18.1 Classification

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18.1.1 DEFINITIONS OF SPECIES

Definitions of Species

- Scientists have been classifying organisms into species for hundreds of years, in order to investigate the diversity of life that exists today and in the past
- There is difficulty in determining whether new organisms discovered belong to an existing species, or a new one
- This is because the most widely accepted definition of a species is:
  - A group of organisms with similar **morphological** and **physiological** features that able to breed together and **produce fertile offspring**
- This is the **biological species concept**, and is reliant on determining whether interbreeding produces fertile offspring – this is difficult and time-consuming to determine in practice
- However there are other discriminating factors that scientists can use to group similar organisms together

Morphological species concept

- In the past, most scientists described organisms by their **physical features** (morphology) as these can be more easily observed
- They group together organisms that **share many physical features** that **distinguish them from other species**
- This is the **morphological species concept**

Ecological species concept

- When there is a population of similar organisms **living in the same area at the same time,** they can be described as an **ecological** species
- This is the **ecological species concept**

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Naming species

- Species are often given common names, but in order to avoid confusion about what group of organisms scientists are talking about, all species are given a two-part scientific name using the **binomial system**
- This naming convention was developed and established by the Swedish scientist Carl Linnaeus in the 18th Century
- The first part of the name is the genus that the species belongs to; this is a group of very similar organisms
- The second part of the name is specific and unique to a single group of organisms that are identified as a species (and occasionally there may be a third name)
- The binomial name is always italicized in writing (or underlined if it is not possible to italicise)
- For example:
  - The most commonly known yeast is ***Saccharomyces cerevisiae***
  - It is common to abbreviate the genus name: ***S. cerevisiae***
  - ***Saccharomyces paradoxus*** is another species of that is a member of the same genus as *cerevisiae*

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18.1.2 THE THREE DOMAINS: ARCHAEA, BACTERIA & EUKARYA

The Three Domains: Archaea, Bacteria & Eukarya

- Taxonomy is the practice of biological classification
- It involves placing organisms into a series of categories or taxa
- By grouping organisms into taxa it can make them easier to understand and remember
- There are several **different ranks** or levels within the hierarchical classification system used in biology
- The highest rank is the **domain**
- **Cell type** has a major role in the classification of organisms into the three domains; but do not confuse cell types and domain
    - **Prokaryotic** cells are easily distinguishable in that they lack a nucleus
    - **Eukaryotic** cells have compartmentalised structures, with at least their genetic material segregated from the rest of the cell in a nucleus
- Based upon molecular analysis of RNA genes in particular, scientists have realised that using cell type to classify organisms is insufficient, and that **prokaryotes** could be divided into two separate groups (domains)
- The **three domains** are:
    - Archaea (prokaryotes)
    - Bacteria (prokaryotes)
    - Eukarya (eukaryotes)

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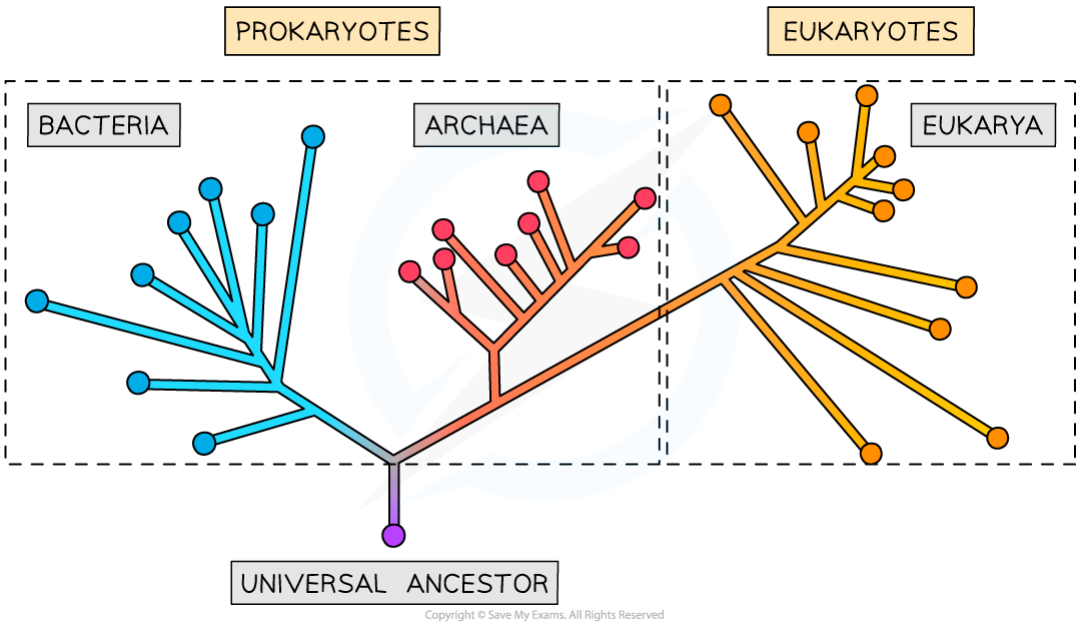

The taxonomic classification system with the three domains

Archaea

- Organisms within this domain are sometimes referred to as the extremophile **prokaryotes,** archaea were first discovered living in **extreme environments,** but not all archaea do
- Archael cells have **no nucleus** (and so are **prokaryotic**)
- They were initially classified as bacteria until several unique properties were discovered that separated them from known bacteria, including:
  - Unique lipids being found in the membranes of their cells
  - No **peptidoglycan** in their cell walls
  - Ribosomal structure (particularly that of the small subunit) are more similar to the eukaryotic ribosome than that of the bacteria
- Archaea a similar size range as bacteria (and in many ways metabolism is similar between the two groups)
- DNA transcription is more similar to that of eukaryotes
- Example: *Halobacterium salinarum* are a species of the archaea domain that can be found in environments with high salt concentrations like the Dead Sea

Bacteria

- These are organisms that have **prokaryotic cells** which contain no nucleus
- They vary in size over a wide range: the smallest are bigger than the largest known-viruses and the largest are smaller that the smallest known single-celled eukaryotes
- Bacterial cells divide by binary fission
- Example: *Staphylococcus pneumoniae* is a bacteria species that causes pneumonia

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Eukarya

- Organisms that have **eukaryotic cells** with nuclei and membrane-bound organelles are placed in this domain
- They vary massively in size from single-celled organisms several micrometres across to large multicellular organisms many-metres in size, such as blue whales
- Eukaryotic cells divide by mitosis
- Eukaryotes can reproduce sexually or asexually
- Example: *Canis lupus* also known as wolves

Exam Tip

It might be worth refreshing your knowledge on the defining features of prokaryotic and eukaryotic cells before tackling this new topic!

Differences between Archaea & Bacteria

- Domains are the highest taxonomic rank that exist within the hierarchical classification system of organisms
- Initially, all organisms within the Archaea domain were classified as Bacteria
- Then several unique features possessed by Archaea were discovered that separated them from both Bacteria and Eukarya
- The main differences between Archaea and Bacteria are seen in:
  - **Membrane lipids**
  - **Ribosomal RNA**
  - **Cell wall composition**

Membrane lipids

- The membrane lipids found in the cells of Archaea organisms are completely **unique**
- They are not found in any **bacterial** or **eukaryotic** cells
- The membrane lipids of Archaea consist of **branched** hydrocarbon chains bonded to glycerol by **ether** linkages
- The membrane lipids of Bacteria consist of **unbranched** hydrocarbon chains bonded to glycerol by **ester** linkages

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Ribosomal RNA

- Both Archaea and Bacteria possess 70S ribosomes
- The 70S ribosomes in Archaea possess a smaller subunit that is **more similar to the subunit found in Eukaryotic** ribosomes than subunits in Bacterial ribosomes
    - The **base sequences of ribosomal RNA** in Archaea show more similarity to the rRNA of Eukarya than Bacteria
    - The **primary structure of ribosome proteins** in Archaea show more similarity to the ribosome proteins in Eukarya than Bacteria

Composition of cell walls

- Organisms from the **Bacteria** domain have cells that always possess cell walls **with peptidoglycan**
- Organisms from the **Archaea** domain also have cells that always possess cell walls, however these **do not contain peptidoglycan**

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Characteristics & features of the three domains table

Feature	Archaea	Bacteria	Eukarya
Cell type	Prokaryotic	Prokaryotic	Eukaryotic
DNA	Circular chromosome	Circular	Linear chromosomes + circular mtDNA and cpDNA
Nucleus in cells	No	No	Yes
Plasmids	Sometimes	Yes	No
Membrane bound organelles	No	No	Yes
Ribosomes	70S ribosomes	70S ribosomes	Larger 80S ribosomes in cytosol and 70S ribosomes in mitochondria and chloroplasts
Cell walls	Always present (without peptidoglycan)	Always present (with peptidoglycan)	No
Histones	No	No	Yes
Cell division	Cells divide by binary fission	Cells divide by binary fission	Cells divide by mitosis

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18.1.3 EUKARYA

Eukarya

- The hierarchical classification system of organisms in biology is used to organise and **group similar organisms together** so that they can be more easily understood
- There are several taxonomic ranks that exist
- **Species is the lowest taxonomic rank** in the system
  - Similar species can be grouped in a **genus**
  - Similar genuses can be grouped in a **family**
  - Similar families can be grouped into an **order**
  - Similar orders can be grouped into a **class**
  - Similar classes can be grouped into a **phylum**
  - Similar phyla can be grouped into a **kingdom**
  - Similar kingdoms can be grouped into a **domain**
- **Domains are the highest taxonomic rank** in the system
- There are a few different rhymes that exist to help you remember the different ranks in the taxonomic classification system. You can always make up your own but the one below is super helpful!
- The first letters of all the different ranks below the domains can be remembered as:
  - **K**ings **P**lay **C**hess **O**n **F**ancy **G**old **S**quares
  - **K**ingdom **P**hylum **C**lass **O**rder **F**amily **G**enus **S**pecies

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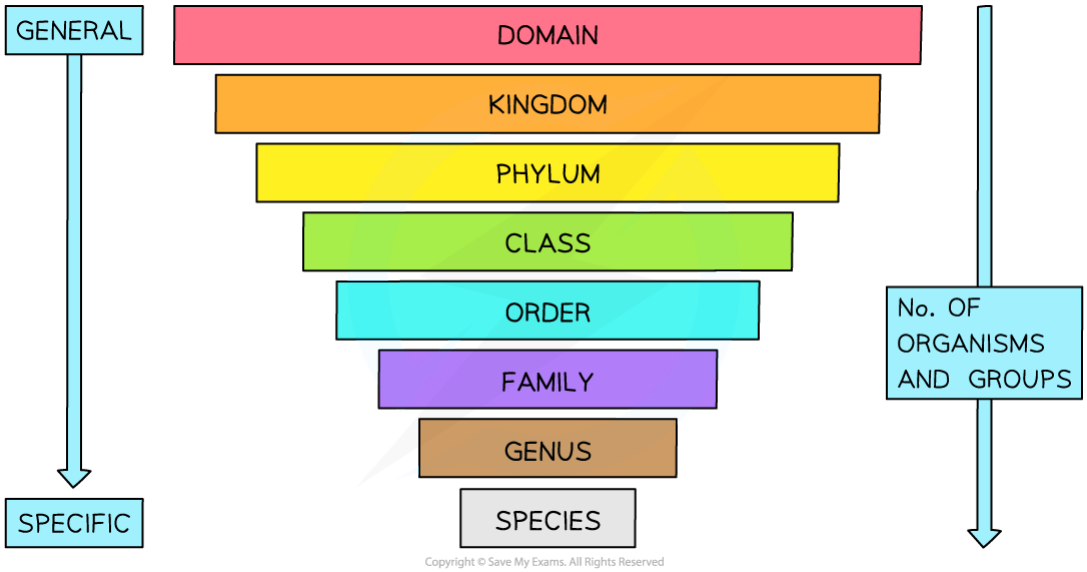

The hierarchical classification system – The higher ranks contain more organisms with less similarity between them. The lower ranks contain fewer organisms with more similarity between them

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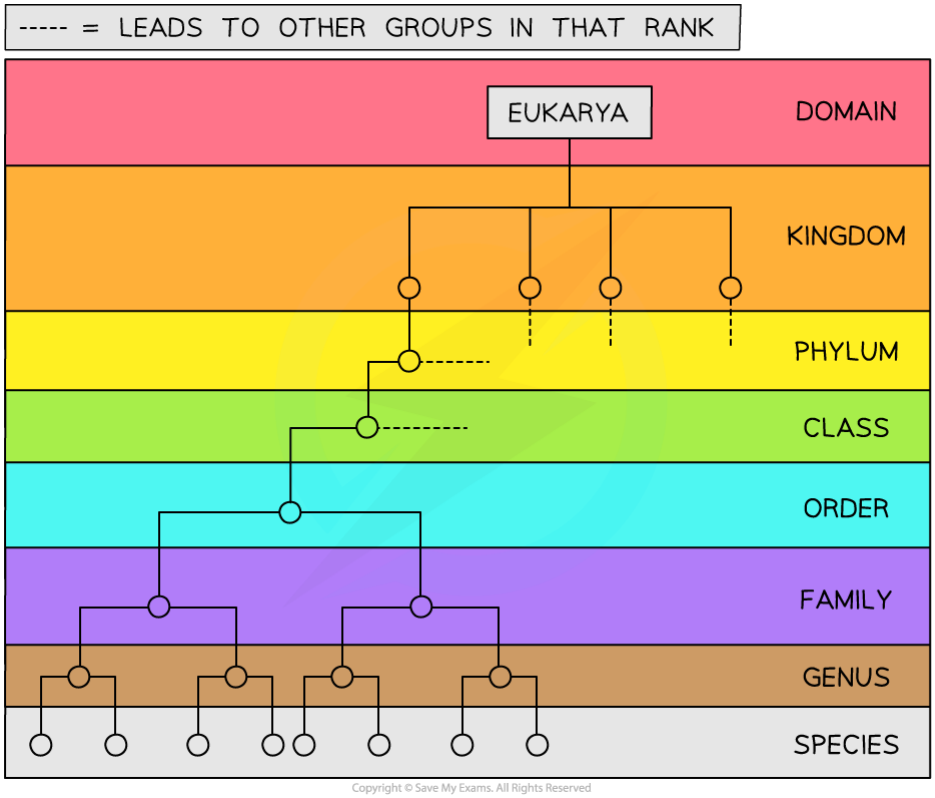
Classification of an organism in the Eukarya domain

- Just like the other domains, **Eukarya** contains the taxonomic hierarchy of kingdom, phylum, class, order, family, genus and species



The classification system is organised within the eukarya domain – Note there are missing groups at each rank

- A wolf is an example of an organism in the Eukarya domain
- It can be classified further into its kingdom, phylum, class, order, genus and species
- A wolf belongs to the following taxonomic groups:
  - Domain: Eukarya
  - Kingdom: Animalia
  - Phylum: Chordata
  - Class: Mammalia
  - Order: Carnivora
  - Family: Canidae
  - Genus: *Canis*
  - Species *Canis lupus*

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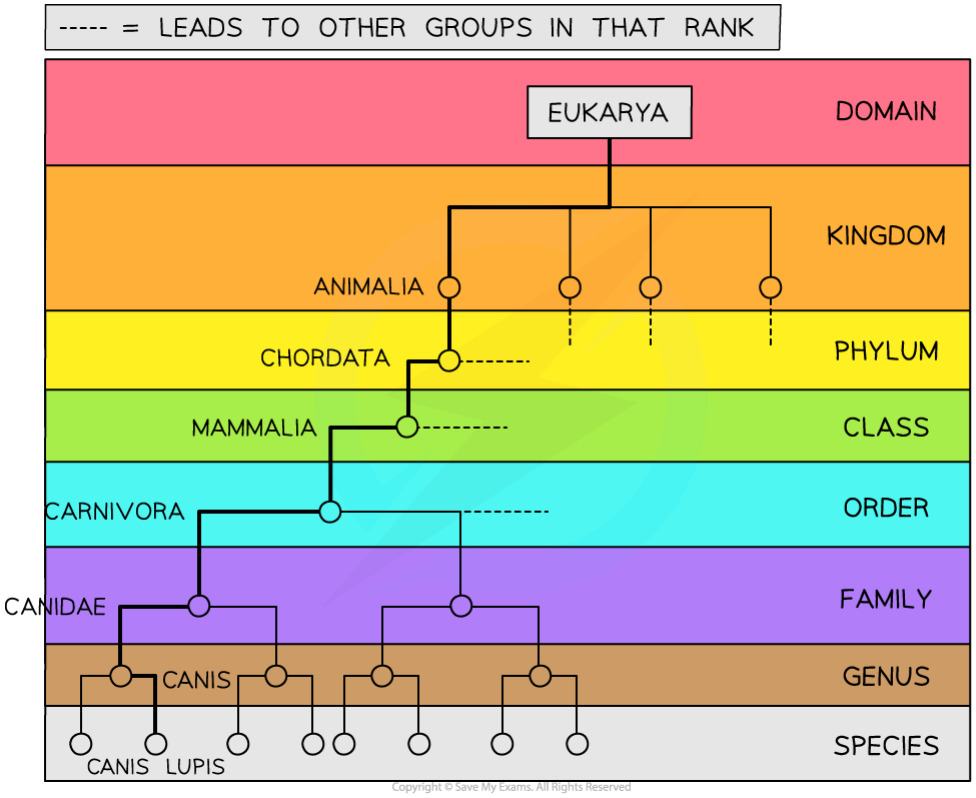

The classification of a Wolf

- The *Hibiscus rosa-sinensis* is another example of of an organism in the eukarya domain
- It is a colourful flowering plant
- It belongs to the following taxonomic groups:
  - Domain: Eukarya
  - Kingdom: Plantae
  - Phylum: Angiospermae
  - Class: Dicotyledonae
  - Order: Malvales
  - Family: Malvaceae
  - Genus: *Hibiscus*
  - Species: *Hibiscus rosa-sinensis*

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A classification table

Taxonomic Rank	Wolf	Hibiscus
Domain	Eukarya	Eukarya
Kingdom	Animalia	Plantae
Phylum	Chordata	Angiospermae
Class	Mammalia	Dicotyledonae
Order	Carnivora	Malvales
Family	Canidae	Malvaceae
Genus	Canis	Hibiscus
Species	Canis Lupus	Hibiscus Rosa-sinensis

Exam Tip

The name of a species always consists of two words: the **genus and species**. This means when provided with the Latin name of a species you are automatically provided with information about the last two taxonomic ranks that the organism belongs to. Remember this when being asked to show or explain the classification of an organism in the exam.

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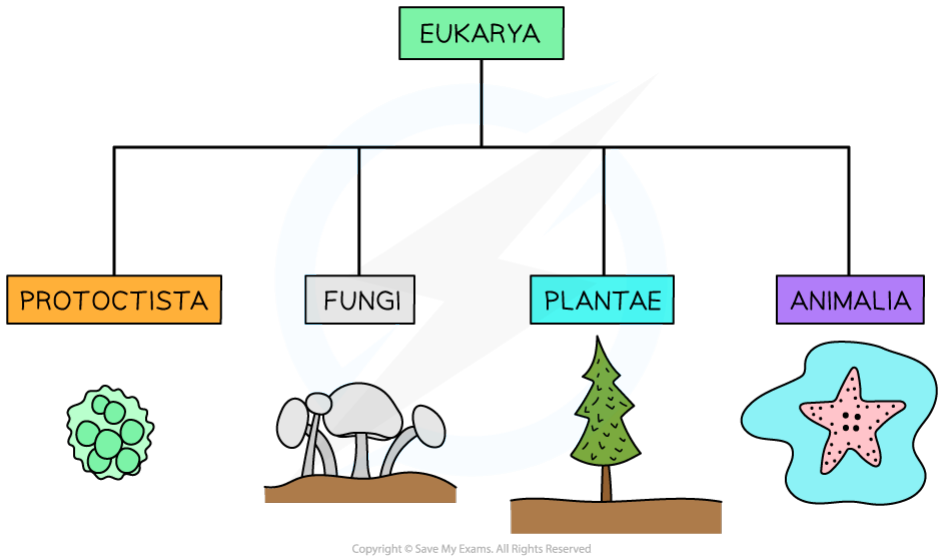
18.1.4 KINGDOMS

Kingdoms

- The domain Eukarya can be divided into 4 kingdoms:
  - **Protoctista**
  - **Fungi**
  - **Plantae**
  - **Animalia**
- Organisms from each of the four kingdoms have **distinct characteristics** and features, but share similarities in that they have cells with membrane-bound nuclei separating genetic material from the cytoplasm, and compartmentalisation within their cells as a result of the presence of other organelles



The four kingdoms within the Eukarya domain: protoctista, fungi, plantae and animalia

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Kingdom Protoctista

- All Protoctista are **eukaryotic,** and this broad group of cellular life encompasses all eukaryotic cells that do not belong to the other three eukaryotic kingdoms
- Members of this kingdom show great diversity in all aspects of life including structure, life cycle, feeding and trophic levels and well as modes of locomotion
- Protoctists can exist as **single-celled organisms** or as a **group of similar cells**
- A group of Protoctista known as protozoa possess cells similar to animal cells
    - Their cells have **no cell wall**
- Another group of Protoctista known as algae possess cells similar to plant cells
    - Their cells have **cellulose cell walls and chloroplasts**
- *Stentor roseli* is a protoctist that has flagella all over its body which help it feed and move

Kingdom Fungi

- The oldest organism in the world is thought to be a fungus aged somewhere between 1500 – 10,000 years old
- All fungi are **eukaryotic** cells
- The cells of fungi:
    - Possess non-cellulose **cell walls** (often made of the polysaccharides **chitin** and **glucans**
    - Don't have cilia
- Fungi are **heterotrophs:**
    - They use organic compounds made by other organisms as their source of energy and molecules for metabolism
    - They obtain this energy and carbon by **digesting dead/decaying matter** extracellularly or from being **parasites** on living organisms
- Fungi **reproduce using spores** that disperse onto the ground nearby
- Fungi have a simple body form:
    - They can be unicellular (like the common baker's yeast *Saccharomyces cerevisiae*
    - Some consist of long threads called hyphae that grow from the main fungus body (mycelium)
    - Larger fungi possess fruiting bodies that release large numbers of spores
- The mould found on bread is actually a fungus: bread mould fungus *Rhizopus nigricans*

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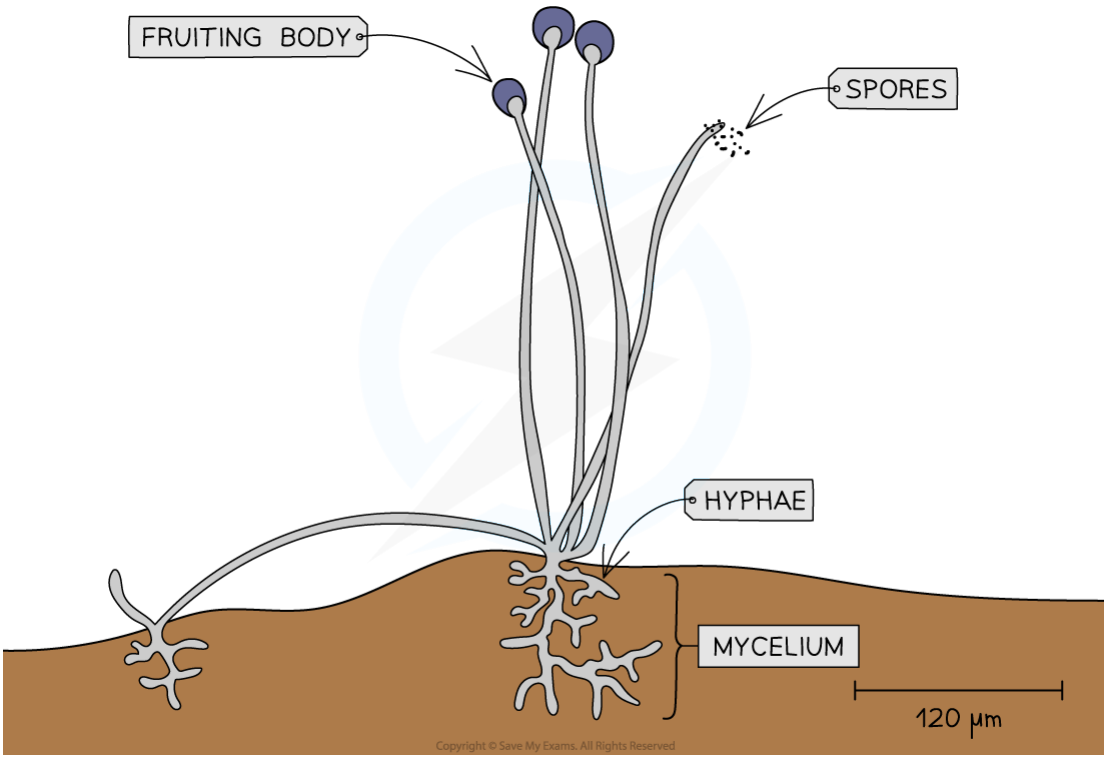

The structure of a fungus with its hyphae, mycelium and fruiting bodies

Kingdom Plantae

- Plants are **multicellular eukaryotic** organisms
- Plant cells:
  - All have **cell walls** composed of cellulose
  - Possess large (and usually permanent) **vacuoles** that provide structural support
  - Are able to differentiate into **specialized cells** to form **tissues and organs**
  - Possess **chloroplasts** that enable **photosynthesis** (not all plant cells have chloroplasts)
  - Can sometimes have **flagella**
- They are **autotrophs**
  - This means they can synthesize their organic compounds and molecules for energy use and building biomass from inorganic compounds
- Plants have **complex body forms**
  - They have branching systems above and below the ground
- Bristlecone pines are found in the USA, it is estimated that some of them could be 3000 years old

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Kingdom Animalia

- Animals are also **multicellular eukaryotic** organisms
- Animal cells:
  - Are able to differentiate into **many different specialised cell types** that can form **tissues and organs**
  - Have **small temporary vacuoles** (for example, lysosomes)
  - Have **no cell walls**
  - Sometimes have cilia
- They are **heterotrophs**
  - They have a wide range of feeding mechanisms
- They have a wide range of body forms:
  - Communication within their complex body forms takes place through a **nervous system and chemical signalling**
- Blue whales are the largest living animal species

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18.1.5 VIRUSES

Viruses

- Viruses are **microorganisms** that can only be seen using an electron microscope
- They have no cellular structure (and so are **acellular** and **no metabolism**
- Viruses **hijack the DNA replication machinery** in host cells
- The energy viruses need for replication is provided by **respiration** in the host cell
- Viruses possess none of the characteristic features used for classifying organisms so they sit **outside** of the three-domain classification system
- There is a wide-ranging debate as to whether viruses should be classified as 'living' or 'non-living' based on their inability to carry out the defining features of life outside of a host cell

Classifying viruses by their genetic material

- Viruses are classified according to the **type of nucleic acid** (RNA or DNA) their genome is made from, and whether it is single-stranded or double-stranded
- In **cellular organisms** like animals and plants, **DNA is always double-stranded** and **RNA is usually always single-stranded**
- However, in **viruses,** DNA and RNA can be **either single-stranded or double-stranded**
- As a result, there are four groups of viruses that exist:
    - DNA single-stranded viruses
    - DNA double-stranded viruses
    - RNA single-stranded viruses (this is the type of genome of SARS-CoV-2, the virus responsible for the COVID-19 pandemic)
    - RNA double-stranded viruses

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Classification of viruses table

Nucleic acid	Single or Double stranded	Virus	Host Organism	Disease
DNA	Single	Canine parvovirus type 2	Dog	Canine parvovirus
DNA	Double	Varicella zoster virus (VZV)	Human	Chickenpox
RNA	Single	Morbillivirus	Human	Measles
RNA	Double	Human immunodeficiency virus	Human	AIDS