Evolution

5:1: Evidence for Evolution

Definition: Evolution: When heritable characteristics of one species change (cumulative)

- DOES NOT include acquired characteristics like tart
- mechanism for evolution: Natural Selection

1. Fossils
- deposits of rock layers (strata) analysed
- We will find a sequence of fossils
- Using radioisotopes
- Major Evidence
  - 1) Sequence of fossils matches expected sequence of evolution. The oldest fossils are
    bacteria and simple algae, followed by fungi and worms, then vertebrates and creatures.
  - 2) Sequence of fossils matches ecology - fossils appear in order with ecology. E.g.: plant fossils
    older than animals, plants on land before animals, etc.
  - 3) The fossil record shows that, over time, evolution has occurred. We find different species in
    rocks of certain ages in a particular and consistent order (law of fossil succession). This
    suggests that an ancestral species was responsible for subsequent species. In addition, the
    existence of transitional fossils show intermediate forms over evolutionary pathways
    of the ancestral species.

- Limitations
  - 1) Fossil record is incomplete, conditions needed for fossilisation are very specific. So we
      have gaps in the fossil record, culminating in a series of missing links.

2. Selective Breeding
- We have deliberately bred particular animals for 1000s of years
- Evidence
  - If we compare domesticated species with their wild counterparts (e.g., hens and
    junglefowl), we will see significant variation.
  - This demonstrates evolutionary change that have been catalysed by artificial

- Limitations
  - 1) It shows how selection causes evolution but not how evolution occurs naturally.
      This is a microevolution, as evolution occurs via natural selection, a process which
      occurs without external intervention.
Homologous + Analogous

Evidence

No Analogous structures

- Structures that have superficial similarities in structure
  - e.g. tail fins of whales and fish
  - They had different origins but converge to form similar structures because they perform the same function. This evolution is dubbed convergent evolution

Homologous structures

- Structures that appear superficially different
  - e.g. pentadactyl limb - same bones but the sizes and functions vary - structural similarities from common ancestor
  - They may too had the same origin but have diverged to perform different functions. This is dubbed adaptive radiation

Evidence

- Comparative anatomy of plants or animals show similar structures/features, implying a common ancestry
  - Example: Frogs, birds, humans, bats all have pentadactyl limbs (Homologous structure)
  - Homologous structures: structures that appear superficially similar but have the same origin
  - Pentadactyl limb in vertebrates have common bone composition, despite different uses for locomotion [whales - swim, birds - fly, humans - (take care)]]
  - This illustrates adaptive radiation - as the same limb has adapted to suit different environmental niches
  - The more similar the homologous features are, the more closely related they are
Speciation - formation of a new species by the splitting of a population

**Def:** Gradual divergence of populations of a species into separate species

**Evidence**
- Natural selection acts differently on populations of the same species
  - Characteristics diverge
- To prove that they have diverged into separate species, we get them to interbreed
  - If offspring is not fertile, new species
- E.g., Lava Lizard on Galapagos Islands (all). But, we have closely related but different species on 6 nearby islands

**Variation**
- Gradual divergence of pops over time leads to continuous variation

**Evidence**
- Because divergence is gradual, we can see individual stages of change
- Therefore, the transition in stages is continuous
  - Example: Red Grouse in Br and Willow Ptarmigan in Norway
  - We can see a continuous range in variation between stages.
  - This evidence proves evolution (i.e., the development of a new species) via evolution

**Melanism**
- Melanistic (dark coloured because of an abundance of melanin) insects are found in polluted areas, as they can be camouflaged
  - Soot from burning blackens trees, enabling camouflage for melanistic insects
- Melanistic moths gradually replaced the peppered moth fault, evidence of evolution
- Found that industrialism caused it (disruptive selection)

Evidence from Homologous Structures
- Structures show superficially different but have the same basic structure
- Have a similar origin, their variations in terms of function (e.g., pentadactyl limb, where same bones, but different function + size). Because of adaptive radiation, they vary in terms of function + structure
- Suggests divergence from a common ancestor.
5.2: Natural Selection

Variation

- Natural selection cannot occur unless there is variation in the species.
- Darwin proposed this idea in the "Origin of all Species."
- If all organisms had identical phenotypic genotypes, none would be favoured more than others.

How do we get variation?

1) Mutation: new alleles are produced, hence the gene pool is enlarged.

2) Meiosis (sexual reproduction)
   - Produces new combinations of alleles by breaking up existing combinations in diploid cells. Each cell would carry new sets of alleles because of crossover + independent assortment.

- Crossover:
   - During prophase I, when homologous chromosomes pair up as bivalents, genetic information is shared between non-sister chromatids.
   - The further apart 2 genes are on a chromosome, the more likely they are to recombine.
   - Can unlink linked genes if they are far apart.

- Independent Assortment:
   - In metaphase I, when homologous chromosomes align at the equator, the paired chromosomes randomly arrange themselves in paternal/maternal or maternal/paternal.
   - When the chromosomes separate in anaphase I, final gametes differ by whether maternal or paternal chromosomes.
   - $2^n$ combinations, where n is the number of haploid chromosomes.

3) Random Fertilisation: fusion of maternal and paternal gametes that are varied.
   - As they have a combo of genes and fertilisation is random, different combos of phenotype occur.
   - Each step -> near infinite variability (recombination).

NOTE: If no sexual reproduction, mutation only source of variation. This generates insufficient variation for rapid evolution duringDarwin's lifetime.
Adaptations
- Characteristics that suit an individual to its environment and niche
- These do not include characteristics developed over a lifetime
- See later examples

Overproduction of offspring
- Species tend to produce more offspring than the environment can support
- The Malthusian dilemma states that populations multiply geometrically, while food sources multiply arithmetically arithmetically.
- This leads to a struggle for existence, stemming from competition for resources.
- Offspring, our resource available for the rest of the population
- Interspecific competition (same species compete for same resources in same ecosystem)
- Mortality rate, pop curve, reaches and oscillates around carrying capacity

Differential Survival and Reproduction
- The better adapted individuals will survive and produce more offspring
- The less adapted tend to die or produce fewer offspring
- Evidence:
  - Giraffes have long necks to eat leaves on tree leaves
  - In dry season, no leaves on ground, so those with high necks could access the food source, whereas those with short necks could not. Better adapted to access food
  - Those with long necks survive and produce more offspring, those without died

Inheritance
- Individuals that reproduce pass their genes on to their offspring
- Variation is heritable
- Behaviour: bird migration patterns
- Body: Europeans have light skin, Indians don't.
- Recall: Acquired characteristics during the lifetime of an individual is not heritable
Progressive Change

- Natural selection increases the frequency of characteristics that make individuals better adapted and decreases the frequency of other characteristics.
- If an individual is well adapted, it will survive and pass on desirable phenotype to its offspring.
- Proportions of individuals with good / desirable characteristics increase.
- Proportions of individuals less well adapted decrease.
- Characteristics of pop gradually change (natural selection).

Sample Question: Explain how natural selection leads to evolution.

- Define natural selection as a theory postulated by Charles Darwin, who named it as, "the survival of the fittest."
- There is inheritable genetic variation in a population.
- Intraspecific competition for resources leads to differential reproduction.
- Organisms with beneficial adaptations are more suited to their niche and will survive and reproduce.
- The genes responsible for the desirable phenotype will be passed down to subsequent generations.
- Over generations, there will be a change in heritable characteristics and allele frequencies in a species = evolution.

Case Studies

1) Galapagos Finches [See DBG]
   - Darwin noted variation in the beak and shape of the finches on Daphne Major.
   - G. fortis, the medium ground finch, together with the small ground finch, dead on small seeds, but G. fortis can eat large seeds.
   - In absence of competition, G. fortis is small and has small beak.
   - 1877 - shortage of small seeds - so G. fortis fed on larger seeds that it could crack open with its large beak.
   - El Nino 1982 - more soft seeds - G. fortis reproduced because food availability increased.
   - Variation caused by genes.
   - Developed wider and stronger beaks.
Antibiotic Resistance

- After an antibiotic is introduced, bacterial resistance appears in a few years
- Proportions of infections caused by resistant strains ↑; resistance spreads to more and more species
- Resistance because of bacterial genes, can be inherited or passed via sex pili
- caused by a mutation in a single bacterium, than when antibiotics administered, there is strong natural selection for resistance; therefore, we have a pop with a great deal of resistant bacteria
- Why? 1) Widespread AB use, ↑ opportunities for development of resistant genes [by treating disease/animal]
  2) Fast bacterial reproduction → generation time < 1 hour
  3) Large populations → ↑ risk of a gene mutation
  4) Can pass genes to each other → by plasmids or pili to pass resistance gene

most important reason (if asked)

5.3: Classification

Binomial system (not \( nCr \cdot (ax)^b \))

- This system is called binomial nomenclature
- tells us the genus and specie
- Genus name first, then species name
- Genus: group of species that share certain characteristics
- Rules
  - All italicized
  - genus name is capitalized
  - After full name used once, we abbreviate from \( Xaenose Sapians \) to \( X. sapians \)
  - We use the earliest published name ([1753 onwards] for plants) and [1958] for animals

Hierarchy of Taxa

- A taxon is a group of something
- plural = taxa
- Ki Domain > Kingdom > Phylum > Class > Order > Family > Genus > Species
- A: you go from species to domain, ↑ no. of species + fewer shared features
Domains

- Previously, only prokaryotes and eukaryotes
- When rRNA base sequences determined, 2 distinct groups of prokaryotes found - Eubacteria and Archaea
- The 3 domains are bacteria, archaea and eukaryota

<table>
<thead>
<tr>
<th>Feature</th>
<th>Bacteria</th>
<th>Archaea</th>
<th>Eukaryota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histones in DNA</td>
<td>absent</td>
<td>proteins similar to histones</td>
<td>present</td>
</tr>
<tr>
<td>Introns</td>
<td>rare/l. absent</td>
<td>Only present in some genes</td>
<td>abundant</td>
</tr>
<tr>
<td>Cell walls</td>
<td>peptidoglycan</td>
<td>Not peptidoglycan</td>
<td>Some organisms</td>
</tr>
<tr>
<td>Cell Membranes</td>
<td>(glycerol-ester lipids, d-glycerol)</td>
<td>glyceral-ester lipids, l-glycerol</td>
<td>glycerol-ester lipids, d-glycerol</td>
</tr>
</tbody>
</table>

Archaea vs Bacteria

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>- L-glycerol and d-glycerol</td>
<td>- d-glycerol and w. other ester lipids</td>
</tr>
<tr>
<td>- not peptidoglycan</td>
<td>- peptidoglycan</td>
</tr>
<tr>
<td>- introns possible</td>
<td>- introns v. rare</td>
</tr>
<tr>
<td>- proteins similar to histones</td>
<td>- no histones</td>
</tr>
</tbody>
</table>

Archaea

- broad range of habitats, e.g. oil deposits
- fossilextreme environments, high [salt] water or T > 100°C
- methanogens are obligate anaerobes and generate methane when they metabolise in cow guts

Why are viruses left out?

- Too few of the characteristics of life to be regarded as living organisms
- Despite this, they have genes that code for proteins using the universal genetic code

Eukaryote Classification

- The principal taxa are Kingdom, phylum, class, order, family, genus, species
- King Peter Crawls On Family's Guest Sofa
- 4 Kingdoms are Plantae, Animalia, Fungi and Protista Prototista
- Prototista is a grey area - name it but don't discuss too much!

Plantae

- multicellular organisms that have their own leaf

Animalia

- multicellular organisms that take in their own food

Fungi

- unicellular or multicellular organisms that absorb food

Prototista

- unicellular organisms more complex than bacteria or archaea.
VIP: Examples.

- **Grey Wolf**
  - Kingdom → Phylum → Class → Order → Family → Genus → Species
  - Animalia → Chordata → Mammalia → Carnivora → Canidae → Canis → lupus

- **Dandelion**
  - Plantae → tracheophyta → angiospermae → asterales → Asteraceae → traxacum → officinale

**Natural Classification**

- In NC, the genus + higher taxa consist of organisms - all the species that have evolved from a common ancestor.
- Because of common ancestry → similar characteristics
- Plants and amniotes were once classified together, as they both had cell walls and did not move. This is artificial classification.
- Convergent evolution made distantly related organisms superficially similar.
- Adaptive radiation made closely related organism appear different.

**Advantage**

1) **Identification of Species** - If an organism is found, and the species is unknown, we assign it to its **Kingdom, Phylum, and Class** and down to **species level**. The logic behind this is that because if an organism appears to have a similar ancestor to another, it follows a similar **taxonomy**.
   - **Cannot use with artificial classification**: as it does not look beyond superficial details.

2) **Prediction of Characteristics** - because all members in a taxon have evolved from a similar ancestor, they have similar characteristics, so we can predict the characteristics of a species in a group. E.g., we can predict a new bat species has a 4-chambered heart and pentadactyl limb.

**Renewing Classification**

- Done when a previous taxon is shown to have species that have evolved from different ancestral species.
- If this is the case, taxa are split.
- Conversely, if species are found to share a common ancestral species → taxa merged.
Humans
- We are in O: Primates and F: Hominidae
- Debate over if great apes are in Hominidae
- Originally, all great apes were placed in F: Pongidae
- However, chimpanzees and gorillas were found to be closer to humans than orang-utans
- Only orang-utans in Pongidae
- However, apes and orang-utans are closer than gorillas and humans

Dichotomous Keys
- dichotomy = division into 2
- Numbered series of pairs of descriptions
- See page 265

External Recognition Features of Plant Phyla

<table>
<thead>
<tr>
<th>Vegetative Organs (parts concerned with growth, not reproduction)</th>
<th>Bryophyta</th>
<th>Filicinophyta</th>
<th>Coniferophyta</th>
<th>Angiospermophyta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhizoids bulbs, few roots, core with stem, leafs, others = thallus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roots, stem, leaves present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular Tissue</td>
<td>No xylem or phloem present</td>
<td>Xylem phloem present</td>
<td>Present, allow dev into trees shrubs</td>
<td></td>
</tr>
<tr>
<td>Cambium</td>
<td>None</td>
<td>None</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td>Pollen - structure holding male gametes</td>
<td>None produced</td>
<td>None produced</td>
<td>Produced in male cones</td>
<td>Produced by anthesis</td>
</tr>
<tr>
<td>Ovules - holds female gametes</td>
<td>None present</td>
<td>None present</td>
<td>Produced in female cones</td>
<td>Held in ovaries</td>
</tr>
<tr>
<td>Seeds</td>
<td>None</td>
<td>None</td>
<td>Seeds produced, dispersed</td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td>None</td>
<td>None</td>
<td>Produced for seed dispersal</td>
<td></td>
</tr>
</tbody>
</table>

1) Bryophyta - mosses, liverworts, hornworts
2) Filicinophyta - ferns
3) Coniferophyta - conifers
4) Angiospermophyta - flowering plants
Invertebrate Animal Body

Bilateral
Mouth and anus

Radial
Mouth only

Jawless
Mouth and anus

None
Neither (filter feed)

Segmented and jointed
Vulva, Bursa, + Segmented

No blood system + Flat bodies
Sting caps

Vertebrates
External skeleton
Bones and cartilage

Soft, no skeleton
Soft, pharynx

Phylum Echinodermata
Spiral symmetry
Small, calcified
Calcification

Phylum Chordata
Segmented and jointed
Vulva, Bursa, + Segmented

Phylum Arthropoda
Legs
Exoskeleton
Mandibles

Phylum Mollusca
Foot
Bivalves
Family Cephalopoda

Phylum Annelida
Feet
Segmented
"Roundworms"

Phylum Cnidaria
Hydroids + Rays + Corals
"Jellyfish"

Phylum Porifera + Trabeculars
Glass sponges
Poriferans
"Sea sponges"
5.4: Cladistics

- **Clades**
  - A clade is a group of organisms that have evolved from a common ancestor.
  - Species evolve over time to split into different species by way of adaptive radiation.
  - Clades are identified by looking for shared characteristics.
  - Include living species, the common ancestor, and extinct species.

- **Evidence for identifying clades**
  - A base sequence of genes: species with a common ancestor will have few differences in the gene base sequences.
  - Amino acid sequence of proteins for the same reason.
  - Using these differences, we can identify points of divergence.
  - In addition, using DNA techniques, we can distinguish between adaptive radiation and convergent evolution, which would have more differences or differences.

- **Molecular Clocks** [Method]
  - The use of a constant rate of mutation to determine the time since species split from ancestral species in a clade.
  - Base sequence and A, C, and G sequence differences gradually accumulate, hence there is a positive correlation between the number of differences between 2 species and the time since they diverged from a common ancestor.
  - Since mutations occur at a regular rate, we can predict the time since the first difference to discover when the species diverged.
  - This logic applies because the differences in amino acid and base sequence are the result of mutation.

**Analogous vs Homologous**

1) Analogous
   - Similar because of convergent evolution, evolved independently to form similar structure.
   - Example: Octopus and human eye = similar morphology (form + structure).

2) Homologous
   - Similar because of similar ancestry.
   - Ex. Pentadactyly (limb in humans + chickens).
NOTE: Because it is difficult to distinguish between homologous and analogous purely by morphology, we use amino acid and DNA base sequencing to test if they are homologous or analogous.

### Cladograms

**Definition:** Tree diagrams that show the most probable sequence of divergence in clades

- based on amino acid and DNA base sequences
- Uses the principle of parsimony; that species evolve with the minimum changes in base sequence
- Not entirely accurate all the time, but most probable
- Branching point = node, which is a hypothetical ancestral species

**Why?**

- determine relative relatedness of species
- order of nesting at sister clades

### Example

![Cladogram Diagram]

This is a primate cladogram, which was made by sequencing the genomes of each of the primate genera. The farther 2 species are, the less related they are. E.g., humans are more closely related to Bonobos and Chimpanzees because they are linked at a node. Conversely, humans are distantly related to Gibbons, since they are connected via a series of nodes.

### What define primates?

1. Teeth arrangement allowing omnivorous diet
2. Larger, complex brain
3. Nail
4. Finger and thumb pads
5. Short snout
6. Forward-facing eyes

### Constructing cladograms

- **Back to cladograms**
- Usually drawn on time scales
- Assumes the smallest number of possible mutations to account for current amino acid/DNA base sequence differences. Thus, flawed, evolution pathways can be more convoluted than this.
Reclassification

- Evidence from cladistics has shown that the classification of some groups based on morphology did not correspond with the evolutionary origins of a species group of species.
- Cladistics, construction of cladograms and identification of clades showed that morphology-based cladistics does not match the evolutionary origins.
- Changes to groups reclassified by:
  - groups merged
  - group split
  - movement of species between groups
- Why reclassify? To reveal unnoticed similarities or differences between previously unconnected groups and species previously assumed to be similar

Figwort Family
- Previously, the figwort family was the second largest family in the angiosperm class.
- Had 275 genera, over 5000 species.
- A project compared base sequences of 3 chloroplast genes in a large number of species in genera assigned to the figwort family and closely related family.
- Results: The species in the figwort family were not a true clade. Made of 5 clades, not one.
- Now: Less than half of the original species remain in the figwort family. 50 genera moved to plantain family, 12 genera of parasitic plants moved to broomrape family. New family created and 2 genera inverted.

Making cladograms

1) Make a table showing each species and the presence of selected traits:

<table>
<thead>
<tr>
<th></th>
<th>Animal</th>
<th>Jaws</th>
<th>Plaunods</th>
<th>Hair</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>x</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Y</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Z</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Place at end: x
- Arrange animals in chlor order: X Y Z