BIOLOGY
LEVELS OF LIFE

TEACHING NOTES

AUSTRALIAN CURRICULUM EDITION

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BRITON BOOKS · BIOLOGY: LEVELS OF LIFE ·

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AUSTRALIAN CURRICULUM EDITION

First published 2019. Revised January 2020, Revised February 2021, Revised April 2023

ISBN 978-0-9577554-6-8

Published by Briton Books, ADELAIDE, SOUTH AUSTRALIA
Designed and Printed by ApplePi Design, SOUTH AUSTRALIA

PROUDLY PRINTED IN SOUTH AUSTRALIA

Cover Photograph:
Cover photograph © Gary Bell/OceanwideImages.com
A leafy seadragon off the coast of Yorke Peninsula, South Australia
Leafy Seadragons*(Phycodurus eques)* are endemic to Australia and are found from Lancelin WA, to Wilsons Promontory, Vic, but are mostly sighted in South Australian waters and southern WA waters. The Leafy Seadragon is the marine emblem of South Australia.

2 The Language of Life

In eukaryotic cells, transcription occurs in the nucleus.

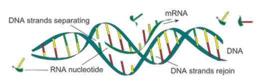
Describe and illustrate the role of DNA, mRNA, transfer RNA (tRNA), ribosomal RNA (rRNA) in transcription and translation.

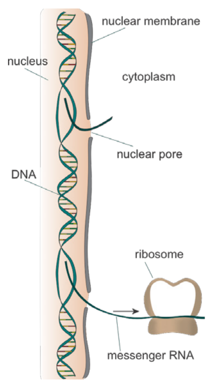
Protein Synthesis

Step 1: Transcription (in the nucleus)

DNA → RNA

- DNA strands separate at the site of the gene
- one strand of the DNA is used as a template for mRNA synthesis (base pairing rules apply, except that U joins to A)
- mRNA breaks away from DNA and travels through nuclear pores to ribosomes in the cytoplasm
- DNA strands rejoin



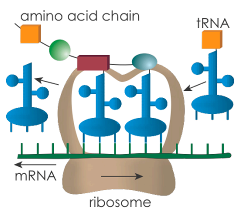


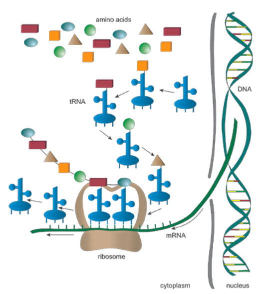
Describe the relationship between DNA codons, RNA codons, anticodons, and amino acids.

Step 2: Translation (in the cytoplasm)

RNA → protein

- mRNA attaches to ribosome
- tRNA molecules bring specific amino acids to the ribosome, according to the codon on the mRNA. (See Fig 2.9 mRNA codons on P16) Complementary base triplets on tRNA are called *anticodons*.
- polypeptide chain grows as the amino acids are joined
- completed polypeptide breaks away from ribosome and folds to form a 3D protein





Distinguish between coding (gene) and template strands of DNA.

A **gene** is a segment of DNA on a chromosome that contains the complete sequence of nucleotide bases that codes for a polypeptide or RNA molecule.

Note that it is the complementary strand of DNA, called the **template** strand, that is transcribed to form mRNA. The other strand is called the **gene**.

Note that the transcribed RNA molecule has the same sequence of bases as the **gene**, with U instead of T.

Recognise that DNA strands are directional and are read 5' to 3'.

By convention, humans read DNA and RNA in the 5' to 3' direction.

Ethical issues of genetic manipulation (optional)

- Environmental problems, other species affected
- Increased food production, cure genetic diseases
- Misuse of DNA technology (privacy, discrimination etc.)

Describe how CRISPR, such as CRISPR-Cas9, can be used to edit and/or transfer genes.

Clustered **R**egularly **I**nterspaced **S**hort **P**alindromic **R**epeats

- makes use of bacterial 'defence' mechanism against viruses
- loads a 'guide RNA' into a bacterial enzyme called Cas9 (**C**rispr **as**sociated protein **9**)
- The Cas9 protein then cuts DNA at a specific site determined by the sequence on the guide RNA
- Crispr is used in live cells to edit genes, switch them on and off, or 'knock them out'.

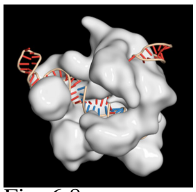


Fig. 6.8

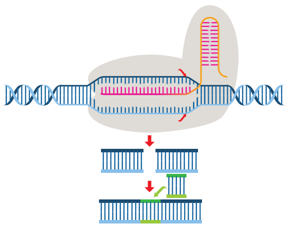


Fig. 6.9

Discuss the design of new proteins and their uses.

Design:
- determine the shape of the protein required
- determine the amino acid sequence need to produce this shape
- use genetic code to construct a DNA molecule to code for this protein
- incorporate DNA into bacterial cells (in plasmids)
- clone bacteria
- harvest proteins

Uses include:
- vaccines
- hollow protein spheres to deliver molecules such as pharmaceuticals
- channel proteins to regulate movement of specific substances across membranes
- proteins that change colour or glow when they detect specific molecules

Could refer to ELISA (enzyme-linked immunosorbent assay) – a test used to detect antibodies, e.g. Zika virus, AIDS, hepatitis C

8 Cell Structure and Function

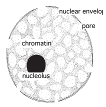
Eukaryotic cells have specialised organelles which facilitate biochemical processes.

Represent the structure and describe the function of:

- nucleus
- nucleolus
- mitochondrion
- chloroplast
- vacuole
- Golgi body (including vesicles)
- endoplasmic reticulum (rough and smooth)
- ribosome
- lysosome
- cytoskeleton

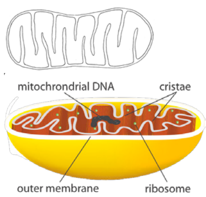
Organelles in eukaryotic cells:

Nucleus
- structure:
  - — nuclear envelope (double membrane) & pores
  - — chromatin (DNA & protein)
  - — nucleolus
- function:
  - — controls activities of the cell

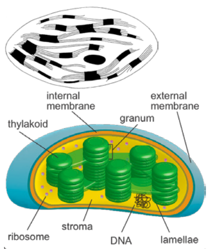


Nucleolus
- structure:
  - — not membrane-bound
  - — located in the nucleus
- function:
  - — synthesis of rRNA

Mitochondrion
- structure:
  - — double membrane with inner membrane folded to form cristae
  - — contains a circular chromosome
- function:
  - — site of latter stages of aerobic respiration, energy released and ATP formed



Chloroplast
- structure:
  - — double membrane
  - — grana (stacks of thylakoids), stroma (fluid)
  - — contains chlorophyll (on thylakoids)
  - — contains a circular chromosome
- function:
  - — site of photosynthesis



Note: mitochondria and chloroplasts divide independently of the cell

8 Cell Structure and Function

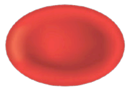
Main functions of the cytoskeleton

- maintain cell shape (e.g. nerve cell, rbc)
- cell movement (within cell and whole cell)
- hold organelles in place
- strengthens cells
- spindle apparatus (during cell division)

Cytoskeleton is made up of protein subunits that can be rapidly removed or inserted — a dynamic structure.

Compare the structures of plant, animal, and fungal cells

Structure	**Plant cell**	**Animal cell**	**Fungal cell**
cell wall	present	absent	present
cell membrane	present	present	present
nucleus	present	present	present
nucleolus	present	present	present
mitochondria	present	present	present
chloroplasts	may be present	absent	absent
vacuoles	large, central	small	present
Golgi body	present	present	present
endoplasmic reticulum	present	present	present
ribosomes	present	present	present
lysosomes	present	present	present
cytoskeleton	present	present	present



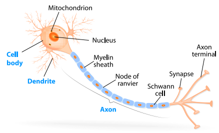


Fig. 8.17 and Fig. 8.18

Also, kinesin 'motors' move microtubules

12 New Cells from Old

Continuity of life requires the replication of genetic material and its transfer to the next generation through processes including binary fission, mitosis, meiosis, and fertilisation.

- Prokaryotic cells divide by binary fission.
- Eukaryotic cells divide by mitosis for growth and asexual reproduction.
- Sexual reproduction in eukaryotic organisms involves meiosis and fertilisation. These processes are explained in more detail in Chapter 13.

The products of binary fission and mitotic division have the same number and type of chromosomes as the parent.

This preserves the genetic information from one generation of cells to the next.

Recognise, describe, and represent the process of binary fission in prokaryotic cells.

Binary fission

Sequence:
- circular DNA (double-stranded) — replicated
- the two DNA loops attach to the cell membrane
- the cell membrane expands, DNA loops separate
- new cell wall is synthesised, cell divides
- the two new cells have identical chromosomes

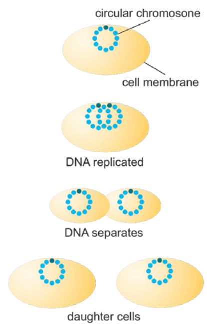


Fig. 12.5

Recognise, describe, represent, and name the phases of mitosis in eukaryotic cells.

Asexual reproduction

- the formation of offspring from a single parent without fertilisation taking place.

The role of mitosis in asexual reproduction

In **eukaryotes** asexual reproduction involves **mitosis**.
- the offspring are genetically identical to the parent – no other source of genetic material (DNA) is used
- genetic variation occurs only by mutation

Note that mitotic cell division is also the mechanism for **growth** (including maintenance and repair) in eukaryotic organisms.

13 Sexual Reproduction and Meiosis

Diploid cells contain pairs of homologous chromosomes. Haploid cells have one chromosome from each homologous pair.

Sexual reproduction

involves the mixing (fusion) of genetic material from two cells.

The cells that fuse are sex cells (gametes).

Production of gametes involves **meiosis**:

- four sex cells are produced
- each sex cell has half the number of chromosomes as original parent cell and is haploid.

Fusion of gametes is called **fertilisation**.

The cell that results from fertilisation is called a **zygote**. It is **diploid**.

Diploid cells contain pairs of **homologous chromosomes** that are chromosomes of the same type.

Haploid cells contain only one member of each homologous pair of chromosomes.

Advantage of sexual reproduction is **genetic variability of the offspring**. This is an important requirement for **natural selection**, the process by which evolution occurs — see Chapter 26.
Genetic variability increases the chances of survival for a species.

The diploid chromosome number is constant within a species.
For example:

human	46	vinegar fly	8
dog	78	goldfish	94
potato	48	koala	16

Recognise, describe, represent, and name the phases of meiosis in eukaryotic cells.

Meiosis - producing gametes

Involves two divisions – called meiosis I and meiosis II.

Four haploid cells produced.

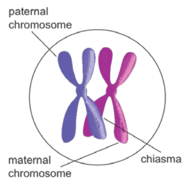


Fig. 13.1

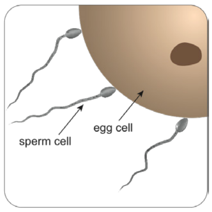


Fig. 13.2

Note that in many organisms, including humans, females produce one egg cell (ovum) and three 'polar bodies' per meiotic cell division. See glossary.

19 Homeostatic Control Mechanisms

Functions:

- filtration of blood from glomerulus to Bowman's capsule
- reabsorption of useful materials such as glucose, amino acids, some water and ions from tubule to blood capillary network.
- most of the wastes such as urea are excreted
- osmoregulation of water and solute balance according to the body's needs

Describe the effect of antidiuretic hormone (ADH) on the nephron in osmoregulation.

- osmoreceptors in the hypothalamus detect an increase in the concentration of solutes in the blood
- the hypothalamus then secretes ADH into the blood
- ADH binds to receptor molecules on the membranes of cells of the collecting ducts
- collecting duct walls become more permeable to water (due to increased presence of aquaporins in the membrane)
- this results in an increased reabsorption of water into the blood – a smaller volume of more concentrated urine is produced.

This is another example of a homeostatic control mechanism – if the osmoreceptors in the hypothalamus detect a *decrease* in the concentration of solute in the blood, there is a *decrease* in the secretion of ADH, and a resultant *decrease* in the reabsorption of water into the blood - a *larger* volume of less concentrated urine is produced.

Discuss the links between osmoregulation, blood volume, and blood pressure.

Osmoregulation is the control of the water and solute balance.

- an increase in the water content of the blood increases the blood volume.
- an increase in blood volume increases blood pressure.
- a *decrease* in water content of the blood decreases blood volume and blood pressure.

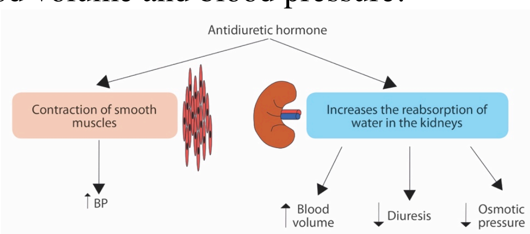


Fig. 19.7

The total reabsorption of water from the filtrate.is about 99%. About 70% of the water in the filtrate is reabsorbed along the renal tubule. The amount of water reabsorbed from the collecting ducts varies, and is regulated by ADH.

Note that ADH is also known as vasopressin.

Other hormones that affect osmoregulation include renin, angiotensin, and aldosterone. This is referred to as RAAS.

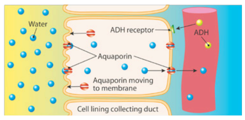


Fig. 19.5

Aquaporins are globular proteins that act as channels for the movement of water molecules across membranes.
(See also P88)

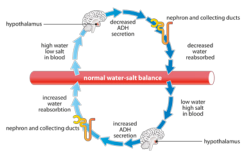


Fig. 19.6

ADH is released in response to lower blood pressure or lower blood volume

22 Evidence for Evolution

Advantage of sexual reproduction is **genetic variability of the offspring**. This is an important requirement for **natural selection**, the process by which evolution occurs — see Chapter 23.

Note: In asexually reproducing organisms mutation is the only source of genetic variation.

> Comparative genomics provides evidence for evolution and helps establish the likely evolutionary relationship between different species.

Remember that all organisms use the same genetic code. (See Chapter 1)

Since all life on Earth has a common ancestor, comparing the DNA sequences of different species provides evidence of their evolutionary relationships. This is called **comparative genomics**.

Describe how evidence from the following techniques may be used:

- sequencing of common proteins (e.g. cytochromes)
- DNA-DNA hybridisation
- DNA sequencing, including rRNA gene sequencing in prokaryotes

Sequencing of common proteins

Comparison of proteins, such as *cytochrome c* can be used, as it is found in all organisms that respire aerobically. The sequence of amino acids in *cytochrome c* of different species varies slightly, and these differences indicate how closely related the species are.

Of course, the amino acid sequence in proteins reflects the base sequence in DNA.

DNA-DNA hybridisation

Describe the technique of DNA-DNA hybridisation

DNA from different species is mixed and then heated to separate the strands. The extent to which strands from different species join on cooling indicates how closely related they are. This can be determined by re-heating the 'hybrid' DNA. The higher the temperature required to separate the strands, the more similar they must be.

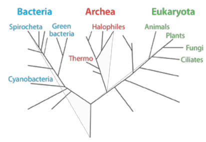


Fig. 22.3

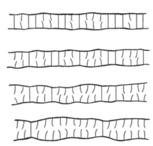


Fig. 22.4

24 Speciation and Evolution

Speciation may result from an accumulation of genetic changes influenced by different selection pressures or genetic drift in geographically isolated populations.

Speciation refers to the formation of two or more species from one.

Allopatric speciation

Describe the process of allopatric speciation.

- A single population may be split into two or more separate populations by a geographical barrier. (Examples of geographical barriers include valleys, rivers, deserts, mountain ranges, oceans.)
- This prevents gene flow between the populations.
- If the environmental conditions on either side of the barrier are different, there will be different selection pressures on each of the separated populations.
- Over many generations the populations may become so different from one another that they can no longer interbreed and produce fertile offspring.
- They have become **reproductively isolated**, and are now separate species.

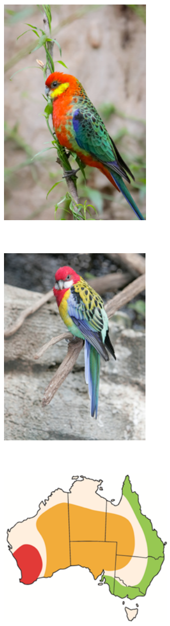


Fig. 24.1

Sympatric speciation (not required from 2023)

Sympatric speciation refers to the formation of two new species from a common ancestor while living in the same area, without separation by a geographical barrier.

For example, some new plant species have formed in the same area as a result of hybridisation and/or polyploidy.

Examples of sympatric speciation in animals are rare. It is more common in plants and bacteria.

Polyploidy results from an organism having more than two sets of chromosomes.

Similar selection pressures on unrelated species may lead to convergent evolution.

Unrelated populations occupying the same ecological niche in different environments are subject to similar selection pressures.

Similar selection pressures may or may not be in the same locations; e.g. the deserts of North America and Australia are different locations, but the ocean as the environment for sharks and dolphins is the same location.

24 Speciation and Evolution

Therefore similar features tend to be selected, resulting in **convergent evolution**.

Recognise and give examples of convergent evolution.

- Australian marsupials and North American placental mammals
- African desert plants and American desert plants
- dolphins and sharks
- the vertebrate eye and the cephalopod eye
- the wings of birds and the wings of bats

Fig. 24.3

Different selection pressures may lead to divergent evolution or adaptive radiation.

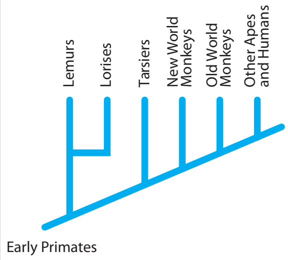


Fig. 24.4a

Recognise and give examples of divergent evolution and adaptive radiation.

Divergent evolution – evolution of different characteristics from a common ancestor.

A common example of divergent evolution is the evolution of primates.

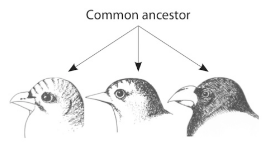


Fig. 24.5

Adaptive radiation – a special case of divergent evolution – a sudden emergence of new species. It is usually due to a change in the environment, or organisms relocating.

Examples of adaptive radiation include:

- Darwin’s finches
- Australian marsupials
- Caribbean anole lizards

24 Speciation and Evolution

Succession is the gradual change in the mix of species over time, following a disturbance.

Communities are continually undergoing change

These changes may be due to environmental changes that happen very slowly or quite rapidly. Examples are:

- very slow —
  change in climate due to continental drift. (Australia is moving towards the equator at about 7cm per year.)
- rapid —
  volcanic eruption (Mt. St. Helens in the USA wiping out a forest in 1980)
  bushfires in Australia
  tsunamis, such as Anak Krakatoa, Indonesia in 2018

Describe the processes of primary and secondary succession.

Succession

leads to a change over time in the mixture of species in a community.

Examples include the recolonisation of the volcanic island Krakatoa off the coast of Java, Indonesia.

There is a natural sequence of the establishment of communities on bare surfaces, such as rock.

- the first organisms, called **colonisers** or **pioneers** are blue-green bacteria, lichens, mosses or simple grasses
- this is followed by larger plants, such as ferns, small shrubs and bushes — the immature phase
- finally, larger and longer-lived plants, such as trees, become established — the climax community

Each stage of organisms in this succession alters the biotic and abiotic conditions of the area, making it suitable for the next stage of organisms.

When the volcano Krakatoa blew up in 1883 bare rock was the result. Succession has resulted in the eventual formation of tropical rainforest.

- **primary succession** — succession on bare rock (no soil)
- **secondary succession** — succession in areas in which soil is present (e.g. following a fire or flood)

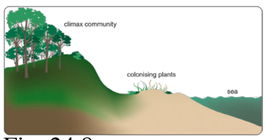


Fig. 24.8

See textbox HUMANS AND SUCCESSION on P191