Chapter 5 —> Evolution

5.1 Evolution evidence

Evolution:

- Describes a change over time —> change refers to the heritable characteristics of a species
- Heritable characteristics —> encoded by genes and transferred between generations as alleles
- Biological evolution —> change in the allele frequency of population gene pool over generations
  —> cumulative changes that occur within a population between generations

Fossils:

- Fossil records provide evidence by revealing features of ancestors for comparison against living descendants —> represents the totality of fossils (both discovered and undiscovered)
- Fossil —> the preserved remains or traces of any organism from the remote past
  —> Body fossils —> provide direct evidence of ancestral form (bones, teeth, leaves, …)
  —> Traces —> provide indirect evidence of ancestral forms (footprints, tooth marks, …)

Law of fossil succession:

- Fossils can be dated by determining the age of the rock layer (strata) in which the fossil is found
- Sedimentary rock layers —> develop in a chronological order —> each strata represents a variable length of time that is classified according to a geological time scale
- The ordered succession of fossils suggests that newer species likely evolved as a result of changes to ancestral species —> prokaryotes appeared in fossil record before eukaryotes
  —> ferms appear in fossil record before flowering plants
  —> Invertebrates appear in fossil record before vertebrate species

Transitional fossils:

- Demonstrate the intermediary forms that occurred over the evolutionary pathway from one gene —> create links between species by exhibiting traits common to both an ancestor and descendant
- Archaeopteryx —> links the evolution of dinosaurs to birds
- The fossil record is incomplete —> because fossilisation requires a set of circumstances in order to occur —> very few organisms become fossils
- Only the hard parts of an organisms are typically preserved —> only fragments are discovered
- With limited fossil data it can be difficult to discern the evolutionary patterns

Fossil evidence:

- Australopithecus —> an early hominid ancestor that first appears in the fossil record 4 million year ago —> demonstrates key evolutionary changes from homo sapiens

Structural Change	Evolutionary Advantage
More downward-facing foramen magnum	Facilitated transition to bipedalism (walking upright without use of hands) – needs to maintain an erect posture – increases weight-bearing on lower limbs – hands available for tool manipulation – head no longer most anterior part of body
S-shaped curvature of spine	
Longer leg : arm length ratio	
Larger heel bone and alignment of big toe	
Shift in position of gluteal muscles	
Reduced brow ridge and jaw protrusion	
Larger cranial capacity	Increased intellectual prowess
Smaller teeth and narrower jaw	Changed dietary requirements (more meat)
Lower and broader pelvis	Altered birthing patterns (for larger infants)
Marked reduction in body hair	Reflects use of fur clothing from hunting
Increased average height	Consequence of improved diet

Selective breeding:

- A form of artificial selection in which man intervenes in the breeding of species to produce desired traits in offspring —> the trait's frequency becomes more common in new generations
- It provides evidence of evolution as targeted breeds can show significant variation in a short period
- Selective breeding of plant crops has allowed for the creation of new types of foods
  —> plants of genus Brassica have been bred to produce different foods by artificial selection
  —> broccoli, cabbage, and kale
- Selective breeding of domesticated animals has resulted in new breeds of offspring
  —> Horses —> have been selectively bred across many generations to produce variation according to a targeted function (race horses speed and draft horses power)
  —> Cows —> have been selectively bred across many generations to produce offspring with improved milk production (increase in muscle)
  —> Dogs —> show an enormous amount of variety due to the targeted selection of traits
  —> Toy dogs were bread to be small while racing dogs were bred to be fast

Comparative anatomy:

- Illustrate adaptive radiation, whereby several new species rapidly diversify from ancestor
- Organisms may show certain structural features that are similar, implying common ancestry
- Homologous structures —> anatomical features similar in basic structure —> the more similar the structures are, the more related the two organisms are
  —> mammals, birds, amphibians and reptiles all share arrangement of bones in their appendages based on a five-digit limb

Speciation:

- The evolutionary process by which two related populations diverge into separate species
- Within a population of any given species there will be genetic variation —> this variation will be continuous and follow a normal distribution curve as the change rate is gradual and cumulative
- If two populations of a species become geographically separated, the will experience different ecological conditions —> they will adapt to different environments and gradually diverge
- Divergence levels depend on the extent of geographical separation and amount of time passed
  —> as the genetic divergence increases, the genetic compatibility decreases
  —> at a certain moment divergence will be such that the two populations cannot interbreed
  —> when they can no longer interbreed and produce fertile, viable offsprings they are considered separate species

Peppered moths (Biston betularia):

- Exist in two distinct polymorphic forms —> light colouration and a darker melanic variant
- Unpolluted environment —> trees are covered by a pale-coloured lichen (camouflage for lighter)
- Polluted environment —> sulphur dioxide kills the lichen while soot blackens the bark (for dark)
- Before industrial revolution environment unpolluted and lighter moth had a survival advantage
- Following industrial rev. the environment became heavily polluted so dark moth advantaged
- Environmental policies nowadays are reducing pollution levels so altering the frequencies again

5.2 Natural selection

Charles Darwin:

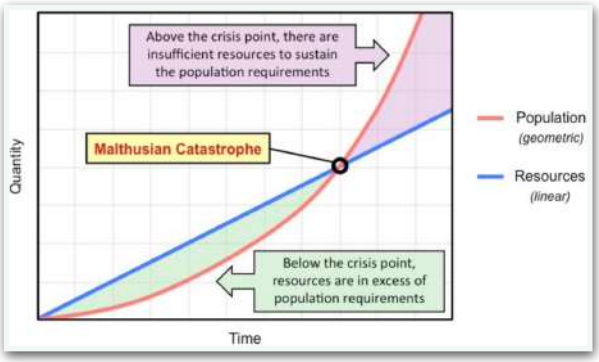
- Theory of natural selection —> it is not necessarily the strongest or most intelligent that survives, but the ones most responsive to change
- Natural selection occurs in response to:
  —> Inherited variation —> genetic variation within a population that can be inherited
  —> Competition —> There is struggle for survival (more offsprings than what supported)
  —> Selection —> Environmental pressures lead to differential reproduction within pop.
  —> Adaptations —> individuals with beneficial traits are more likely to survive + pass trait
  —> Evolution —> over time, change in allele frequency within the population gene pool

Variation:

- Natural selection requires variation among members of a species in order to differentiate survival
  —> can manifest as either discontinuous (distinct class) or continuous (just a characteristic)
- There are three main mechanisms by which genetic variation may occur:
  —> Mutations —> changing the genetic composition of gametes changes characteristics
  —> Meiosis —> via either crossing over (prophase I) or independent assortment (meta I)
  —> Sexual reproduction —> combination of genetic material creates new gene combination

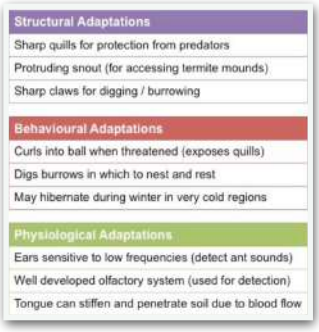
Competition:

- Species tend to produce more offspring than the environment can sustainably support
- Malthusian dilemma (Thomas Malthus) —> populations multiply geometrically while food resources only increase arithmetically
- If left to course, a stable population will inevitably outgrow its resource base —> competition



Adaptations:

- Features of organisms that aid their survival by allowing them to be better suited to environment
- May be classified in different ways:
  —> Structural —> physical differences in biological structure (neck in the giraffe)
  —> Behavioural —> differences in patterns activity
  —> Physiological —> variations in detection and response by vital organs
  —> Biochemical —> differences in molecular composition of cells and enzyme functions
  —> Developmental —> variable changes that occur across the life span of an organism
- Organisms with beneficial adaptations will be more likely to survive enough to reproduce and pass on these genes
- Adaptations of Echidna are shown on the left



Allele frequency:

- The variation that exists within a population is heritable and is determined by presence of alleles
  —> alleles may be passed from parent to offspring via sexual reproduction
- Alleles encode for the phenotypic polymorphisms of a particular trait and may be:
  —> Beneficial —> alleles will better equip the organisms to survive (more offsprings)
  —> become more frequent during time
  —> Neutral —> alleles will not affect the organisms survival prospects
  —> Detrimental —> alleles harm the survival prospects of an organism (fewer offsprings)
  —> become less frequent during time
- Due to natural selection the proportion of different alleles will change across generations

Adaptive radiation:

- Describes the rapid evolutionary diversification of a single ancestral line
- It occurs when members of a single species occupy a variety of distinct niches with different environmental conditions —> members evolve different morphological features in response to the different selection pressures
- Daphne major —> adaptive radiation can be seen in the variety of beak types seen in the finches
  —> is a volcanic island that forms part of the archipelago of Galapagos islands
  —> finches show marked variation in beak size and shape according to diet

Antibiotic resistance:

- Antibiotics —> chemicals produced by microbes that either kill or inhibit the growth of bacteria
  —> commonly used by man as a treatment for bacterial infections
- Antibiotic resistance via gene mutation may occur over many generations because:
  1) when treated with antibiotics, resistant bacteria will survive and reproduce
  2) it will flourish in the absence of competition from strains of bacteria killed by antibiotic
  3) resistance may be transferred to susceptible strains (transferring plasmid via conjugation)
  4) the introduction of the antibiotic has caused the resistant gene to become more frequent

- Straphyloccoccus aureus —> has antibiotic resistance due to evolution
  —> can cause infections to the skin (lesions) or more serious infections (meningitis)
  —> historically these infections were cured by using the antibiotic methicillin
  —> bacterial strains resistant to methicillin developed —> these strains proliferated
  —> MRSA infections are especially present in hospitals where use of methicillin
  —> medical practitioners now prescribe alternate antibiotic agents to treat infections

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5.3 Classification

Binomial system:

- The formal system by which all living species are classified (taxonomy)
- Periodically assessed and updated internationally every 4 years
- It provides value because:
  —> it allows for identification and comparison of organisms based on characteristics
  —> it allows all organisms to be named according to a globally recognised scheme

—> it can show how closely related organisms are, allowing for prediction of evolution
—> it makes it easier to collect, sort and group information about organisms

- Every organisms is designated a scientific name with two parts
  1) The genus —> written first and is capitalised
  2) The species —> follows the genus and is written in lower case

Domains of life:

1) Eukarya —> eukaryotic organisms that contain a membrane-bound nucleus (protist, plants, fungi and Animalia)
2) Archaea —> prokaryotic cells lacking a nucleus and consist of the extremophiles (methanogens, thermophiles, …)
3) Eubacteria —> prokaryotic cells lacking a nucleus and consist of the common pathogenic forms (E. coli, S. aureus, …)

Hierarchy of Taxa:

- Taxonomy —> the science involved with classifying groups of organisms on the basis of shared characteristics
- Organisms are grouped according to a series of hierarchical taxa (the more taxa the more related)

Animal Example	Taxonomic Rank	Plant Example
Animalia	**Kingdom**	Plantae
Chordata	**Phylum**	Angiospermophyta
Mammalia	**Class**	Eudicotidae
Primate	**Order**	Ranunculales
Hominidae	**Family**	Ranunculacae
Homo	**Genus**	*Ranunculus*
sapiens	**Species**	*acris*
Human	Common Name	Buttercup

Classification:

Artificial classification:
- Involves arbitrarily selecting unifying characteristics first to then group organisms accordingly
- Advantage —> such schemes are easy to develop and relatively stable
- Disadvantage —> do not generally show evolutionary relationships so are not commonly used

Natural classification:
- Involves grouping organisms based on similarities first to then identify shared characteristics
- All members of a particular group would have shared a common ancestor —> so can be used to predict characteristic shared by species within a group
- All members that share a lower taxa must share all higher taxes
- Advantage —> it identifies traits based on groupings rather than assigning groups based on traits
- Disadvantage —> the schemes are highly mutable and tend to change when info. is discovered

Phylogenetic classification:
- Now being used to differentiate organisms based on genetics
- Organisms who share a greater level of homology in their DNA or amino acid sequences are expected to be more closely related

Plant phyla:

	Structures	Vascularisation	Reproduction	Other Features	Examples
Bryophyta	No 'true' leaves, roots or stems	None	Spores	Anchored by rhizoids	Mosses
Filicinophyta	Have leaves, roots and stems	Present	Spores	Leaves are pinnate	Ferns
Coniferophyta	Have leaves, roots and stems	Present	Seeds (in cones)	Woody stems	Conifers
Angiospermophyta	Have leaves, roots and stems	Present	Seeds (in fruits)	Have flowers & fruits	Flowers

- The plantae kingdom has 12 phyla

Animal phyla:

- The Animalia kingdom can be sub-divided into two main groups (invertebrates and vertebrates)
- Chordata —> have bilateral symmetry, have a separate mount and anus, and have a notochord and a hollow, dorsal nerve tube for at least some period of their life cycle

	Symmetry	Body Cavity	Segmentation	Other Features	Examples
Porifera	Asymmetrical	None (have pores)	None	Spicules for support	Sea sponge
Cnidaria	Radial	Mouth but no anus	None	Stinging cells (cnidocytes)	Jellyfish, coral, sea anemone
Platyhelmintha	Bilateral	Mouth but no anus	None	Flattened body (↑ SA:Vol ratio)	Tapeworm, planaria
Annelida	Bilateral	Mouth and anus	Segmented	Move via peristalsis	Earthworm, leech
Mollusca	Bilateral	Mouth and anus	Non-visible (mantle & foot)	May have a shell (made by mantle)	Snail, octopus, squid, bivalves
Arthropoda	Bilateral	Mouth and anus	Segmented	Exoskeleton (chitin)	Insects, spiders, crustaceans

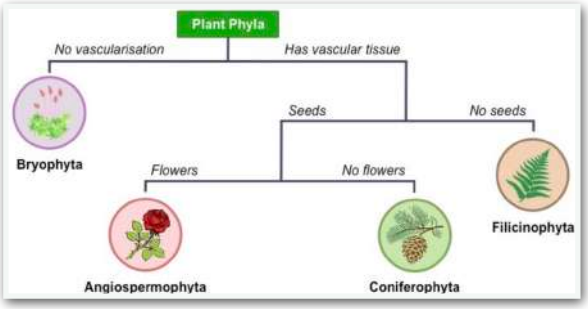
Vertebrates:

- Some chordates, develop the nerve tube into a spine and the notochord will form a protective backbone —> grouped in the sub-phylum vertebrata

	Body covering	Reproduction	Breathing	Temperature	Other Features
Fish	Scales made out of bony plates	External	Gills	Ectothermic	Have a swim bladder
Amphibian	Moist skin	External	Simple lungs (and via skin)	Ectothermic	Larval state in water, adult state on land
Reptile	Scales made out of keratin	Internal (lays soft eggs)	Lungs with extensive folding	Ectothermic	Simple teeth with no living tissue
Bird	Feathers	Internal (lays hard eggs)	Lungs with bronchial tubes	Endothermic	Have wings and beaks with no teeth
Mammal	Hair	Internal – live births (except monotremes)	Lungs with alveoli	Endothermic	Feed young with milk from mammary gland

Dichotomous keys:

- Method of identification whereby groups of organisms are divided into two categories repeatedly
- With each sequential division more info is known about the specific features of the organism
- When the organism no longer shares characteristics with any organism it has been identified
- Better to use immutable features to identify specimens

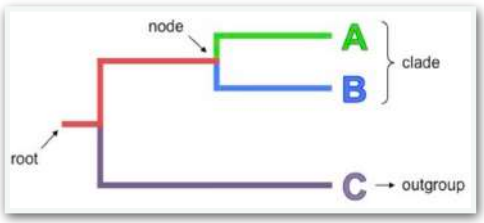


5.4 Cladistics

Clades:

- Cladistics —> a method of classifying organisms into groups of species called clades
- Each clade consists of an ancestral organisms and all of its evolutionary descendants
- Members of a clade will possess common characteristics as a result of their share lineage
- Cladograms —> tree diagrams where each branch point represents the splitting of two new groups from a common ancestor —> distinct species are formed via divergent evolution
- Show the likely evolutionary history (phylogeny) of a clade

Cladograms:



Molecular evidence:

- Organisms use DNA+RNA as genetic material + genetic code for protein synthesis is universal
- This means that base and amino acid sequences can be compared to ascertain relatedness
- The more similar the base sequences of two species are, the more related the species are
- When comparing molecular sequences, scientist may use:
  —> Non-coding DNA provides best comparison as mutations will occur more readily
  —> Gene sequences mutate at a slower rate as may affect protein structure and function
  —> Amino acid sequences have the slowest rate of change due to codon degeneracy
- Molecular clock —> some genes or protein sequences may accumulate mutations at constant rate
  —> different genes or proteins may change at different rates
  —> rate of change for a particular gene may differ between different organisms
  —> Over long periods, earlier changes may be reversed by later changes

Structural evidence:

- Historically classification was based primarily on morphological differences
- Closely related species were expected to show similar structural features
- Two key limitations in morphological differences:
  —> closely related organisms can exhibit very different structural differences due to adaptive radiation
  —> distantly related organisms can display very similar structural features due to convergent evolution
- Convergent ev. —> independent evolution of similar features in species with distinct lineages
  —> may occur when different species in the same habitat (same selection pressures)
- Homologous structures —> traits similar because they are derived from common ancestry
- Analogous structure —> traits superficially similar, but derived by separate evolutionary patterns

Figwort plant family:

- Were the 8th largest family of flowering plants (275 different genera)
- Taxonomists examined the chloroplast gene in figworts and decide to split the figwort species into five different clades —> now 36th largest group among angiosperms

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Extra:

Evidence of evolution:

- Fossil record, selective breeding and comparative anatomy are three of the most widely recognised pieces of evidence
- Biogeography, vestigial structures and comparative embryology provide evidence for evolution
- Molecular evidence is now being used to demonstrate evolutionary relationships

- Vestigial structures —> some species show the presence of functionless and reduced remnants of organs that were once present in their ancestors —> not needed anymore
  —> demonstrate the evolutionary divergence of a species from a past activity
  —> pelvic bone in whales —> suggests they were terrestrial mammals
- Biogeography —> describes the distribution of lifeforms over geographical areas
  —> related species are usually found in close physical proximity
  —> fossils found in a region tend to closely resemble the modern organisms
  —> it suggests that closely distributed species share a common lineage
  —> most modern marsupials are found almost exclusively in Australia
  —> continental drift —> over 250 million years ago there was only one continent
- Comparative embryology —> studies show that growing embryos in animals or plants show that closely related species have similar stages of development —> common evolutionary pattern
  —> all terrestrial animals have non-functioning gill slits (aquatic)
  —> many vertebrates demonstrate a primitive tail at early stages

Fossilisation:

- Rare process as the vast majority of deceased organisms disappear without leaving a trace
- In order to occur —> hard body parts needed
  —> preservation of remains
  —> high pressure to promote mineralisation of remains
  —> anoxic conditions to protect against oxygen damage and prevent decomp.

1) Death and decay —> only hard body parts remain
2) Deposition —> hard remains are covered with slit and sand
3) Permineralisation —> pressure causes the hard organic material to be replaced by minerals
4) Erosion / exposure —> movement of land return the fossil to the surface

Geological time scale:

- Earth formed 4.6 billion years ago and the earliest forms of life appeared 3.5 billion years ago
- The geological time scale measures time on a scale involving four units:
  —> epoch —> the smallest unit of time on the scale
  —> periods —> epochs are grouped together into larger units calle periods
  —> era —> periods are combined to make a subdivision called era
  —> eon —> the largest division of geological time

Radioactive dating:

- Common method to determine the age of fossils
- Radioisotopes are alternative forms of an element (same protons but different neutrons) —> these isotopes are unstable and decay at a constant rate (three types of radioactive decay)
  —> Alpha decay —> atom releases two protons and two neutrons to form a new element
  —> Beta decay —> a neutron decays to produce a proton, electron and anti-neutrino
  —> Gamma decay —> involves the release of electromagnetic radiation (no mass change)
- ^{14}C has an half-life of only 5730 years —> can only data samples less than 60000 years old
- ^{40}K is released in lava and has an half life of 1.3 billion years —> long range dating

Theories of evolution:

- Evolutionary theories began emerging in the 1800's as new geological and biological discoveries reformed existing knowledge —> before "fixity" (man was always man)
- Jean-Baptiste Lamarck —> proposed that species changed as result of habitual use of features
  —> modified features could be passed to successive generations
  —> was essentially flawed —> cutting a tail does not produce tail-less
- Charles Darwin —> based on a combination of Lamarckian ideas and recent fossil discoveries
  —> species living today changed over time form a single ancestral organism
  —> limiting natural factors will restrict growth
  —> organisms with useful traits have an adaptive advantage (reproduce more)
- Neo Darwinism —> the synthesis of Darwinian theory and modern genetics
  —> Gregor Mendel describes how traits are inherited
  —> Watson and Crick elucidated the genetic basis of inheritance

Selection pressures:

- External agents which affect an organism's ability to survive in a given environment
- Can be negative (trait presence diminishes) or positive (increases presence of trait)
- Include resource availability, environmental conditions and biological factors

Density Dependent Factors
Predators
Availability of resources (e.g. shelter, water)
Nutrient supply (i.e. food source)
Disease / pathogenic spread
Accumulation of wastes
Density Independent Factors
Phenomena (e.g. natural disasters)
Abiotic factors (e.g. temperature, CO_2 levels)
Weather conditions (e.g. floods, storms, etc.)

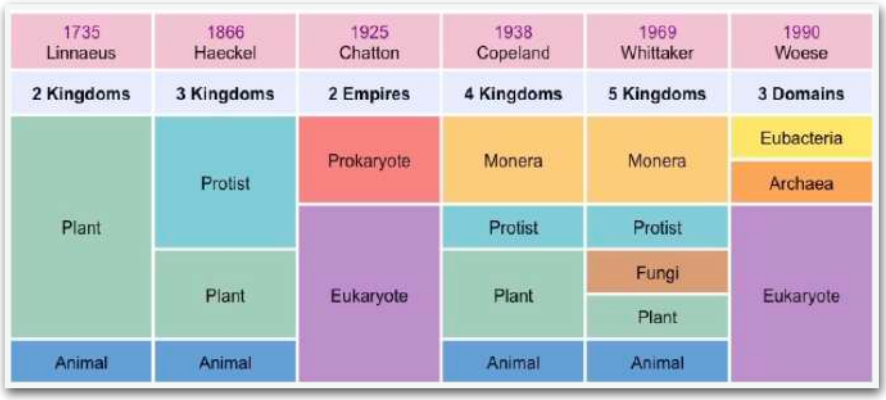
Species diversification:

- Evolution —> all cumulative changes that occur in the heritable characteristics of a population
- Microevolution —> describes evolutionary changes that occur within a short period of time
  —> gene mutations, sexual reproduction and gene flow
  —> genetic drift —> change in the gene pool as a result of an event
  —> natural selection
- Macroevolution —> describes evolutionary changes that occur over relatively long geological periods (results in speciation)
  —> changes in large populations (mostly due to significant env. changes)

Artificial gene transfer:

- Vertical gene transfer is due to reproduction by organisms across generations
- Horizontal gene transfer occurs instead within a single generation (plasmids in bacteria)
- Humans can extract plasmids and use them as a vector to deliver genes of interest

Past nomenclatures:



Archaea, Eubacteria and Eukarya:

Characteristic	Archaea	Bacteria	Eukarya
Membrane lipids with branched hydrocarbons	✔		
Chromosomes are circular	✔	✔	
Lacks nuclear envelopes	✔	✔	
Lacks membrane bound organelles	✔	✔	
Methionine is the initiator amino acid for protein synthesis	✔		✔
Lack peptidoglycan in the cell wall	✔		✔
Growth not inhibited by streptomycin and chloramphenicol	✔		✔
Histones are associated with DNA	✔		✔
Contains several types of RNA polymerase	✔		✔

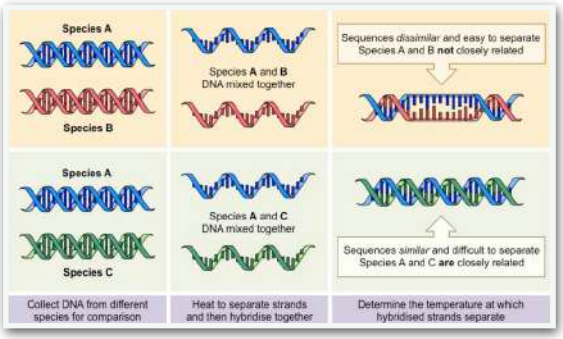
Animal complexity:

- Body symmetry —> describes the alignment of body parts around a central axis
  —> Porifera —> the most primitive as lack any body symmetry
  —> Cnidaria —> sedentary and have radial symmetry
  —> all other animals have bilateral symmetry (allows directional movement)
- Body openings —> Porifera —> the most basic invertebrate and have no body openings
  —> Cnidaria and platyhelminths —> have a singular body opening
  —> all other phyla have two body openings (result in tubular digestive system)
- Body segmentation —> allows for the specialisation of function in these different areas
  —> Porifera and Cnidaria lack distinctive body segmentation
  —> may not be clearly visible but still present
- Chordates —> all have notochord, hollow dorsal nerve tube, pharyngeal slits and postanal tail

Viruses:

- Do not share the same classification system as organisms because they are not considered alive
- Are classified mainly according to phenotypic characteristics:
  —> morphology
  —> nucleic acid type (DNA or RNA)
  —> method of viral replication
  —> host organisms
  —> types of disease caused

In situ Hybridisation:



Mitochondrial DNA (mtDNA):

-Is an important tool for tracing evolutionary relationships within a specie
-Is better than nuclear DNA when determining phylogenetic pathways as:
—> Maternal inheritance —> mtDNA is inherited only by the mother (more direct lineage)
—> No recombination —> as passed only by mother
—> Higher mutation rate
—> High copy number —> as many mitochondria