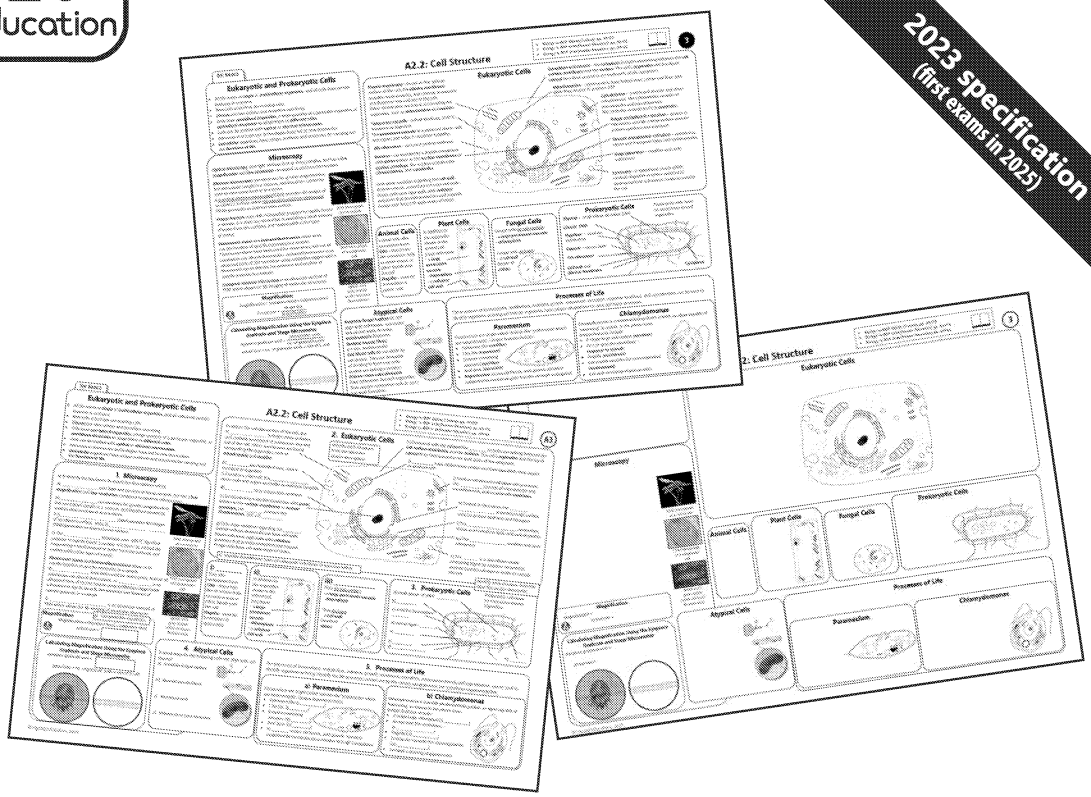
Zig Zag Education

Biology International Baccalaureate Diploma Programme

2023 specification (first exams in 2025)



Topic on a Page

for IB Biology:

Theme A – Unity and Diversity

zigzageducation.co.uk

POD 12758

Contents

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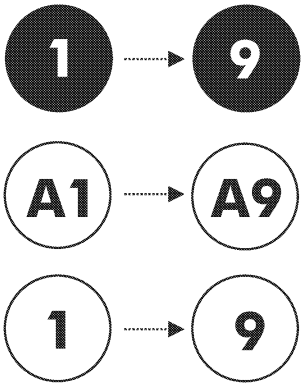
Teacher's Introduction

This Topic on a Page resource has been designed to help your students revise the key points of each topic and test their knowledge after you have taught each section of the **IB Biology: Theme A Unity and Diversity** specification from topics 1 to 4. Each page is closely tied to the IB specification, ensuring all aspects of the course are covered.

There are four sections to this resource, each with its own features:

1. **Summary posters**: these are the main pages which intend to clearly consolidate and recap all the key information from the IB Biology course.
2. **Activity worksheets**: these are identical to the Summary posters, but contain a variety of tasks, from filling in missing words to performing calculations. The activity worksheets aim to ensure the student understands all the key knowledge required of them and gives them the opportunity to demonstrate how well they have remembered and understood the content of the course.
3. **Outline-only pages**: these are the Summary posters, but with most of the content removed. Students can research the topics, e.g. for homework, and fill in as much information as they can.
4. **Mark scheme**: full answers for the activity worksheets.



The Summary posters, Activity worksheets and Outline-only pages are designed to be A3 size, although they are still useable at A4 with no loss of detail. If using at A4 size, we suggest photocopying each A3 'worksheet' (for writing answers) as a double-sided A4 page to avoid shrinking the space available for answers.

Each page presents information in a variety of ways, including:

- **Key terms** – key terms are identified in bold type. Students should be encouraged to make a glossary of these key terms and ensure that they know the exact meaning of each one.
- **Bullet point processes** – complex processes and lists have been summarised into quick, easy-to-learn points.
- **Illustrative diagrams** – detailed diagrams that visually represent a concept.
- **Exam tips** – aid memorisation, revision and exam technique in areas where students typically struggle.
- **Textbook links** – allow students to refer to specific, related material in the major textbooks: *Biology for the IB Diploma Programme* (Hodder Education), *Higher Level Biology for the IB Diploma Programme* (Pearson Education) and *2023 Edition Biology Course Companion* (Oxford University Press).

Additional higher level content has been marked with this symbol for easy reference. Note that some subtopics are HL only.

We hope you find these pages useful during your teaching and your students' revision.

Students' Introduction

This Topic on a Page resource is designed to help you revise the 2023 IBDP Biolog
at A3 size, but detail is still clear at A4.

There are four sections to this resource, each with its own features:

1. **Summary posters**: these are the main pages, with key words shown in bold,
identified with darker backgrounds and a symbol, plenty of diagrams, and a
concepts. It is recommended that you make a glossary of all of the key term
important that you make sure you can define and describe each word!

2. **Activity worksheets**: these are identical to the Su[illegible]ry posters, but with o
from filling in missing words to sketching gra[illegible]hs.

3. **Outline-only pages**: these a[illegible] mary posters, but with most of the co
chance to research the topics and fill in as much information as you can.

4. **Mark s[illegible]**: this has the answers for every question in the activity worksh
given to each answer. It also says what answers would and would not be acc
make sure you get it right on the day!

The basic way of using this resource to revise is to read a page, cover it, complete
worksheet, and then check your answers, using either the main topic page or the
that – it's up to you! Other ways of using this resource to revise include:

- copying boxes onto flash cards
- using the key words to make mind maps
- colouring in boxes once you are confident you know them
- keeping track of revision by colouring in the activity page numbers once you
- copying out diagrams, tables and graphs and testing your knowledge comple
- or just wallpaper your room with them and keep looking at them bit by bit!

We hope you find these pages useful during your revision and good luck with you

THE BASICS

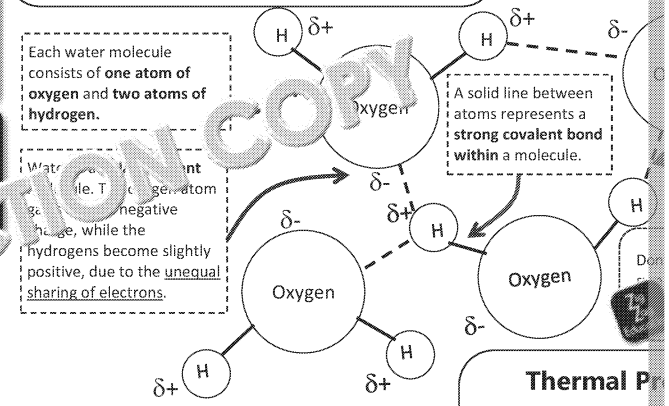
A1.1: Water

Water

- Due to its unique properties, water is the medium for life.
- The polar covalent bonds within water molecules lead to hydrogen bonds between water molecules, and between water molecules and other substances leading to many of water's unique properties.

- Earth's water has an extraplanetary origin.
- The **'Goldilocks zone'** represents the region of a solar system which could contain planets with **liquid water**, and refers to the **habitable zone** around a star.

Molecular Structure of Water

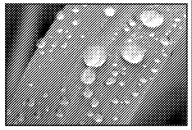


Cohesion and Adhesion

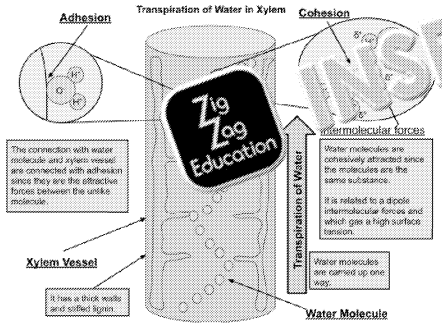
Cohesion is the force of attraction between water molecules. It is generated by hydrogen bonds which form between the hydrogen atoms and oxygen atoms of **different** water molecules.

Cohesion generates the high **surface tension** of water, which is important for many small aquatic organisms which make water their habitat.

Adhesion is the force of attraction between a water molecule and another material, such as the **cellulose** which plant cell walls are made of.

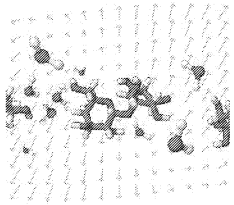


Cohesion and adhesion work in combination in **capillary action**; this is when water is drawn up a vessel in a narrow column, due to strong force of cohesion created between water molecules, and the strong force of adhesion created between the water molecules and the material of the vessel walls. The most obvious biological use for this is **transport** in plants, but it also allows water to soak up through soils making it available to plants, and allows our tears to drain through our tear ducts.



Water as the Universal Solvent

Due to its polar nature, water is an excellent **solvent**. Ionic molecules such as salts are easily 'pulled apart' by water due to the attraction the ions have with different parts of the water molecule. Small organic molecules such as sugar also dissolve easily in water due to the hydrogen bonding which forms between the individual sugar molecules and the water.



Solution of sucrose in water

This means that water is an excellent medium for life, allowing:

- reactions between dissolved molecules; thus essential for metabolism.
- easy transport of dissolved molecules (e.g. mineral ions, nutrients, and hormones in the blood)
- holding many dissolved substances in the same space (e.g. a cell)

Molecules which dissolve easily in water are known as **hydrophilic**, while those which do not (usually lipid-based molecules) are known as **hydrophobic**.

Application

Emulsion Test

- Add ethanol, shake
- Add water, shake
- Turns cloudy if lipids are present

Why does the emulsion test for lipids work? What is happening which causes the mixture to turn cloudy?

Thermal P

The **specific heat ca** 4200 J/(kg•°C); it tak water by just 1 °C. T the temperature of organisms themselv their water content. Water also has a rela **conductivity**. This is become hypotherm

Buoyanc

Due to the strong at between water mole water is quite dense pulled apart. This ge which helps marine o their depth under wa

Water acts as a **meta**

- **Condensation** rea (e.g. cellulose, str
- **Condensation** rea (e.g. starch an
- **Hydrolysis** re

Application: C

Black-throated loon

- Lighter but non-holl also allow the loon
- Adaptations to the h **viscosity** of water m difficult for loons to
- Interlocking feather generates a barrier and provides insula

THE BASICS

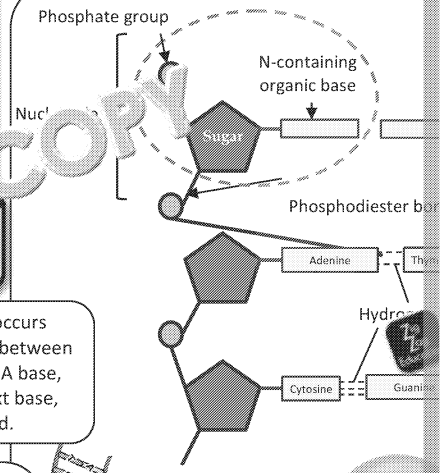
A1.2: Nucleic Acids

DNA and RNA

- **DNA** is the **genetic material** in all organisms, while the **genetic code** is shared by all known life. This universality is evidence for the shared ancestry of all life on Earth.
- A **nucleotide** consists of a sugar (**deoxyribose** or **ribose**), a **phosphate** group, and a **nitrogenous base** (**adenine**, **guanine**, **cytosine**, **thymine** (DNA only), or **uracil** (RNA only).
- The bases form a code, while **complementary base pairing** ensures accurate transfer of this code.
- The possible diversity in the sequence of bases is effectively infinite.

HL

- Bonding between **purines** and **pyrimidines** helps to ensure genet[illegible]
- The work of multiple scientists, including Hershey, Chase, Chargaff, [illegible] provided evidence which allows us to understand the stru[illegible] and processes involving DNA.

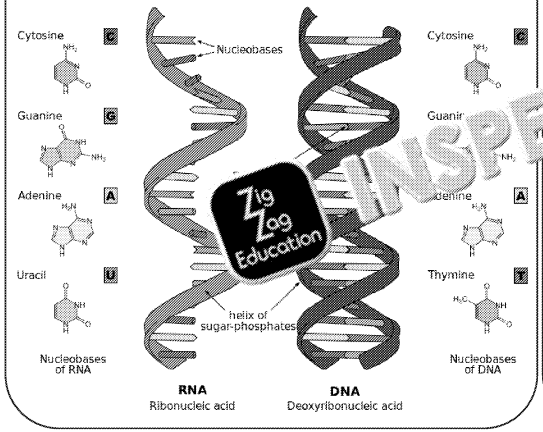


Polymerisation of nucleic acids occurs through condensation reactions between the phosphate of one DNA or RNA base, and the pentose sugar of the next base, forming the phosphodiester bond.

RNA vs DNA structure

There are a few key differences between DNA and RNA.

Ribonucleic acid (RNA)	Deoxyribonucleic acid (DNA)
• **Ribose** sugar	• **Deoxyribose** sugar
• **Uracil**	• **Thymine**
• Short, single chain	• Long, double-stranded helix
• Temporary less-stable molecule	• Long-lived stable molecule
• Transfers genetic information during protein synthesis	• Stores genetic information
• A structural component of **ribosomes**	• Can exist in association with **histone** proteins to form **chromatin** (the material **chromosomes** are made of)
• Three main kinds: rRNA, mRNA and tRNA	

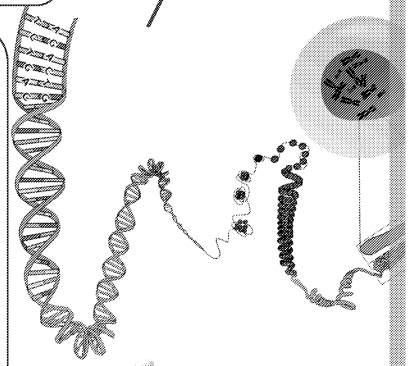


DNA consists of a sequence of four bases, which can occur in any order, while the DNA molecule can be any length. The number of possible sequences in a DNA molecule can be mathematically calculated using the formula 4^n, where n is simply the length of the DNA molecule in terms of the number of bases.

e.g. for a molecule 8 base pairs long:

$4^8 = 65\,536$ possible sequences

This means that DNA can effectively store an infinite amount of info[illegible]

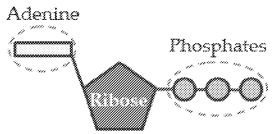


ATP

Adenosine triphosphate (ATP) is very similar in structure to an RNA nucleotide. Through hydrolysis, it provides an **immediate** source of energy for cells.

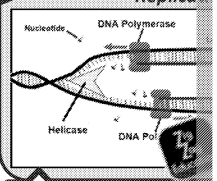
Used in:

- muscle contraction
- nerve cells
- active transport
- metabolic processes



HL

Whether in DNA replic[illegible] **5' to 3' direction**. This [illegible] ***Replica[illegible]***



HL

Scientist	
Hershey and Chase	Used ra[illegible] proteins
Chargaff	Used pa[illegible] amount

THE BASICS

A2.2: Cell Structure

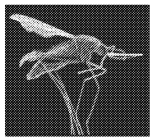
Eukaryotic and Prokaryotic Cells

- All life exists as **single** or **multicellular organisms**, and all cells have certain features in common.
- New cells arise from pre-existing cells.
- **Viruses** are non-cellular and therefore non-living.
- Cells have **specialised organelles**, a large quantity of a particular organelle, or **specialised structures** to adapt them to **different roles**.
- Cells can be studied with **optical** or **electron microscopes**.
- Advances in microscope technologies have led to new discoveries.
- **Unicellular** organisms have unique methods and structures for carrying out the **functions of life**.

Microscopy

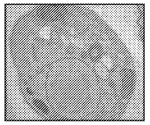
Optical microscopy uses light and can look at living specimens, but has **low magnification** and **low resolution** compared to electron microscopes.

Electron microscopes use electrons to give greater magnification, but use a dead sample in a vacuum and therefore cannot be used to view movement or living specimens.
A scanning electron microscope (SEM) provides 3D images of an object's surface, while transmission electron microscopy (TEM) generates an internal cross section.



SEM micrograph of a mosquito

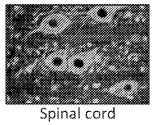
Freeze-fracture uses -190 ºC liquefied propane to rapidly freeze a sample. It is then cut, etched (by evaporating a small amount of water from the surface), and coated (with a thin layer of metal).



TEM micrograph of a eukaryotic cell

Fluorescent stains and **immunofluorescence** allow us to see the location of specific molecules in a sample.
Fluorescent stains have been used for many years, but not all substances can absorb these stains. Immunofluorescence is an advanced form of this technique using antibodies tagged with a fluorescent dye to identify the presence and location of specific proteins in a sample.

Cryogenic electron microscopy is an advanced method of TEM which allows for 3D imaging of molecular structures.



Spinal cord grey matter under immuno-fluorescence

Magnification

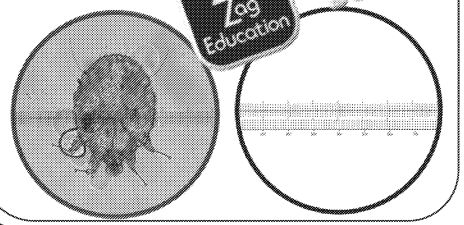
Magnification = (eyepiece lens) × (objective lens)

$$\text{Actual size} = \frac{\text{Image size}}{\text{Magnification}}$$

Calculating Magnification Using the Eyepiece Graticule and Stage Micrometer

eyepiece graticule unit = $\frac{\text{micrometer units}}{\text{no. of graticule units}}$

actual size = no. of graticule units × eyepiece graticule unit



Eukary

Plasma membrane – found on the outside surface of the cell, the **plasma membrane** includes many proteins, and controls movement of substances into and out of the cell. Other membranes are found surrounding the organelles, such as mitochondria and vesicles.

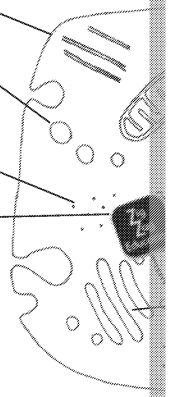
Temporary vacuole – fluid-filled sac, used in digestion

Permanent vacuole in a plant cell stores salts and sugars and helps to maintain turgidity.

80s ribosomes – carry out protein synthesis

Nucleus – surrounded by a double membrane with **pores** known as the **nuclear membrane** or **nuclear envelope**, the nucleus contains the **chromosomes**, and a **nucleolus**

Cells show variation regarding the **cell wall**: Animal cells (as shown) do not have cell walls. Plants cells have rigid walls with **cellulose** polymers that provide protection and support. Fungal cells have cell walls made of chitin.

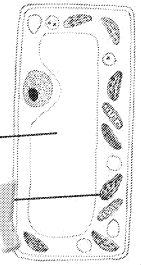


Animal Cells

Animal cells also sometimes have:
Cilia – these hair-like structures help to move mucus or other liquids past the cell
Flagella – used for locomotion in sperm cells

Plant Cells

In addition to the organelles shown in the animal cell, plant cells have:
- a **large permanent vacuole**
- **chloroplasts**
- **cell wall**



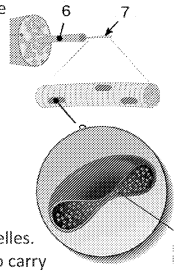
Fu

Fungal cells
- a **large** per
- **chloroplas**

Fungal cells
- a **cell wal**
(made of **chitin**)

Prokaryotic Cells

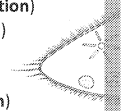
Prokaryotic cells do not follow cell theory, due to the lack of end walls, forming **multinucleate** filaments.
Skeletal muscle fibres are also multinucleate.
Red blood cells do not abide by cell theory. They are incapable of dividing to form new cells, as they are lacking a nucleus.
Phloem sieve tube elements have cytoplasm, but lack organelles. They require companion cells to carry out most functions.



The processes of homeostasis, metabolism identify organisms as living. Unicellular

Paramecium

Paramecium are single-celled 'animals' that are heterotrophic. Unique features include:
- Cytosome (for **nutrition**)
- Cilia (for **movement**)
- Enzyme-containing vacuoles (**nutrition**)
- Anal pore (**excretion**)
- **Reproduction** occurs via fission, with supported by horizontal gene transfer



A2.1: Origins of Cells & A2.2: Cell Structure - additional higher level only

HL

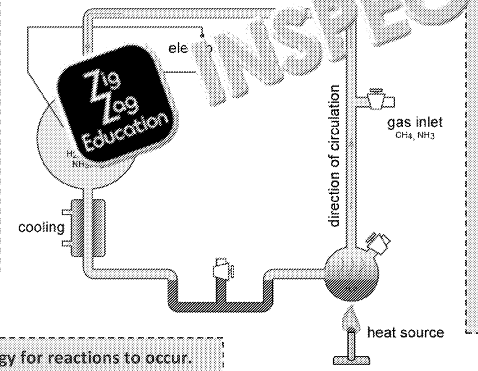
THE BASICS

How could life begin?

- The early **atmosphere** was very different from what it is like today.
- The first **cells** represent the first life.
- There is evidence supporting the **spontaneous generation** of various cell components: including carbon compounds (Miller–Urey experiment), RNA, and vesicles.

The Miller–Urey Experiment

Replicating the early atmosphere. A mixture of CH_4, NH_3 and H_2 was placed in a 5L flask in the ratio 2:2:1, while H_2O was evaporated from a smaller flask.



Provision of energy for reactions to occur. An electrical spark was continuously discharged from two electrodes to simulate the frequent lightning expected to occur in conditions on the early Earth.

Collecting the molecules. The apparatus was cooled so that water vapour condensed and collected in a u-shaped tube at the bottom of the apparatus.

The evidence. The water collecting gradually changed from clear, to pink, to dark red, and became increasingly turbid. Chromatography of the mixture proved the presence of 3–5 amino acids.

Recent repeats of this experiment have yielded many more amino acids, probably due to more advanced detection methods.

Conditions on Ear

Earth formed roughl... ...n years ago. Gases would have ... atmosphere ... be... very different from what it is to...

- ... ..., if a... ...ee **oxygen**
- ...o **ozo**... ...ng to high levels of **UV radiation**)
- ...vels of CO_2 and CH_4 (leading to **high temperatures**)

Ocean chemistry is also likely to have been quite different, ... significantly from as low as pH 5 to as high as pH 11.

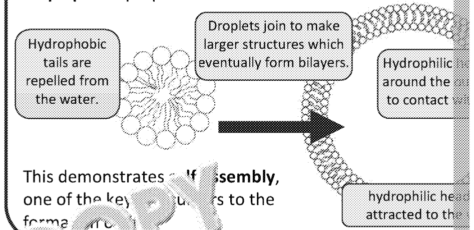
Such conditions may have allowed a variety of carbon comp... would not be possible today.

- High levels of UV could have provided the activation ene... spontaneously today.
- Frequent lightning could also have been a source ...
- **Pre-biotic carbon compounds** could have formed in a va... droplets, hydrothermal vents, and hot springs.

Vesicle Formation

Compartmentalisation, the separation of cell componen... reactions from an external environment, is an essential precursor to life. This function could have been carried ou... **vesicles** which spontaneously formed.

Phospholipids naturally form vesicles in water due to thei... **amphipathic** properties.



This demonstrates ...lf ...ssembly, one of the key ... ...rs to the forma...

THE BASICS

Last Universal Common Ancestor

- The **universal genetic code** and **shared genes** found in all known organisms provide strong evidence for the existence of a **LUCA**.
- The **LUCA** is expected to have existed around 3.4–4.5 bya
- Evidence points towards the **LUCA** evolving around h... ...

LU...

The ...iv...sa... of the genetic code s...p...s the theory that all life on Earth is descended from a single common ancestor species (**LUCA**).

Certain cellular proc... ...carr... ...t... ...cells are supported by enzymes or sections of RNA which remain ... ...l ext... ...organisms, from bacteria to humans. This further supports the idea of a **universal c**... ...**r**.

Rocks dating to aroun... ...ya have been shown to contain fossil-like structures. Isotopic analysis of these 'fossils' also suggests they formed from once living material. Meanwhile stromatolites (rock formations formed by colonies of cyanobacteria) have been dated to 3.4 bya. It is important to note that other early life may have pre-existed LUCA, but was later outcompeted by LUCA. Estimates for when LUCA existed range from 3.4 to 4.5 bya.

Due to their presence in modern-day bacteria and archaea it is thought that LUCA possessed genes for anaerobic metabolism and nitrogen fixation. This suggests that LUCA could have evolved around hydrothermal vents which have high concentrations of hydrogen, and iron sulfide.

The First RNA

DNA has several advantages to RNA as a genetic storage molecule, but RNA is capable of performing many more functions.

RNA could have performed the function of **catalysis**, providing control over reactions essential to the first life.

It is also capable of **self-replication** – an essential precursor to life and the means to inheritance and replication of successful variants.

Some RNA enzymes (**ribozymes**) have been found in modern cells.

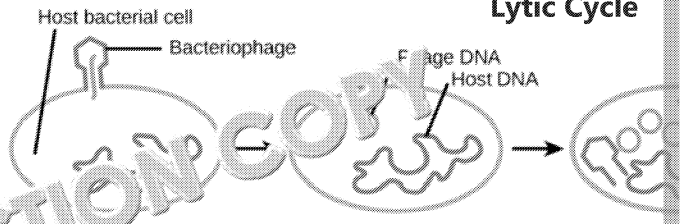
THE BASICS

Viruses

- All life exists as single or multicellular organisms, and all cells have certain features in common.
- Viruses are non-cellular and therefore non-living.
- Viruses cannot perform many of the functions of life and must use host cells to replicate.
- Viruses can usually only be studied with electron microscopes due to their size.
- Viruses replicate through means of the lytic and lysogenic cycles.
- Viral genomes are very small and highly diverse.
- Some viruses evolve rapidly causing challenges for effective vaccination and treatment.

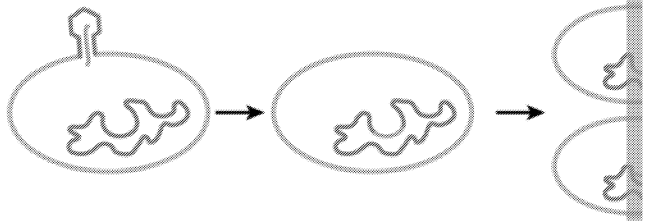
HL A2.3: Viruses (additional higher le

Lytic Cycle



The phage infects a cell. The phage DNA circularizes, remaining separate from the host DNA. Phage DNA phage prote... New pha... assem...

Lysogenic Cycle

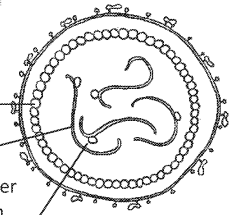


The phage infects a cell. The phage DNA becomes incorporated into the host genome. The cell div... prophage D... on to daugh...

...es

Viruses are extremely ... do s... certain features:

Viruses are extremely s... (20–300 nm) and have a... size – they cannot grow.



Viral nucleic acids are enclosed in a protein coat called the **capsid**. These nucleic acids (DNA or RNA) can be either **single** or **double stranded**, and contain a small number of genes (as low as 4) in comparison to even the simplest of bacteria.

Viruses may or may not have **enzymes** – if present these are few in number and usually attached to the DNA ready to convert it into RNA once in a host cell.

There is no **cytoplasm**. Some viruses are encapsulated in a cell membrane from the host organism.

The lipid envelope contains **attachment proteins** that allow the virus to identify and attach to a host cell. These may also be **antigens**, surface molecules specific to the virus which allow it to be recognised by the immune system.

Origins of Viruses

The exact origin of viruses is unknown. The simplicity of vi... leads to the conclusion that they were the first '... evolve. However, their extreme variation ... their genetic material (e... or R... stranded or double str... ever ... DNA and RNA), makes it likely they hav... existence on more than one occasion.

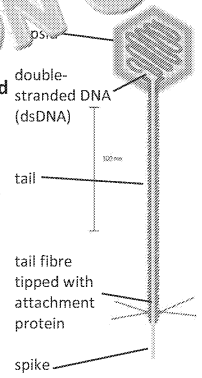
Theories of viral origins in...de:

- Virus-first hypothesis
- Escaped genes hypothesis
- Regressive hypothesis

All viruses share an extreme form of obligate parasitism. This means that similarities in their function could be due to convergent evolution.

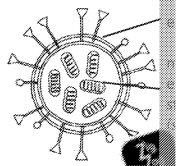
Bacteriophage Lamb...

The bacteriophages wer... the earliest gr... of virus... ...ere ...ps... T... ...e **non-enveloped** viruses, and contain double-stranded DNA. They are very small and use various bacterial cells as their hosts.



Coronaviruses

Coronaviruses are a large family o... of which are well known, including the common cold, flu, and the virus which caused the COVID-19 pandemic.



Coronaviruses are **enveloped** singl... (ssRNA) viruses which infect animal... quickly due to the use of RNA replic... their genetic material. This enzyme ... 'proofread' like DNA polymerase. R... which easily occurs due to the virus... containing multiple RNA molecules... flu and swine flu, as well as SARS a...

THE BASICS

A3.1 Diversity of Organisms

Diversity of Organisms

- There is great variation both within and between species.
- Genetic similarity between organisms indicates relatedness.
- The binomial naming of organisms includes both the genus and species name, and provides a standard which can be understood by scientists globally.
- Members of the same species are able to breed and produce healthy fertile offspring.
- Chromosome numbers and karyotypes are a key identifying feature of species.
- Genome sequencing has advanced dramatically in recent d…, having multiple present and future uses.

HL

- Asexual reproduction and horizont… (in …cteria) generate issues fo… he B… …es concept.
- Dichotomous ke… …tructu… to support the identification … given area or taxonomic group.
- Environmental DNA and DNA barcodes can be used to identify the presence of a species in a sample area.

Variatio…

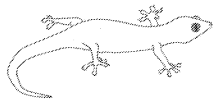
There is always **variation** between individuals, even when they a… **characteristics** can have a purely genetic cause, or be fully or par… organism makes during its lifetime. For example, monozygotic tw… different amounts of exer… …times, genetically controlled … species look very d… …s is known as **sexual dimorphism**.

The im…age … the n… …ows the male and female of two differe… S… …frica… …es e and f show the male and female of *Hetero…* …male and female of *Heterochelus detritus*. This image d… …riation between different species, and one type of **intraspecifi…** members of the same species. If we think about humans, we can … intraspecific variation, such as hair colour, eye colour, height, we… Some of this variation is inherited, while some is influenced by o…

Environmental DNA, and genetic barcoding

DNA barcodes are sequences of DNA from within a gene which are distinctive between species. When DNA is extracted from the environment, such as in a water or soil sample, these sequences allow scientists to identify which species are present in the environment. This technology is extremely useful for ecology and conservation.

Naming Organisms



Hemidactylus frenatus

The **genus name** is given first, with a capital letter. Species in the same genus share many features in common. There are over 190 described species in this genus.

The **species name** comes second and does not begin with a capital letter. Organisms within a species share other features in common which are not shared by other members of the genus.

Both the genus name and species name should be typed in italics, or underlined if handwritten.

Biological Species Concept

The biological species concept is used to determine whether two populations belong to the same species. If they can interbreed and produce fertile offspring, they are of the same species.

However, if they do not mate due to differences in mate recognition, or the offspring are infertile, they are said to be different species.

Difficulties Applying the Biological Species Concept

HL

Defining a species is difficult if two species occasionally produce fertile offspring (e.g. horses and donkeys) or are in the process of **speciation**.

Crosses between species often for… …e h… …as the parents have different numb… not have homologous p… …all … the… …osomes, and cannot produce viable ga…

Each species ha… chromosome n…

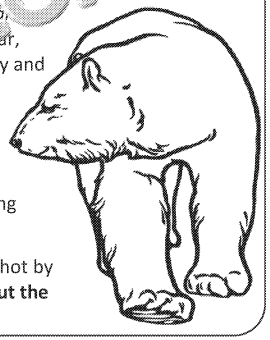
The human **ka…** karyotypes of … likely that two … the karyotype … became fused … human evoluti…

The two subsp… an example of … where part of … upside down.

The banding pa… the **centrome…** consistent with… number of chr… and it can be u…

Application: *Ursus maritimus*: Species or Subspecies?

The polar bear (*Ursus maritimus*) and the brow… …b… of which there are three main subspeci… (E… …own …ear, grizzly bear, and Kodia… …ve qu… …orphology and lifestyle, with the fo… …ll ad… …d for life in Arctic waters and on Arctic …



Due to climate change … bear range is being pushed southwards, with bears forced to find food on land in the absence of ice. Meanwhile the brown bear's range is expanding northwards as mean temperatures rise.

Surprisingly many F1 and F2 hybrid bears have been seen or shot by hunters in the past few decades. **What does this suggest about the relatedness of these two bears?**

Genome…

- → The **genome** is the entire genetic sequence of a …
- → Genome sequencing began with certain bacteri…
- → The human genome project then began in 1990 … mapping of the human genome wasn't 10…
- → Many thousands of individual human geno… 100 million **single nucleotide polymorphisms** (S… to differ in more than 1% of the population. Mo… sequence can also occur, usually resulting in a lo…
- → Geneticists have now sequenced the genomes … that it is now much quicker, and much cheaper … less than $1000 for each complete genome.
- → By understanding the genome, diseases with … lead to personalised medicine.
- → Sequencing of other organisms has greatly im…

THE BASICS

HL A3.2: Classification and Cladistics (additional higher lev

Classification and Cladistics

- Classification facilitates a variety of biological studies, allowing predictions to be made based on the **relatedness** of organisms.
- It is often difficult to fit organisms into the traditional taxonomic hierarchy, with **unranked 'clades'** now being used in most taxonomic studies.
- Traditionally classification was based on **morphology**.
- **DNA technology** has led to advances and changes in taxonomic understanding, as it provides direct evidence of mutations.
- The gradual accumulation of mutations can be used as a '**molecular clock**' to determine when different clades diverged from one another.
- The node of a cladogram represents the **common ancestor** [illegible] organisms within the consequent clade.
- The highest level of classification consists of [illegible] classified according to rR[illegible] se[illegible] bacteria, and eukaryota).

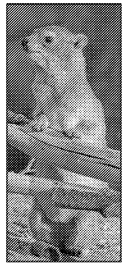
Th[illegible]ecular Clock

The molecular clock is based on the concept that DNA mutations occur at a relatively constant rate. By examining the number of differences between the base sequences of two related organisms we can estimate how long ago they are likely to have shared a common ancestor.

Applying Classification

Traditional classification is based on morphology, but this can be misleading due to **convergent evolution**.

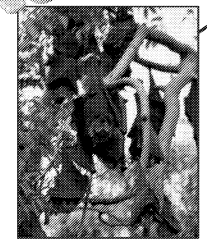
The rock hyrax looks a lot like a rodent, and even behaves very much like a ground squirrel. Its feet and teeth make it clear that it does not belong in this taxonomic group, even in traditional methodology. However, it was quite an enigma until DNA evidence revealed it to be a relative of elephants.



Rock hyrax (*Procavia capensis*)

The Chiroptera (bats) are one group of mammals which have been difficult to place under traditional morphological methods, with various theories as to their evolutionary origins. The significant differences between the smaller insectivorous bats (traditionally classified under the suborder Microchiroptera) and the large fruit-eating bats (traditionally classified under the suborder Megachiroptera) led to their classi[illegible] amor[illegible] the Archonta, a mammalian superorder including primat[illegible] ar[illegible] colugos. At the same time, some scientists propo[illegible] at [illegible] olved twice in mammals, with the m[illegible]ts be[illegible] re[illegible] primates, but the microbats belongin[illegible] Inse[illegible]

DNA evidence has led to [illegible]tivora and Archonta being aban[illegible] **monophyletic** groupings. C[illegible]ptera are now placed in the Laurasiatheria with even-toed ungulates, carnivores, and pangolins.
The Chiroptera itself has also been split differently, based on DNA evidence, with the unranked clade Rhinolophoidea placed within the unranked clade Yinpterochiroptera.



Spectacled flying fox (*Pteropus conspicillatus*)
A member of the **unranked clade** Megachiroptera

Phylogenetic Classification and Tax[illegible]

Analysing **phylogenetic relationships** allow[illegible] life to be classified into a **taxono**[illegible]
For example, red deer would be c[illegible]

Eukarya — Anim[illegible]cho[illegible] — M[illegible]malia — Artiodactyla — Cervi[illegible]

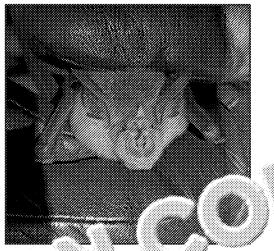
Dom[illegible] Kin[illegible]om[illegible]ylum — Class — Order — Fam[illegible]

Rem[illegible] that according to scientific naming convention the binomial nam[illegible] e species should be used in any scientific context, with both the genus name and species name typed in italics, or underlined if handwritten. The re[illegible] deer should therefore be *Cervus elaphus*.

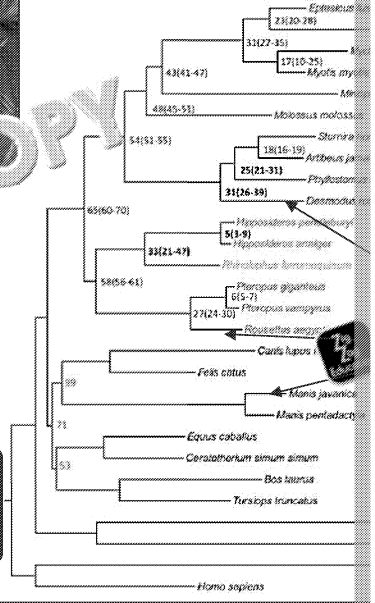
Species can look very similar; for example, an okapi looks like a cross between a horse and a zebra, but is actually the closest relative of giraffes. The **inaccuracy** of **anatomical classification** makes it necessary to compare **DNA**, **mRNA** or **amino acid** sequences in order to determine accurate evolutionary relationships.

There are **three domains** in the highest taxonomic rank:

Bacteria	Archaea	
Single-celled prokaryotes	Single-celled prokaryotes	Single-[illegible]
Small 70s ribosomes	Small 70s ribosomes	La[illegible]
Murein cell walls	Non-murein cell walls	Cellulo[illegible]



[illegible]eshoe[illegible]
[illegible]inolophus ferrumequinum)
A member of the **unranked clade** Rhinolophoidea



The **root** represents a common ancestor of all organisms shown in a cladogram and is found at the base.

THE BASICS

A4.1: Evolution and Spec

Evolution and Speciation

- Evolution is a gradual change in the inherited characteristics of a population.
- **Phenotypic variation**, DNA and RNA sequences, and amino acid sequences in specific proteins all provide evidence for evolution.
- Easily observable evidence for evolution includes **selective breeding** (aka artificial selection) and **homologous structures**, while **analogous structures** provide evidence for **convergent** evolution.
- **Speciation** is the generation of new species often occurring through **differential selection** and supported by **reproductive isolation**.

HL

- There are two major forms of speciation, **allopatric** and **sympatric**, which have both similarities and differences.
- **Adaptive radiation** occurs to fill vacant niches in a new or heav… degraded ecosystem, and leads to an increase in speci…
- Pre-zygotic and post-zygotic **reproductive iso… …sm.** …ent the mixing of alleles between species.
- **Hybridisation** and … …n pla… …dapt speciation.

D… …d Acquired Traits

- Traits which are used t… …re an evolutionary line are known as derived traits. For example, feathers are a derived trait used to distinguish birds from reptiles, and used to classify birds as a single clade with a shared ancestor.
- There are different theories which have been used in the past to explain inheritance of traits. Two theories of note are:
  - **Lamarckism:** John Baptiste Lamarck (1744–1829) theorised that traits **acquired** during a lifetime, for example a blacksmith's strong arm muscles, would be passed to the next generation.
  - **Darwinism:** originating from Charles Darwin's (1809–1882) theory of evolution, **Darwinism** states that individuals who possess beneficial traits (via means of mutation and inheritance) are more likely to pass these traits to the next generation (by producing more offspring). Traits are **derived** through mutation and **inherited** from our parents.

Evidence for Evolution

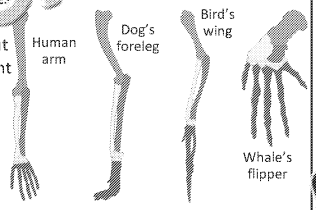
Comparing sequences

DNA, RNA and amino acid sequences allow us to identify mutations, in turn allowing us to tr… …k inheritance and the level of the relationship b… …ividuals or populations.

Ho… …s S…uctures

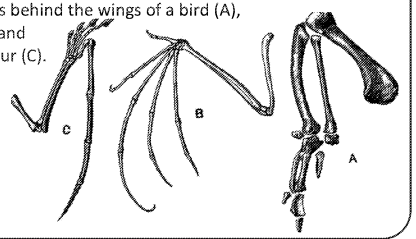
Homolog… …str…res …re …rme… …rom …he … …tarting point but … …y represent different evolutionary journeys to achieve different functions.

The image shows how the basic skeletal structure of the **pentadactyl limb**, found in all tetrapods, has been modified into the human arm, a dog's foreleg, a bird's wing, and a whale's flipper.



Analogous Structures

Analogous structures may look superficially similar due to evolving for the same function, but have different evolutionary origins. The image shows the differing skeletal structures behind the wings of a bird (A), a bat (B) and a pterosaur (C).

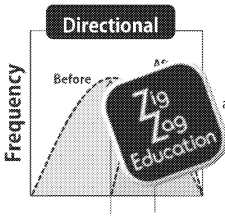


Natural Selection

- There is significant variation in every population; a lot of which is heritable (i.e. caused by genetics, not the environment).
- Specific variants offer benefit to some individuals, e.g. they might be bigger, stronger, or more attractive to a mate.
- The differing ability of individuals in a single population to survive and reproduce is termed **differential reproductiv… …e**. The… …are also likely to be more individuals in the next generation which carry this allele. This leads to an increa… …d **allel… …uency**. The process that leads to this change in allele frequency is called **natural selection**.
- The direction in which this change in allele frequency occurs is known as a **selectio… …** …is d… …ined by the environment in which the population lives. The same trait may be advantageous in one… …ent … …ou… …rable in another.
- Selection pressures may be directional, stabilising or disruptive.

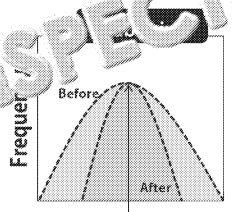
Directional

Selection may act against one extreme and for the other.



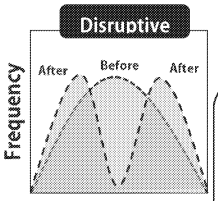
Stabilising

…agai… …th extremes, keeping the mean



Disruptive

Selection may act against the mean, and for two extreme values.

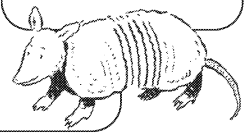


Selective breeding

Evolution isn't always a natural process. Humans often control breeding between organisms to produce new breeds for a particular purpose. This is sometimes called **artificial selection**. Wolves were domesticated to form domestic dogs, which have now been selectively bred to form over 100 distinct breeds, such as the Border collie (for sheep herding), the St. Bernard (for mountain rescue), and terriers (for catching rodents). The wild mustard was selectively bred to form all cruciferous vegetables including the cabbage, broccoli, cauliflower, Brussel sprouts and kohl rabi.

Gene pool

Term used to describe the collection of all genes present in all individuals in a population.



Adaptive radiation … forming many new …
- following a maj…
- when a single sp…

Hybridisation amon… chromosome numb… such hybrids are ab… new species. A… P…

HL

and … Mat… sper…

Post… amo… Hybr…

THE BASICS

A4.2: Conservation of Biodi

Conservation of Biodiversity

- **Biodiversity** is the variation which exists among living things. It includes genetic, species, and ecosystem level components.
- Biodiversity has an overall upward trend over time.
- **Mass extinction** events have caused dramatic and sudden drops in diversity, followed by periods of diversification.
- Human activities are causing a **biodiversity crisis**, characterised by ra and ecosystem loss, high extinction rate, enough to be conside mass extinction.
- There are many approaches to conservation, including ***in situ*** and ***ex situ*** methods.
- The **EDGE** programme of ZSL helps to prioritise conservation efforts.

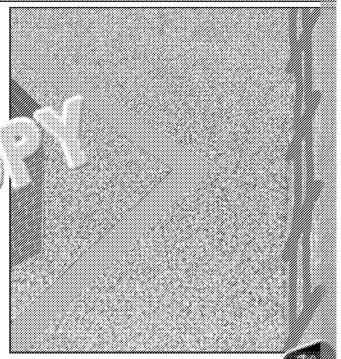
Species diversity includes both **species richness** and **species evenness**. It can be measured through a biodiversity index such as the **Simpson's Index** or **Shannon Index**.

Species richness is simply the number of different species in the area of interest.

It is clear that the species richness in the garden on the left is lower than the garden on the right, which has a greater number of plant species.

Species evenness describes the distribution of individuals amor differe species. If the population sizes of different species w n axo mic oup (e.g. amphibians), or ecological guild (e.g. de ughly equal, this is a sign that the ecosystem is well l d lik be more **resilient**. If, however, one species is do ng e n with much higher numbers, this is a **lov e.ce**.

The gra h is inated by a particular grass species due to

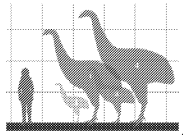


North Island Giant Moa

The image on the right shows the approximate size of the North Island Giant Moa (*Dinornis novaezelandiae* - 3) in comparison to a human, and three other moa species including the South Island Giant Moa (*Dinornis robustus* - 4).

Native to the North Island of New Zealand, and unable to disperse naturally due to its flightless nature, these large birds disappeared over the course of about 200–300 years, following the arrival of humans on the island. Causes of extinction included:

- Hunting by Maori people
- Predation of chicks by the Polynesian dogs (introduced by the human settlers)
- Destruction of eggs by both the Polynesian dogs and Polynesian rats (also accidentally introduced by human settlers)



The Biodiv

Various human activities have led to rapid popul species. Rapid increase in human population alo

- **Overharvesting** (including overhunting)
- **Habitat destruction** (most notably **deforest** (through land-use change including for agric unsustainable use of natural resources inclu water for irrigation)
- Introduction of **invasive species** – which dist native species becoming **out-competed**
- **Pollution** (includes **eutrophication** from ferti smelting works; note that this can also lead t
- Rapid climate change (which is occurring so

The **background extinction rate** is thought to b Meanwhile, current rates of extinction are estim Such a high rate has led many scientists to refer **biodiversity crisis**, and evidence that we are no (the **sixth mass extinction**).

Evidence:

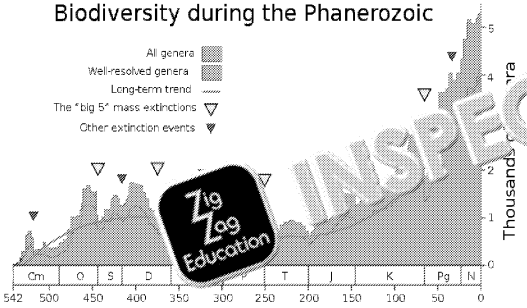
- IP governmental Science-Policy Pla ed i 2012 by 94 countries – aims to su making regarding conservation and bio itizen science – data collection carried out Birdwatch which has helped to track change Britain's birds
- Such programmes are essential given the sca allows far greater amounts of data to be coll Participants are required to follow a set pro which allow the data to be combined reliabl

Diversity Over Geological Time

Biodiversity has a tendency to increase over time, as can be seen in this graph of the richness of genera since the Cambrian explosion.

Mass extinctions can be caused by rapid and significant changes in the abiotic conditions and weather patterns of Earth, leading to sudden **biodiversity loss**. This has happened *five times* in Earth's history.

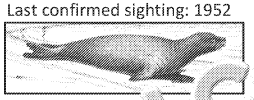
Biodiversity during the Phanerozoic



Mass extinctions are followed by periods of rapid **diversification** and the generation of new species (**speciation**), as survivors adapt and evolve to fill vacant **ecological niches**.

Caribbean Monk Seal

Officially declared extinct: 2008
Last confirmed sighting: 1952



Reasons for ex t :

- Hu g r oil and ex t ed by their c re and lack of nstinct to flee from humans
- Overfishing of the reefs in which the seals hunted, causing many seals to die of starvation

Conservation

In Situ Conservation

Conservation methods which occur within the natural habitat.

- **Protected areas (National parks, Nature reserves)**
- Tracking and monitoring
- Reintroductions (including **rewilding**)
- Ecosystem restoration (**reclamation** of destroyed or degraded ecosystems)

Ex Situ Co

Conservation methods which happ

- **Captive breeding** programmes - S black-footed ferret and Arabian o
- **Gene** or **seed banks**
- Research
  - Behavioural research can help b efforts making them more likel
  - Genetic and reproductive rese programmes and to identify th

THE BASICS

A1.1: Water

Water

- Due to its unique properties, water is the medium for life.
- The polar covalent bonds within water molecules lead to hydrogen bonds between water molecules, and between water molecules and other substances leading to many of water's unique properties.

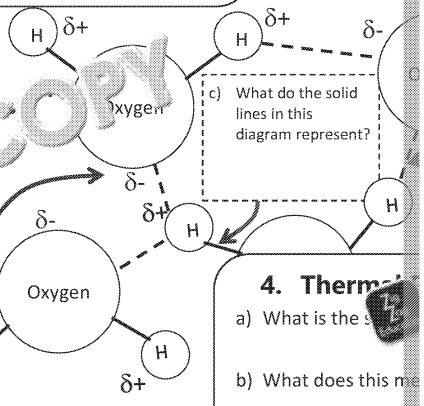
- Earth's water has an extraplanetary origin.
- The **'Goldilocks zone'** represents the region of a solar system which could contain planets with **liquid water**, and refers to the **habitable zone** around a star.

1. Molecular Structure of Water

a) What atoms make up a water molecule?

b) [illegible] to be polar [illegible]

c) What do the solid lines in this diagram represent?



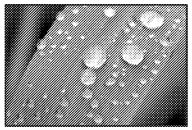
2. Cohesion and Adhesion

a) i. Define the term [illegible] the context of water.

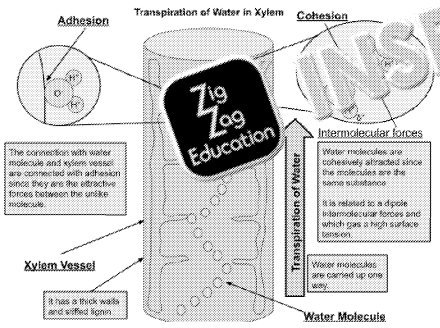
ii. What is the link between cohesion and surface tension?

iii. Why is this important for aquatic life such as the water strider?

b) Define the term adhesion in the context of water.



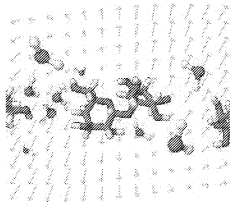
c) Describe how these properties support the transport of water up a plant stem. Use the diagram to help you.



3. Water as the Universal Solvent

a) Which characteristic of water makes it an excellent solvent?

b) What happens to ionic molecules such as salts when placed in water?



Solution of sucrose in water

c) What happens to small organic molecules such as sugar when placed in water?

d) Why is this chem[illegible]per[illegible]of water so important in the [illegible]xt [illegible]ings? (List as many reasons [illegible]hin[illegible]f.)

e) What is the name given to molecules which
i. dissolve easily in water?
ii. do not dissolve in water?

f) Identify whether or not the following substances can dissolve in water:

	Can dissolve	Cannot dissolve
Triglyceride		
Testosterone		
Fructose		

4. Therm[illegible]

a) What is the s[illegible]

b) What does this m[illegible]

c) How does this pro[illegible] living things in ge[illegible]

d) What are the cons[illegible] high thermal cond[illegible] life in air?

5.

a) What causes buo[illegible]

b) Why is this impor[illegible]

a) Define the term co[illegible]

b) Define the term hy[illegible]

c) Identify two key p[illegible]

d) Identify two [illegible]

7. Application[illegible]

a) Identify adaptations [illegible]
- buoyancy
- viscosity
- high thermal co[illegible] of water

THE BASICS

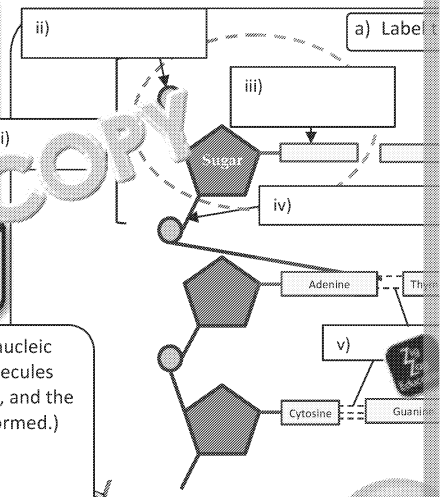
A1.2: Nucleic Acids

DNA and RNA

- **DNA** is the **genetic material** in all organisms, while the **genetic code** is shared by all known life. This universality is evidence for the shared ancestry of all life on Earth.
- A **nucleotide** consists of a sugar (**deoxyribose** or **ribose**), a **phosphate** group, and a **nitrogenous base** (**adenine**, **guanine**, **cytosine**, **thymine** (DNA only), or **uracil** (RNA only).
- The bases form a code, while **complementary base pairing** ensures accurate transfer of this code.
- The possible diversity in the sequence of bases is effectively infinite.

HL

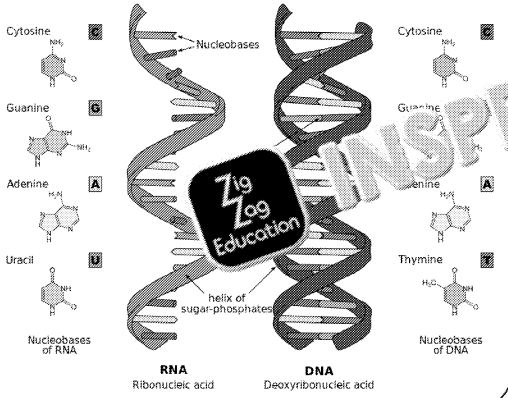
- Bonding between **purines** and **pyrimidines** helps to ensure genet[illegible] i[illegible].
- The work of multiple scientists, including Hershey, Chase, Chargaff, [illegible] vided evidence which allows us to understand the stru[illegible] an[illegible] esses involving DNA.



1. RNA vs DNA Structure

Complete the table below to highlight the differences between RNA and DNA.

Ribonucleic acid (RNA)	Deoxyribonucleic acid (DNA)
	Adenine, guanine, cytosine and thymine
Short, single chain	
	Long-lived stable molecule
	Stores genetic information
Three kinds (____, ____, and ____). _____ is a structural component of ribosomes.	Can exist in association with _____ proteins to form _____ and form chromosomes



2. How does polymerisation of nucleic acids occur? (Identify the molecules involved, the type of reaction, and the name of the resulting bond formed.)

3. DNA has four different bases

a) How many possible sequences of these bases exist?

b) What is the length of a DNA molecule?

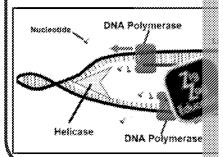
c) How is the number of possible sequences for a DNA molecule of a given length mathematically calculated?

HL

Whether in DNA replic[illegible]

i) _____ **direction**

ii) _____



4. ATP

Through hydrolysis, **adenosine triphosphate** (ATP) provides an **immediate** source of energy for cells.

a) How is adenosine triphosphate similar to an RNA nucleotide?

b) How is ATP different from an RNA nucleotide?

HL

Scientist	
Hershey and Chase	Used ra[illegible]
Chargaff	Used pa[illegible]

THE BASICS

Eukaryotic and Prokaryotic Cells

- All life exists as **single** or **multicellular organisms**, and all cells have certain features in common.
- New cells arise from pre-existing cells.
- **Viruses** are non-cellular and therefore non-living.
- Cells have **specialised organelles**, a large quantity of a particular organelle, or **specialised structures** to adapt them to **different roles**.
- Cells can be studied with **optical** or **electron microscopes**.
- Advances in microscope technologies have led to new discoveries.
- **Unicellular** organisms have unique methods and structures for carrying out the **functions of life**.

A2.2: Cell Structure

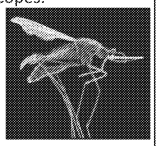
1. Microscopy

a)-f) Identify the key terms to match the descript[illegible]o

a) _____ _____ use[illegible] can [illegible]s, but has a **low magnification** and **low r**[illegible] pare[illegible]on microscopes.

b) _____ _____ u[illegible] greater magnification, but use a dead sample in [illegible] therefore cannot be used to view movement or p[illegible]sses.

A i) _____ _____ _____ (SEM) provides 3D images of an object's surface, while ii) _____ _____ _____ (TEM) generates an internal cross section.

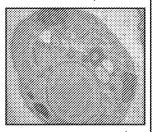


SEM micrograph of a mosquito

c) The _____ _____ technique uses -190 ºC liquefied propane to rapidly freeze a sample. It is then cut, etched (by evaporating a small amount of water from the surface), and coated (with a thin layer of metal).

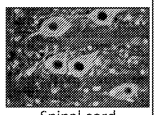
Fluorescent stains and **immunofluorescence** allow us to see the location of specific molecules in a sample.

d) _____ _____ have been used for many years, but not all substances can absorb these stains. e) _____ is an advanced form of this technique using antibodies tagged with a fluorescent dye to identify the presence and location of specific proteins in a sample.



TEM micrograph of a eukaryotic cell

f) _____ _____ _____ is an advanced method of TEM which allows for 3D imaging of molecular structures.



Spinal cord grey matter under immuno-fluorescence

g) Complete the equations.

Magnification

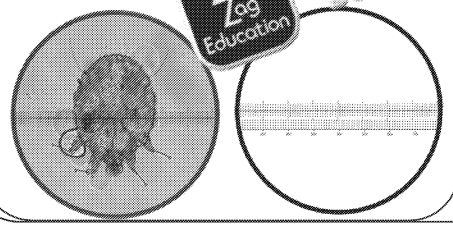
Magnification = (eyepiece lens) × (objective lens)

Actual size = [ ]

Calculating Magnification Using the Eyepiece Graticule and Stage Micrometer

eyepiece graticule unit = [ ]

actual size = no. [illegible]its × [illegible] 1 unit



Found on the outside surface of the cell, the a) _____ _____ includes many proteins, and controls movement of substances into and out of the cell. Other membranes a[illegible]nd surrounding the organelles su[illegible] **mitochondria** and [illegible]es.

b) _____ [illegible]e fluid[illegible]sacs, used in [illegible]r dig[illegible]

c) [illegible] plant cell, the _____ _____ [illegible]es salts and sugars and helps to maintain turgidity.

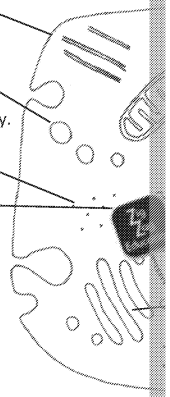
d) _____ carry out protein synthesis

e) Surrounded by a double membrane with **pores** known as the **nuclear membrane** or **nuclear envelope**, the _____ contains the **chromosomes**, and a f)_____

g) Cells show variation regarding the _____: Animal cells (as shown) do not have cell walls. Plants cells have rigid walls with **cellulose** polymers that provide protection and support. Fungal cells have cell walls made of chitin.

2. Eukar[illegible]

Identify each st[illegible] from the label[illegible] and/or descrip[illegible]



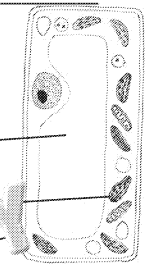
o) Identify the different types of eukaryotic cell shown in each box be[illegible]

i) _____

They also sometimes have:
Cilia – these hair-like structures help to move mucus or other liquids past the cell
Flagella – used for locomotion in sperm cells

ii) _____

In addition to the organelles shown in the animal cell, they have:
- a **large permanent vacuole**
- **chloropl**[illegible]
- **cell w**[illegible]



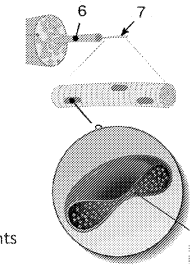
iii) _____

They do no[illegible]
- a **large p**[illegible]
- **chloropl**[illegible]

They do ha[illegible]
- a **cell wal**[illegible] (made of **chitin**)

[illegible]. [illegible]typical Cells

[illegible]t ways [illegible] following cells not align with [illegible]eptate fungal hyphae



b) Skeletal muscle fibres

c) Red blood cells

d) Phloem sieve tube elements

The processes of homeostasis, metabo[illegible] identify organisms as living. Identify th[illegible]

a) Para[illegible]

Paramecium are single-celled 'an[illegible] are heterotrophic. Unique features inc[illegible]

- Cytosome (for i) _____)
- Cilia (for ii) _____)
- Enzyme-containing vacuoles (iii) _____)
- Anal pore (iv) _____)
- v) _____ occurs via fission, wit[illegible] supported by horizontal gene tra[illegible]

A2.1: Origins of Cells & A2.2: Cell Structure - additional higher level only

HL

THE BASICS

How could life begin?

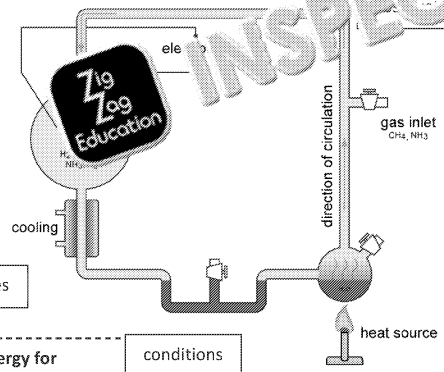
- The early **atmosphere** was very different from what it is like today.
- The first **cells** represent the first life.
- There is evidence supporting the **spontaneous generation** of various cell components: including carbon compounds (Miller–Urey experiment), RNA, and vesicles.

1. The Miller–Urey Experiment

Identify the missing [illegible] using the cl[illegible]

a) Replicating the early atmosphere.
A mixture of ____, ____ and ____ was placed in a 5L flask in the ratio 2:2:1, while ____ was evaporated from a smaller flask.

molecules



d) The evidence.
The water collecting gradually changed from _____, to _____, to _____, and became increasingly _____.
Chromatography of the mixture proved the presence of 3–5 amino acids.

processes

conditions

b) Provision of energy for reactions to occur.
An _____ spark was continuously discharged from two electrodes to simulate the frequent _____ expected to occur in conditions on the early Earth.

c) Collecting the molecules.
The apparatus was cooled so that water vapour _____ and _____ in a u-shaped tube at the bottom of the apparatus.

e) Recent repeats of this experiment have yielded many more _____ _____, probably due to more advanced detection methods.

results

2. Conditions on E[illegible]

Identify the missing wo[illegible] fill in the gaps in the passage be[illegible]

Earth formed [illegible] a) _____ years ago. Gases wo[illegible] first at[illegible] ere [illegible] have been very c) _____ from [illegible]

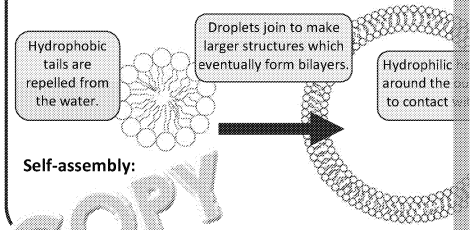
- [illegible]ery lit[illegible] if [illegible]ee d) _____
- [illegible] _____ (leading to high levels of f) _____
- g) _____ levels of CO_2 and CH_4 (leading to **high** h) _____
- Ocean chemistry is also likely to have been quite different [illegible] vary significantly from as low as j) _____ 5 to as high as [illegible] Such conditions may have allowed a variety of carbon com[illegible] would not be possible today.
- High levels of UV could have provided the l) _____ occur spontaneously today.
- m) _____ lightning could also have been a sc[illegible]
- **Pre-biotic carbon compounds** could have formed in a [illegible] o) _____ droplets, p) _____ vents, an[illegible]

3. Vesicle Formation

Explain the link between these keywords and vesicles in [illegible] context of the origins of life.

Compartmentalisation:

Amphipathic:



Self-assembly:

4. The First RNA

While RNA is less stable than DNA, its single-stranded structure makes its role more flexible.

Identify the important roles which RNA could have played in life processes:

a) Providing control over re[illegible] essential to the first life. C_ _ _ _ _ _ _ _

Some RNA enzymes (ribozyme[illegible] have been found in modern cells.

b) An essential precursor to life and the means to inheritance and replication of successful variants RNA and ribozymes are capable of: S_ _ _ - _ _ _ _ _ _ _ _ _ _ _ _

THE BASICS

Last Universal Commo[illegible]tor

- The **universal genetic code** and [illegible]s fo[illegible] all known organisms provide str[illegible]dence [illegible] [illegible]nce of a **LUCA**.
- The **LUCA** is ex[illegible] ex[illegible] around 3.4–4.5 bya.
- Eviden[illegible]s [illegible]rd [illegible]UCA evolving around **hydrothermal vents**.

5. LUCA

Identify the missing words to fill in the gaps in the passage.

The **universality** of the a) _____ b) _____ supports the theory that all life on Earth is descended from a single common c) _____ species (**LUCA**).

[illegible] cellular processes that are carried out in all cells are supported by d) _____ or sections of e) _____ which remain very similar in all extant f) _____, from bacteria to humans. This further supports the idea of a g) _____ **common ancestor**.

Rocks dating to around 3.0–3.5 h) _____ have been shown to contain i) _____-like structures. Isotopic analysis of these 'fossils' also suggests they formed from once living material. Meanwhile j) _____ (rock formations formed by colonies of k) _____) have been dated to 3.4 bya. It is important to note that other early life may have pre-existed LUCA, but was later outcompeted by LUCA. Estimates for when LUCA existed range from 3.4 to l) _____ bya.

Due to their presence in modern-day bacteria and m) _____ it is thought that LUCA possessed genes for n) _____ metabolism and nitrogen fixation. This suggests that LUCA could have evolved around hydrothermal o) _____ which have high concentrations of hydrogen, and iron p) _____.

THE BASICS

Viruses

- All life exists as single or multicellular organisms, and all cells have certain features in common.
- Viruses are non-cellular and therefore non-living.
- Viruses cannot perform many of the functions of life and must use host cells to replicate.
- Viruses can usually only be studied with electron microscopes due to their size.
- Viruses replicate through means of the lytic and lysogenic cycles.
- Viral genomes are very small and highly diverse.
- Some viruses evolve rapidly causing challenges for effectiv… vaccination and treatment.

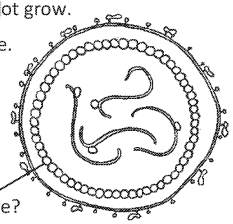
HL A2.3: Viruses (additional higher le…

1. …ise

Viruses are extremely … do s… certain features:

Viruses have a fixed siz… ot grow.

Different types show va… in size.



a) What range of size is possible?

b) How are viral nucleic acids protected?

c) What is the name of this structure?

d) What are the four possible forms of viral nucleic acid?

e) What is the smallest number of genes possible for a virus?

f) Why do many viruses not have any enzymes?

g) When present, what is the function of viral enzymes?

h) Where are viral attachment proteins found?

2. Origins of Viruses

The exact origin of viruses is unknown.

a) What conclusion has been drawn from the ap… simplicity of viruses?

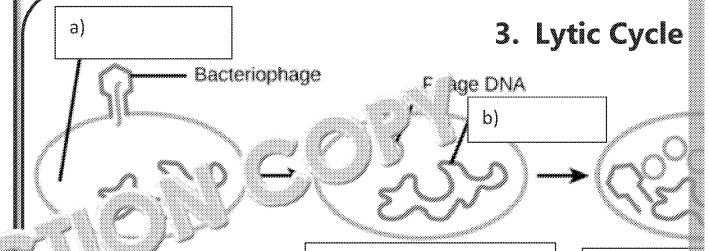
b) What conclusion ha… fro… great variation shown among virus… regarding differences in their genetic materia…

c) Collectively, what are the Virus-first hypothesis, Escaped genes hypothesis and Regressive hypothesis?

All viruses share an extreme form of obligate parasitism.

d) What does this suggest about their evolutionary relationships?

3. Lytic Cycle

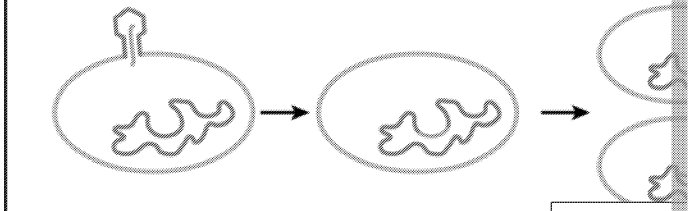


… phage infects a cell.

remaining separate from the host DNA.

New pha… assem…

4. Lysogenic Cyc…

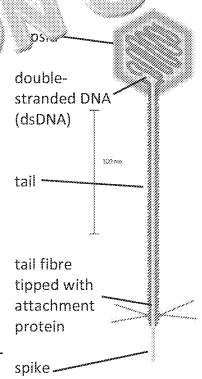


prophage D… on to daugh…

Identify the missing words in sections 5 to 7…

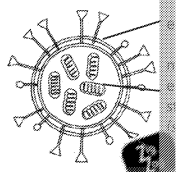
5. Bacteriophage Lam…

a) _____ wer… the b) _____ rou… of virus… T… e… c) _____ viruses, and contain double-stranded d) _____. They are very small and use various e) _____ cells as their hosts.



6. Coronavirus…

Coronaviruses are a large a) _____ viruses, many of which are well kno… including the common b) _____, flu, and the virus which caused the COVID-19 c) _____.



Coronaviruses are **enveloped** d) _____ (ssRNA) viruses which infect e) _____ f) _____ due to the use of RNA re… copying their genetic material. This … 'g) _____' like DNA polymerase. … which easily occurs due to the virus… containing multiple RNA molecules … flu and swine flu, as well as SARS a…

THE BASICS

Diversity of Organisms

- There is great variation both within and between species.
- Genetic similarity between organisms indicates relatedness.
- The binomial naming of organisms includes both the genus and species name, and provides a standard which can be understood by scientists globally.
- Members of the same species are able to breed and produce healthy fertile offspring.
- Chromosome numbers and karyotypes are a key identifying feature of species.
- Genome sequencing has advanced dramatically in recent d[illegible]s, having multiple present and future uses.

HL

- Asexual reproduction and horizont[illegible] (in [illegible]cteria) generate issues fo[illegible]he b[illegible]es concept.
- Dichotomous ke[illegible]tructu[illegible]o support the identification [illegible] given area or taxonomic group.
- Environmental DNA and DNA barcodes can be used to identify the presence of a species in a sample area.

2. Naming Organisms

a) Complete the annotations stating what this part of the name represents and describing the scientific convention for writing it.

Hemidactylus frenatus

i)

ii)

Species in the same genus share many features in common. There are over 190 described species in this genus.

Organisms within a species share other features in common which are not shared by other members of the genus.

Both the genus name and species name should be typed in _____, or _____ if handwritten.

b) [illegible]y the [illegible]s[illegible]g[illegible]rds:

5. Difficulties Applying th[illegible]gical Species Concept

a) Describe one situa[illegible]use. [illegible]cul[illegible]y in applying the biological species concept.

b) Why are hybrids between closely related species often infertile?

HL

A3.1 Diversity of Organis[illegible]

1. Variat[illegible]

a) Explain why even genetically identical organisms (e.g. asexual[illegible]y

b) Identify two specific causes of [illegible]riation in human monozygotic

c) Define the term [illegible]orp[illegible]m.

d) [illegible]e[illegible]ribe [illegible]e [illegible] of gene expression in sexual dimorphism.

e) Images e and f show two individuals of one monkey beetle spe[illegible] g and h show a different species. What types of variation are [illegible]

HL

3. Environmental DNA, and genetic barcoding

a) Define the term DNA barcode.

b) Identify two environmental components from which DNA can be extracted.

1. 2.

c) What information can be determined from such environmental DNA samples?

4. Biological Species Concept

The biological species concept is used to determine whether two populations belong to the same species. To be members of the same species, individuals from different populations must interbreed successfully.

a) What determines reproduction to be 'successf[illegible]'?

b) What would 'unsuccessf[illegible] rep[illegible]duct[illegible]' look like?

Each species ha[illegible] chromosome n[illegible]

a) What does [illegible] show abou[illegible] and the oth[illegible] have happe[illegible] human evol[illegible]

b) When looki[illegible] differences [illegible] are the thre[illegible] to look for[illegible]

7. Genom[illegible]

→ The a) _____ is the entire genetic sequenc[illegible]
→ Genome b) _____ began with certain ba[illegible]
→ The c) _____ genome project then d) _____ concluded in 2003, but mapping of the hu[illegible]
→ Many f) _____ of individual human g[illegible] than 100 g) _____ **single** h) _____ **po[illegible]** that are known to differ in more than 1% of the [illegible] to the DNA sequence can also occur, usually re[illegible]
→ Geneticists have now sequenced the genomes [illegible] mean that it is now much quicker, and much m[illegible] now costs less than $1000 for each n) _____
→ By understanding the genome, diseases with [illegible] may lead to p) _____ medicine.
→ Sequencing of other organisms has greatly im[illegible]

THE BASICS

HL

A3.2: Classification and Cladistics (additional higher lev

Classification and Cladistics

- Classification facilitates a variety of biological studies, allowing predictions to be made based on the **relatedness** of organisms.
- It is often difficult to fit organisms into the traditional taxonomic hierarchy, with **unranked 'clades'** now being used in most taxonomic studies.
- Traditionally classification was based on **morphology**.
- **DNA technology** has led to advances and changes in taxonomic understanding, as it provides direct evidence of mutations.
- The gradual accumulation of mutations can be used as a '**molecular clock**' to determine when different clades diverged from one another.
- The node of a cladogram represents the **common ancestor** [illegible] organisms within the consequent clade.
- The highest level of classification consists of [illegible] line, classified according to rR[illegible] sequ[illegible] bacteria, and eukaryota).

1. Phylogenetic Classification and Ta

Analysing **phylogenetic relationships** allows life to be classified into a **taxono**

a) Identify the taxonomic ranks which [illegible] each of these classification gro

Eukarya — Animalia — [illegible] — M[illegible]malia — Artiodactyla — Cervi

[illegible] name for the red deer according to scientific naming convent

Species can look very similar; for example, an okapi looks like a cross between a horse and a zebra, but is actually the closest relative of giraffes. Due to this **inaccuracy** modern classification is not based on morphology.

c) What is used in modern classification to determine more accurate evolutionary relationships?

There are **three domains** in the highest taxonomic rank:

d) Identify the correct headings for the table:

Single-celled prokaryotes	Single-celled prokaryotes	Single- o
Small 70s ribosomes	Small 70s ribosomes	La
Murein cell walls	Non-murein cell walls	Cellulo

2. [illegible]olecular Clock

Examining the number of differences between the base sequences of two related organisms allows us to estimate how long ago they are likely to have shared a common ancestor.

Explain the principle behind this calculation.

3. Applying Classification

Identify the missing words to complete the passage below.

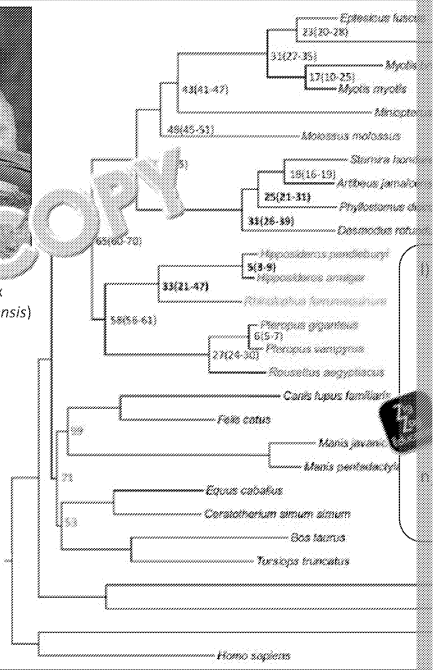
Traditional classification is based on a) _____, but this can be misleading due to b) _____ **evolution**.

The rock hyrax looks a lot like a c) _____, and even behaves very much like a ground squirrel. Its feet and teeth make it clear that it does not belong in this d) _____ group, even in traditional methodology. However, it was quite an enigma until DNA evidence revealed it to be a e) _____ of elephants.

[illegible] hyrax (*Procavia capensis*)

The Chiroptera (bats) are one group of f) _____ which have been difficult to pla[illegible] under traditional morphological methods, with various theories as to their [illegible]y origins. The significant g) _____ between the smaller insectivorous bats (traditionally classified under the suborder Microchi[illegible] fruit-eating bats (traditionally classified under the subor[illegible]era, due to their h) _____ among th[illegible], a n[illegible]order including primates, tree shrews and colugos. At [illegible]son [illegible] _____ proposed that flight had evolved twice in mamm[illegible]gabats being closely related to primates, but the microbats belonging to th[illegible]ectivora.

DNA j) _____ has led to both the Insectivora and Archonta being abandoned as non-**monophyletic** groupings. Chiroptera are now placed in the Laurasiatheria with even-toed ungulates, carnivores, and pangolins. The Chiroptera itself has also been split differently, based on DNA evidence, with the unranked k) _____ Rhinolophoidea placed within the unranked clade Yinpterochiroptera.



THE BASICS

Evolution and Speciation

- Evolution is a gradual change in the inherited characteristics of a population.
- **Phenotypic variation**, DNA and RNA sequences, and amino acid sequences in specific proteins all provide evidence for evolution.
- Easily observable evidence for evolution includes **selective breeding** (aka artificial selection) and **homologous structures**, while **analogous structures** provide evidence for **convergent** evolution.
- **Speciation** is the generation of new species often occurring through **differential selection** and supported by **reproductive isolation**.

HL

- There are two major forms of speciation, **allopatric** and **sympatric**, which have both similarities and differences.
- **Adaptive radiation** occurs to fill vacant niches in a new or heavily degraded ecosystem, and leads to an increase in species.
- Pre-zygotic and post-zygotic **reproductive isolation** [illegible] prevent[illegible] mixing of alleles between species.
- **Hybridisation** and **polyploidy** in plant[illegible] [illegible]ipt[illegible]ciation.

A4.1: Evolution and Spec[illegible]

1. [illegible]nd Acquired Traits

- Traits which are used [illegible] an evolutionary line are known as derived traits.
- There are different the[illegible]ich have been used in the past to explain inheritance of traits. Two theories of note are:
  - **Lamarckism:** John Baptiste Lamarck (1744–1829) theorised that traits **acquired** during a lifetime would be passed to the next generation.
    a) Give an example of an acquired trait.
  - **Darwinism:** originating from Charles Darwin's (1809–1882) theory of evolution, **Darwinism** states that individuals who possess beneficial traits are more likely to pass these traits to the next generation.
    b) What process creates new traits?
    c) How are such traits passed to the next generation?

5. Evidence for Evolution

Comparing sequences

a) What types of molecules can be sequenced to provide evidence for evolutionary rela[illegible]nships?

Ho[illegible]s S[illegible]uctures

b) Define [illegible]e ter[illegible]hor[illegible]o[illegible]us structure.

c) How does this concept link with the concept of divergent evolution?

d) What skeletal structure is shown by the diagram?

e) What functions has this structure been modified to perform (hint: in the diagram)?

Analogous Structures

f) Define the term analogous structure.

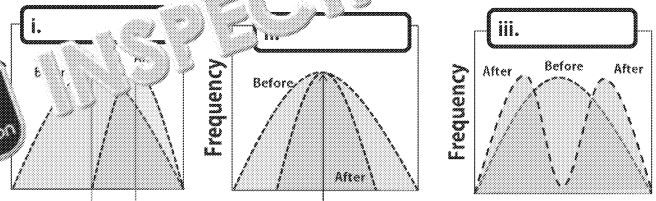
g) How does this concept link with the concept of convergent evolution? You may support your answer with an example.

Identify the missing words to complete the passages below.

2. Natural Selection

- There is significant variation in every a) _____; a lot of which is heritable (i.e. caused by genetics, not the b) _____).
- Specific variants offer benefit to some individuals, e.g. they might be bigger, stronger, or more attractive to a mate.
- The c) _____ ability of individuals in a single population to survive and d) _____ is termed **differential repro[illegible]e[illegible]cess**.
- If an allele offers an organism an e) _____, it is therefore more likely to be **inherited** (passed on to the [illegible]ion). There are also likely to be more individuals in the next generation which carry this allele. This leads t[illegible]nc[illegible]se i[illegible]h[illegible]allele f) _____. The process that leads to this change in allele frequency is called **natural selec[illegible]n**.
- The direction in which this change in allele frequency occurs is known as a **selectio[illegible]** and[illegible]termined by the environment in which the population lives. The same trait may be advanta[illegible]one [illegible]nt but undesirable in another.
- Selection pressures may be directional, stabilising or disruptive.

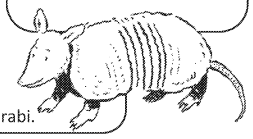
h) Identify the three selection types shown by the graphs.



3. Selective breeding

a) _____ isn't always a natural process. Humans often b) _____ breeding between organisms to produce new breeds for a particular c) _____. This is sometimes called **artificial selection**. Wolves were d) _____ to form domestic dogs, which have now been selectively bred to form over 100 distinct e) _____, such as the Border collie (for sheep herding), the St. Bernard (for mountain rescue), and terriers (for catching rodents). The f) _____ mustard was g) _____ bred to form all cruciferous vegetables including the cabbage, broccoli, cauliflower, Brussel sprouts and kohl rabi.

4. Define the term **gene pool**.



a) Define the term [illegible]

b) Identify two sit[illegible]

a) Define the term [illegible]

b) Explain how po[illegible]

9. Spli[illegible]

ma[illegible]
hy[illegible]
spe[illegible]
hy[illegible]
hy[illegible]
be[illegible]
te[illegible]

THE BASICS

A4.2: Conservation of Biodi

Conservation of Biodiversity

- **Biodiversity** is the variation which exists among living things. It includes genetic, species, and ecosystem level components.
- Biodiversity has an overall upward trend over time.
- **Mass extinction** events have caused dramatic and sudden drops in diversity, followed by periods of diversification.
- Human activities are causing a **biodiversity crisis**, characterised by rap and ecosystem loss, high extinction rate, enough to be conside mass extinction.
- There are many approaches to conservation, including ***in situ*** and ***ex situ*** methods.
- The **EDGE** programme of ZSL helps to prioritise conservation efforts.

2. Species diversity

a) Define:

i. species richness

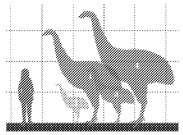
ii. species evenness

iii. biodiversity index

b) Describe the differenc p e. between the two gardens:

5. North Island Giant Moa

Native to the North Island of New Zealand, and unable to disperse naturally due to its flightless nature, these large birds disappeared over the course of about 200–300 years, following the arrival of humans on the island.



List the three main causes of their extinction:

7. The Biodi

Various human activities have led to rapid popula

a) Identify the five core reasons for the biodiver population and long-term unsustainable pra

1.
2.
3.
4.
5.

The **background extinction rate** is thought to b

b) What is the range of estimates for the curre

This extremely high rate of biodiversity loss is w **biodiversity crisis.**

c) Meanwhile, the evidence that this rapid extin current time what name in ecological contex

d) What is IPBES?

e) W ole of IPBES in the biodiversity c

f) hat is citizen science?

g) Give an example of citizen science

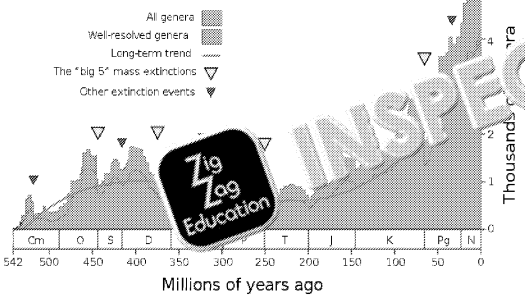
h) What are the key features of citizen science w

1. Diversity Over Geological Time

a) Using the graph below, what is the general trend seen in biodiversity over time?

Mass extinctions can be caused by rapid and significant changes in the abiotic conditions and weather patterns of Earth, leading to sudden **biodiversity loss**. This has happened *five times* in Earth's history.

Biodiversity during the Phanerozoic



b) What appears to happen following a major or mass extinction?

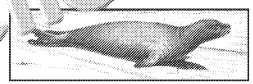
c) Why does this happen?

6. Caribbean Monk Seal

a) When was the Caribbean monk seal officially declared extinct?

b) When was the last confirmed sighting of the Caribbean monk seal?

c) List the two mai caus of their extinc



10. Conservation

a) Define the term ***in situ*** conservation.

One well-known example of *in situ* conservation is protected areas, including:

- **National parks**
- **Nature reserves**

b) List other methods of *in situ* conservation that you can think of:

c) Define the term ***ex situ*** conservatio

This includes **captive breeding progra** programmes to save the black-footed

d) Describe the role of **gene** and **see**

e) Describe the role of research in ***ex***

THE BASICS

A1.1: Water

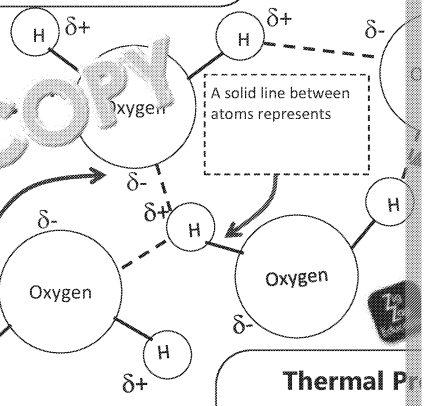
Water

- Earth's water has an extraplanetary origin.
- The **'Goldilocks zone'**...

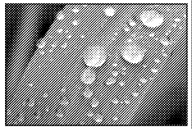
Molecular Structure of Water

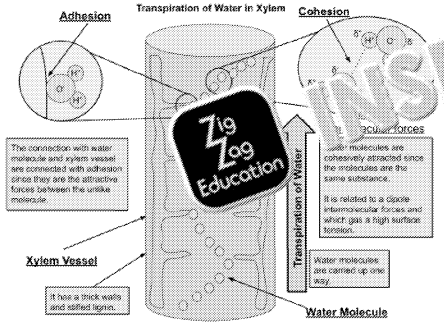
Each water molecule consists of

A solid line between atoms represents

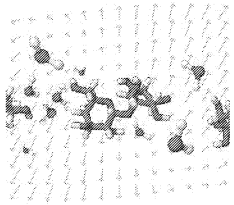


Cohesion and Adh





Water as the Universal Solvent



Solution of sucrose in water

Application

Emulsion Test

Why does the emulsion test for lipids work? What is happening which causes the mixture to turn cloudy?

Thermal P

Buoyanc

Application: C

Black-throated loon

THE BASICS

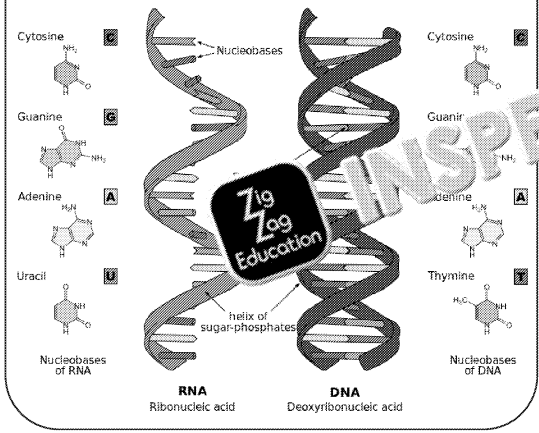
A1.2: Nucleic Acids

DNA and RNA

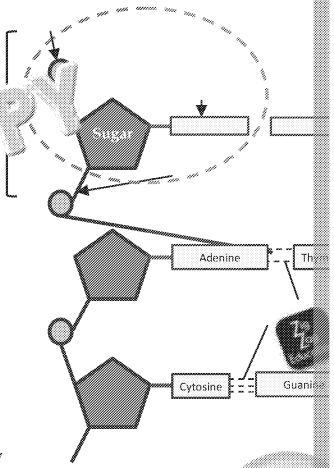
- Bonding between...
- The work of multiple scientists...

HL

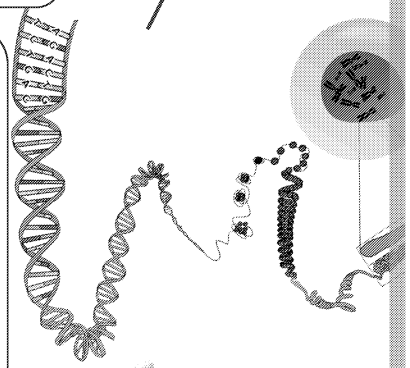
RNA vs [illegible]ucture



Polymerisation



DNA consists of a sequence of four bases...



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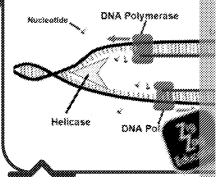
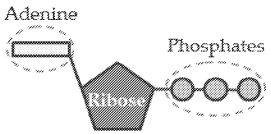


HL

Scientist	

ATP



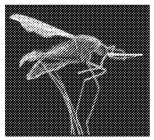
THE BASICS

A2.2: Cell Structure

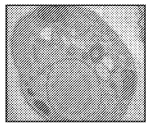
Eukaryotic and Prokaryotic Cells

Eukary

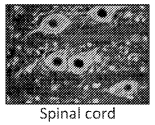
Microscopy



SEM micrograph of a mosquito



TEM micrograph of a eukaryotic cell



Spinal cord grey matter under immuno-fluorescence

Magnification

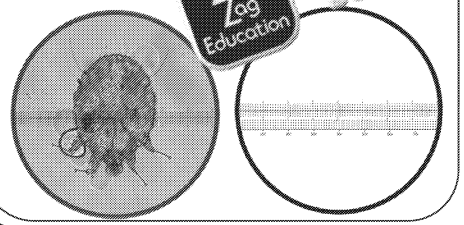
Magnification =

Actual size =

Calculating Magnification Using the Eyepiece Graticule and Stage Micrometer

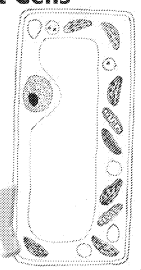
eyepiece graticule unit =

actual size =



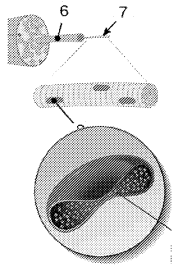
Animal Cells

Plant Cells

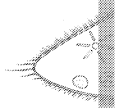


Fu

bial Cells



Param



A2.1: Origins of Cells & A2.2: Cell Structure - additional higher level only

HL

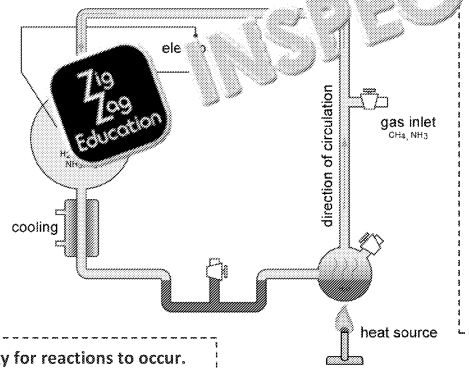
THE BASICS

How could life begin?

Conditions on Ea

The Miller–Urey Experiment

Replicating the early atmosphere.



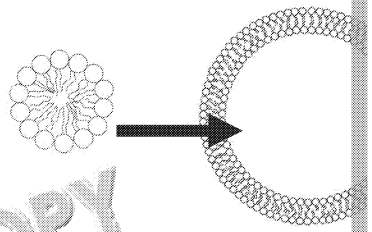
The evidence.

Provision of energy for reactions to occur.

Collecting the molecules.

Recent repeats of this experiment...

Vesicle Formation



THE BASICS

Last Universal Common Ancestor

LU

The First RNA

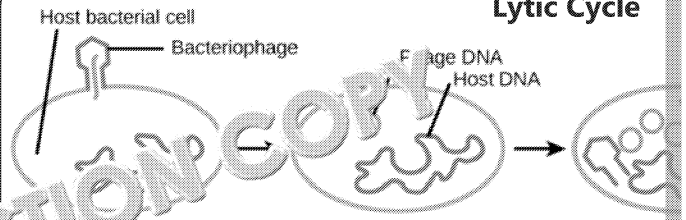
THE BASICS

HL

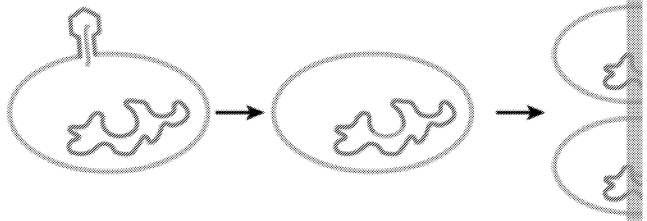
A2.3: Viruses (additional higher le

Viruses

Lytic Cycle

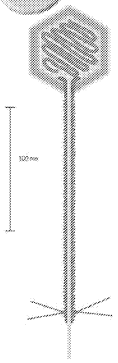


Lysogenic Cycle

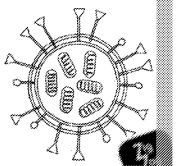


Origins of Viruses

Bacteriophage Lamb



Coronaviruses



THE BASICS

A3.1 Diversity of Organisms

Diversity of Organisms

Variation

- Asexual reproduction...
- Dichotomous ke...
- Environmental DNA...

HL

Environmental DNA, and genetic barcoding

Naming Organisms

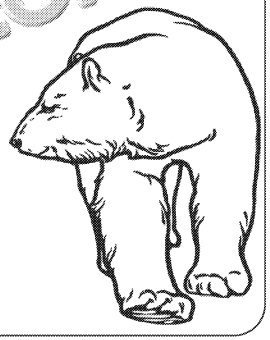
Biological Species Concept

Difficulties Applying the Biological Species Concept

HL

Crosses between species...

Application: *Ursus maritimus*: Species or Subspecies?



THE BASICS

HL

A3.2: Classification and Cladistics (additional higher lev

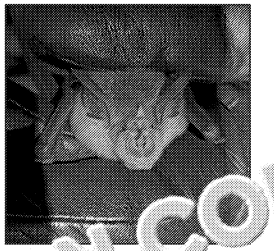
Classification and Cladistics

Phylogenetic Classification and Tax

T... Molecular Clock

Applying Classification

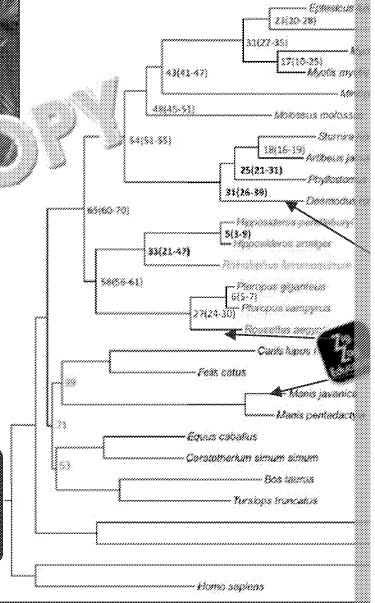
Rock hyrax
(*Procavia capensis*)



...eshoe bat
...inolophus
...ferrumequinum)
A member of the **unranked clade** Rhinolophoidea

Spectacled flying fox
(*Pteropus conspicillatus*)
A member of the **unranked clade** Megachiroptera

The **root**...



THE BASICS

A4.1: Evolution and Spec

Evolution and Speciation

- There are two major forms of speciation...
- **Adaptive radiation**...
- Pre-zygotic...
- **Hybridisation**...

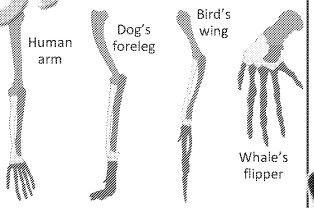
HL

D… Acquired Traits

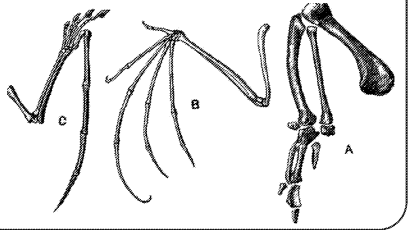
Evidence for Evolution

Comparing sequences

Ho… S…uctures

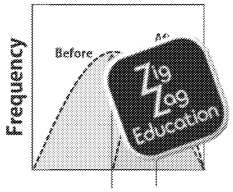


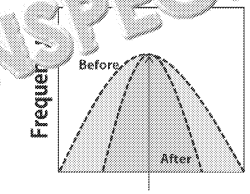
Analogous Structures

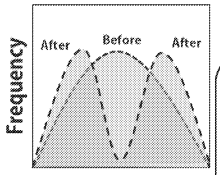


Natural Selection

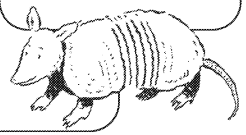
Selecti… …eedi…







Gene pool



HL

THE BASICS

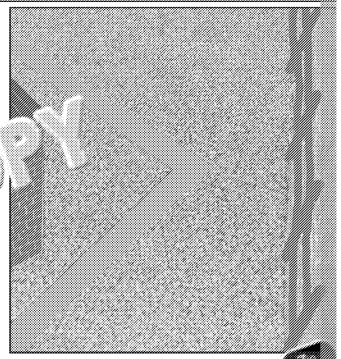
A4.2: Conservation of Biodi

Conservation of Biodiversity

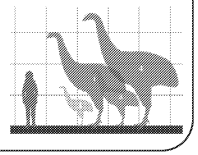
Species diversity

Species richness

Species evenness

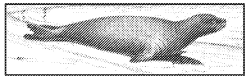


North Island Giant Moa



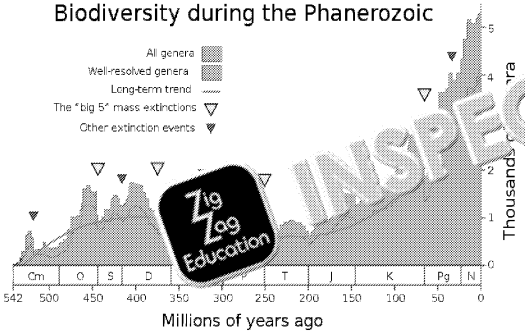
The Biodiv

Caribbean Monk Seal



Diversity Over Geological Time

Biodiversity during the Phanerozoic



Conservation

IB Topic on a Page, Theme A: Mark S

A1.1 Water

1. a) 1 oxygen atom, 2 hydrogen atoms
   b) Unequal sharing of electrons (between the oxygen and hydrogen atoms); leads oxygen), and a slight positive charge (on the hydrogens) / leads to slight opposi parts of the molecule
   c) (Strong) covalent bond <u>within</u> the molecule
   d) (Weak) hydrogen bonds between adjacent molecules
2. a) i. A force of attraction between water molecules
      ii. Surface tension is generated/made/created by / exists because of the cohe
      iii. Small aquatic organisms such as the water strider are able to walk on the
   b) A force of attraction between water molecules and another molecule (e.g. cellu
   c) In combination the strong <u>cohesive</u> force between water molecules, and the st water and walls of the xylem vessels / cellulose, gives capillary action; in which that is the xylem vessel. (While the column of water is held together by cohesio water and the xylem vessels also work against gravity, preventing water from fl Removal of water molecules at the top of the xylem vessels via transpiration, th water up the xylem (due to the cohesion between molecules).
3. a) Po ure)
   b) Ion molecules such as salts are easily 'pulled apart' by water due to the attracti of the water molecule
   c) Small organic molecules often dissolve easily in water due to the hydrogen bond the hydrogens or oxygens on the outer surface of the organic molecule
   d) An excellent **medium** for life; essential for cell **metabolism** (as reactions can occu molecules); easy transport of dissolved molecules (e.g. mineral ions, nutrients, a dissolved substances can be held in the same space (e.g. a cell)
   e) i. **Hydrophilic** ii. **Hydrophobic**
   f)

	Can dissolve	Cannot dissolve
Triglyceride	×	✓
Testosterone	×	✓
Fructose	✓	×

4. a) 4200 J/(kg•°C)
   b) It takes 4200 J to heat up one litre of water by 1 °C
   c) A lot of energy is needed to change the temperature of water; this means that environments, and even organisms themselves (due to the high water content important to allow enzymes to work effectively, as this will only happen at the
   d) Water can carry energy away from organisms that it is in contact with; aquatic good insulation to survive in an aquatic environment; (this is also why you are in cold water than in cold air)
5. a) Buoyancy is generated by the strong attraction between water molecules, whic liquid and also means that water resists being pulled apart
   b) This allows marine organisms to float or remain close to the surface, and also to
6. a) Condensation reactions are chemical reactions which result in the release of w when two organic molecules are joined
   b) Hydrolysis reactions are chemical reactions which require the input of water; i molecule into two smaller ones
   c) Synthesis of structural polymers (e.g. cellulose, structural proteins); synthesis o and glycogen
   d) Di breakdown of glycogen to glucose in the liver and muscle cells
7. a) Buoyancy – lighter but non-hollow bones provide some buoyancy, but also allo birds; viscosity – due to adaptations for the higher viscosity of water, loons have legs set further back on the body and slightly flattened leg bones makes loons viscosity water, but this also makes it difficult to walk on land; high thermal co feather structure generates a barrier to water, and provides the insulation nece in water, due to water's high thermal conductivity
   b) Buoyancy – denser bones allow the seal to stay submerged without effort; visco adaptation to water's high viscosity; high thermal conductivity of water – the se warm underwater: outer coat of fur (traps air), and thick blubber; high specific mechanisms due to steady temperature of habitat

8. a) **(HL)** Almost 1.4×10^9 km^3
   b) **(HL)** Early Earth was very hot (with little to no atmosphere), meaning any water
   been lost back out to space
   c) **(HL)** During the first few hundred million years, Earth was bombarded by thousa
   contained water
   d) **(HL)** 1. Earth is the perfect distance from the Sun to maintain water in a liquid s
   2. Earth's **gravity** is sufficient to hold liquid water (and even some gases) i
   e) **(HL)** The Goldilocks zone is the region of space which is close enough to the sola
   to generate liquid water, while also being far enough from the Sun to be cool e
   boil/evaporate away
   f) **(HL)** It is the region of a solar system capable of supporting life

A1.2 Nucleic Acids

1. Completed table should be as below – essential w d ar completed blanks are und

Ribonucleic acid (RNA)	Deoxyri
Contains the sugar ribose	Contains
Adenine, guanine, cytosine and uracil	Adenine, guan
Short, single chain	Long, d
Short-lived unstable molecule	Long-li
Transfers genetic information during protein synthesis	Stores
Three kinds (mRNA, tRNA, and rRNA). rRNA is a structural component of ribosomes.	Can exist in associati chromatin

2. Through condensation reactions; between the phosphate of one (DNA or RNA) base
   base, forming the phosphodiester bond
3. a) Infinite
   b) Any length is possible
   c) Using the formula 4^n, where n is the length of the DNA molecule in terms of the
4. a) The ATP molecule consists of a nitrogenous base (adenine), ribose sugar, and p
   b) The ATP molecule includes a string of three phosphate groups, rather than just
5. a) i. nucleotide; ii. phosphate group; iii. N-containing base; iv. phosphodiester bon
   b) i. deoxyribose; ii. nitrogenous bases; iii. phosphate; iv. anti-parallel, v. hydrogen
   viii. function; ix. division; x. inherited; xi. backbone; xii. stable; xiii. weak; xiv. thy
   xvii. code; xviii. chromosomes
   c) **(HL)** i. purines; ii. single; iii. size/width; iv. supercoiling; v. histone; vi. 8; vii. linke
6. **(HL)** Gap in text, i. 5' to 3'; Headings, ii–iv. Replication, Transcription, Translation
7. **(HL)** Completed table should read:

Scientist	What they did	Conc
Hershey and Chase	Used radioactively tagged sulfur and phosphorus in viral proteins and DNA to track its / the DNA's location.	Proved that DNA responsible for t
Chargaff	Used paper chromatography to separate (and measure amounts of) the four bases.	Analysis of frequ A+G = T+C. From complementary

A2.2: Cell Structure

1. a) Optical microscopy
   b) Electron microscopes
      i. scanning electron microscope
      ii. transmission electron microscopy
   c) freeze-fracture
   d) Fluorescent stains
   e) Immunofluorescence
   f) Cryogenic electron microscopy
   g) Equation 1: Actual size = $\frac{\text{Image size}}{\text{Magnification}}$

      Equation 2: Eyepiece graticule unit = $\frac{\text{Micrometer units}}{\text{Number of graticule units}}$
2. a) plasma membrane; b) temporary vacuole; c) permanent vacuole; d) 80s ribosome; e) nucleus; f) nucleolus; g) cell wall; h) cytoplasm; i) mitochondria; j) cytoskeleton; k) rough endoplasmic reticulum; l) smooth endoplasmic reticulum (SER); m) Golgi body / Golgi apparatus; n) lysosome; o) i. animal; ii. plant; iii. fungus
3. a) plasmid; b) circular DNA; c) flagella; d) capsule; e) 70s ribosome; f) cell wall; g) plasmid
4. a) No cell walls; form **multinucleate** filaments
   b) **Multinucleate**
   c) Incapable of dividing to form new cells; lack genetic material / a nucleus
   d) Have cytoplasm, but lack organelles, therefore cannot carry out most functions (need other cells for most life functions)
5. a) i. nutrition; ii. movement; iii. nutrition; iv. excretion; v. reproduction
   b) i. nutrition; ii. response to stimuli; iii. movement; iv. homeostasis

A2.1: Origins of Cells HL & A2.2: Cell Structure HL

a) CH_4, NH_3, and H_2 (in any order), H_2O
b) electrical, lightning
c) condensed, collected
d) clear, pink, dark
e) amino acids

2. a) billion; b) gradually; c) different; d) oxygen; e) ozone; f) UV; g) high; h) temperature; i) 100; j) 25; k) spontaneously; l) activation; m) frequent; n) energy; o) water; p) hydrothermal; q) 4.1
3. Compartmentalisation: the separation of cell components and reactions from an external environment is a precursor to life. This function could have been carried out by **vesicles** which spontaneously form. Amphipathic: the amphipathic nature of phospholipids allows them to naturally form bilayers. Self-assembly: the spontaneous formation of vesicles in water, and the compartmentalisation that would allow the process of **self-assembly**, an essential key precursor to the formation of life.
4. Catalysis; Self-replication
5. a) genetic; b) code; c) ancestor; d) enzymes; e) RNA; f) organisms; g) universal; h) 3.5; i) 3.5; j) stromatolites; k) cyanobacteria; l) 4.5; m) archaea; n) anaerobic; o) vents; p) sulfide
6. a) i. An early cell, which was probably quite large but inefficient at respiration, engulfed a more efficient prokaryotic cell.
      ii. Rather than digesting this prokaryote, the large cell provided a safe and nutrient rich environment for the cell to live. In return, the small cell provided significant amounts of ATP. This was beneficial when the cells divided. Over time the small prokaryote developed into the mitochondrion.
      iii. (At a later point) another prokaryote / a photosynthetic prokaryote / a cyanobacterium underwent a similar process
   b) 1. Mitochondria and chloroplasts have <u>DNA</u> (which is circular like prokaryotes)
      2. <u>Ribosomes</u> (a characteristic feature of prokaryotic cells) found in both
      3. These organelles are <u>self-replicating</u> even though they can no longer survive
7. a) Housekeeping genes control certain activities which are necessary in all cells (such as respiration)
   b) 4000
   c) Differentiation pathways
   d) Turning new genes 'on', and sometimes turning others 'off'
   e) Gene expression
8. 1. (Allows) sexual reproduction / increases genetic variation
   2. (Allows) greater complexity / the ability to fill a wide range of ecological niches / increased body size
   3. Increased lifespan

A2.3: Viruses (HL only)

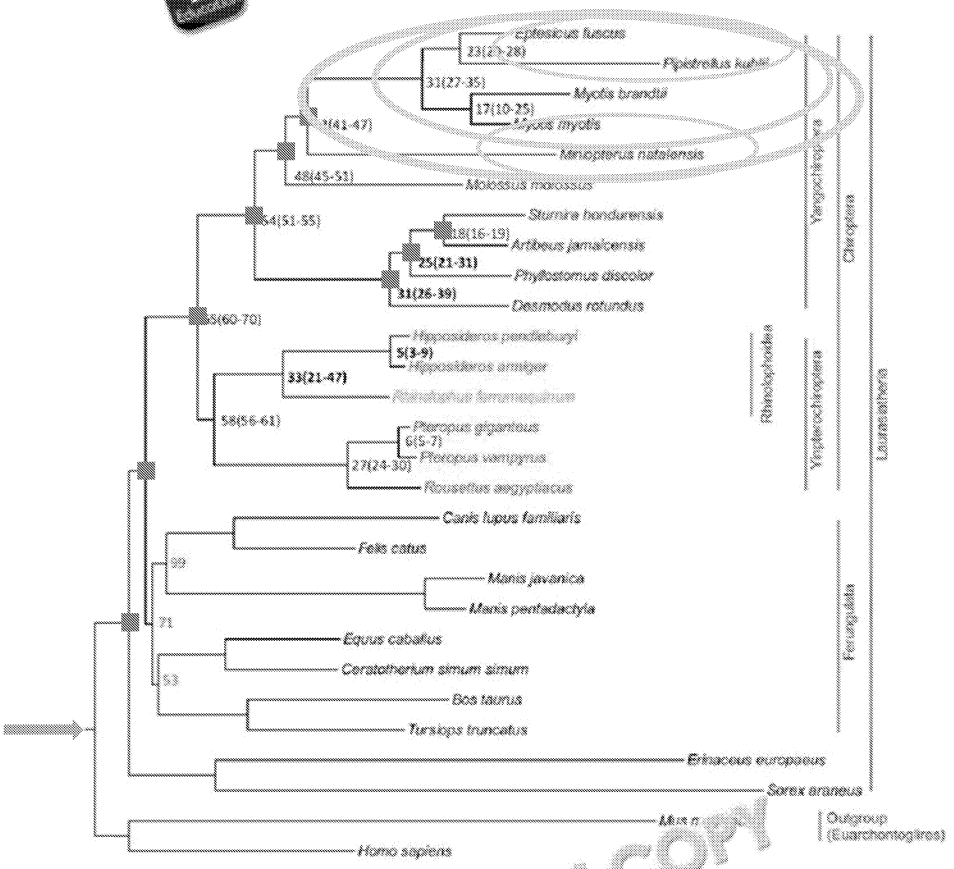
1. a) 20–300 nm
   b) By a protein coat
   c) Capsid
   d) Single-stranded DNA; double-stranded DNA; single-stranded RNA; double-stra
   e) 4
   f) They do not carry out any chemical reactions as they rely on host cell metaboli
   g) Conversion of viral RNA into DNA
   h) In the lipid envelope / on the outside or final layer of the virus
2. a) Viruses were probably among the first life forms to evolve
   b) It is likely that viruses 'came into existence' more than once
   c) Theories of viral evolution
   d) It is very possible that their similarities are due to co[illegible]ent evolution
3. a) Host bacterial cell; b) Host DNA; c) Phage DNA [illegible]s; d) Phage proteins are
4. a) The phage infects a cell; b) The phage DN[illegible] ir[illegible]porated / joined with / merges
   c) The (host) cell divides; d) Under [illegible]fu[illegible]en) conditions
5. a) Bacteriophages; b) ear[illegible] [illegible]eloped; d) DNA; e) bacterial
6. a) family; b) cold[illegible]mic; d) single-stranded RNA; e) animals; f) quickly; g) proo
7. a) retro[illegible]) n[illegible]hanism; c) mutations; d) immune
8. a) 1. [illegible]infection with the virus does not lead to immunity from future infecti
      2. Vaccines must be continually developed (e.g. the flu vaccine, for which th
      this causes an economic drain on society
   b) 1. Opportunities for **recombination**
      2. Large population size
      3. Shorter replication cycles
      4. Mode of replication – RNA viruses tend to have higher mutation rates as r
      'checking' mechanisms
      5. **Transmissibility** – viruses which are highly contagious move from host to h
      opportunities for mutation

A3.1 Diversity of Organisms

1. a) Fully or partially determined by the environment in which the organism is living
   b) Note: answers will vary – credit any sensible suggestion
   Expected answers include: eating different food, doing different amounts of exe
   different levels / types of exercise
   c) The observable differences in the size and shape / morphology, between males
   d) Particular genetically controlled characteristics / genes are only **expressed** in a
   females of the same species look very different
   e) Interspecific variation / the genetic variation between different species; and sex
2. a) i. **Genus name**, given first, written with a capital letter
   ii. **Species name**, given second, written with a lower-case letter
   b) italics, underlined
3. a) **(HL)** A sequence of DNA from within a gene which is distinctive between species
   b) **(HL)** Water and soil
   c) **(HL)** Environmental DNA sequencing allows scientists to identify which species are
   can be useful for ecological and conservation)
4. a) If individuals from the two populations are able to mate, and produce healthy, f
   b) Individuals from the two populations may not mate at all due to reproductive is
   mechanical isolation, temporal isolation, behavioural isolation), or offspring will
5. a) **(HL)** During the process of speciation it may be difficult but not impossible for th
   interbreed successfully, causing mixed findings; asexually reproducing species d
   apply the biological species concept implies all individuals are separate species
   Alternative answer: asexually reproducing species which never use sexual repro
   each individual is a separate species if the biological species concept were strict
   able to breed with others of its kind
   b) **(HL)** The parents have different numbers of chromosomes. The offspring do not
   their chromosomes, and cannot produce viable gametes during meiosis.
6. a) The human **karyotype** is similar to the karyotypes of the other great apes, indic
   The human chromosome 2 is homologous to chromosomes 2p (2a/13) and 2q (
   karyotype. As the smaller chromosomes exist in all great apes, this indicates tha
   during human evolution.
   b) Number of chromosomes, the banding patterns on each chromosome, and the
7. a) genome; b) sequencing; c) human; d) began;
   e) institutions (accept suitable alternatives, e.g. universities, research teams, or coun
   h) nucleotide; i) sequence; j) function; k) organisms; l) technology; m) cheaper; n) co
   p) personalised; q) evolution
8. **(HL)** There should always be only two possibilities at each branching point in the diag

A3.2: Classification and Cladistics HL

1. a) Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species (in that order)
   b) *Cervus elaphus*
   c) **DNA**, **mRNA** or **amino acid** sequences
   d) Bacteria, Archaea, Eukarya (in that order)
2. DNA mutations occur at a relatively constant rate. Using this information combined with differences between two organisms allows for the calculation of an estimate of how common ancestor.
3. a) morphology; b) convergent; c) rodent; d) taxonomic; e) relative; f) mammals; g) cl i) scientists; j) evidence; k) clade
   l) i. A terminal branch is any end point on the right-hand side of the diagram branch ends with a species name.
      ii. The nodes are the branching points on the clado[illegible]n. A few possible answ diagram below. Any branching point co[illegible]lly [illegible]elled should be credited.
      iii. Clades are groups of organisms which share a common ancestor. This can relationship, as all members of the clade are descended from a single anc single clade, but there are many smaller ones too. Some possible answers ovals in the lower part of the diagram.
      iv. [illegible]ro[illegible]s the starting point of the cladogram, identified by an arrow in t

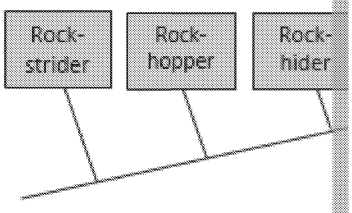


   m) The root represents the shared com[illegible]n[illegible]or of all species and groups sho
   n) Each **node** represents the h[illegible]common ancestor between the species

4. a)

	Rock-hopper	Twin-tailed rat	Rock-strider	Rock-hider	Desert-scurrier
Rock-hopper	-				
Twin-tailed rat	2	-			
Rock-strider	1	3	-		
Rock-hider	1	1	2	-	
Desert-scurrier	2	0	3	1	-

b)



A4.1: Evolution and Speciation

1. a) Note: answers will vary – credit any suitable suggestion
   Possible answers include: large muscles from strenuous work or body building
   b) Mutation
   c) Inheritance / The transfer of genetic information from parent to offspring / Ve
2. a) population; b) environment; c) differing; d) reproduce; e) advantage; f) frequency;
   h) i. Directional, ii. Stabilising, iii. Disruptive
3. a) Evolution; b) control; c) purpose; d) domesticated; e) breeds; f) wild; g) selectively
4. All the genes and alleles present in all individuals in a population
5. a) DNA, RNA, and protein / amino acids
   b) Structures which are similar across a clade, although they may look very different
   c) Homologous structures are evidence of shared ancestry, and form through the
   when closely related organisms gradually evolve to a different environmen
   d) Pentadactyl limb
   e) Grasping; lifting; walking / running / terrestrial locomotion; flying; swimming
   f) Structures which are superficially similar (appear similar on the surface) due to
   which share no common ancestry
   g) Convergent evolution occurs when unrelated organisms (often in different loca
   of similar) analogous structures to appear through different evoluti
   of birds and pterosaurs look superficially similar but are very different on
   separate evolutionary origins)
   A pair of marsupial and placental mammals, or Old World and New World anim
6. a) Reproductive isolation / no gene flow, and the accumulation of genetic differe
   b) Change in allele frequencies; creation of new alleles via mutation (in one popul
   through duplication); chromosomal changes
   c) **Reproductive isolation**: if genes are able to flow between the two populations,
   the populations will be shared, such that divergence cannot happen
   Differing selection pressure: when two populations are subjected to different s
   the divergence of their gene pools, as different alleles and genes will be favour
   Mutation: genetic mutations generate new alleles; when there is no gene flow
   mutation will be restricted to one population, adding to the genetic differences
   d) If the genetic differences between the two populations are sufficient to preven
   populations from breeding successfully (able to produce fertile offspring), then
   e) The Congo River
   f) They are no longer the same species / their genetics have become too dissimila
7. a) **(HL)** When one species or one small group of species adapts to fill many vacant
   in the process
   b) **(HL)** Following a major extinction event; when a single species finds its way to a
   low diversity (e.g. Darwin's finches)
8. a) **(HL)** When the karyotype is duplicated, generating a karyotype of 4n, 6n, or eve
   b) **(HL)** Hybridisation among plants sometimes causes duplication of the chromoso
   which the chromosome number may be 4n, 6n, or even 8n. Occasionally such h
   themselves but not with the parent population, instantaneously generating a n
9. **(HL)** Pre-zygotic: mate recognition, sperm recognition, behavioural isolation, tempor
   Post-zygotic: hybrid inviability, hybrid breakdown, hybrid infertility

A4.2: Conservation of Biodiversity

1. a) General increase over time
   b) Periods of rapid **diversification** and the generation of new species (**speciation**)
   c) Survivors adapt and evolve to fill vacant **ecological niches** through the process
2. a) i. **Species richness** – the number of different species in the area of interest
      ii. **Species evenness** – describes the distribution of individuals among differen
      iii. **Biodiversity index** – a calculation / an equation used to measure species d both species richness and species evenness
   b) The species richness in the garden on the left appears lower than the garden o number of plant species. The garden on the left is dominated by a particular gr
3. a) The variation which exists within the physical environment, including both biot diversity means that within the ecosystem there are many different 'micro' ha
   b) The garden shown on the right shows small changes s as adding a fruit tree and choosing not to remove 'weeds' which h gr y increased the **habitat** d abiotic factors such as light intensity a oi isture in different areas of the
4. a) The variation which exists wit e **gene pool** of a particular population (Higher genetic dive ad to greater **resilience**, making a population more its environm
   b) A the grass in the garden to seed between mowings could have allowed on t to increase
5. Hunting by Maori people; Predation of chicks by the Polynesian dogs (introduced by eggs by dogs and rats (also accidentally introduced by human settlers)
6. a) 2008
   b) 1952
   c) Hunting by people for oil and meat (exacerbated by their docile nature and lac Overfishing of the reefs in which the seals hunted (causing many seals to die o
7. a) 1. **Overharvesting** and overhunting; 2. **Habitat destruction** and degradation (in 3. Introduction of **invasive species**; 4. **Pollution**; 5. Rapid climate change
   b) Around 100 to 1000 species per year
   c) The **sixth mass extinction**
   d) Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Servi
   e) (Founded in 2012 by 94 countries) IPBES aims to support the use of scientific in conservation and biodiversity
   f) Data collection carried out by 'non-scientists'
   g) Note: answers will vary – credit any appropriate response. It is likely most stud the full ToaP sheet: e.g. the RSPB's Big Garden Birdwatch (which has helped to distributions of Britain's birds)
   h) **Anyone can be involved**, so citizen science allows for much greater amounts o There is a **set procedure**, or certain combinations of data required to be submi combined reliably.
8. a) Previous logging industry, and current expansion of the palm oil industry
   b) Population decline of many animals and plants (e.g. orangutan, endemic dipter Massive biodiversity loss (though rates are unknown due to large proportion o
9. a) Climate change, pollution, and damage from divers and fishing boats
   b) Coral bleaching and biodiversity loss, and major loss ocal economy and cu
10. a) Conservation methods which occur within th tu habitat
    b) Tracking and monitoring, reintroduc re ing, ecosystem restoration / re degraded ecosystems
    c) Conservation meth h happen outside the natural environment
    d) Gene d s provide a store of genetic material which can be used to sup to to main genetically viable, and possibly even bring back extinct species
    e) Be al research can help by informing in situ conservation efforts, making Genetic and reproductive research helps to support captive breeding program populations of a species.
    f) Evolutionarily Distinct and Globally Endangered
    g) The Zoological Society of London (ZSL)
    h) By effectively identifying priority species
    i) 1. Belonging to a very small clade, with few or no close relatives (Evolutionarily of extinction, usually all known populations are threatened, or there may be o (Globally Endangered)