISPR-Cas9 functions as a primitive adaptive immune system in bacteria. They should know that CRISPR is a specialised sequence of DNA that has two important features: nucleotide repeats and spacers. The spacers are segments of DNA cut from invading viruses (bacteriophages) that allow the bacteria to recognise the same virus in the event of subsequent invasions. Students should recognise that Cas9 is an endonuclease associated with CRISPR and acts like a pair of molecular scissors capable of precisely cutting both strands of DNA. They should understand that Cas9 will only cut out the target sequence if it recognises a very short nucleotide sequence adjacent to the target spacer called a protospacer adjacent motif (PAM) sequence. The PAM sequence plays an essential role in distinguishing self from non-self. Students should understand that the gene editing in eukaryotes using CRISPR-Cas9 technologies relies on the use of Cas9 protein and single guide RNA (sgRNA) molecules. Knowledge of other Cas enzymes and the other forms of RNA involved is not required. Students should understand that the CRISPR-Cas9 system is an easy and cost-effective way of editing an organism's genome, with many applications. Increasing photosynthetic efficiencies and increasing crop yields are the specific examples that teachers should use to demonstrate the use and application of CRISPR-Cas9 technologies. However, students should also be able to apply their understanding to other areas of the study design and to other unfamiliar situations and contexts.

## Are students required to consider the ethical implications of biotechnological applications in Unit 3?

Students should be able to apply the key science skill 'analyse and evaluate bioethical issues using relevant approaches to bioethics and ethical concepts, including the influence of social, economic, legal and political

factors relevant to the selected issue' to any bioethical issue-based questions that may arise from key knowledge included in the study design.

## Do students need to know specific examples of physical, chemical and microbiota barriers in Unit 4?

Students should understand that physical, chemical and microbiota barriers act as a first line of defence by preventing or impeding the entry of a pathogen. They should understand that physical barriers act to prevent entry of pathogens; chemical barriers act to inhibit the growth or development of pathogens and/or act to destroy pathogens; and microbiota barriers act to prevent the growth or colonisation of microorganisms that may be pathogenic. Teachers may choose their own examples of each type of barrier to teach the key knowledge, noting that students should be able to apply their knowledge of physical, chemical and microbiota barriers to unfamiliar situations and contexts involving both animals and plants.

## Do students need to know specific examples of pathogens in Unit 4?

Students should understand that causative agents of disease can be cellular (bacteria, fungi, parasites or protists) or non-cellular (prions or viruses). They should be able to distinguish cellular from non-cellular disease-causing agents based on their structure and by comparing their mode of reproduction. Teachers may choose their own examples to teach the key knowledge, noting that students should be able to apply their knowledge of pathogens and disease to other areas of the study design and other unfamiliar situations and contexts. Knowledge of specific parasites is not required.

## To what depth do students need to understand allergens in Unit 4?

Students should understand that an allergen is often a substance that initiates an allergic response by binding to antibodies that are already bound to receptors on mast cells. The response involves the release of histamine from mast cells, which causes an inflammatory response that can vary in severity. Specific examples of allergens are not required, however, students should be able to apply their knowledge to other areas of the study design and other unfamiliar situations and contexts.

## To what depth do students need to understand the steps in an inflammatory response in Unit 4?

Students should understand the characteristics and role of different immune cells in an inflammatory response. This includes the function of complement proteins and cytokines; the involvement of mast cells and the action of histamine; and the role of macrophages and neutrophils (including phagocytosis and the role of lysozymes). Students should understand that the physical signs of the inflammatory response, such as redness and swelling, can be related to events at the cellular level.

## Do students need to know specific examples of extracellular and intracellular threats in Unit 4?

Students should understand that many threats are extracellular and pathogenic in nature. They should also recognise that there are other forms of threats, such as allergens or malfunctions of the immune response, and that threats may also be intracellular, such as from invading viruses or accumulative mutations causing a cell to become cancerous. Teachers may choose their own examples to teach the key knowledge, noting that students should be able to apply their knowledge of extracellular and intracellular threats to other areas of the study design, such as the development of monoclonal antibodies to treat cancer, and other unfamiliar situations and contexts.

## Do students need to know the structure of an antibody in Unit 4?

Yes. Students should understand that an antibody has a quaternary structure, consisting of two heavy polypeptide chains and two light polypeptide chains arranged in a 'Y' shape. They should understand that the stem of the antibody is known as the constant region and that the tops of the arms of the antibody are known as the variable region. Students should know that all antibodies produced in the body have two binding sites (at the top of the arms) for the same specific complementary antigen.

## Do students need to know about MHC Class I and MHC Class II markers in Unit 4?

Yes. Students should understand that in vertebrates MHC Class I markers are on all nucleated body cells and act to identify the cells' self antigens from non-self antigens. They should also understand that MHC Class II markers are found primarily on professional antigen-presenting cells (for example, macrophages, B lymphocytes and dendritic cells) and that these cells present antigen fragments on their MHC Class II markers to T lymphocytes and other immune cells.

## Do students need to know about clonal selection when considering the characteristics and roles of components of the adaptive immune response in Unit 4?

Yes, students should know what is meant by 'clonal selection theory', including the recognition of a complementary antigen by a B lymphocyte (by direct binding) or T lymphocyte (via MHC), followed by activation and proliferation of these cells into either effector cells (antibody-secreting B cells or helper and cytotoxic T cells) or memory cells that confer long-term immunity.

## Do students need to know specific examples in relation to the emergence of new pathogens and re-emergence of known pathogens in Unit 4?

When considering the emergence and re-emergence of pathogens, students should understand the meaning of the terms 'pandemic' and 'epidemic' in terms of the rate of spread of disease and their distinction from a disease that is 'endemic'. Teachers may choose their own examples of new pathogens that have emerged and pathogens that have re-emerged to teach the key knowledge, noting that students should be able to apply their understanding to unfamiliar situations and contexts.

## Do students need to know specific examples of active and passive strategies for acquiring immunity in Unit 4?

Students should understand that natural active immunity is acquired when an organism is exposed to a disease-causing agent. This exposure results in the formation of B and T memory cells that confer long-term immunity. Students should compare this with natural passive immunity, where an offspring may receive antibodies from their mother via the placenta or during breastfeeding. Students should also be able to distinguish between artificial active immunity (acquired through vaccination) and artificial passive immunity (acquired typically through injected antibodies). Students should consider the immune components involved and the effectiveness of each strategy in terms of the length of protection conferred.

## To what depth do students need to know about scientific and social strategies employed to identify and control the spread of pathogens in Unit 4?

Students should understand that scientific strategies act to reduce or stop transmission of and infection by a particular pathogen and to potentially develop treatments to control or eliminate the pathogen. These treatments may include antibiotics, antivirals and fungicides. Social strategies are strategies that support the scientific effort to reduce and control the spread of a pathogen in a population. Students should understand the difference between infectious and non-infectious diseases, recognising that contagious diseases are a subset of infectious diseases. Transmission of infectious diseases may be direct, including via air, droplets and/or bodily fluids, or indirect, including via vectors, food, water and/or host animals. Students should consider the relationship between modes of transmission of a particular pathogen and scientific and social strategies to control the spread of the pathogen. Knowledge of specific antibiotics, antivirals and fungicides is not required. Teachers may select their own examples of infectious diseases to demonstrate the key knowledge, noting that students should be able to apply their understanding to unfamiliar situations and contexts.

## Do students need to know about vaccination programs for specific diseases in Unit 4?

Students should understand that herd immunity through artificial active immunity is the desired outcome of any vaccination program. They should understand the meaning of the term ‘herd immunity’ and that the percentage of a population that must be exposed to a disease or a vaccine to achieve herd immunity varies widely for different diseases. Teachers may choose their own specific examples to teach the key knowledge, noting that students should be able to apply their understanding of the key knowledge to unfamiliar situations and contexts.

## To what depth do students need to understand the development of immunotherapy strategies in Unit 4?

The use of monoclonal antibodies for the treatment of autoimmune diseases and cancer are the two specific examples that teachers should use to teach the development of immunotherapy strategies. Students should understand the nature of monoclonal antibodies, recognising that different ways of producing monoclonal antibodies have been developed. They should understand how monoclonal antibodies are used to treat autoimmune diseases and cancer and should understand that monoclonal antibodies may stimulate, suppress or have no effect on the immune response. Students are not required to know names of specific monoclonal antibodies or how specific monoclonal antibodies function. Students should be able to apply their knowledge of immunotherapy strategies to other areas of the study design, such as the adaptive immune response, and to other unfamiliar situations and contexts.

## To what depth do students need to understand causes of changing allele frequencies in a population’s gene pool in Unit 4?

Students should be able to apply a qualitative treatment to changing allele frequencies in a population. They may be required to do basic numerical analysis. Students should understand how allele frequencies can change due to environmental selection pressures, gene flow, genetic drift (bottleneck effect and founder effect) and point mutations. Students should be aware that chromosomal mutations can also alter allele frequencies (block mutations) and produce polyploids (additional sets of chromosomes).

## To what depth should students understand the manipulation of gene pools through selective breeding programs in Unit 4?

Students should understand that humans have used agricultural and horticultural practices to manipulate gene pools of plants and animals through selective breeding practices and they should consider the biological consequences of such practices. Teachers may choose their own examples to teach the key knowledge, noting that students should be able to apply their understanding of the key knowledge to unfamiliar situations and contexts.

## To what depth do students need to understand the consequences of bacterial resistance to antibiotics and viral antigenic drift and shift in Unit 4?

Students should consider the consequences of bacterial resistance to antibiotics and the scientific and social challenges that this presents in terms of treatment strategies for diseases caused by bacterial pathogens. They should also distinguish between viral antigenic drift and shift and the scientific and social challenges that these present in terms of the treatment strategies and vaccination programs for diseases caused by viral pathogens.

## Do students need to consider ethical implications when evaluating challenges and strategies for the treatment of disease in Unit 4?

Yes. Students should be able to 'analyse and evaluate bioethical issues using relevant approaches to bioethics and ethical concepts, including the influence of social, economic, legal and political factors relevant to the selected issue', as per the key science skills table in the study design. They should be able to apply this analysis and evaluation to any bioethical issue-based questions that may arise from key knowledge included in the study design. Further advice regarding approaches to bioethics and ethical concepts is available on pages 15 and 16 of the study design.

## Are students required to understand the consequences of environmental events on Earth's biodiversity as part of Unit 4?

No, the consequences of major environmental changes in Earth's conditions, such as changes in plate tectonics, atmospheric composition, temperature and climate, are studied as part of VCE Environmental Science.

## Are students required to know dates for the changes in life forms in Earth's history, and which specific life forms should be considered in Unit 4?

Students should understand that Earth's history can be represented on a geological time scale as a 'calendar' of chronological events that is divided into distinct periods and eras, however, no knowledge of the placement of specific events, periods or eras is necessary. They should understand that species do not appear randomly in the fossil record but appear in an order of 'fossil succession', from single cellular forms to structurally complex multicellular forms. Teachers may choose their own specific examples to illustrate trends in fossil succession. Students should also understand that through Earth's history, life forms have undergone mass extinctions, whereby many species have become extinct on a regional or global scale, and such events provide an evolutionary opportunity for other species to thrive and diversify. Knowledge of which

periods or eras mass extinctions occurred in and the environmental causes of mass extinctions is not required.

## To what depth should students understand absolute dating of fossils in Unit 4?

Students should understand and distinguish between relative and absolute measurements of time. In terms of absolute dating techniques, students should know that the ratio of decaying radioactive isotopes to decay products is measured. Knowledge of the decay of  $^{14}\text{C}$  isotopes is required but knowledge of other isotopes that may be used in radiometric dating or other absolute dating techniques is not required.

## Are the Galapagos finches as an example of allopatric speciation and *Howea* palms on Lord Howe Island as an example of sympatric speciation the only examples students need to know in Unit 4?

Students should understand what a species is and consider speciation over time from a common ancestor due to geographical and reproductive isolating mechanisms. The Galapagos finches and *Howea* palms on Lord Howe Island are the two specific examples that teachers should use to teach the concepts of allopatric speciation and sympatric speciation. Students should be able to apply their knowledge of speciation events to unfamiliar situations and contexts.

## Do students need to demonstrate knowledge of convergent and divergent evolution in Unit 4?

No, students do not need to know or be able to distinguish between convergent and divergent evolution; however, teachers may choose to teach or revise these concepts to support students' understanding of the concepts of speciation included in Unit 4 Biology.

## Do students need to know about developmental biology and biogeography as evidence of relatedness between species in Unit 4?

No. When considering relatedness between species, students should understand how specific types of evidence obtained from structural morphology (homologous and vestigial structures) and molecular homology (DNA and amino acid sequences) can be used to explain relatedness between species. They do not need to demonstrate knowledge of the DNA hybridisation technique, however, teachers may wish to teach the steps in the DNA hybridisation technique to demonstrate relatedness between sequences.

## To what depth do students need to understand the biological consequences of hominin evolution in Unit 4?

Students should understand the shared structural and physiological characteristics that place mammals, primates, hominoids and hominins into their respective taxonomic groups. They should understand that humans, as part of the taxonomic tribe *Hominini*, have specific biological adaptations that allow for bipedalism, such as, but not limited to, the position of the foramen magnum, curvature of the spinal column and shape of the pelvis. They should also understand that hominins have adaptations that enable the wrists and hands to manipulate objects and use tools. Students should also consider skull differences between hominoids and hominins and understand that, compared with other apes, humans are capable of advanced cognitive capacity, and complex language and belief systems. In terms of considering major trends in evolution from the genus *Australopithecus* to the genus *Homo*, students should focus specifically on trends

for changes in brain size and limb structure, including evidence of changes in volume of the cranium, changes in arm and leg length, and changes in the length and curvature of the fingers and toes.

## Do students need to understand cultural evolution as part of the evidence for trends in hominin evolution in Unit 4?

Students should recognise that human culture is a consequence of human biological change, however, specific examples of culture and the ability to distinguish between biological evolution and cultural evolution are not required.

## In relation to the human fossil record, do students need to know which species evolved from which in Unit 4?

No. Students should understand that as a biological classification scheme, the human fossil record is open to different interpretations and changes based on new evidence from fossil and/or DNA discoveries. They should also understand that several putative *Homo* species have been inferred based on partial or fragmentary fossil or genetic evidence, such as *Homo luzonensis* and the Denisovians. Students should be able to apply their understanding to consider different interpretations of information and to unfamiliar contexts and situations.

## To what depth should students understand the migration of modern human populations around the world in Unit 4?

Students should understand that there is considerable DNA evidence (mtDNA and whole genomes) to support the hypothesis that early hominins migrated out of Africa, commencing approximately 150,000 years ago, to populate the rest of the world. DNA evidence also supports that modern hominins migrated somewhat later into Europe and the Middle East and, for a period of time, interbred with Neanderthals. DNA evidence also suggests that modern hominins reached the Australian continent approximately 55,000 years ago from South-East Asia (although earlier dates are suggested from the dating of cultural artefacts), with distinct groups, from a single initial migration, spreading rapidly down the western and eastern coasts to occupy particular geographical areas. The extinction of the Australian megafauna approximately 42,000 years ago is also evidence for the rapid migration of modern hominins across the continent. Evidence from DNA and cultural artefacts varies as to the amount of migration and gene flow between specific populations, however, there is evidence for prolonged connection over time of specific populations in specific areas of the Australian continent, in agreement with Aboriginal and Torres Strait Islander peoples' cultural beliefs and their central cultural attachment to Country and Place. Further advice regarding the concepts of Country and Place are provided on page 14 of the study design.

## Do all students need to perform completely different experiments for the Unit 4 Area of Study 3 student-designed practical investigation?

No. In some schools it may not be practical to have all students performing completely different investigations, due to student numbers and/or availability of resources. Further, science is often a collaborative exercise and classes and/or groups of students may wish to work together to select a particular area of investigation. However, for VCE Biology, all students need to be assessed individually on their capacity to design investigations, either prior to undertaking their own investigation, or at the conclusion of the investigation by suggesting an extension or coupled experiment. Students also need to be assessed on their own logbook entries and individual scientific poster. Teachers should note that it may not be possible for students to undertake some proposed student-designed investigations due to factors such as time and/or

space feasibility, availability of resources, safety and ethics. Further advice regarding Scientific Investigations is available under Planning in the [Biology Support Materials](#).

## Do students need to complete a risk assessment for the Unit 4 Area of Study 3 student-designed practical investigation?

This will depend on the nature of the selected scientific investigation methodology and the individual policy at the school. However, teachers are responsible for ensuring that all investigations meet with health and safety regulations and demonstrate ethical conduct, as specified on pages 4 and 5 of the study design. It is expected that students will understand and manage any risks associated with their own investigations.

Teachers should note that the national [Australian School Science Information Support for Teachers and Technicians \(ASSIST\) website](#) contains useful resources related to laboratory safety and provides an online advisory service for teachers and laboratory technicians. A variety of commercial products are also available.