BIOZONE

HSC | BIOLOGY YEAR 12

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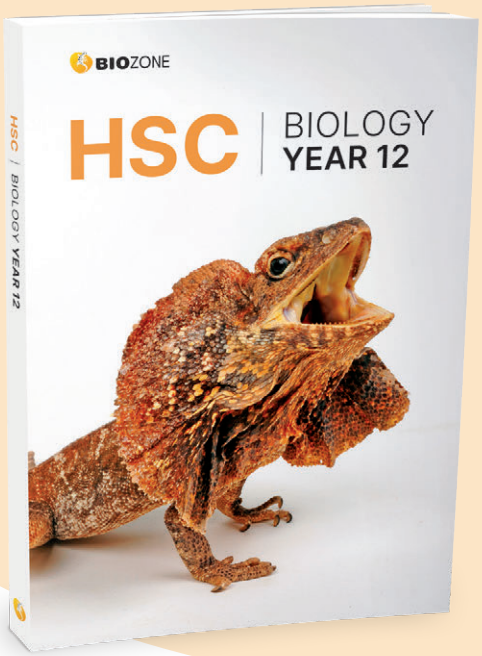


HSC Biology: YEAR 12

Available in PRINT + DIGITAL formats.

This edition of **HSC Biology: Year 12,** has been written to meet the Biology Year 12 syllabus (2025) requirements for New South Wales.

The unique design of **HSC Biology: Year 12** allows students to keep written answers and annotations organised and in one place. A key feature of the worktext is that it allows students to evaluate, return to, and improve their written responses, precisely where the stimulus material is located, creating a powerful learning and revision tool. The organisation of the chapters and coding system allow easy navigation through the course, and the activities, investigations, and assessment tasks have been specifically **designed to meet HSC Biology: Year 12 requirements**.

Further learning support is available in the linked digital **Resource Hub**, containing a wide-range of useful videos, weblinks, and spreadsheets. Many pages have direct QR code links to 3D models which allow direct interaction with graphics.

ISBN: 978-1-99-101485-6
Edition: 2nd
No. Pages: 404

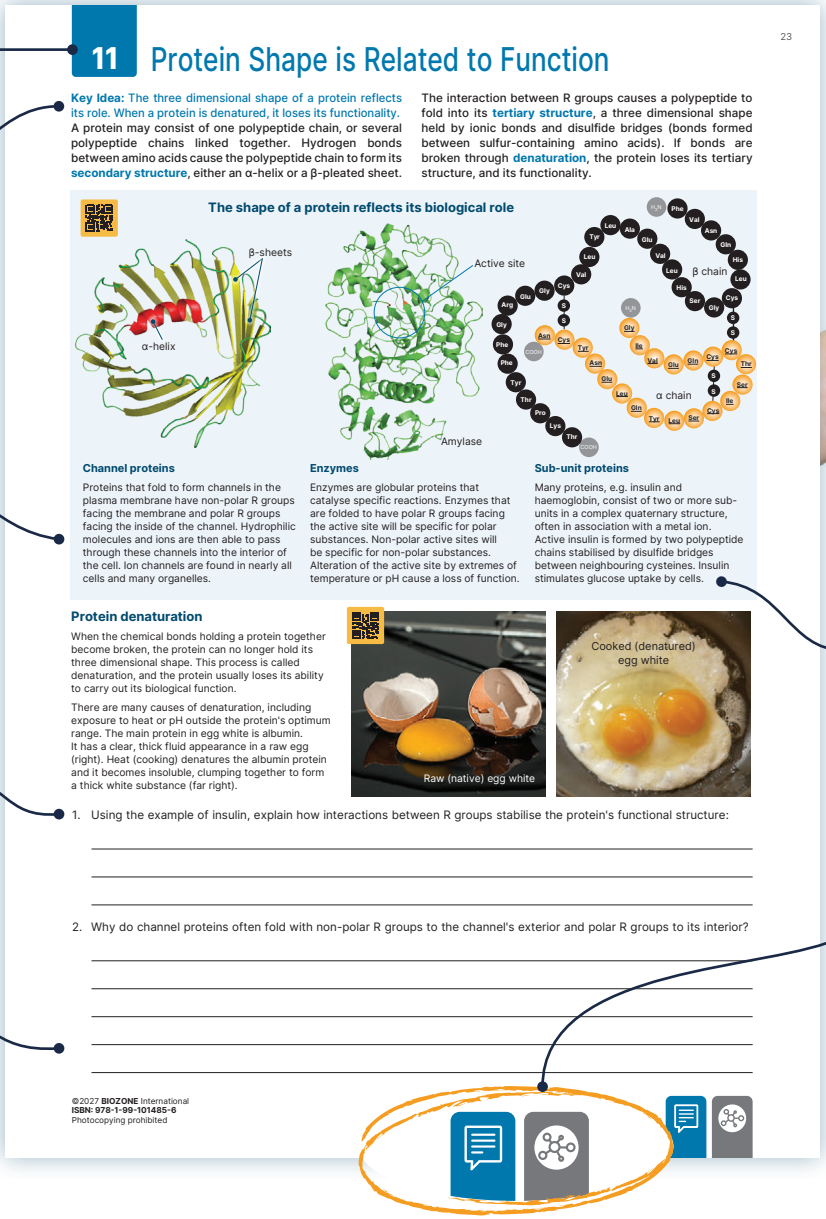
Activity number
Activities are numbered to make navigation through the book easier.

Key idea
A key idea provides a primary focus for the activity. It helps students to understand where the activity's emphasis lies.

Comprehensive diagrams
Provide an engaging, highly visual delivery of the important information.

Critical thinking questions
A direct questioning style helps students easily interpret the question. A wide range of tasks, including free response, data analysis and presentation, and the interpretation and evaluation of evidence, scaffold student learning to build confidence and competence.

Write-on answers
Students write their answers directly onto the page. This becomes their record of work and helps students revise for tests and exams.



23

11 Protein Shape is Related to Function

Key Idea: The three dimensional shape of a protein reflects its role. When a protein is denatured, it loses its functionality.

A protein may consist of one polypeptide chain, or several polypeptide chains linked together. Hydrogen bonds between amino acids cause the polypeptide chain to form its **secondary structure**, either an α-helix or a β-pleated sheet.

The interaction between R groups causes a polypeptide to fold into its **tertiary structure**, a three dimensional shape held by ionic bonds and disulfide bridges (bonds formed between sulfur-containing amino acids). If bonds are broken through **denaturation**, the protein loses its tertiary structure, and its functionality.

The shape of a protein reflects its biological role

β-sheets
α-helix
Active site
Amylase
β chain
α chain

Channel proteins
Proteins that fold to form channels in the plasma membrane have non-polar R groups facing the membrane and polar R groups facing the inside of the channel. Hydrophilic molecules and ions are then able to pass through these channels into the interior of the cell. Ion channels are found in nearly all cells and many organelles.

Enzymes
Enzymes are globular proteins that catalyse specific reactions. Enzymes that are folded to have polar R groups facing the active site will be specific for polar substances. Non-polar active sites will be specific for non-polar substances. Alteration of the active site by extremes of temperature or pH cause a loss of function.

Sub-unit proteins
Many proteins, e.g. insulin and haemoglobin, consist of two or more sub-units in a complex quaternary structure, often in association with a metal ion. Active insulin is formed by two polypeptide chains stabilised by disulfide bridges between neighbouring cysteines. Insulin stimulates glucose uptake by cells.

Protein denaturation

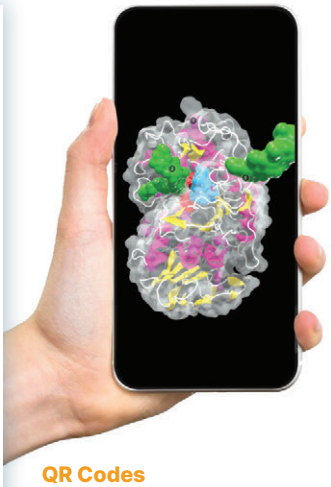
When the chemical bonds holding a protein together become broken, the protein can no longer hold its three dimensional shape. This process is called denaturation, and the protein usually loses its ability to carry out its biological function.

There are many causes of denaturation, including exposure to heat or pH outside the protein's optimum range. The main protein in egg white is albumin. It has a clear, thick fluid appearance in a raw egg (right). Heat (cooking) denatures the albumin protein and it becomes insoluble, clumping together to form a thick white substance (far right).

Raw (native) egg white
Cooked (denatured) egg white

1. Using the example of insulin, explain how interactions between R groups stabilise the protein's functional structure:

2. Why do channel proteins often fold with non-polar R groups to the channel's exterior and polar R groups to its interior?



QR Codes
Scan the QR code to directly interact with 3D models.

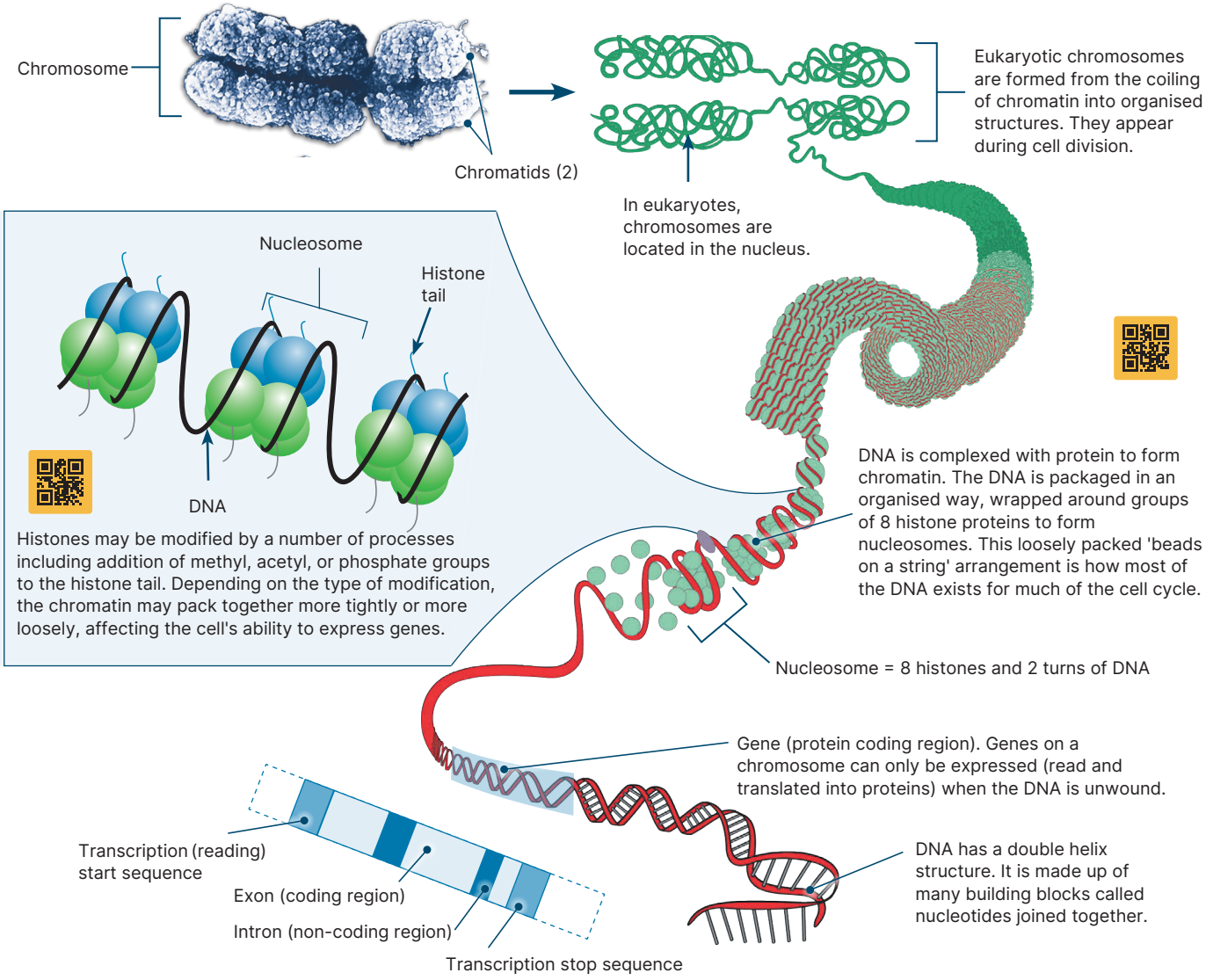
Content organisation
Logically organised content makes it easier for students to access and engage with the information.

Activity coding system
Tabs indicate online support via BIOZONE's Resource Hub and identify the key components of the working scientifically outcomes.

See our website for more details and local pricing
BIOZONE.com/au

1 Eukaryotic DNA and RNA

Key Idea: In eukaryotes, DNA is stored as linear chromosomes. The DNA in eukaryotes is packaged as discrete linear chromosomes. The number of chromosomes varies from species to species. The extent of DNA packaging changes during the life cycle of the cell, but classic chromosome structures (below) appear during metaphase of mitosis.



1. Explain why eukaryotic DNA needs to be packaged to fit inside a cell nucleus: _____

2. How do histone proteins help in the coiling up of DNA? _____

3. Suggest why a cell coils up its chromosomes into tight structures when it is going to divide: _____

4. Explain how the packaging of DNA in an organised way enables closer regulation of gene expression: _____

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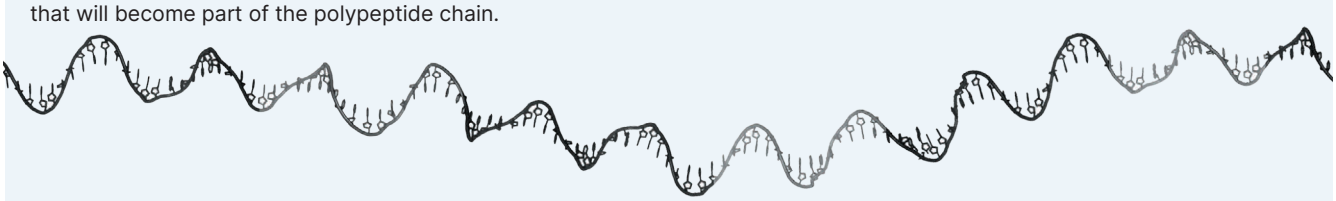
mRNA structure

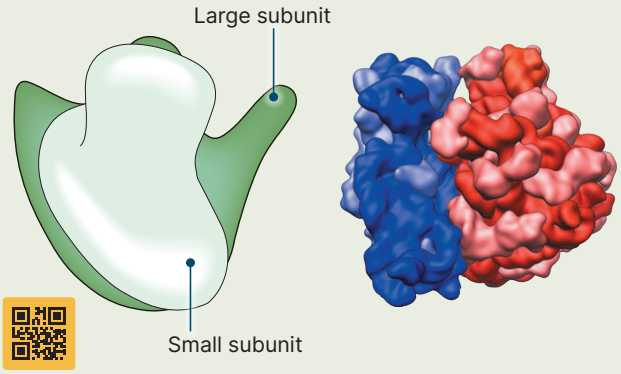
Messenger RNA (mRNA) is the molecule that links the genetic information in DNA to the molecular machinery that makes proteins. A gene in the DNA is transcribed by RNA polymerase enzymes as a single, long mRNA molecule with the nucleotide sequence encoded in the mRNA, corresponding to the nucleotide sequence of the gene. The mRNA is translated by ribosomes into a polypeptide (protein). Every three nucleotides on the mRNA, called a codon, codes for a specific amino acid that will become part of the polypeptide chain.



Ribosome structure

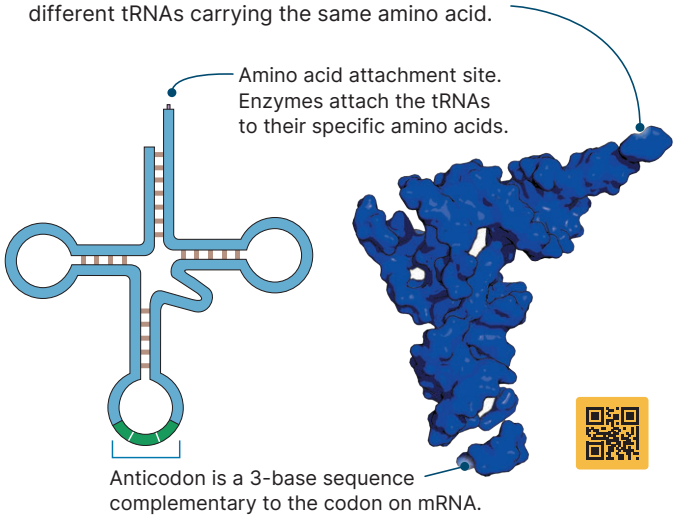
Ribosomes are made up of a complex of ribosomal RNA (rRNA) and ribosomal proteins. These small cellular structures direct the catalytic steps required for protein synthesis and have specific regions that accommodate transfer RNA (tRNA) molecules loaded with amino acids.

Ribosomes exist as two separate sub-units (below) until they are attracted to a binding site on the mRNA molecule, when they come together around the mRNA strand.



tRNA structure

tRNA molecules are RNA molecules, about 80 nucleotides long, which transfer amino acids to the ribosome as directed by the codons in the mRNA. Each tRNA has a 3-base anticodon, which is complementary to a mRNA codon. There is a different tRNA molecule for each possible codon and, because of the degeneracy of the genetic code, there may be up to six different tRNAs carrying the same amino acid.



1. What is the role of mRNA in the cell? _____

2. (a) What is a codon? _____

   (b) What is an anticodon? _____

3. Describe the structure and function of a ribosome: _____

4. What is the role of tRNA in the cell? _____

5. Write a brief description of how proteins are produced in the cell: _____

ISBN: 978-1-99-101410-8

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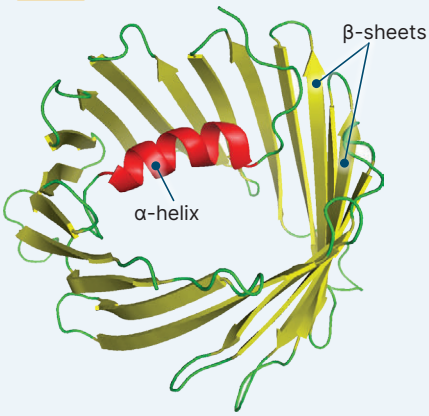
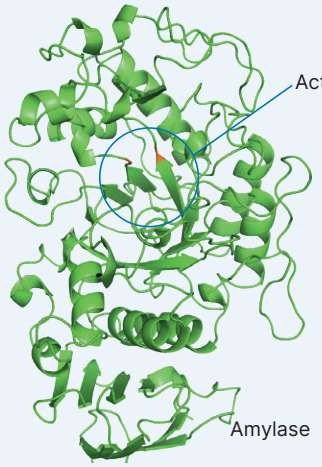
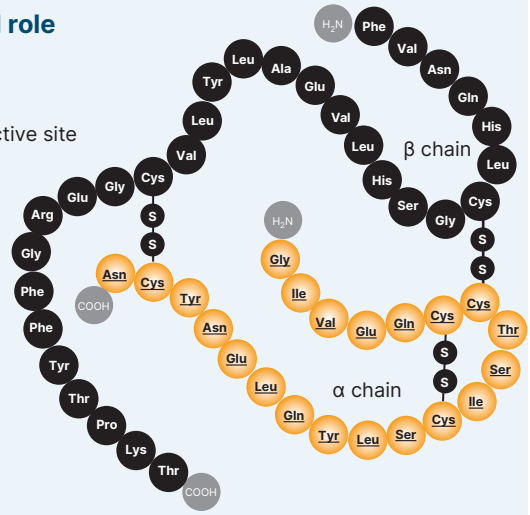
The shape of a protein reflects its biological role







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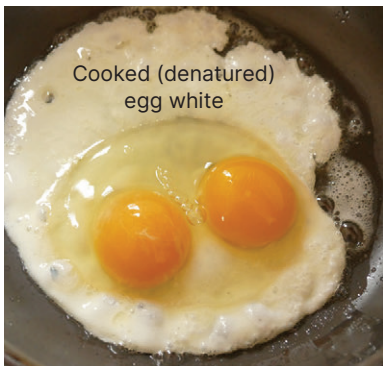

1. Using the example of insulin, explain how interactions between R groups stabilise the protein's functional structure:

2. Why do channel proteins often fold with non-polar R groups to the channel's exterior and polar R groups to its interior?

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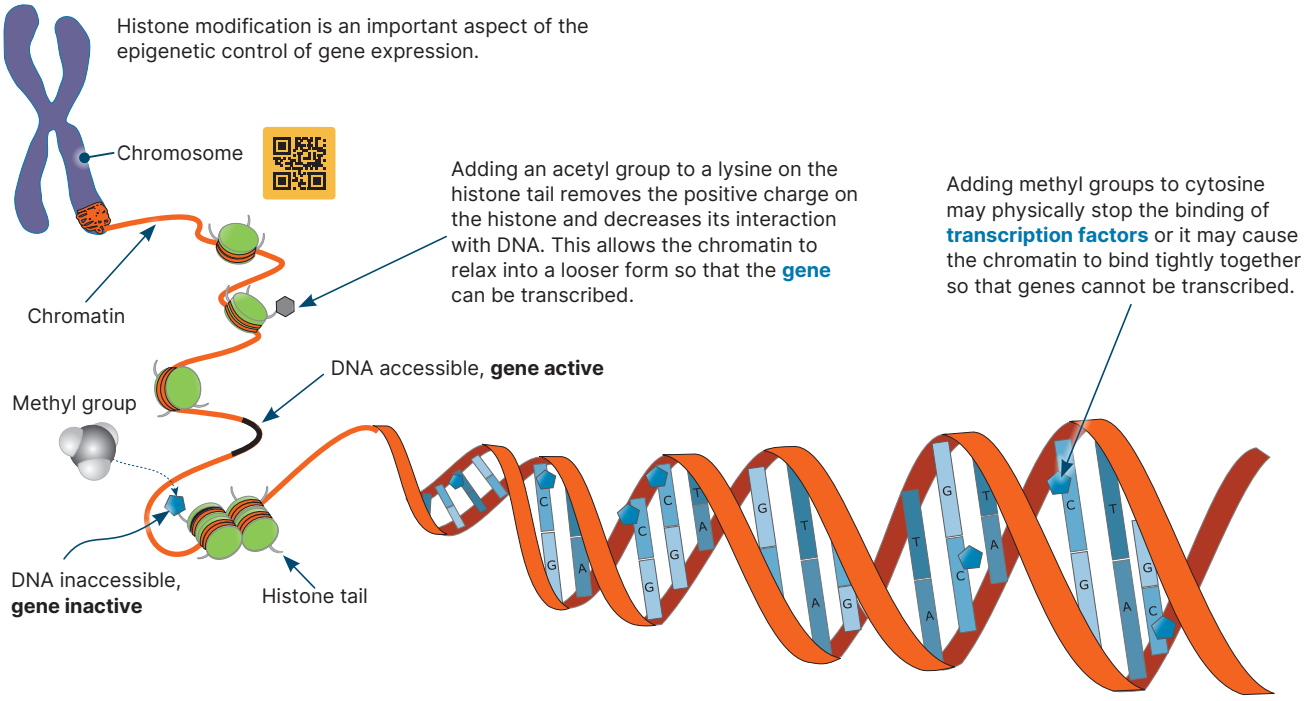
17 Epigenetic Regulation of Gene Expression

Key Idea: The mechanisms by which the environment modifies the expression of genes are often epigenetic.

Gene expression can be influenced, in part, by the environment. But how is the influence of environment moderated? Sometimes (as with colour pointing) the environment directly influences a **protein**'s function. Most often though, the regulation is **epigenetic**. Epi- means 'on top of' or 'extra to'. Thus, epigenetic factors are those external to the gene itself (e.g. chemical tags) that influence how that gene is expressed. Epigenetic regulation is achieved by modifying the way the **DNA** is packaged and its availability to be transcribed. The DNA sequence is unchanged.

The regulation of gene expression in eukaryotes is a complex process beginning before the DNA is even transcribed. The packaging of DNA regulates gene expression either by making the nucleosomes in the chromatin pack together tightly (heterochromatin) or more loosely (euchromatin). This affects whether or not RNA polymerase can attach to the DNA and transcribe the DNA.



1. What is epigenetics? _____

_____

_____

2. (a) Describe the effect of histone modification and adding methyl groups on DNA packaging: _____

_____

_____

(b) How do these processes affect transcription of the DNA? _____

_____

_____

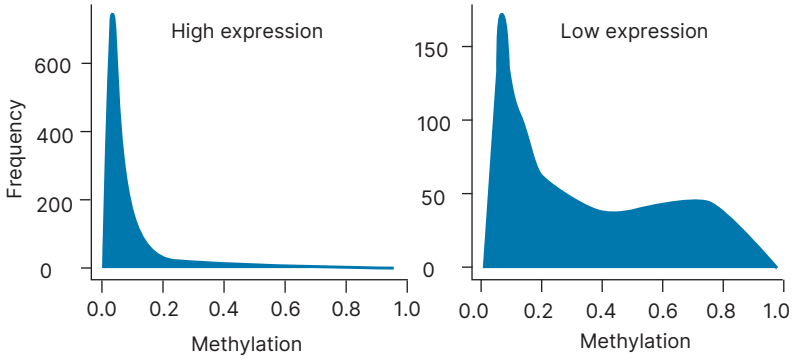
3. The graphs, right, show the relative amount of genomic methylation and the effect of this on the frequency of gene expression. Describe the relationship between methylation and gene expression:

_____

_____

_____

_____



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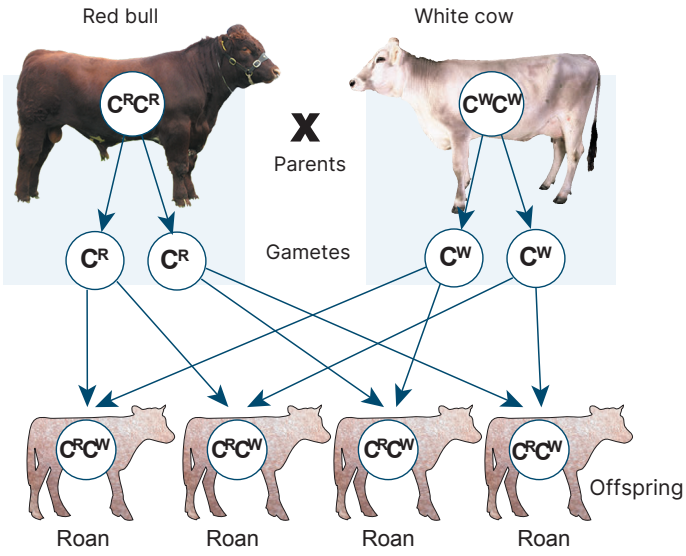
31 Codominance

Key Idea: In the inheritance of codominant alleles, neither allele is recessive. Both alleles are equally and independently expressed in the heterozygote.

Codominance is an inheritance pattern in which both alleles in a heterozygote contribute to the phenotype, and both alleles are independently and equally expressed. Examples include the human blood group AB, and certain coat colours in horses and cattle. Reddish coat colour is equally dominant with white. Animals that have both alleles have coats that are roan (both red and white hairs are present).



In the shorthorn cattle breed, coat colour is inherited. White shorthorn parents always produce calves with white coats. Red parents always produce red calves. However, when a red parent mates with a white one, the calves have a coat colour that is different from either parent: a mixture of red and white hairs, called roan. Use the example (left) to help you to solve the problems below.

1. Explain how codominance of alleles can result in offspring with a phenotype that is different from either parent:

_____

2. A white bull is mated with a roan cow (right):

   (a) Fill in the spaces to show the genotypes and phenotypes for parents and calves:

   (b) What is the phenotype ratio for this cross?

   _____

   (c) How could a cattle farmer control the breeding so that the herd ultimately consisted of only red cattle?

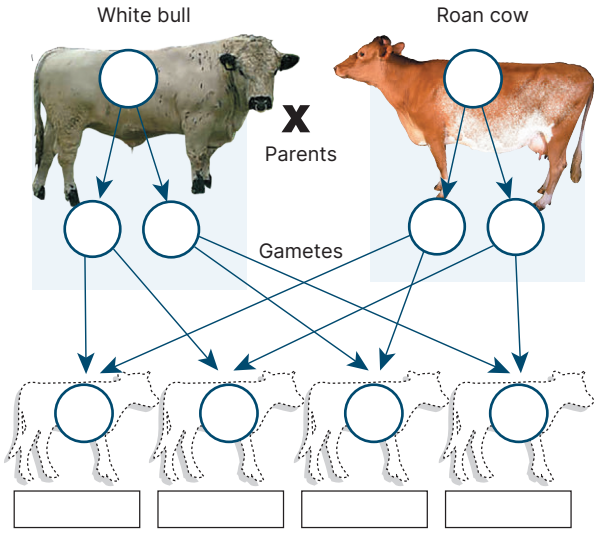
   _____

   _____

   _____

   _____

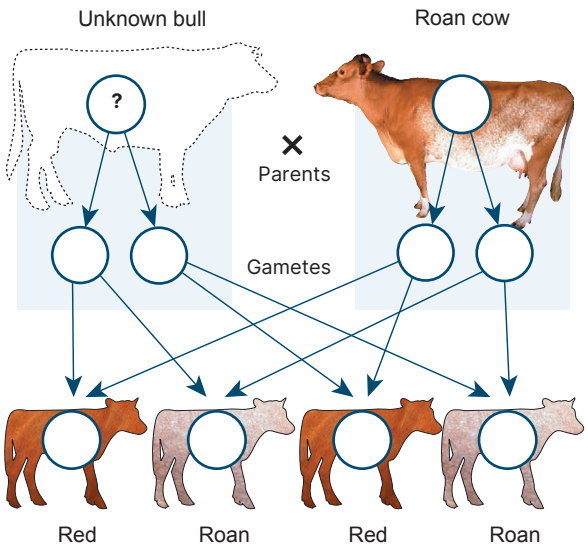
   _____



3. A farmer has only roan cattle on his farm. He suspects that one of the neighbours' bulls may have jumped the fence to mate with his cows earlier in the year because half the calves born were red and half were roan. One neighbour has a red bull, the other has a roan.

   (a) Fill in the spaces (right) to show the genotype and phenotype for parents and calves.

   (b) Which bull serviced the cows, red or roan? _____



4. Describe the classical phenotypic ratio for a codominant gene resulting from the cross of two heterozygous parents, e.g. a cross between two roan cattle:

_____

_____

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38 Pedigree Analysis

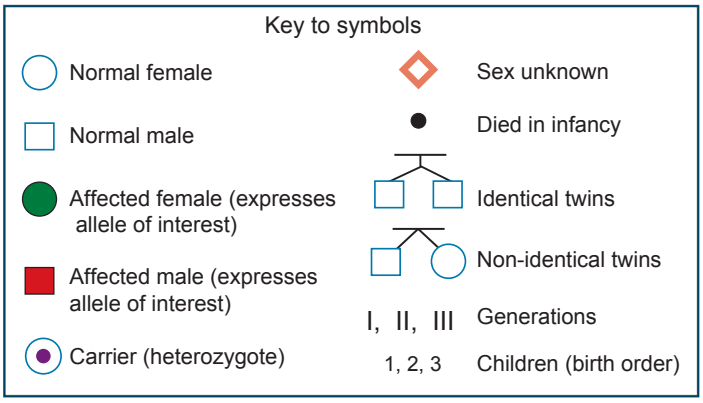
Key Idea: Pedigree charts are a way to graphically illustrate inheritance patterns over a number of generations.

One way in which to analyse the family history of an observable **trait** is to use a **pedigree chart** which follows certain rules and uses particular symbols to indicate the sex and **genotype** of individuals across generations.

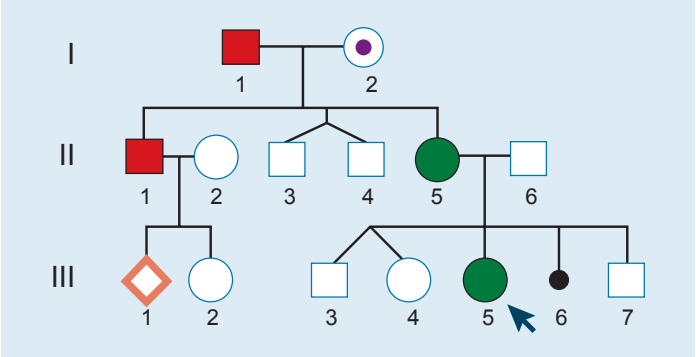
Pedigree charts

A pedigree chart is a diagram that shows the occurrence of a particular **gene** or trait from one generation to the next. In humans, pedigree charts are often used to analyse the inheritance of heritable conditions. In domestic animals, pedigree charts are often used to trace the inheritance of traits in selective breeding programs.

Pedigree charts use symbols to indicate an individual's particular traits. The key (right) explains the meaning of the symbols. Particular individuals are identified by their generation number and their order in that generational row. For example, **II-6** is the sixth person in the second generation. The arrow indicates the person through whom the pedigree was discovered (i.e. reported the condition).



The chart on the right represents three generations: grandparents (I-1 and I-2) with three sons and one daughter. Two of the sons (II-3 and II-4) are identical twins, but did not have any children. The other son (II-1) had a daughter and another child (sex unknown). The daughter (II-5) had two sons and two daughters, plus a child that died in infancy. Pedigrees can also indicate if a trait shows autosomal or **sex linked** inheritance. In autosomal patterns, both males and females are generally equally affected (more or less).



For the particular trait being studied, the grandfather was expressing the **phenotype** (showing the trait) and the grandmother was a carrier. One of their sons and one of their daughters also show the trait, together with one of their granddaughters (arrow).

1. (a) Very few traits are truly monogenic (controlled by a single gene). Most traits that behave in a monogenic way are in fact the outcome of multiple linked-genes inherited as one unit, effectively acting as a single gene. The ability to taste phenylthiocarbamide or PTC is one such trait. PTC is an organic molecule that for some people tastes very bitter, and for others is tasteless. The ability to taste PTC follows a very strong dominant/recessive inheritance pattern. The ability to taste PTC (T) is dominant to not tasting (t).

   A PTC tasting man (A), whose mother is a nontaster and whose father is a taster, marries a nontasting woman (B) whose parents both PTC tasters. They have a daughter who is a nontaster. Draw a pedigree showing all four grandparents, the two parents, and the daughter. Indicate each individual's possible genotype. Use filled shapes to indicate the recessive trait.

(b) Identify the individuals that are definitely heterozygous (carriers): _____

(c) Identify the individual that could be heterozygous (a carrier): _____

(d) What is the probability of couple A and B having a nontaster boy as their next child? _____

(e) Explain your reasoning: _____

ISBN: 978-1-99-101485-6

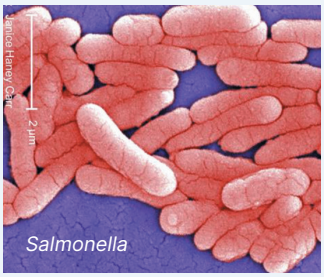
60 Pathogens and Infectious Disease

Key Idea: Pathogens are infectious agents that spread between organisms and cause infectious disease.

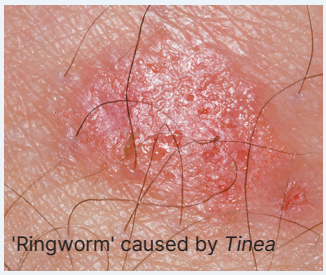
Pathogens are disease-causing agents and cause infectious disease. An infectious disease is a disease which can be spread between individuals. Pathogens can be classified in a number of different ways. Those which can be seen with the naked eye are called macroorgansims, while those which are too small to be seen with the naked eye are microorganisms. Pathogens can also be categorised depending on whether they are living organisms (cellular pathogens) or non-living organisms (non-cellular pathogens). Some common groups of pathogens are described below.

Cellular pathogens

Cellular pathogens are living organisms. They possess all the cellular machinery they need to carry out their life process and reproduce. Bacteria and eukaryotic pathogens (fungi, protists, and parasitic worms) are cellular pathogens. Cellular pathogens cause a wide range of diseases in plants and animals. The severity of the diseases they cause varies greatly: some have very mild effects (e.g. athlete's foot or ringworm), while some can cause death (e.g. TB or malaria).



CDC: Janice Haney Carr



Bacterial pathogens

Pathogenic bacteria can be transmitted through food, water, air, or by direct contact. Bacteria have caused widespread, devastating diseases, but the discovery and use of antibiotics and aseptic (sterile) techniques has reduced deaths.

Fungal pathogens

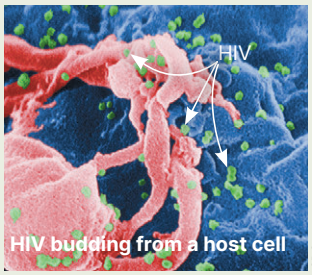
Pathogenic fungi are more common in plants than in animals. They spread by spores and the infections they cause are generally chronic (long-lasting, low grade) infections because fungi grow relatively slowly. However, some can be fatal.

Protistan pathogens

Protists are a large and diverse group of eukaryotes. A number of species are significant pathogens of animals or plants. Pathogenic protists have very complex life cycles, often involving a number of different hosts and several life stages.

Non-cellular pathogens

Non-cellular pathogens are non-living entities. Viruses and prions are both non-cellular pathogens. They do not have their own cellular machinery and must use a host's cellular machinery to reproduce.

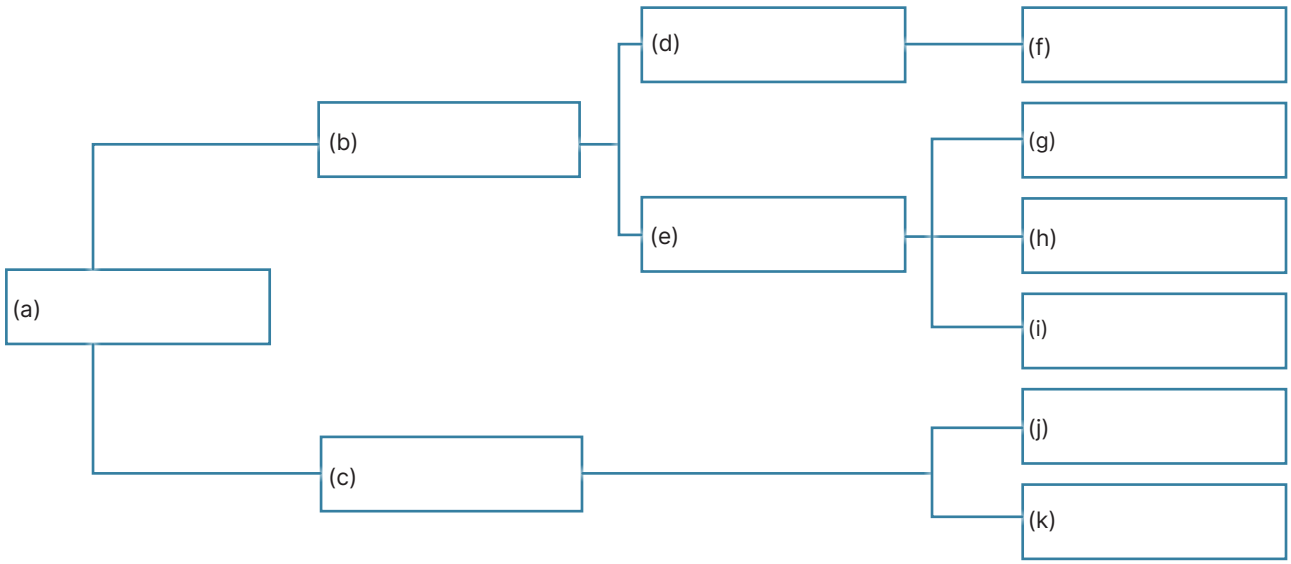


CDC

Viruses and prions

Viruses consist of a protein coat surrounding their genetic material. They cause a wide variety of diseases.
Prions are infectious, abnormal proteins which can damage other proteins. They cause a range of serious diseases.

1. Use the template below to categorise pathogens. Use the following word list to help you: *Cellular pathogen, virus, prokaryote, fungi, non-cellular pathogen, bacteria, pathogen, protist, parasitic worm, prion, eukaryote.*



2. Explain the difference between cellular pathogens and non-cellular pathogens: _____

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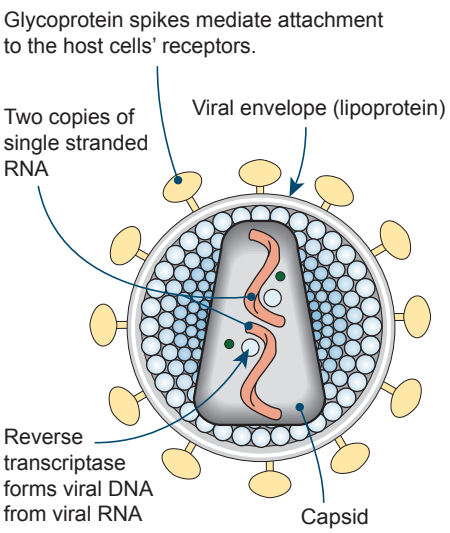
64 Viral Diseases

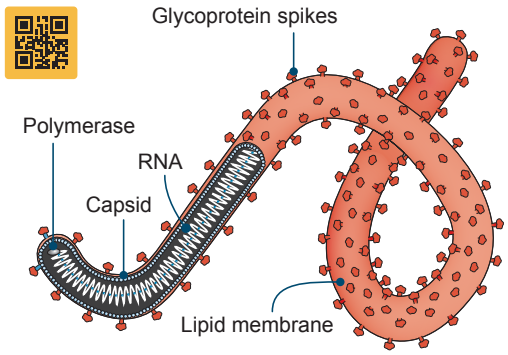
Key Idea: Viruses are infectious, highly specialised intracellular parasites. They are acellular and non-living.

Viruses are disease-causing agents (pathogens), which replicate (reproduce themselves) only inside the living cells of other organisms. Viruses are acellular, they are not made up of cells, so they do not conform to the existing criteria upon which a five or six kingdom classification system is based. A typical virus contains genetic material (DNA or RNA) encased in a protein coat (capsid). Some viruses have an additional membrane, called an envelope, surrounding the capsid. Many viruses have glycoprotein receptor spikes on their envelopes that help them to attach to the surface of the host cell they are infecting. Viruses vary greatly in their appearance and the type of host they infect (below).

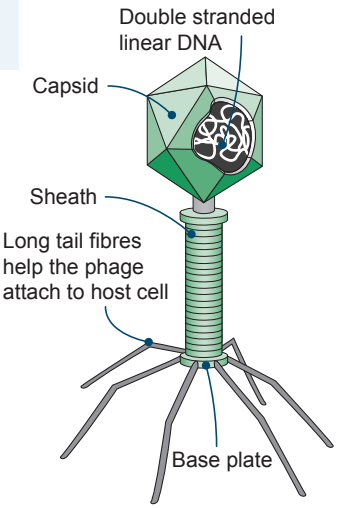
Viruses are not organisms! Viruses are metabolically inert until they are inside the host cell and hijacking its metabolic machinery to make new viral particles. However, they are often called microorganisms.



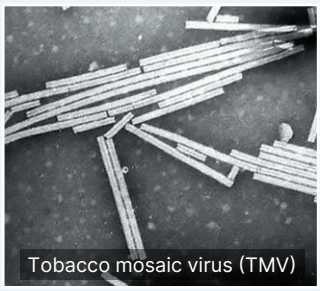
Structure of HIV, an enveloped retrovirus.



Structure of Ebola virus, an RNA filovirus that causes Ebola haemorrhagic fever.

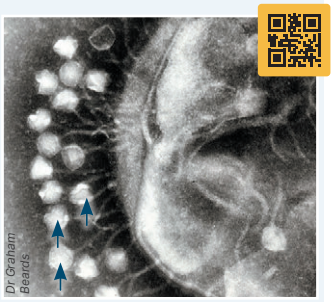


Structure of Lambda phage, a bacteriophage that infects E.coli.



After replication, new viral particles (virons) leave the host cell to infect more cells. In animals, enveloped viruses bud from the host cell, e.g. HIV (above left). Plant viruses cannot bud from the host cell due to the rigid cell wall. Instead, plant viruses, e.g. TMV (above right), move through the plasmodesmata connecting plant cells.

Viruses cause a wide variety of human diseases, e.g. colds, influenza, chickenpox, measles, Mpox, Covid-19 and life-threatening diseases such as Ebola (above).



Bacteriophages (arrowed) infect bacteria. They use tail fibres to attach to the host cell and a contractile region to inject their DNA into the cell.

1. Viruses are non-living. How do they replicate? _____

2. Describe the basic structure of a generalised virus, identifying the features they all have in common: _____

3. Describe the purpose of the following:

   (a) Glycoprotein spikes: _____

   (b) A bacteriophage's tail fibres: _____

   (c) Protein capsid: _____

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69 The Innate Immune Response

Key Idea: The innate immune response provides a rapid response to contain and destroy pathogens. Inflammation is an important part of the response.

The innate immune system provides protection against a pathogen, even if it has never encountered it before. The **innate response** is very fast and provides general protection (it is not **antigen** specific), but does not provide long lasting **immunity**. Many different cells and processes are involved. The primary outcome is to destroy and remove the cause of infection. This is achieved through containing the infection through **inflammation** and then recruitment of immune cells to destroy the **pathogen**. During this process, a series of biochemical reactions (the complement system) are activated to destroy the pathogen and recruit immune cells to the site.

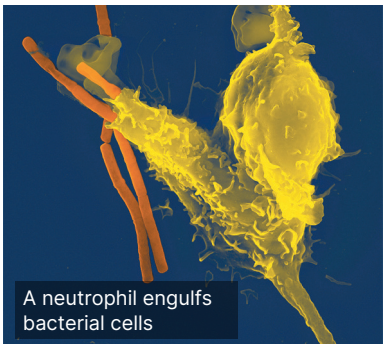
Phagocytic cells of the innate immune system


A macrophage stretches its 'arms' to engulf pathogens

Obli cc 2.0

Macrophage

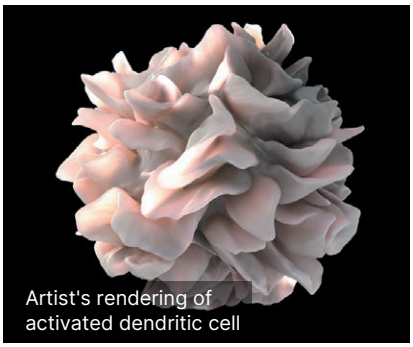
Macrophages are very large and are highly efficient **phagocytes**. They are found throughout the body and move using an amoeboid movement (above) to hunt down and destroy pathogens. Macrophages also have a role in recruiting other immune cells to an infection site.


A neutrophil engulfs bacterial cells

Volker Brinkmann PLOS cc 2.5

Neutrophil

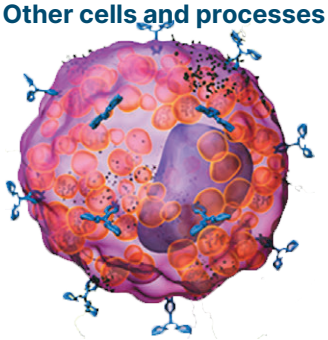
Neutrophils are the most abundant type of phagocyte and are usually the first cells to arrive at the site of an infection. They contain toxic substances that kill or inhibit the growth of bacteria and fungal pathogens. Neutrophils release cytokines which amplify the immune response and recruit other cells to the infection site.


Artist's rendering of activated dendritic cell

Dendritic cell

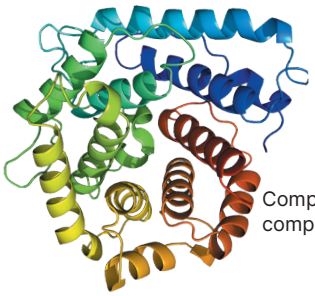
Dendritic cells are present in tissues that are in contact with the external environment (e.g. skin, and linings of the nose, lungs, and digestive tract). They act as messengers between the innate and **adaptive immune** system by presenting **antigen** materials to the **T lymphocytes** of the immune system.

Other cells and processes of the innate immune response



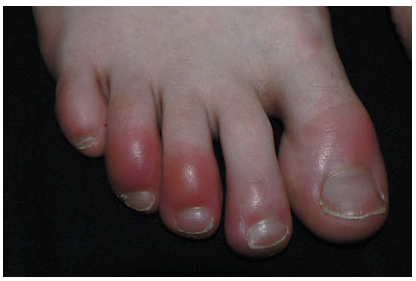
Mast cells

Mast cells contain a lot of histamine, a chemical involved in both inflammation and allergic responses. When activated, histamine is released from the mast cell causing the blood vessels to dilate and become leaky. The increased permeability allows phagocytes to reach the site of infection.


Complement component 3 (C3)

Complement proteins

The **complement system** comprises a number of different proteins. The proteins circulate as inactive precursors until they are activated. Complement proteins have three main roles: phagocytosis, attracting macrophages and neutrophils to the infection site, and rupturing the membranes of foreign cells.



The process of inflammation

The inflammatory process is a protective response to pathogen invasion. It has several functions: (1) to destroy the cause of the infection and remove it and its products from the body; (2) if this fails, to limit the effects on the body by confining the infection to a small area; (3) replacing or repairing tissue damaged by the infection.

1. Outline the role of the following phagocytes in the innate immune response:

(a) Macrophages: _____

_____

(b) Neutrophils: _____

_____

(c) Dendritic cells: _____

_____

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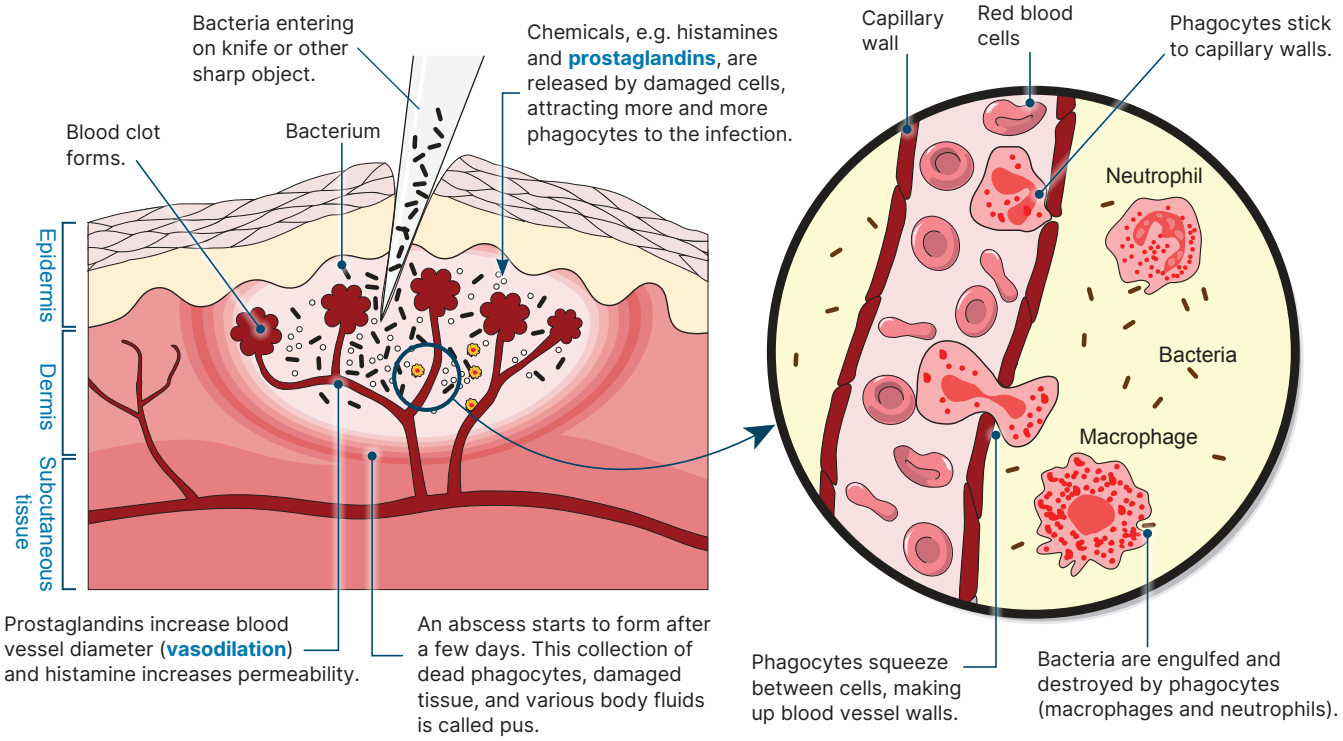
The inflammatory response



Stages in the inflammatory response

Increased diameter and permeability of blood vessels

Prostaglandins signal blood vessels to increase their diameter (vasodilation) and permeability in the area of damage. This increases blood flow to the area and allows defensive substances to leak into tissue spaces.

Phagocyte migration and phagocytosis

Within one hour of injury, phagocytes appear on the scene. They squeeze between cells of blood vessel walls to reach the damaged area, where they destroy invading microbes.

Tissue repair

Functioning cells or supporting connective cells create new tissue to replace dead or damaged cells. Some tissue regenerates easily (skin) while others do not at all (cardiac muscle).

2. What role does the complement system play in immunity? _____

_____

_____

3. Outline the three stages of inflammation, and identify the beneficial role of each stage:

(a) _____

_____

(b) _____

_____

(c) _____

_____

4. What role do mast cells play in inflammation? _____

_____

_____

5. Why does pus form at the site of infection? _____

_____

_____

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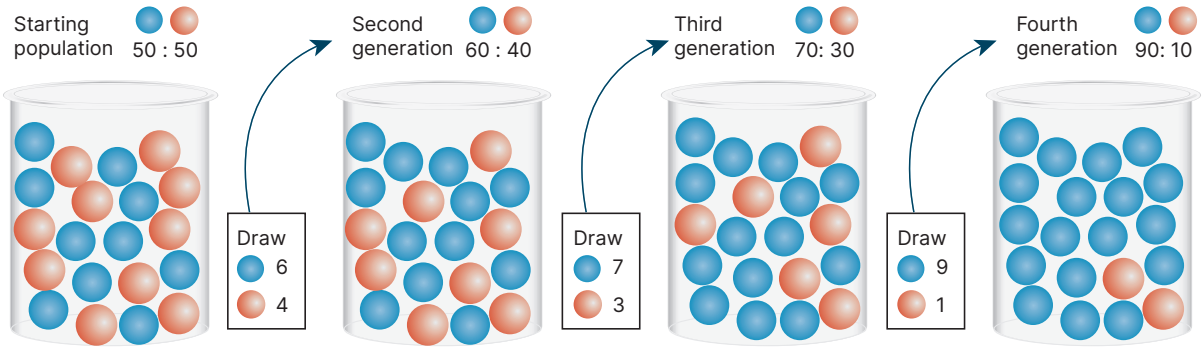
122 Genetic Drift

Key Idea: Genetic drift describes the random changes in allele frequency that occur in all populations. It has a more pronounced effect in small populations.

Not all individuals, for various reasons, will be able to contribute their genes to the next generation. Some individuals may suffer random events, e.g. dying in a storm, that prevent them from mating. This causes a random change in allele frequencies from generation to generation that is called **genetic drift**. It is the result of 'sampling error' in the selection of alleles from the current **gene pool** for the next generation (it is not an error of how we might observe or record breeding events). Genetic drift can cause alleles to become lost from the gene pool (frequency = 0%) or fixed as the only allele present for the gene (frequency = 100%). The effect of genetic drift on a gene pool is more pronounced in small populations

How does genetic drift reduce variation in populations?

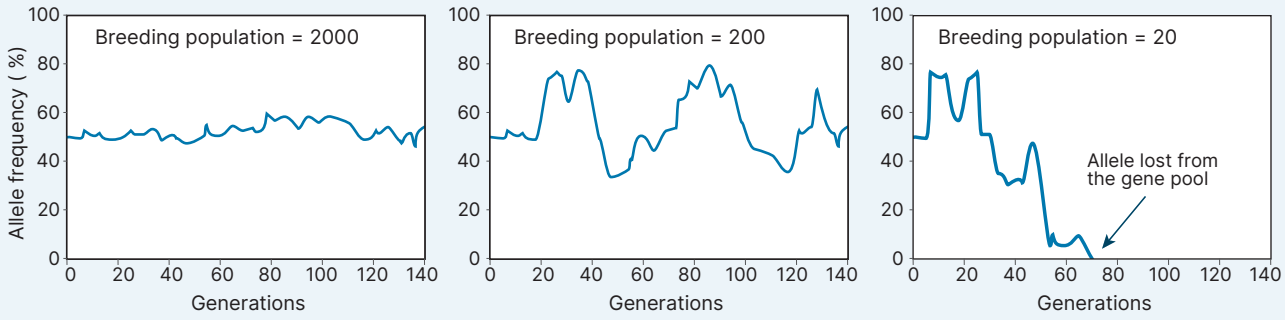
The change in allele frequencies within a population through genetic drift can be illustrated using the random sampling of marbles from a jar. The diagram below represents a population of 20 individuals. The different alleles are represented by blue and orange marbles. The starting population contains an equal number of blue and orange marbles. Random mating is represented by selecting 10 marbles at random. Twenty marbles representing the new allele proportions are placed into a new jar to represent the second generation, and the process is repeated for subsequent generations.



Computer simulations of genetic drift

- Computer simulations are used to carry out population experiments which are impractical to fully observe in wild populations. For example, the generation times may be too long or obtaining genetic samples impossible, or the population size can be changed, to observe the effect.
- In the example above, the orange marbles are becoming less frequent within the population and the amount of genetic variation within the population is reducing. Unless the proportion of orange marbles increases, it will eventually be lost from the population altogether and the allele for the blue marble becomes fixed (the only variant). How might the effect of genetic drift change larger populations of marble?

Below are displayed the change in allele frequencies in a computer simulation showing random genetic drift. The breeding population progressively gets smaller from left to right. Each simulation was run for 140 generations.



Large breeding population
Fluctuations are minimal because large numbers buffer the population against random loss of alleles. On average, losses for each allele type will be similar in frequency and little change occurs.

Small breeding population
Fluctuations are more severe in smaller breeding populations because random changes in a few alleles cause a greater percentage change in allele frequencies.

Very small breeding population
Fluctuations in very small breeding populations are so extreme that the allele can become fixed (frequency of 100%) or lost from the gene pool altogether (frequency of 0%).

1. What is genetic drift and why are its effects more pronounced in smaller populations?

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Island platypus and the perils of genetic drift

- A 2012 study of genetic diversity in platypus populations on mainland Australia, Tasmania, King Island, and Kangaroo Island has revealed very low immunological diversity in the island populations. The study (Lillie *et al.*) looked at the diversity of the MHC DZB gene and three MHC associated markers, all of which are involved in immune function. High allelic diversity in immune genes is important because it provides the variation necessary to resist different kinds of diseases. Without genetic variation, the population is likely to have low resistance to new diseases and environmental change.
- The study found that populations on the Australian mainland and in Tasmania have high levels of genetic diversity within their populations, with 57 DZB alleles identified in 70 individuals. However platypuses on King Island and Kangaroo Island (see maps), had very low levels of genetic diversity. For the King Island populations, there was no variation at all (only one allele at the DZB locus).
- Why is the genetic diversity of these island populations so low compared to the mainland populations? The Kangaroo Island population was founded from an introduction of around 20 animals in the 1930s and 1940s (founder population). The population on King Island is endemic, separated for some 14,000 years since the last ice age.
- Inbreeding in a small population and genetic drift have resulted in the loss of alleles and a dangerously low diversity in immune genes. These island populations will now need careful management to protect them from disease risk.

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Source: Diversity at the Major Histocompatibility Complex Class II in the Platypus, *Ornithorhynchus anatinus* Mette Lillie *et. al.* Journal of Heredity 2012:103(4):467–478

4. What factors have contributed to the low genetic diversity of the platypus populations on King Island and Kangaroo Island? Explain their effect(s):

5. Why would genetic drift have more impact on the genetic diversity of these populations than those on the mainland?

6. (a) Describe why a population with low MHC diversity is more likely to be affected by a new disease than a population with high MHC diversity:

   (b) Why is it important to try to keep small, isolated populations free of new diseases?

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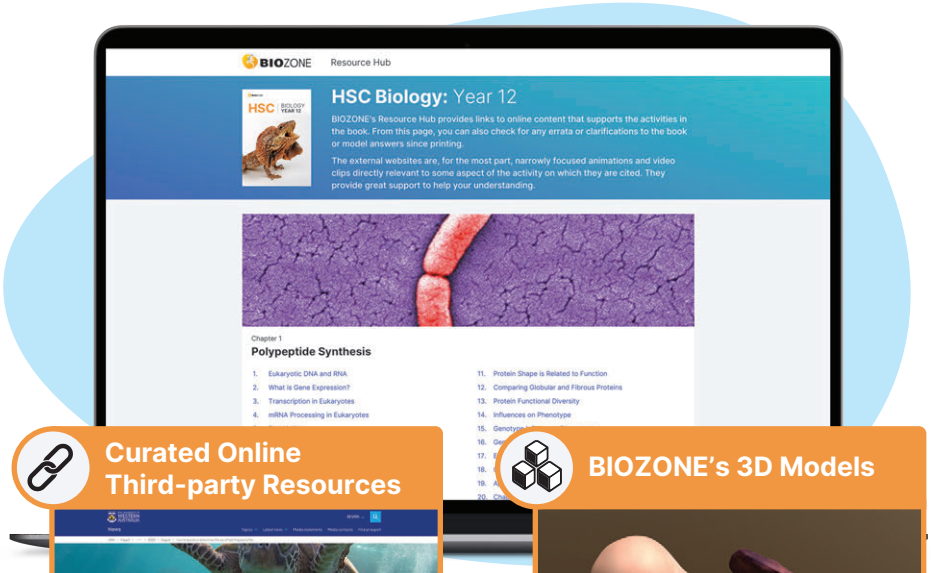

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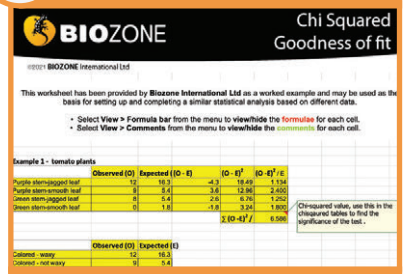

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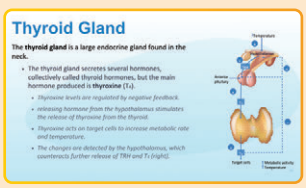

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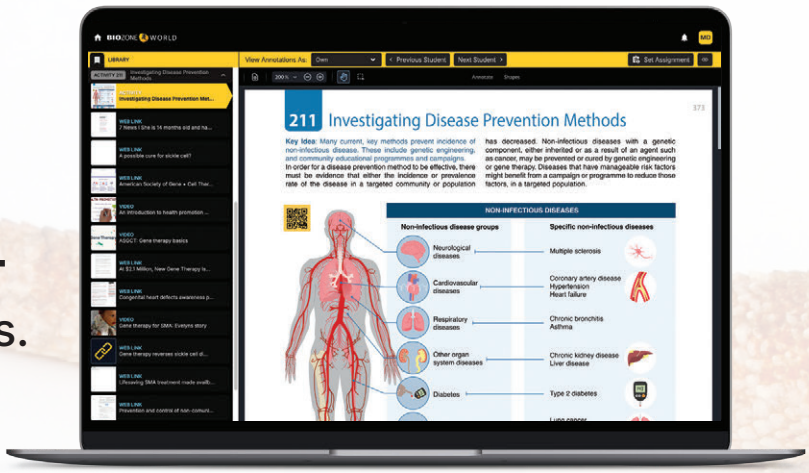

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