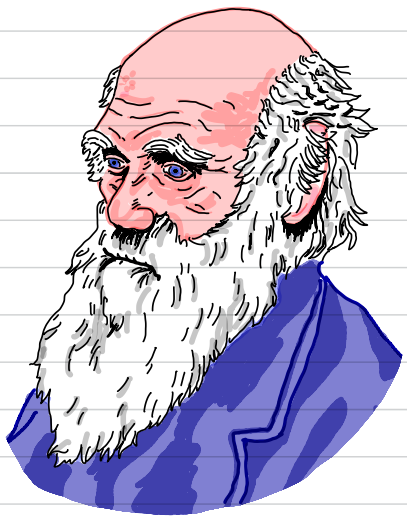
# Evolution via Natural Selection

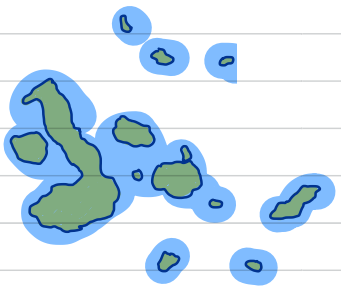
## Learning Outcomes

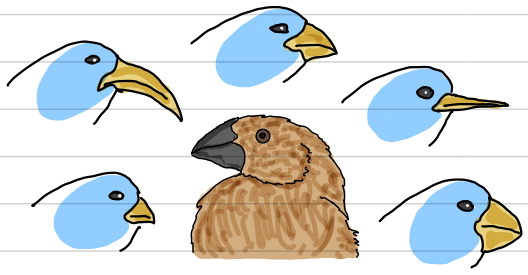
- *18.3.1* – **Describe** natural selection with reference to:
  a) genetic variation within populations
  b) production of many offspring
  c) struggle for survival, including competition for resources
  d) a greater chance of reproduction by individuals that are better adapted to the environment than others
  e) these individuals pass on their alleles to the next generation
- *18.3.2* – **Describe** selective breeding with reference to:
  a) selection by humans of individuals with desirable features
  b) crossing these individuals to produce the next generation
  c) selection of offspring showing the desirable features
- *18.3.3* – **Outline** how selective breeding by artificial selection is carried out over many generations to improve crop plants and domesticated animals and apply this to given contexts
- *18.3.4* – **Describe** adaptation as the process, resulting from natural selection, by which populations become more suited to their environment over many generations
- *18.2.1* – **Describe** an adaptive feature as an inherited feature that helps an organism to survive and reproduce in its environment
- *18.3.5* – **Describe** the development of strains of antibiotic resistant bacteria as an example of natural selection
- *18.3.6* – **Outline** the differences between natural and artificial selection

# Natural Selection



From 1830-1836 a young Charles Darwin took part in a survey expedition which stopped in many areas, famously the Galápagos. At each stop, Darwin studied and cataloged plants and animals He made several observations and afterwards, through much research, experimentation and consultation with other scolars (like Wallace and Malthus) he published "On the Origin of Species by Means of Natural Selection" in 1859 Here are his key postulates:





① Variation exists among individuals of a species and this variation is heritable

② More individuals are produced each generation than can survive - which leads to competition

③ Those individuals with heritable traits allowing them to better-compete. **adaptive features**, will be more likely to survive and leave more offspring

→ inherited feature that helps an organism to survive and reproduce in its environment

④ Over generations, population will become more **adapted** or suited to their environment

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

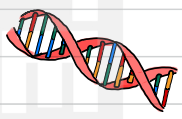
* Genetics has improved our understanding of this. Today: **Evolution**: the change in allele frequency in a population over time

Evolution is what is occuring in populations, Natural Selection is how it's occuring

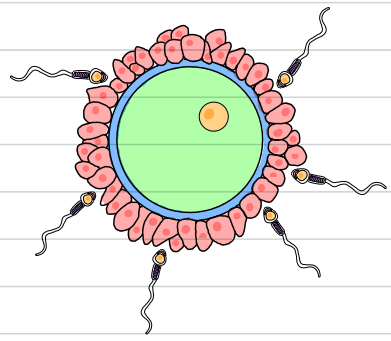
## Process of evolution via natural selection:

① there must be **genetic variation** amongst individuals in a population ← Causes:

- random mutation creates new alleles



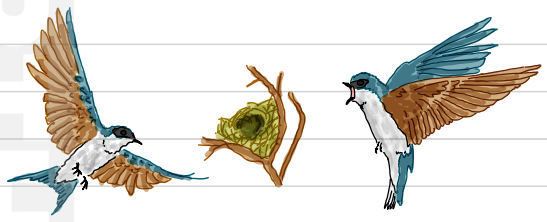
- meiosis shuffles alleles to produce unique gametes
- random fertilization of gametes during sexual reproduction



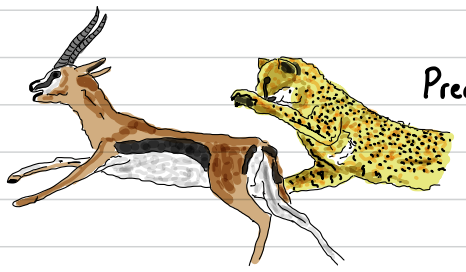
② This variation (genotipic and/or phenotypic) must be **heritable**

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

competition for food



competition for space

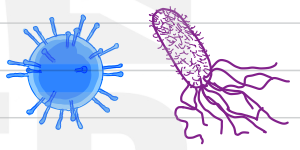


Predation

Parasitism

④ Struggle for survival

**Selection pressure** *



disease

Competition for mates

⑤ Selection of characteristics

**Disadvantageous characteristics**
selected against ✕ less likely to survive
↓
less likely to reproduce and pass on disadvantageous allele to offspring
↓
frequency of disadvantageous allele decreases in population

**Advantageous characteristics**
selected for ✓ more likely to survive
↓
more likely to reproduce and pass on advantageous allele to offspring
↓
frequency of advantageous allele increases in population

⑥ change in population allele frequency

↓

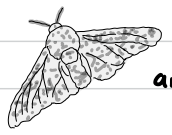
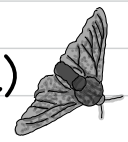
⑦ population evolves to become better-adapted to environment

* **selection pressure**: factor that increases or decreases reproductive success in a population
ex: predation

※ note: population evolves not individuals

# Examples of Adaptation

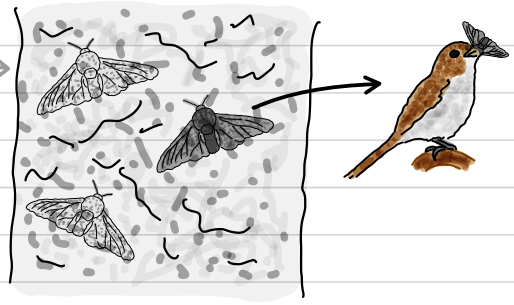
## Melanism in Peppered Moths

In Great Britain, in 1850 there were two natural variants of the Peppered Moth: white  and black (melanic) 

Colouration is controlled by alleles that code for melanin - which causes black pigmentation

↳ naturally live on trees covered by white lichens

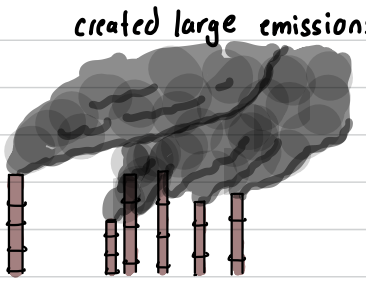

white variant is well-camouflaged making it difficult for bird predators to see and eat them



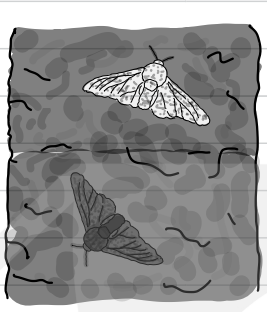
Black variant poorly camouflaged (conspicuous) making it easier for bird predators to see and eat them

∴ more white moths survive and reproduce
more alleles for white passed onto next generation
population of moths mostly white variant (~98%)

Change in the environment: Industrial revolution created large emissions



pollution killed lichens and deposited soot, turning trees black

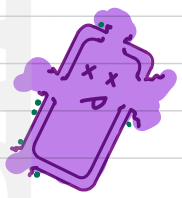


white variant easily visible → more likely to die and not reproduce → less white allele passed onto offspring → decrease in white allele frequency


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

after several generations... (by 1895) → change in allele frequency in population → more black moths less white moths → population of moths better adapted to their environment

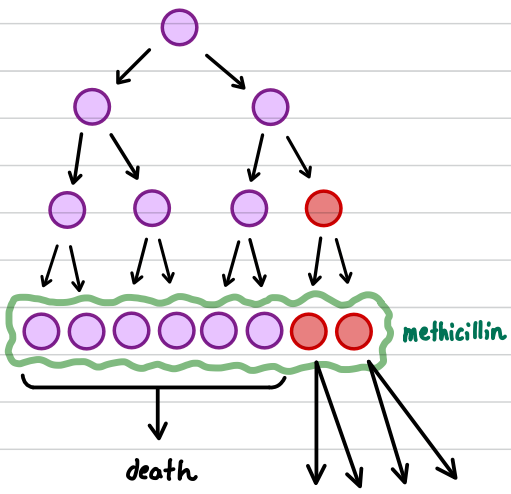
## Antibiotic resistance in bacterial strains

Bacteria, like S. aureus are pathogens that can cause serious disease in humans if they enter bloodstream
Antibiotics are drugs that kill bacteria. Ex: Penicillins, like Methicillin inhibits cell wall synthesis →  which causes cell to be unable to maintain osmotic pressure, leading to cells bursting and dying

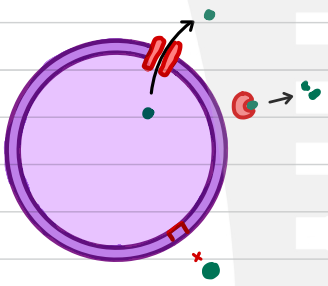
※ as animal cells do not have cell walls, these antibiotics do not affect human cells (or viruses)

↳ antibiotics were a revolutionary medical advancement and started being used in a widespread fashion

* Bacteria reproduce very quickly and form colonies in the millions very quickly - as such, the likelihood of mutations in individuals occuring is high




① S. aureus population reproduces quickly.

② Due to random mutation, some S. aureus become resistant to methicilin due to certain adaptive features → 

MRSA (Methicillin-resistant S. aureus) strain

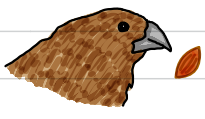
1. produces more pumps to send methicillin out
2. produces enzyme to inactivate methicillin
3. new binding protein which prevents methicillin from entering

③ Antibiotic, methicillin administered to population: strong natural selection for resistance
↳ S. aureus individuals without resistance are more likely to be killed
↳ S. aureus individuals with resistance (MRSA) are more likely to survive, reproduce, and pass resistance to new individuals

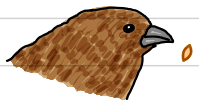
④ Population of MRSA evolved and became adapted to its environment - Methicillin no longer is effective

## Beak size in Darwin's Finches on Daphne Major

On Daphne Major (a small island in the Galapagos) lives a population of medium ground finch (G. fortis). The birds exhibit heritable continuous variation amongst each other primarily in the sizes of their beaks →



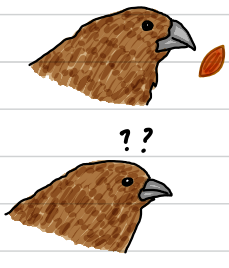
those with large beaks are better-able to crack open larger hard seeds



those with small beaks are better-able to feed on smaller, soft seeds

From 1974-1977, extended cooler climate and droughts (due to La Niña) caused there to be more larger hard seeds and few small soft seeds available

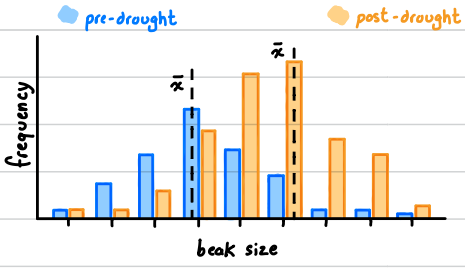
↳ 




finches with large beaks more successful at acquiring food → more likely to survive and reproduce → more alleles for large beak passed onto offspring

finches with small beaks less successful at acquiring food → less likely to survive and reproduce → less alleles for small beak passed onto offspring

→ population evolved: mean beak size increased



# Artificial Selection

**Artificial Selection**: aka Selective Breeding is when humans select and breed organisms for specific desible traits

↳ the process occurs as follows:

variation in the chosen population

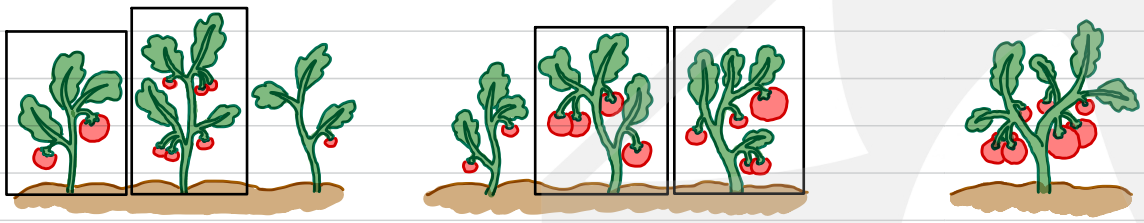
- individuals without desired feature → prevented from reproducing → decreased frequency of desired feature in following generation
- individuals with desired feature selected → selected individuals bred together → increased frequency of desired feature in following generation

## Selectively breeding crops

Humans have been artificially selecting characteristics in crops for thousands of years.

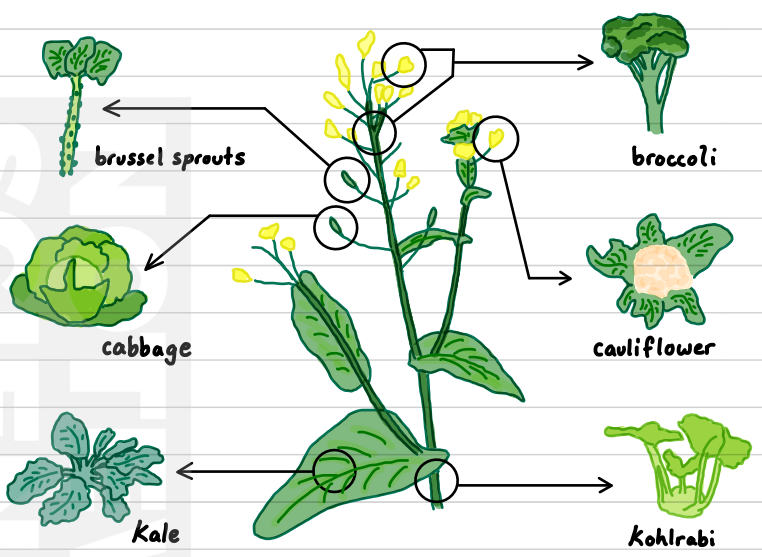
↳ Desired traits examples: height, fruit colour/size/shape/flavour, resistance to disease/frost/drought, roots, etc.

ex: selecting for fruit size and yield in tomatoes



plants with large fruits crossed with large yield and seeds planted → process repeated: only seeds of desired trait is selected and planted → over several generations most plants have large yield and size - population changed

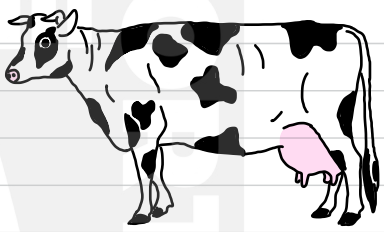
Wild mustard plant has been selectively bred into many varieties




## Selectively breeding animals

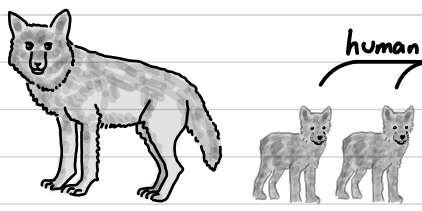
Humans have been breeding animals for many traits over thousands of years

↳ Desired traits examples: speed, loyalty, size, colour, shape, intelligence, strength, etc.



farm animals (like cows) have been bred for increased milk production, muscle mass and disease-resistance

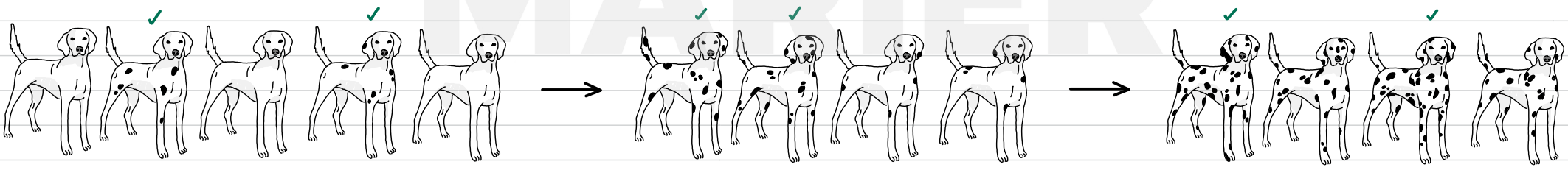
ex: domestication of wolves and dog breeding



wild, aggressive wolf

humans remove wolf pups → feed and raise them, making them dependent on humans → select wolves which are obidient and calm in nature and breed them → repeat over generations, selecting and breeding only wolves which are tame and not those aggressive → over time, tame wolves become so different that speciation occured, splitting into dogs

ex: Selective breeding of dogs (desired trait: spots)



Dog litter shows variation in spots on fur
Dogs with spots selected and bred together → most/all dogs in litter have spots
dogs with most spots selected and bred → over many generations, spots become more and more common in this breed

| Natural Selection | Artificial Selection |
|---|---|
| occurs without human interference | occurs only with human interference |
| typically slow process | faster process as only selected individuals allowed to reproduce |
| traits which are adaptive to environment (useful for survival/reproduction) selected and become more frequent in population | traits which are favourable to humans (not necessarily for survival/reproduction) selected and become more frequent in population |
| alters frequencies of alleles but does not eliminate them outright | can eliminate alleles as some varieties forbidden to reproduce |

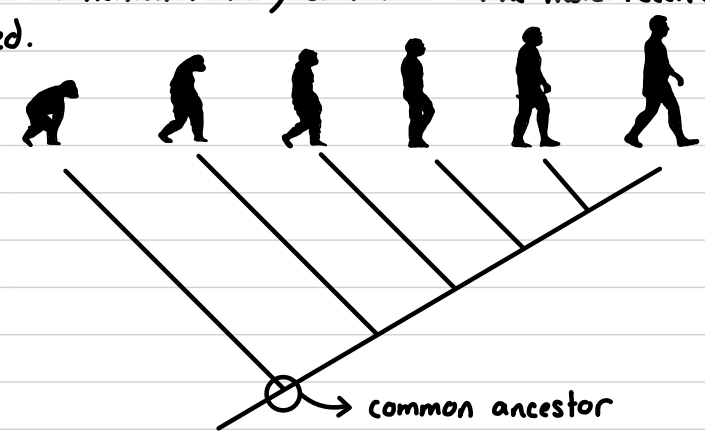
"Nothing in biology makes sense except in the light of evolution."

Theodosius Dobzhansky

| 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 ~ |
| ✗ Evolution is unscientific as it cannot be tested and is unfalsifiable | ✓ Evolution has and is frequently upheld by tests, whether in lab or in the field. At the micro-level this is very common such as observing bacteria, viruses, fruit flies, or mice. At the macro-level, evidence such as the fossil record can still be used to form and test hypotheses. Evolution, like all theories, are falsifiable - evidence just needs to be produced. evidence for intelligent design or spontaneous generation have not been found. |
| ✗ Evolution causes one species to evolve into another, i.e. monkeys evolved into humans | ✓ Evolution is not a ladder or linear, one species doesn't become another. Rather it is like a tree, where different species share common ancestors. Humans and monkeys share an ancestor that was neither monkey or human. The more recent the ancestor, the more closely related. |

observations → hypothesis —tested→ corroborated —repeated→ corroborated unquestionably —accepted→ Theory

hypothesis —tested→ not corroborated (evidence doesn't support hypothesis)




"Evolution never looks to the future"

Richard Dawkins

# Assessment Tasks

Answer the following questions:

1. Darwin is the most well-known scientist concerning evolution but there were many other important figures.
   For the following scientists, research and summarize their contribution to evolutionary theory *note: there are many others, these are a few
   - James Hutton and Charles Lyell
   - Jean Baptiste Lamarck
   - Alfred Russel Wallace

2. Using one example (not found in this lesson), explain how natural selection leads to evolution of a population
   * some examples you can use are mouthparts in soapberry bugs, DDT resistance in mosquitoes, neck in giraffes

3. Adaptive features help an organism to survive and reproduce in its environment.
   Research one example of an adaptive feature in animals in one in plants. For each explain how the feature is adaptive to the organisms environment.

4. Evolution is strongly supported by multiple lines of evidence including:
   homologous structures, analogous structures, vestigial structures, fossil evidence, biogeography, direct observation, molecular (DNA) evidence
   Choose and research one line of evidence and explain how it supports the theory.

5. Using one example (not found in this lesson), explain how artificial selection works and how it allows us to model evolution via natural selection

6. Antibiotic resistant bacteria are a very serious global health issue. Explain how this occured and how it can be mitigated / addressed.

7. In 1983, there was a strong El Niño event with heavy rain and abundant supply of small seeds on Daphne Major.
   Predict and explain how the population of finches might evolve in the following generations.

8. Explain why sexually-reproducing species are more resilient to a changing environment than bacteria.

9. Explain why variation and a struggle for survival are required for evolution via natural selection.