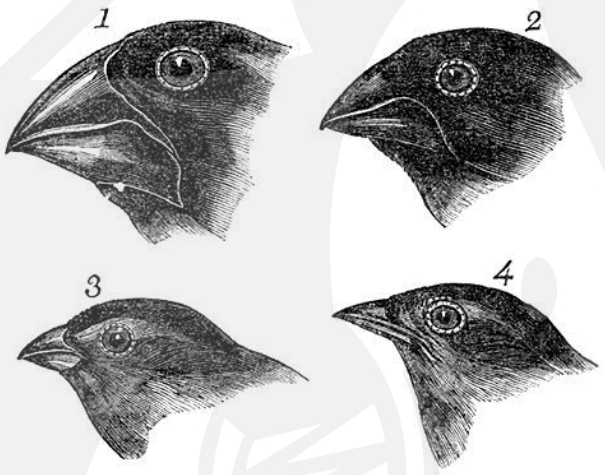
Evolution via Natural Selection

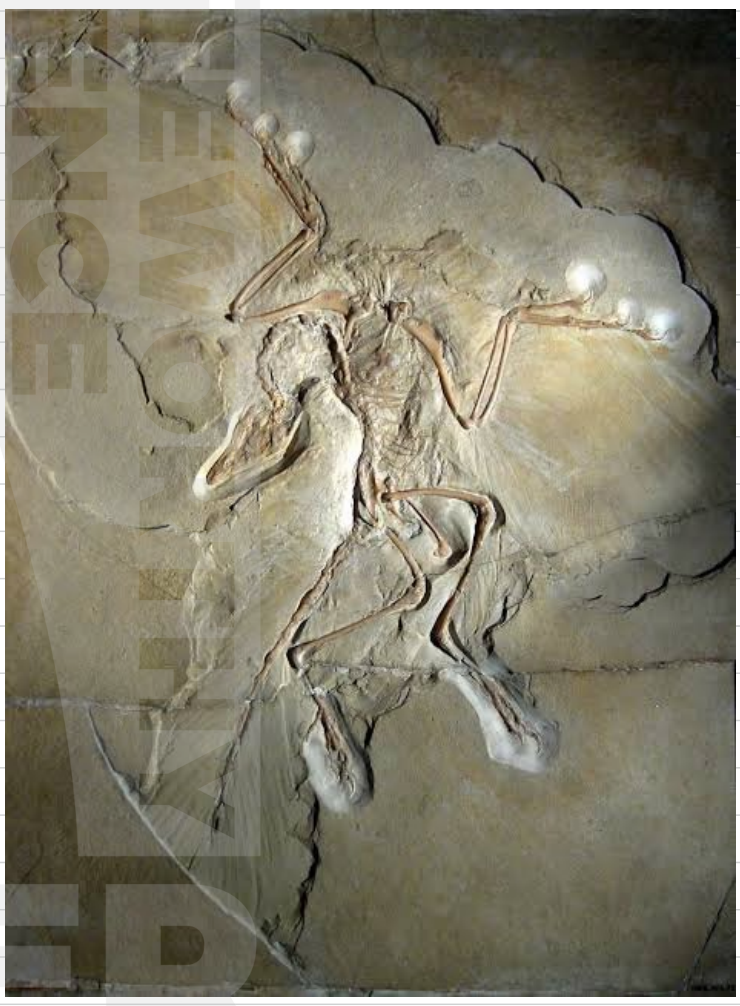
Learning outcomes

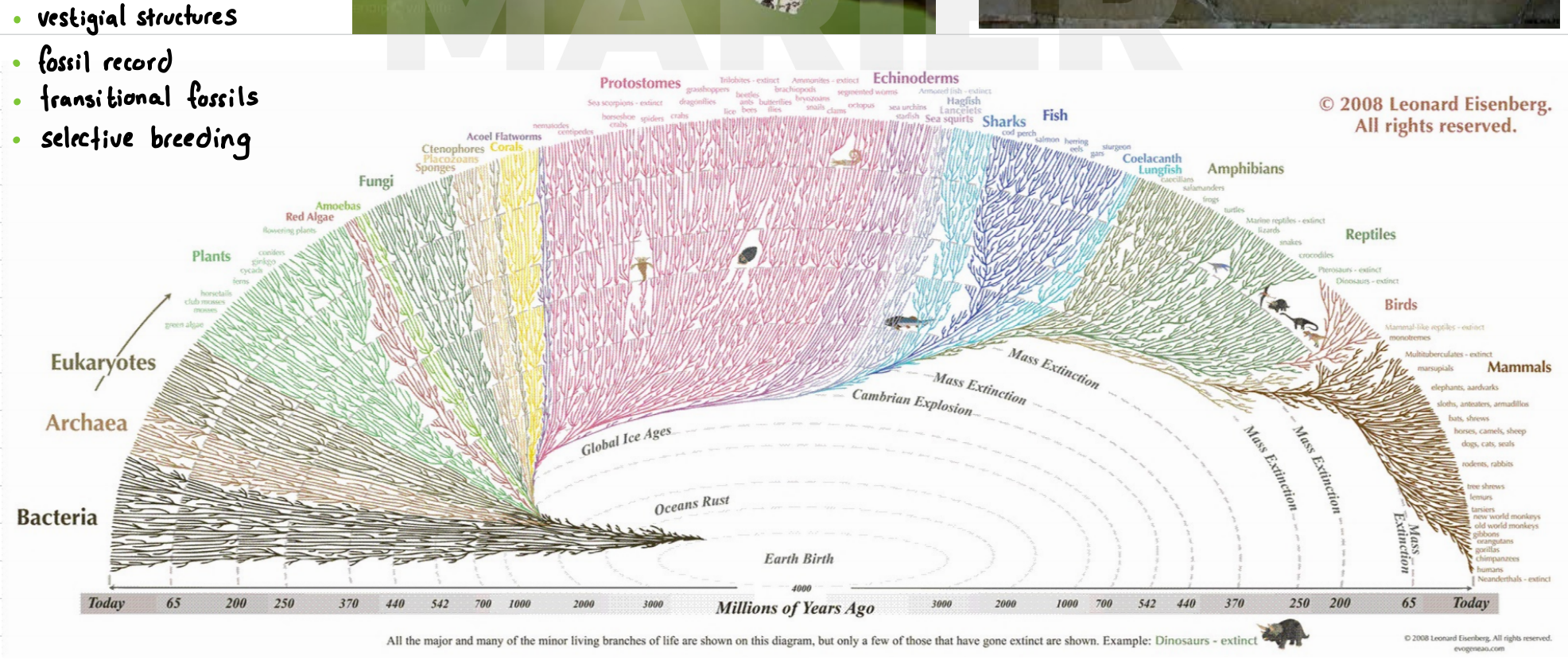
- [x] Understand Darwin's observations and his postulates
- [x] Understand key concepts concerning evolution and natural selection
- [x] Understand the process of evolution via natural selection including an example of your choice
- [x] Understand how speciation can occur both allopatrically or sympatrically including examples of your choice
- [x] Understand how to read phylogenetic trees to deduce evolutionary relationships
- [x] Understand how evolution is supported by multiple lines of evidence including:
  homologous, analogous and vestigial structures, biogeography, fossils, selective breeding, direct observation, DNA evidence

Key terms

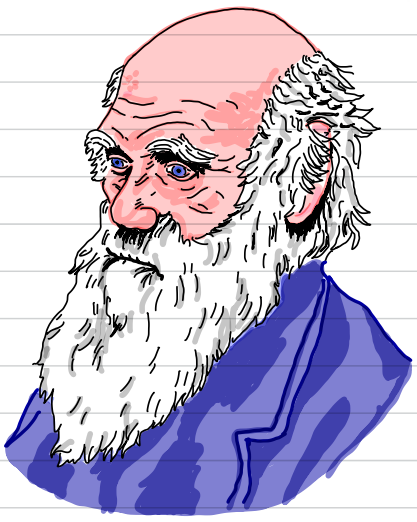
- population
- adaptation
- evolution
- theory
- law
- selection pressure
- species
- speciation
- reproductive isolation
- sympatric speciation
- allopatric speciation
- phylogenetic tree
- homologous structures
- analogous structures
- adaptive radiation
- convergent evolution
- divergent evolution
- vestigial structures
- fossil record
- transitional fossils
- selective breeding



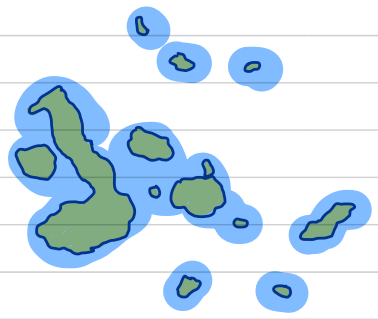




Descent with Modification



From 1830-1836 a young Charles Darwin took part in a survey expedition that stopped in Australia, Africa, South America, famously at the Galápagos. At each stop, Darwin studied and cataloged plants and animals.
He made Key observations:



- Individuals of the same **population** (members of a species living in the same area at same time) vary from one another, even offspring of the same generation
- Much of this variation (traits) is heritable - passed from parent to offspring
- More offspring are produced than the environment can support → competition for limited resources

From these observations, collaboration with other scientists (Wallace), research, and experimentation, Darwin published "On the Origin of Species by Means of Natural Selection" in 1859. Here are his postulates:

① In a population, some individuals will have inherited traits that help them survive and reproduce (in their current environment) Individuals with these helpful traits will leave more offspring than those without

② These helpful traits are heritable and will become more common in the population in the next generation

③ Over generations, the population will become adapted to its environment.

Adaptation: structure, behaviour, or physiological process that helps an organism survive and reproduce in an environment

* He called this process "descent with modification" and its mechanism "Natural Selection"

Genetics has improved our understanding of this. Today - **Evolution:** the change in allele frequencies in a population over time

"Evolution never looks to the future"
Richard Dawkins

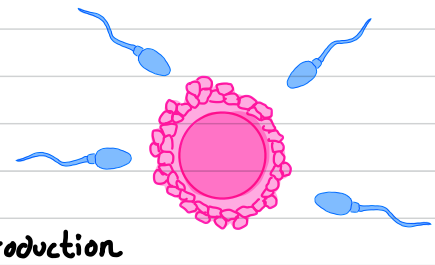
Myth	Fact
✗ Evolution is "just" a theory i.e. opinion/ hypothesis / guess it's not a law ex: a have a theory as to why you are always late	✓ In science, **theory:** a well-supported explanation which has been repeatedly tested and confirmed through observation and experimentation. Evolution via Natural Selection is a theory. A **law:** a statement based on repeated experimental observations that describes a phenomenon (usually via equations)
✗ Individuals evolve during their lifespan	✓ Individual organisms do not evolve - populations evolve. When a population is evolving, the ratio of different alleles changes - individuals do not. ~ Genes mutate. Individuals are selected. Populations evolve. ~
✗ Humans are the 'most evolved'	✓ No such thing as more or less 'evolved'. Humans are not 'more evolved' than any other species.
✗ Natural selection involves organisms trying to adapt	✓ Natural selection involves species adapting over time but does not involve trying or wanting. Either an organism has the alleles that are good enough to survive and reproduce or it doesn't
✗ Natural selection gives an organism what it 'needs'	✓ Natural selection has no intentions or senses. Natural selection acts on genetic variation in a population, which is generated by random mutation - a process unaffected by needs.
✗ 'Survival of the fittest' means the strongest survive	✓ More like 'survival of the fit enough'. Organisms with many different genetic variations survive, reproduce, and pass on genes not just those with 'the best'. 'Fitness' in the evolutionary sense means its ability to pass on genes to the next generation. The more fertile offspring, the more fit
✗ All traits of organisms are adaptations. Evolution produces organisms perfectly suited to environments	✓ While some traits are adaptive, many are not and merely chance results Natural selection is not all-powerful and doesn't produce perfection. Natural selection can only select what is already present and changing a feature 'for the better' might change another for the worse. ~ don't change what's not broken ~

observations → hypothesis —tested→ corroborated —repeated→ corroborated unquestionably —accepted→ Theory
hypothesis —tested→ not corroborated (evidence doesn't support hypothesis)

Natural Selection

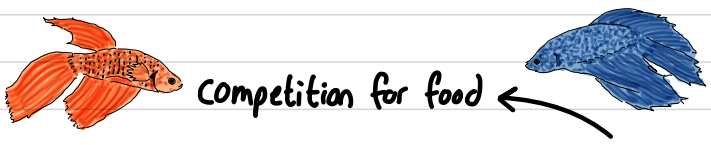
Evolution is <u>what</u> is occuring in populations,
Natural selection is <u>how</u> it's occuring

1. For natural selection to occur there <u>must</u> be **variation** amongst individuals in a population
   - random mutation
   - production of unique gametes
   - random fertilization during sexual reproduction

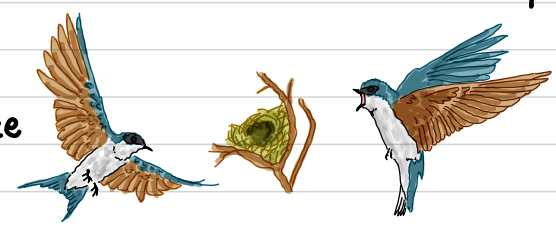


2. This variation must be **heritable**

3. Populations produce more offspring than the environment can support ⟶ not all individuals will survive to reproduce

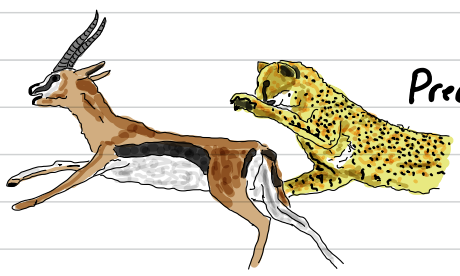


Competition for food



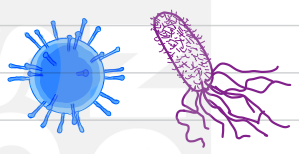
Competion for space

4. Struggle for survival (selection pressure)
   - Predation



   - Parasitism

   - disease



   - competion for mates

5. Selection of characteristics

Disadvantageous characteristics	Advantageous characteristics
selected against ✗ less likely to survive	selected for ✓ more likely to survive
less likely to reproduce and pass on disadvantageous allele	more likely to reproduce and pass on advantageous allele
frequency of allele decreases in population	frequency of allele increases in population

6. change in allele frequency

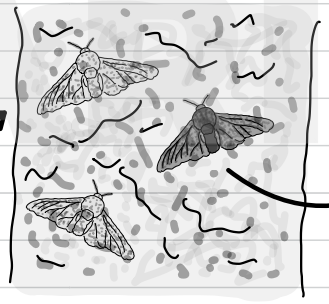
7. population evolves to become better adapted to environment

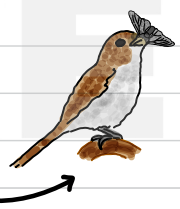
Case study - Melanism in the Peppered Moth

2 natural variants of the Peppered Moth: white  and black  colouration for melanin controlled by allele

naturally live on tree covered by white lichens

white variant well-camouflaged
↳ making it difficult for bird predators to see and eat them

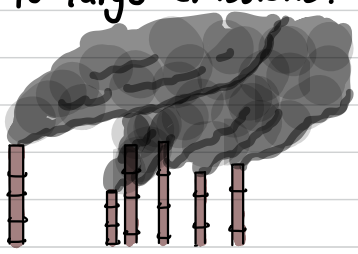




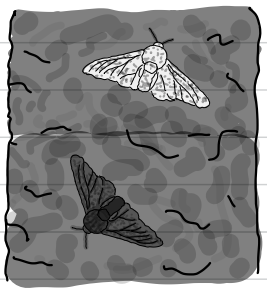
Black variant poorly camouflaged
↳ easier for bird predators to see and eat black variant

∴ more white moths survive and reproduce
↳ more alleles for white passed on to next generation
↳ population is mostly white variant (98%)

Industrial revolution lead to large emissions.



Pollution killed lichens and turned the trees black



white variant easily visible → more likely to die and not reproduce → less white allele passed on → decrease in white allele frequency

Black variant camouflaged → less likely to die and not reproduce → more black allele passed on → increase in black allele frequency

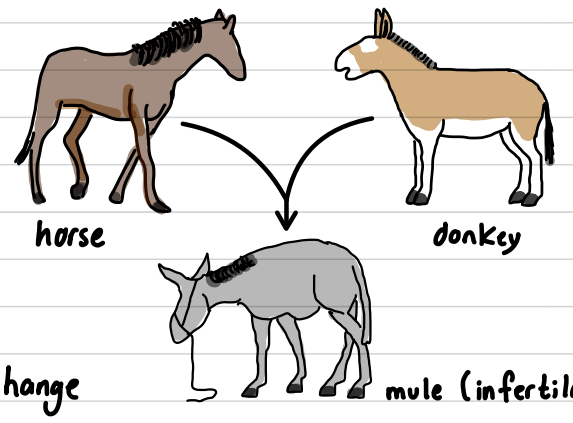
change in allele frequency in population → more black moths less white moths → population of moths better-adapted

New **selection pressure**
↳ factor that increases or decreases reproductive success of a population

Speciation

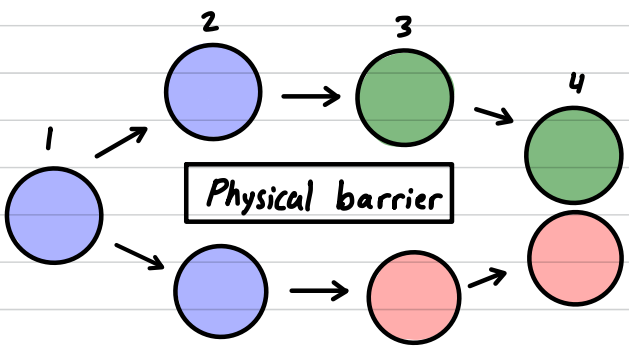
Species: a group of organisms that can interbreed to produce fertile offspring → can produce offspring

↳ this means that different species **cannot** produce fertile offspring



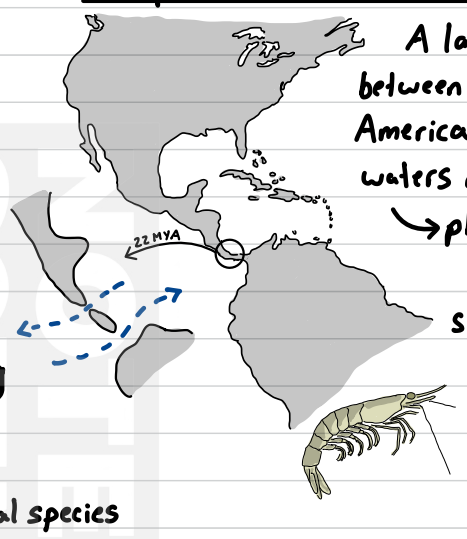
Speciation: when populations evolve to become distinct species

↳ due to natural selection acting on selective pressures, populations change. When they change <u>so much</u> that if individuals from one population found and tried to mate with individuals from another, and were not able to produce fertile offspring
→ said to be **reproductively isolated** and speciation has occured



1- original population
2- physical barrier (mountain, ocean, canyon, etc.) separates population into 2 groups
3- populations become adapted to different local conditions
→ become genetically different
4- reproductive isolation occurs. If species meet they cannot interbreed to produce fertile offspring

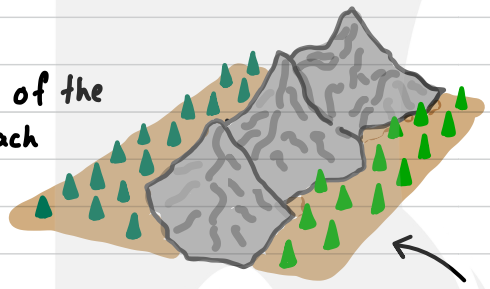
<u>example - Isthmus of Panama</u>



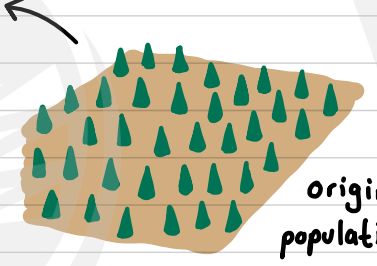
A land bridge formed between North and South America - dividing the waters on either side
→ physical barrier
↓
speciation of aquatic organisms

Allopatric Speciation

speciation when 2 populations of the same species become isolated from each other due to geographic changes



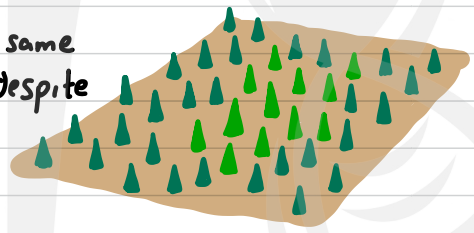
Factors that cause Reproductive Isolation



original population

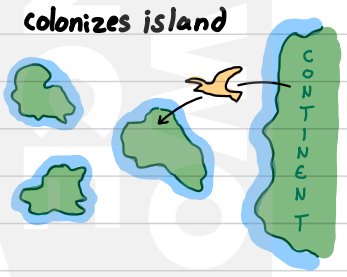
Sympatric speciation

speciation when 2 populations of the same species become reproductively isolated despite living in the same geographic area

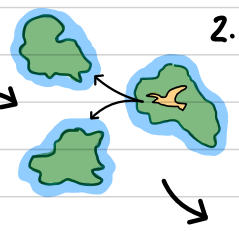


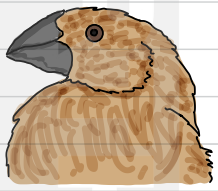
<u>example - Galapagos finch</u>

1. ancestral species colonizes island



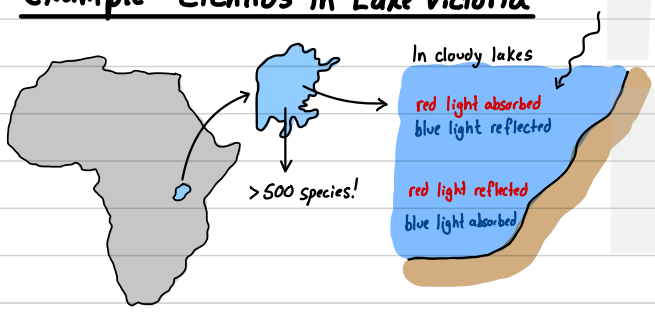
2. species colonizes neighbouring islands

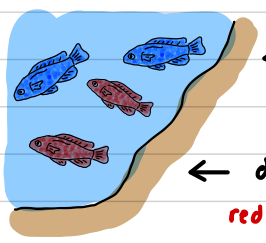




3. populations evolve into different speciss due to different conditions

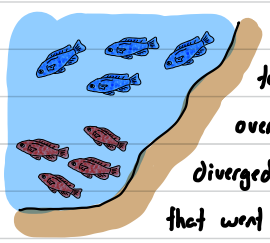
<u>example - cichlids in Lake Victoria</u>





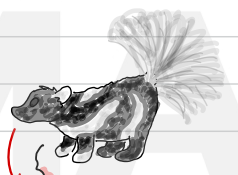
← shallow depth favours blue colour + blue sensitivity

← deeper depth favours red colour + red sensitivity

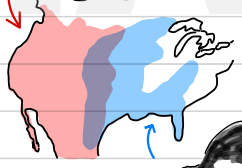


females prefer males of to the colour they are sensitive to over generations, populations diverged and speciated as blue males that went deeper were unsuccessful and vice versa for red males

<u>example - spotted skunk</u>



Western spotted skunk only breeds in <u>late summer</u>



range overlaps <u>but</u> reproductively isolated by time

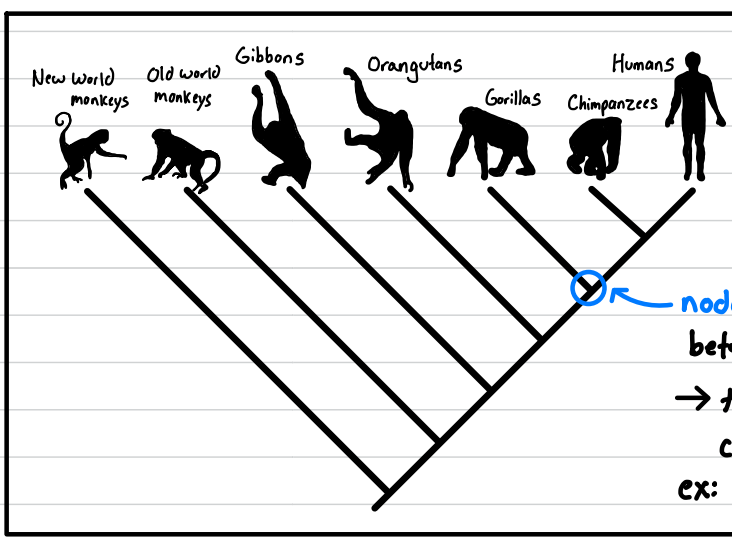
Easter spotted skunk only breeds in <u>late winter</u>

<u>example - meadowlark</u>

Eastern and Western meadowlark look nearly identical, live in same habitat and mate in similar seasons

<u>but</u>

their courtship behaviour (song) is different females only mate with males of specific song



Phylogenetic tree is a branching diagram that shows evolutionary relationships

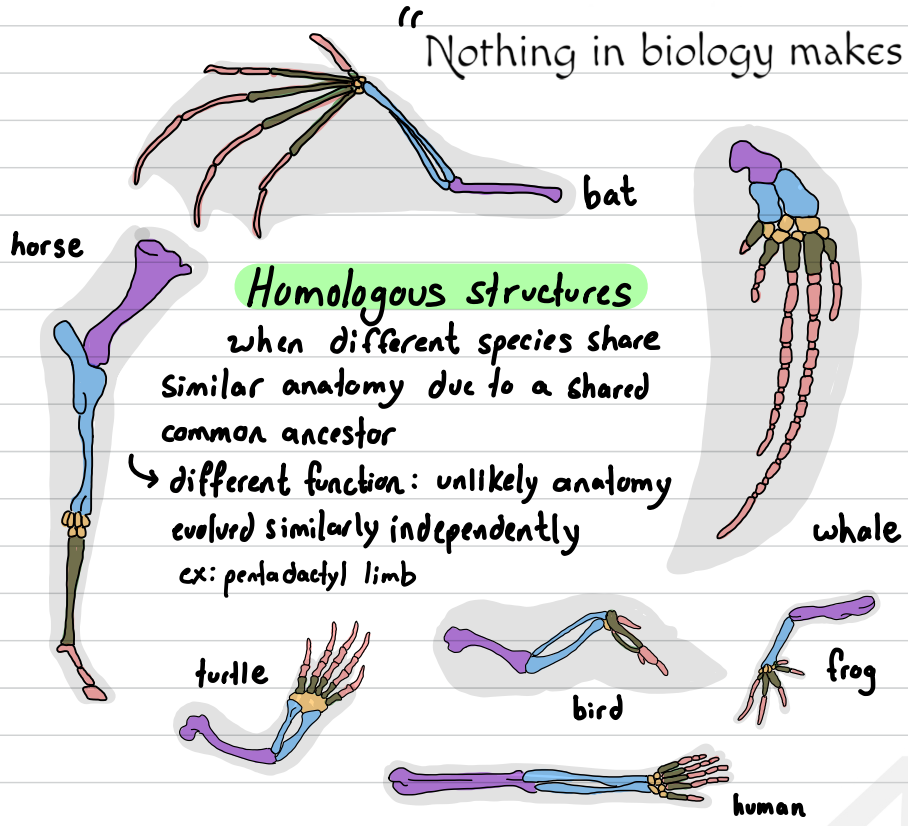
* these are hypotheses based on evidence

node represents most recent common ancestor between lineages
→ the more recent the common ancestor, the closer in relatedness
ex: Humans more related to chimps than gorillas

Evidence for Evolution

"Nothing in biology makes sense except in the light of evolution."

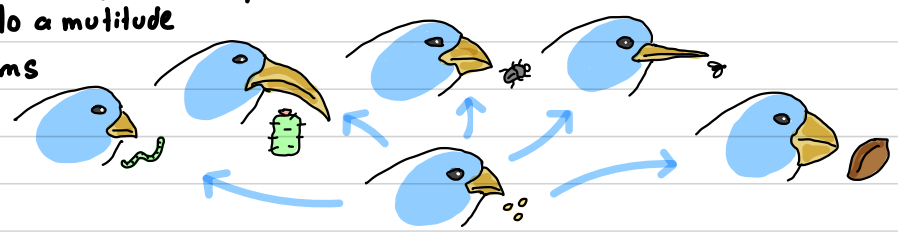
Theodosius Dobzhansky



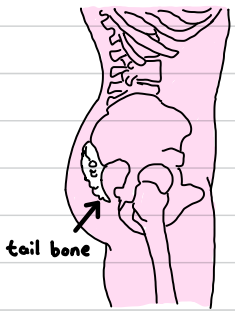
Homologous structures
when different species share similar anatomy due to a shared common ancestor
↳ different function: unlikely anatomy evolved similarly independently
ex: pentadactyl limb

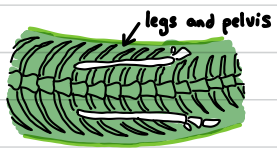
Adaptive radiation via **divergent evolution**
organisms diversify rapidly from an original ancestor into a multitude of new forms

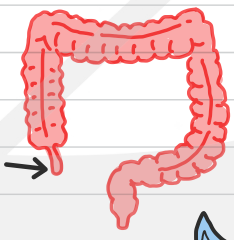
accumulation of differences between closely related populations within a species → leads to speciation



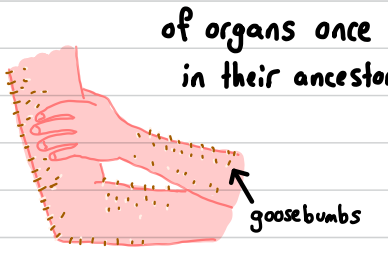
Convergent evolution process where organisms not closely related independently evolve similar features due to needing to adapt to similar environments

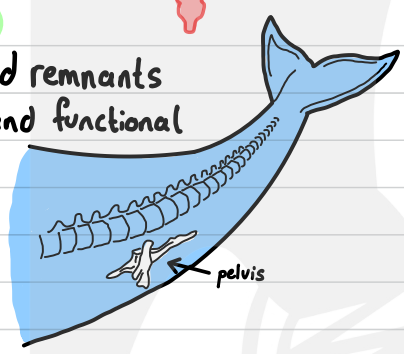




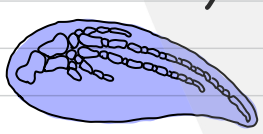


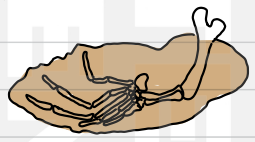
Vestigial structures
functionless and reduced remnants of organs once present and functional in their ancestors

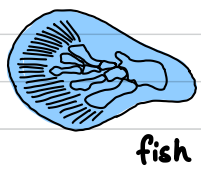


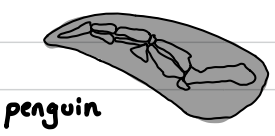


Analogous structures
adaptations that possess similar function but different origin (and anatomy)
→ occurs when they are exposed to common selection pressure

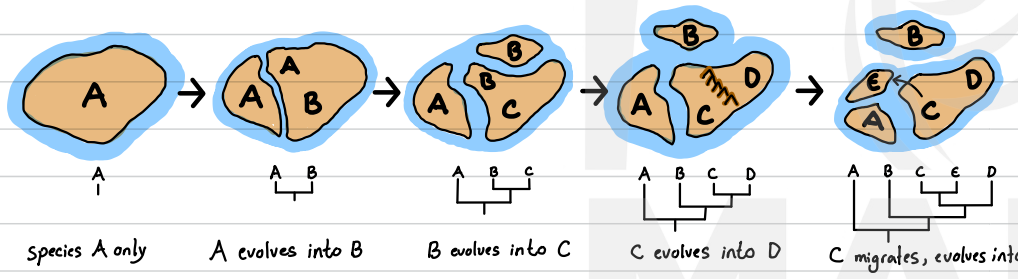

dolphin

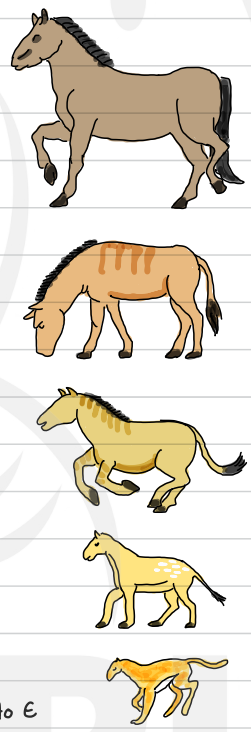

sea turtle

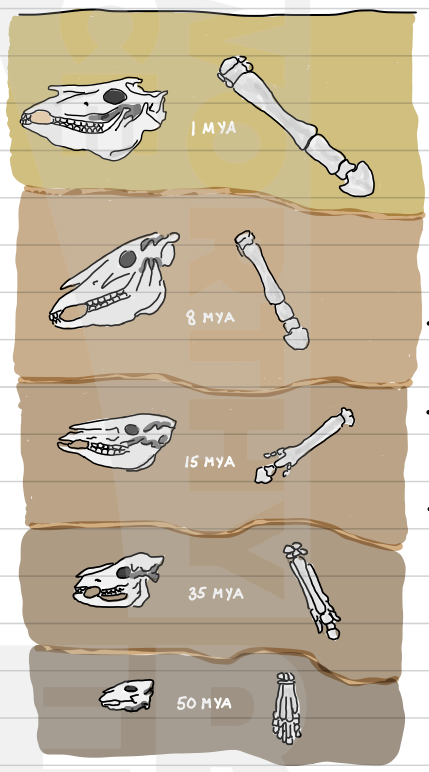

fish


penguin

Biogeography: the study of where organisms live and how they came to live there.
→ geographically close environments are more likely to be populated by related species than those separated but environmentally similar
→ suggests species share common lineage - distribution nonrandom



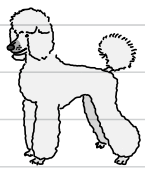




Fossil record
The preserved remains or traces of an organism from the past and their relative placement in rock

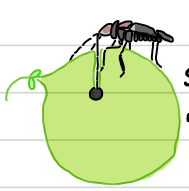
→ layers provide a timeline deeper = older
→ age of layers and fossils can be determined
→ fossils show chronological sequence in which characteristics appear and develop/change

Selective breeding: aka 'artificial selection' is where humans breed animals and plants for specific traits



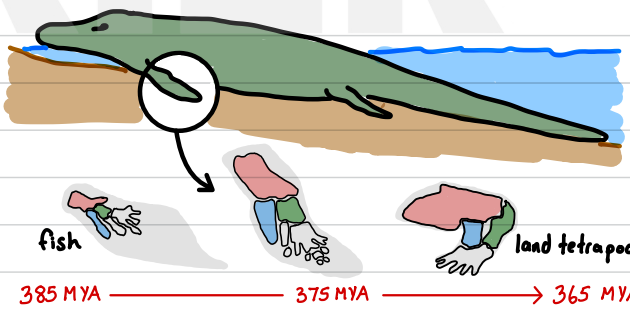
Populations show variation
→ individuals with desired trait chosen to breed together
→ next generation shows increased frequency of the desired trait
repeat
→ individuals without desired trait not allowed to breed

Direct observation: in organisms that reproduce quickly and in large numbers, evolution can be observed directly
→ if selection pressure is known, this change can be predicted


Soapberry bugs mouthparts

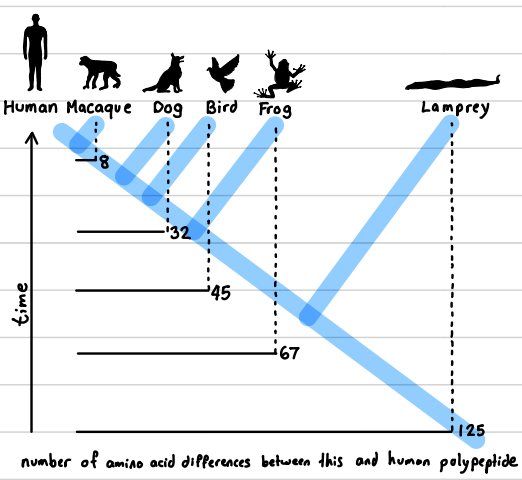

DDT resistance in mosquitoes


MRSA bacteria antibiotic resistance



Transitional fossil
fossil which shows links between groups by exhibiting traits common to both
ex: Tiktaalik is a fossil which has features of both fish and terrestrial tetrapods

Molecular evidence
As mutations build-up in DNA over time, compare different species in terms of similarities in:
→ non-coding sequences
→ gene sequences
→ polypeptide sequences



Assessment Tasks

1. There was a large gap in time between when Darwin made his initial observations to when he published his findings. Research and provide some reasons why this was

2. Darwin is the most well-known scientist concerning evolution but there were many other important figures. For the following scientists, summarize their contribution to evolutionary theory
   - James Hutton and Charles Lyell
   - Jean Baptiste Lamarck
   - Alfred Russel Wallace

3. Using <u>one</u> example (other than insect melanism), explain how natural selection leads to evolution of a population
   → Choose from: Beack size of finches on Daphne Major, DDT resistance in mosquitoes, mouthpart size in Soapberry bugs, antibiotic resistance in MRSA bacteria

4. The term "species" is defined differently in various disciplines. Why? Watch the following video to learn. Which definition do you prefer and why?
   → https://learn.genetics.utah.edu/content/evolution/species

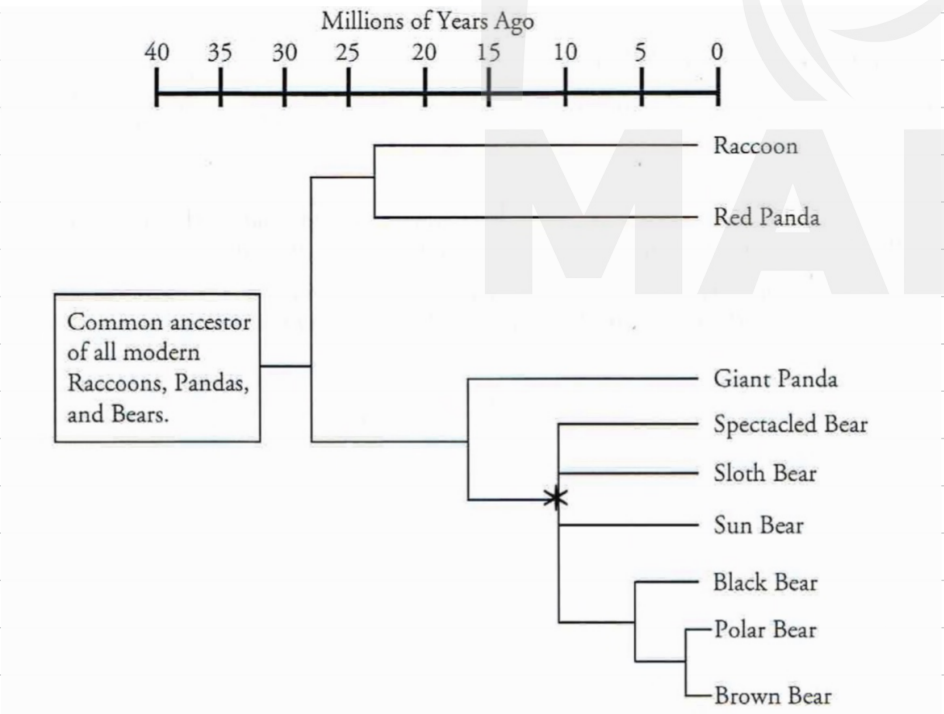
5. Watch the following video explaning speciation. Summarize the process of how birds of paradise evolved into separate species
   → https://youtu.be/8yvEDqrc3XE _

6. Explain in detail the process of allopatric and sympatric speciation using <u>one</u> example of each

7. Visit the following interactive website and summarize how biogeography lead to diversity in birds of paradise
   → http://www.birdsofparadiseproject.org/content.php?page=113

8. Research <u>one</u> example of selective breeding.
   a) explain the process
   b) why is this strong evidence of evolution?

9. Refer to the following phylogenetic tree



a) how long ago did the common ancestor of all the organisms on this tree exist?

b) list all modern descendents of the organism that was alive at the point indicated by *

c) what animal shares the most recent common ancestor with the Brown Bear?

d) which are <u>more</u> closely related:
   the Giant Panda and Red Panda or
   the Giant Panda and Polar Bear
   Justify your answer.

Extension:

Cytochrome c is a protein located in the mitochondria of cells involved with cellular respiration. Below is a table showing the amino acid sequences for cytochrome c in several organisms.

Organism	**Biochemical Data**
Amoeba	Amino Acid Sequence: ISO-SER-ASP-GLN-PHE-ILE-LEU-GLN-SER-ARG-LEU-LEU-HIS DNA Sequence: ATTAGCGACCAGTTTATCCTACAATCCCGTCTACTTCAT
Kangaroo	Amino Acid Sequence: LEU-ISO-PRO-PRO-PHE-ILE-LEU-LEU-SER-HIS-LEU-LEU-SER DNA Sequence: CTAATCCCCCCGTTTATCCTACTTTCCCATCTACTAAGT
Earthworm	Amino Acid Sequence: LEU-ISO-ASP-PRO-PHE-ILE-LEU-HIS-SER-ARG-LEU-LEU-ARG DNA Sequence: CTTATCGACCCGTTTATCCTACATTCCCGTCTACCTTCGT
Cat	Amino Acid Sequence: LEU-ISO-PRO-PRO-PHE-ILE-LEU-LEU-SER-HIS-LEU-LEU-SER DNA Sequence: TTAATCCCCCCGTTTATCCTACTTTCCCATCTACTAAGT
Shark	Amino Acid Sequence: LEU-ISO-PRO-PRO-PHE-ILE-LEU-LEU-SER-ARG-LEU-LEU-ARG DNA Sequence: CTTATCCCCCCGTTTATCCTACTTTCCCGTCTACTTCGT
Dolphin	Amino Acid Sequence: LEU-ISO-PRO-PRO-PHE-ILE-LEU-LEU-SER-HIS-VAL-VAL-SER DNA Sequence: CTAATCCCCCCGTTTATCCTACTTTCCCATGTAGTAAGT
Lizard	Amino Acid Sequence: LEU-ISO-PRO-PRO-PHE-ILE-LEU-LEU-SER-ARG-LEU-LEU-ARG DNA Sequence: CTAATCCCCCCGTTTATCCTACTTTCCCGTCTACTTCGT
Sponge	Amino Acid Sequence: ISO-ISO-ASP-GLN-PHE-ILE-LEU-HIS-SER-ARG-LEU-LEU-ARG DNA Sequence: ATTATCGACCAGTTTATCCTACATTCCCGTCTACTTCGT

the more amino acids an organism has in common, both type and order, indicates a closer relationship the same is true for nucleotides. Compare the data above.

a) Which organism is most closely related to the lizard? Justify your answer

b) Which organism is most closely related to the dolphin? Justify your answer