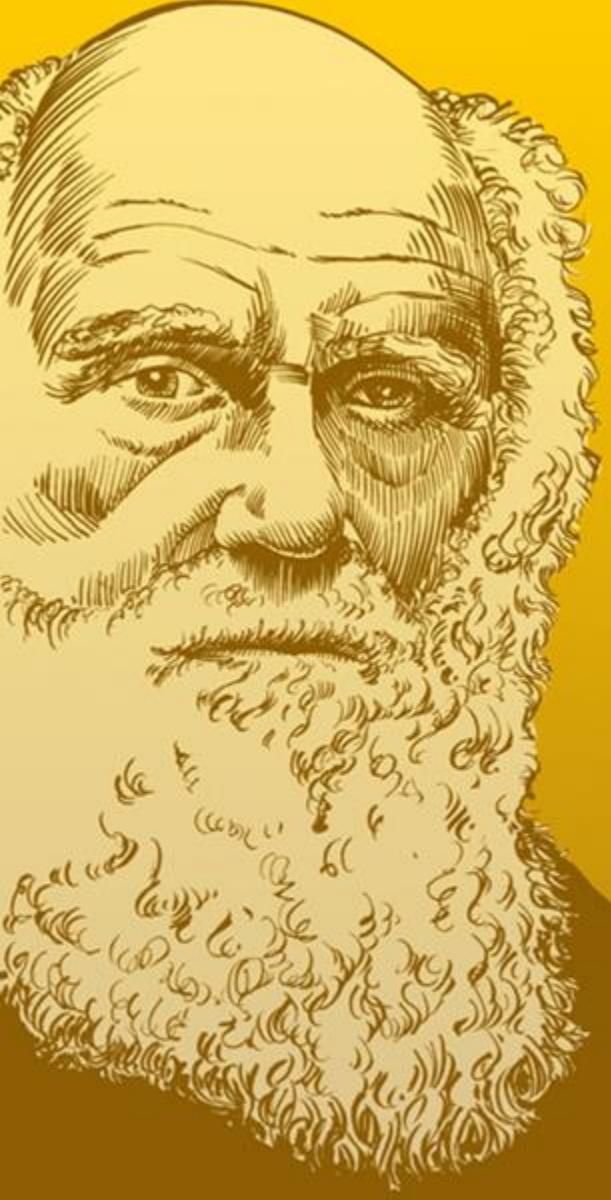
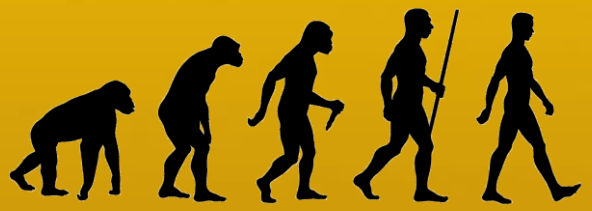


EVOLUTION



OR

FACT

MYTH?

Learning outcomes:

4(a) Explain why **variation** (as a result of **mutation**, **meiosis** and **sexual reproduction**) is important in natural selection

(b) Explain, with **examples**, how environmental factors act as **forces of natural selection**

(c) Explain the role of **natural selection** in evolution.

(d) Explain why the **population** is the **smallest unit that can evolve**.

(e) Explain how **genetic variation** (including **harmful recessive alleles**) may be **preserved** in a natural population.

Concept of Species

- **Biological Species Concept**
- Ecological Species concept
- Morphological Species concept
- Genetic Species concept
- Phylogenetic Species concept

Same species or Different species?

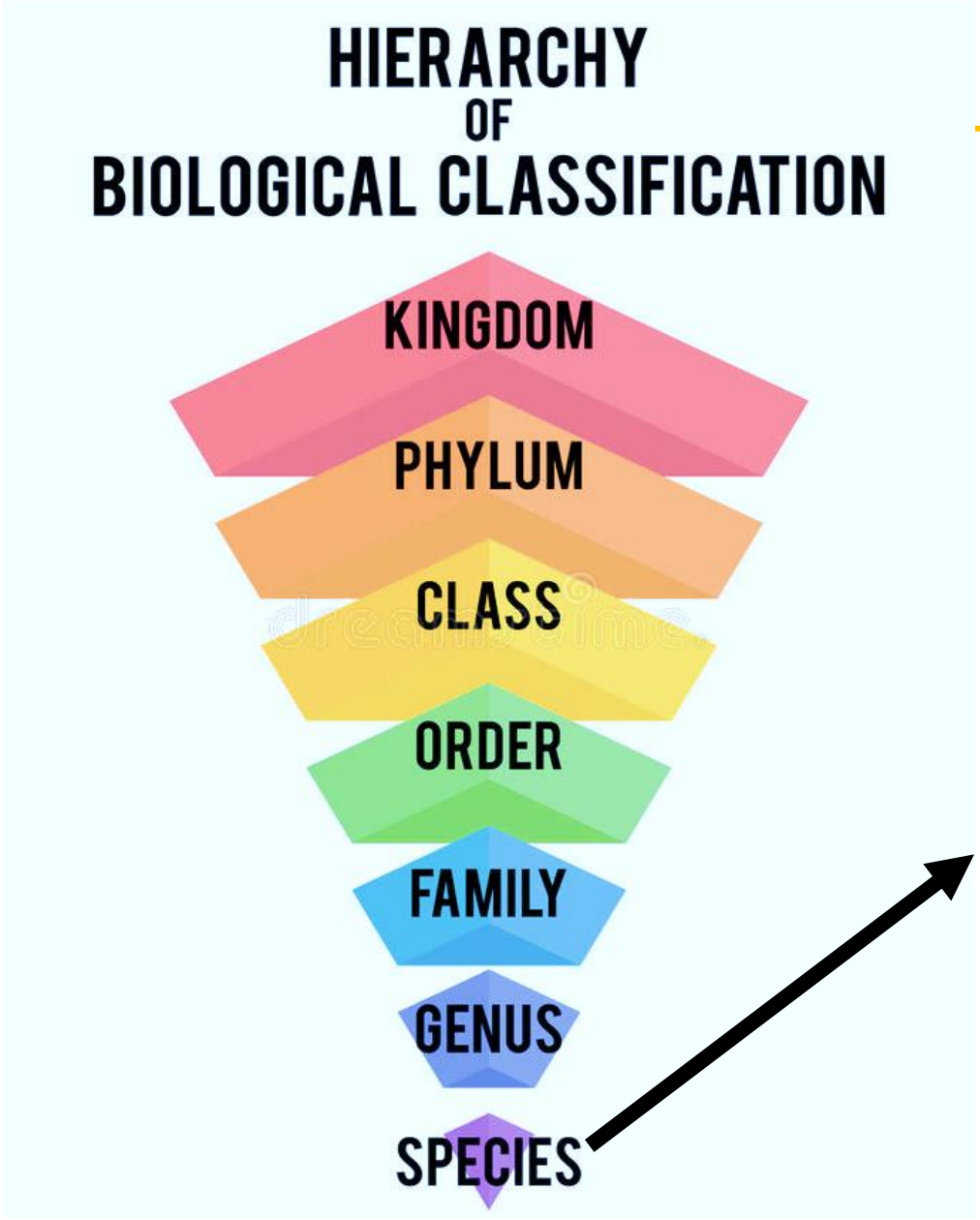
Same species, different breeds

What defines a “species”?

- There are different approaches to defining how species are identified; each approach is known as a **species concept**.
- The concept of species may be defined in a variety of ways:

(A) **Biological** species concept
(B) **Ecological** species concept
(C) **Morphological** species concept
(D) **Genetic** species concept
(E) **Phylogenetic** species concept

1. Definition
2. Advantages
3. Limitations



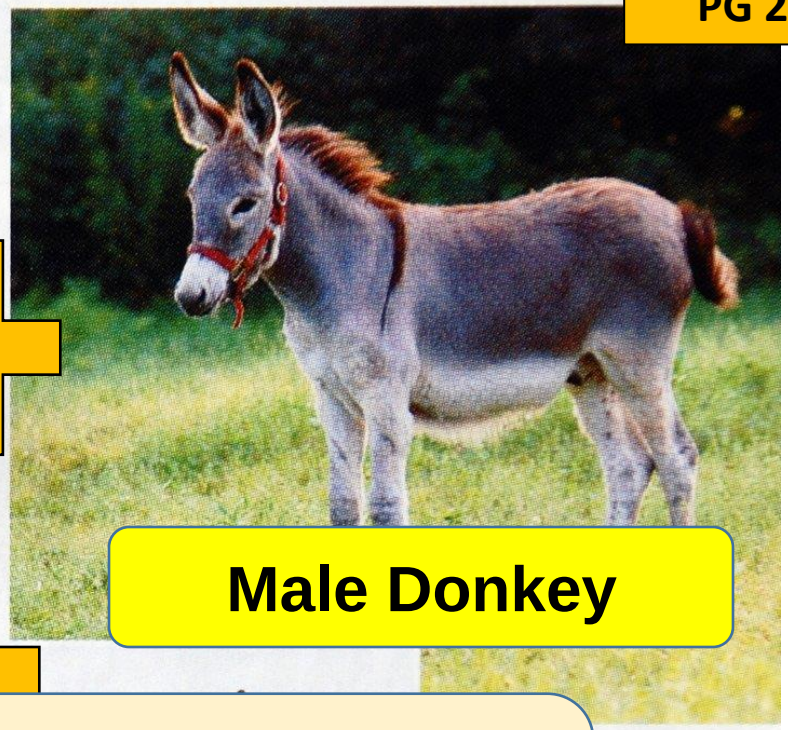
Species is the **lowest taxa** in the hierarchy of biological classification

Biological species concept

- **Definition:** A species refers to a group of closely related organisms which are **capable of interbreeding** in nature to produce **viable, fertile offspring** and are **reproductively isolated** from other species.

Female Horse

+



Male Donkey

Horse & donkey are *not* the same species

Mule

Viable but sterile!

Figure 14.3D Hybrid sterility: a horse and a donkey may produce a hybrid (and sterile) offspring, a mule

Tigress

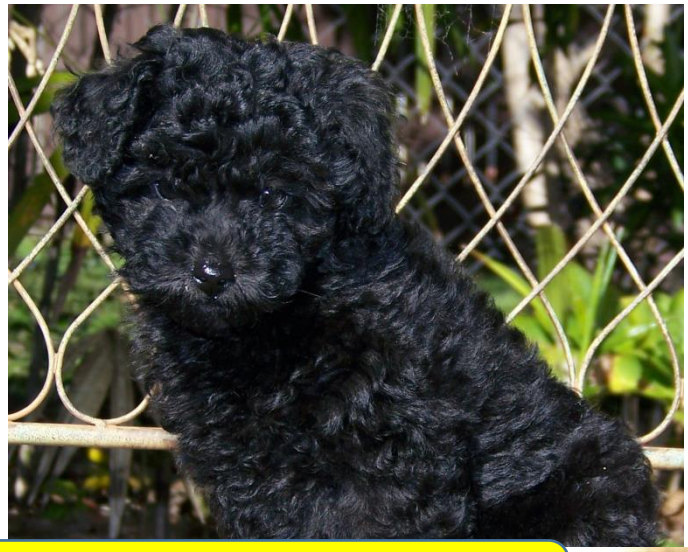
+

Male Lion

Tiger and Lion are *not* the same species

Liger

Viable but sterile!



Mini

Schnauzer

Poodle and Schnauzer:
same **species**

TEST YOURSELF

Schnoodle

Viable
&
Fertile!

How to use the Biological Species Concept?

Members of one species usually cannot produce fertile offspring with members of another

Observe for interbreeding / Mating

(Censored pictures)

Observe the offspring

Biological species concept

Advantage:

- Applicable to many ecological studies as the concept based on a **mechanism**

Objective and observable

Limitation:

- Cannot be applied to **asexually reproducing organisms** and **extinct species** whose breeding behavior cannot be observed.

No mating involved

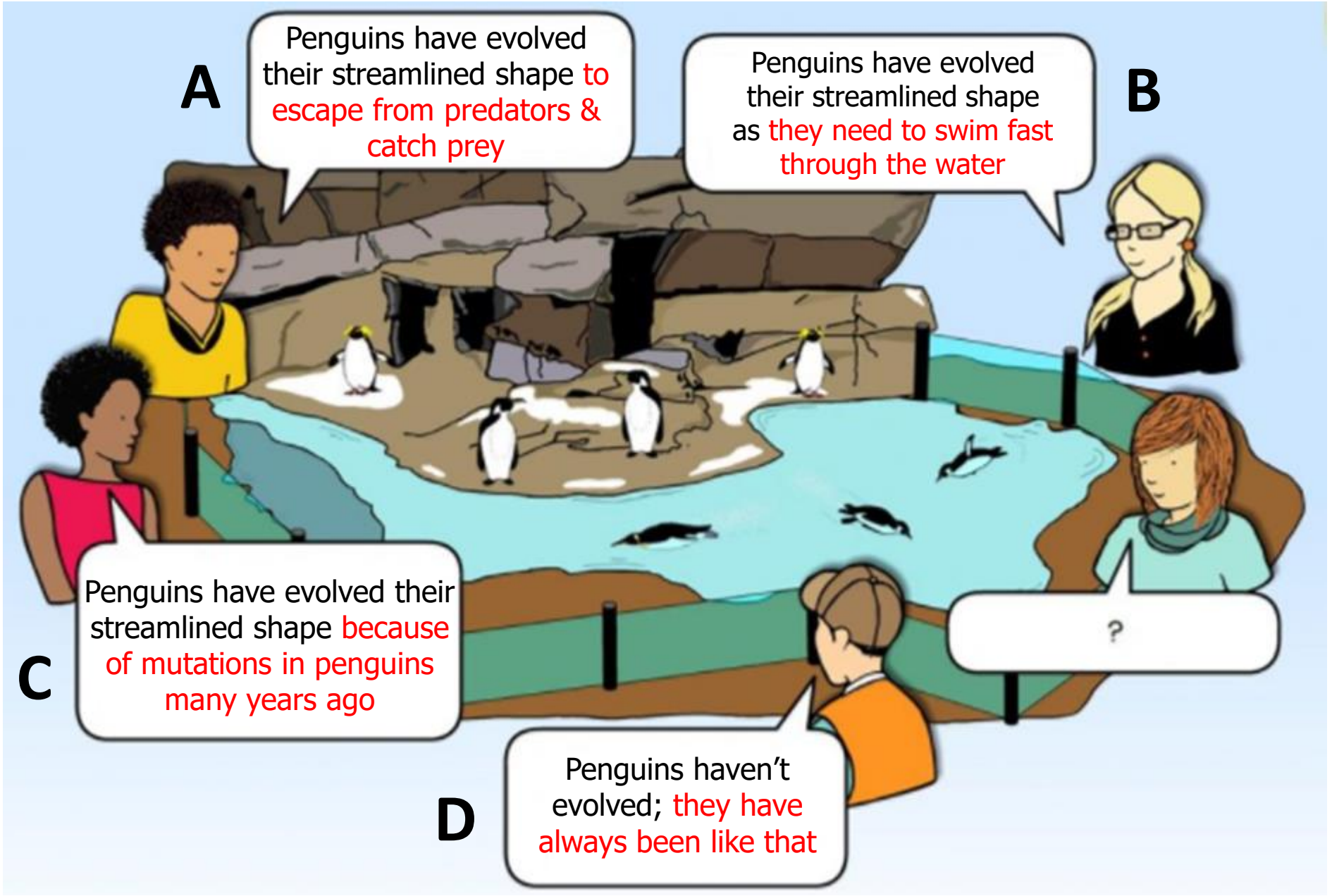
Hydra: budding

Bacteria: Binary fission

BIOLOGICAL EVOLUTION

Microevolution

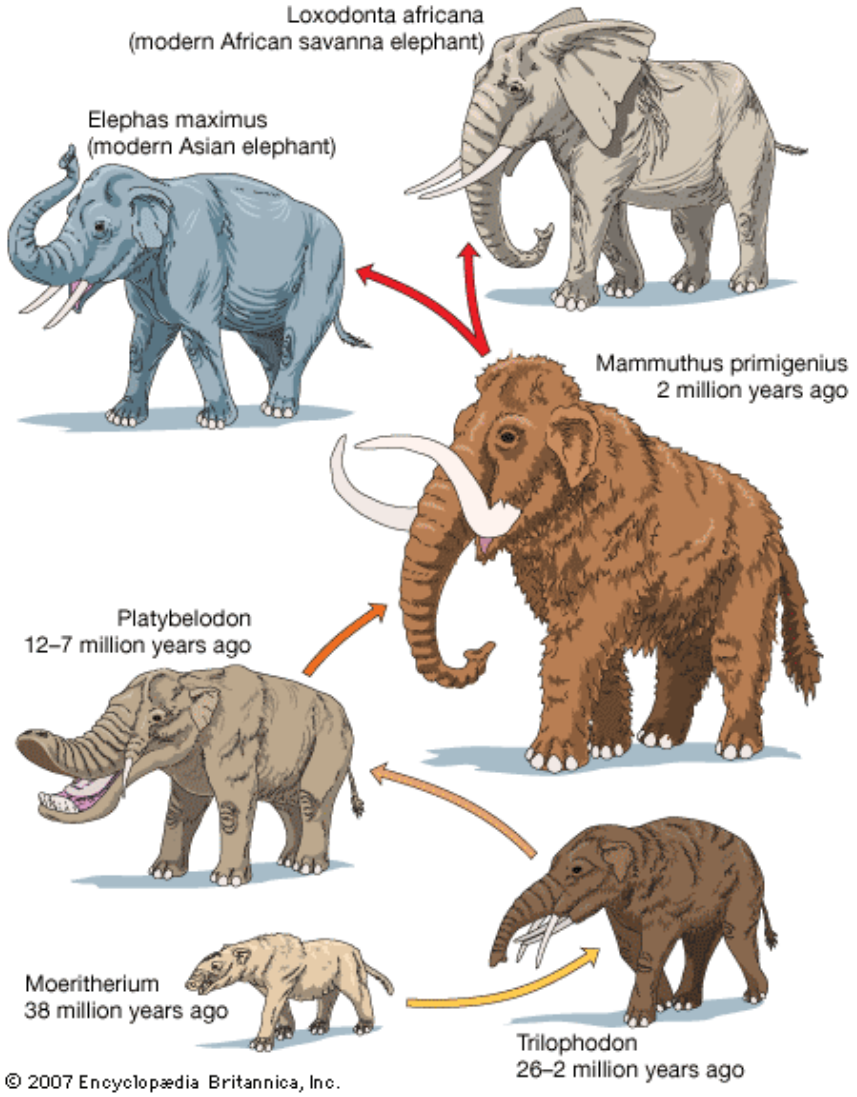
Macroevolution



Why do penguins have streamlined bodies?

What is "Evolution"?

- Definition - "**descent with modification**"
- **Process** of development of **new** forms of organisms from **pre-existing** forms over a period of time by **accumulated** changes.
- It is believed that all living organisms share a **common ancestor**.



Microevolution

- Microevolution - Refers to **changes in allele frequencies** that occur in a gene pool of a population over time.
- Macroevolution: Large scale **descent of species from a common ancestor** over many generations

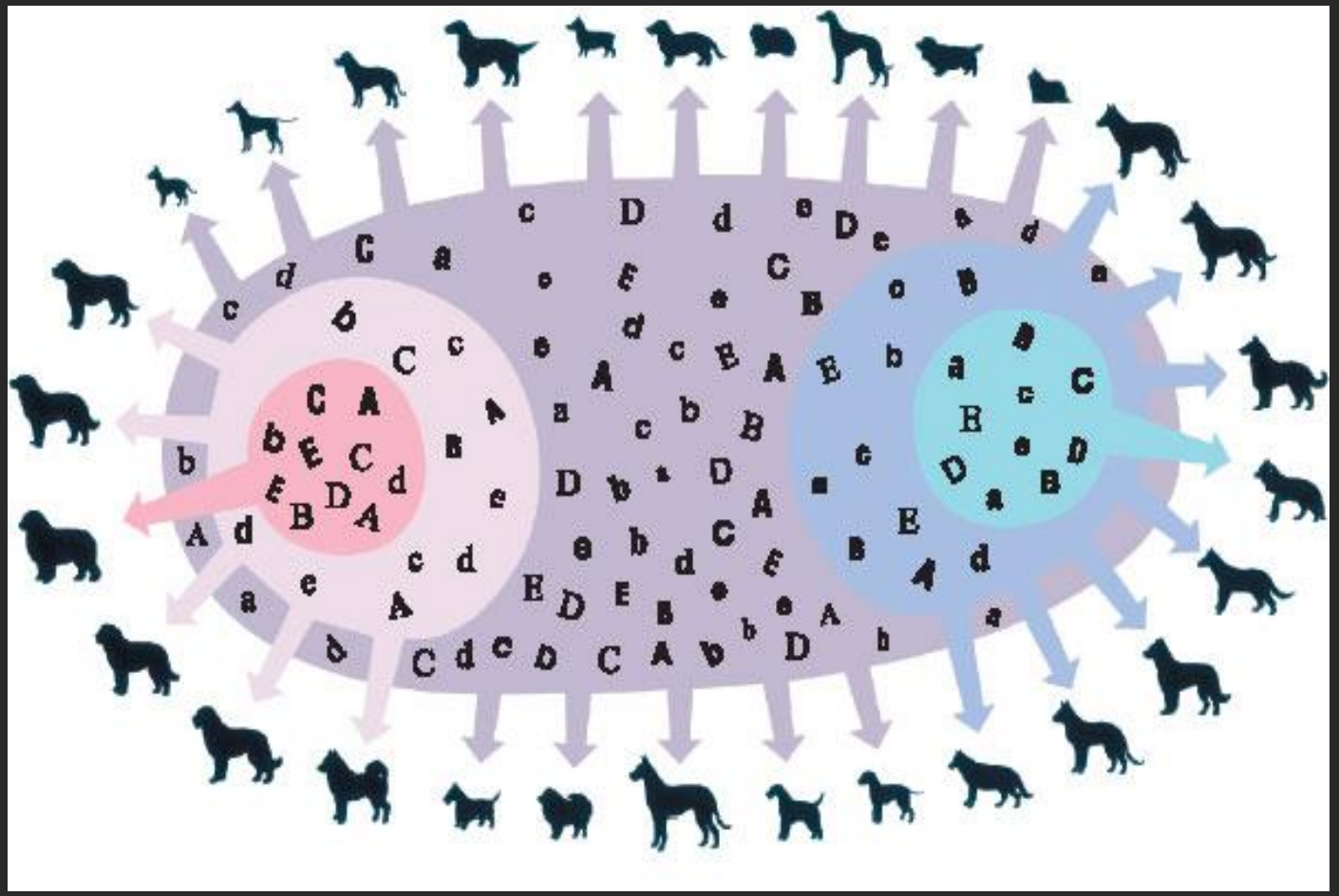
***Gene pool**: **all the alleles present** in an interbreeding population at any given point of time

***Allele frequency**: **relative proportion** of alleles in a population

Not in notes

"What is Evolution?"

* **Gene pool**: all the alleles present in an interbreeding population at any given point of time



Not in notes

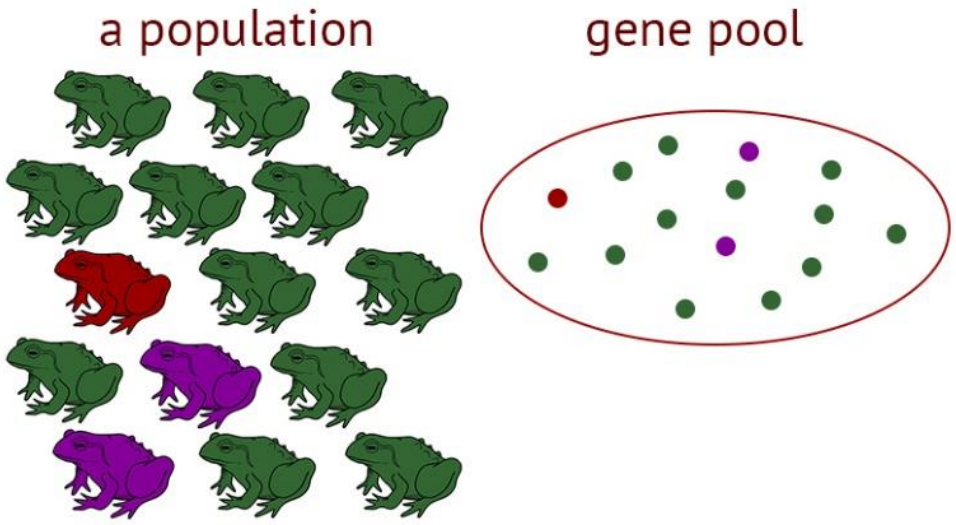
Gene Pool & Allele Frequency

- **Gene pool**: Alleles coding frog skin colour – green, red and purple
- **Allele frequency**: (assuming each frog is homozygous)

  Allele frequency of red allele = 1/15 = 0.067

  Allele frequency of purple allele = 2/15 = 0.133

  Allele frequency of green allele = 12/15 = 0.800



Not in notes

Gene Pool & Allele Frequency

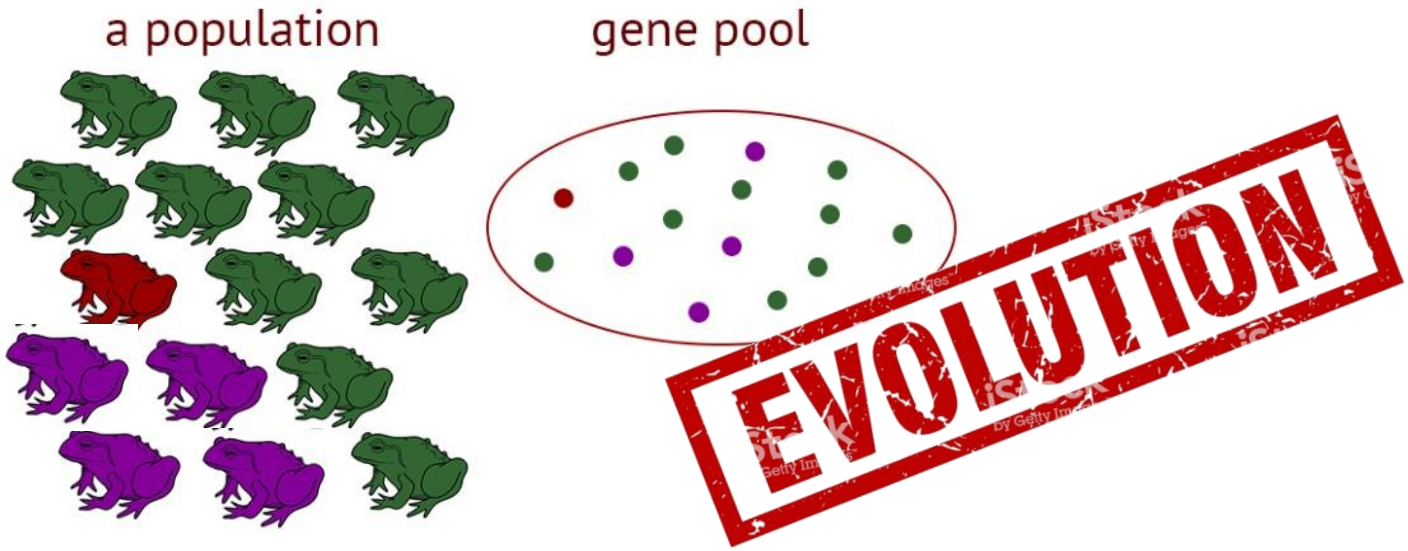
- **Gene pool**:

- **Allele frequency**: (assuming each frog is homozygous)

  Allele frequency of red allele =

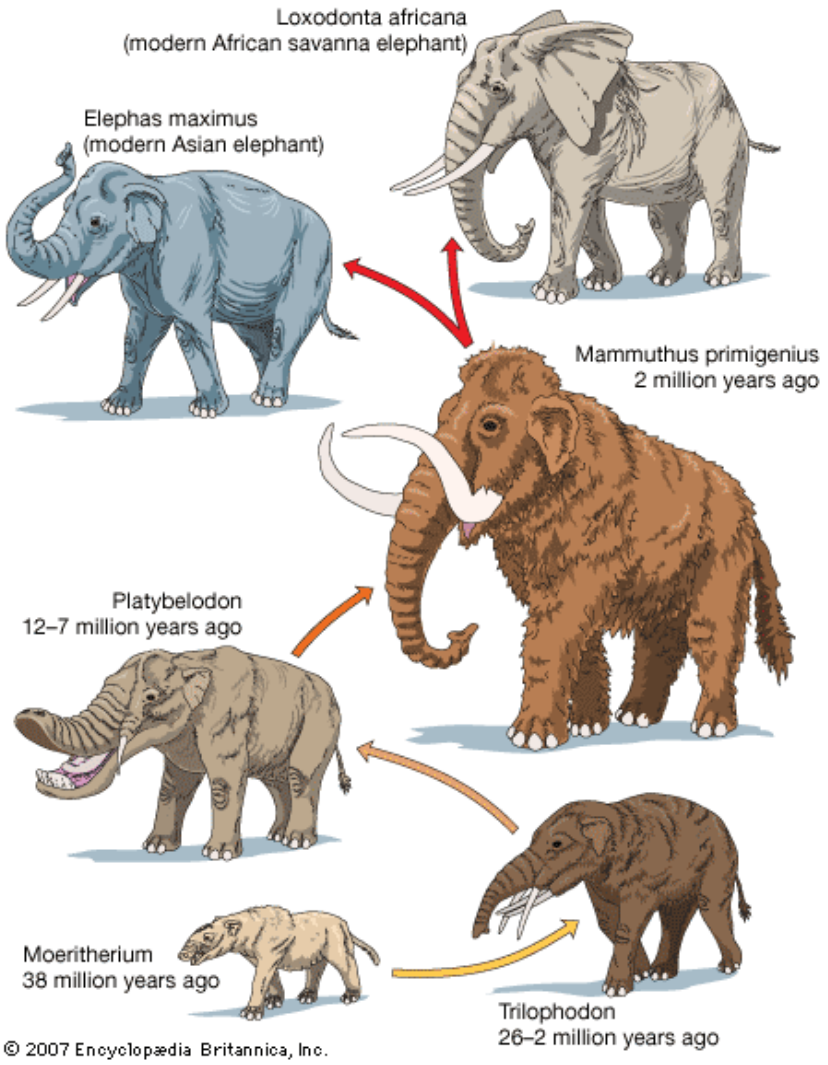
  Allele frequency of purple allele =

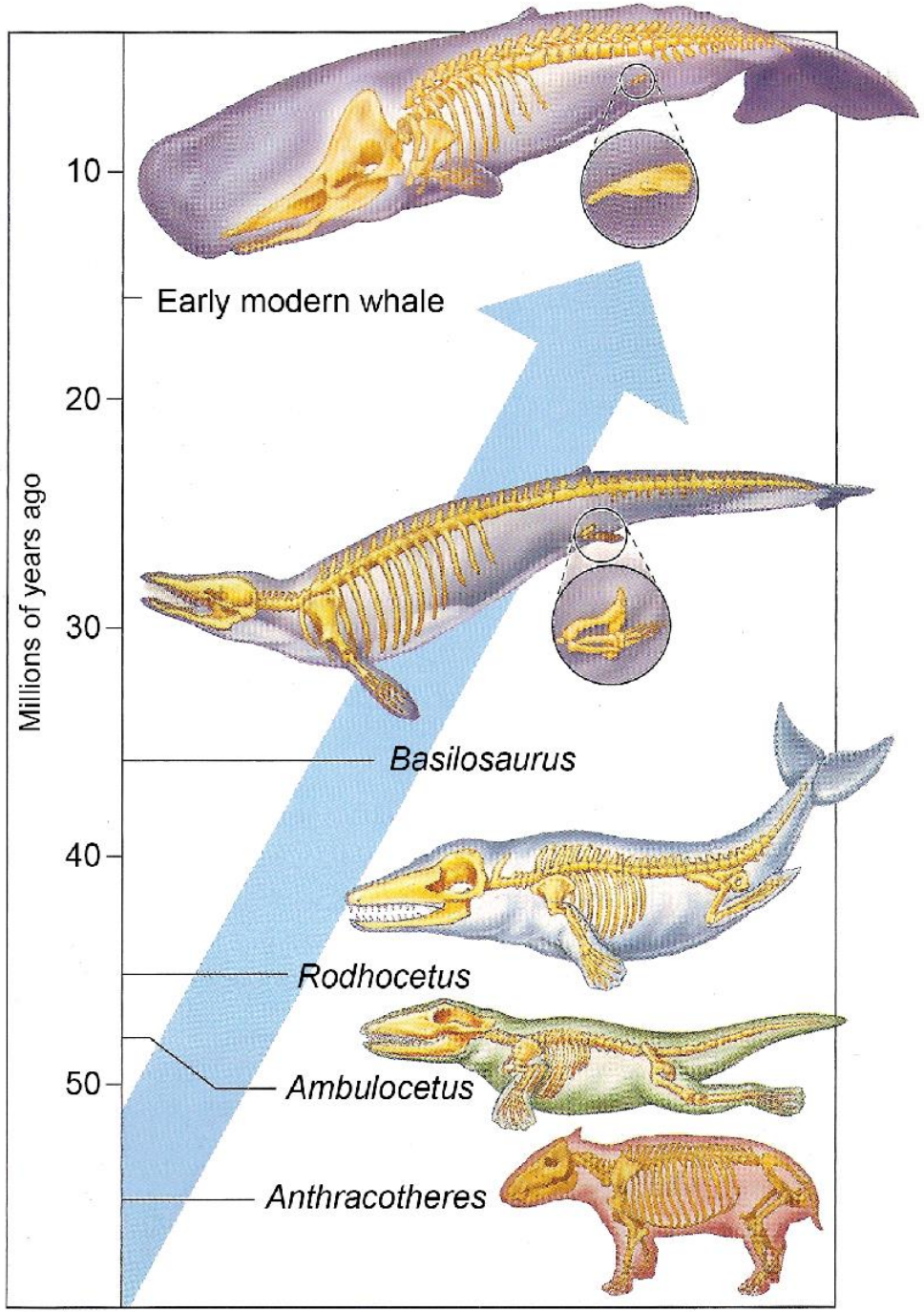
  Allele frequency of green allele =

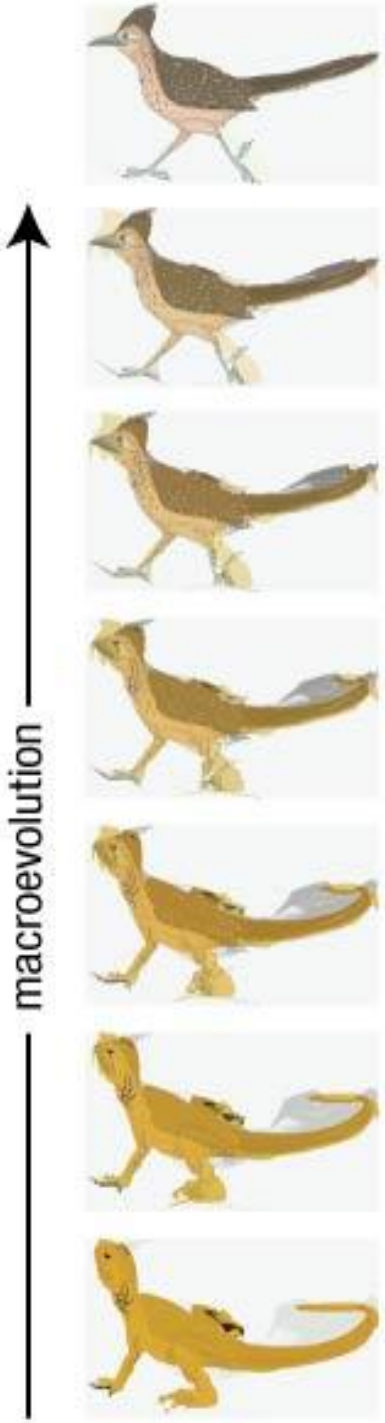


Macroevolution

- Large scale **descent of species from a common ancestor** over many generations.



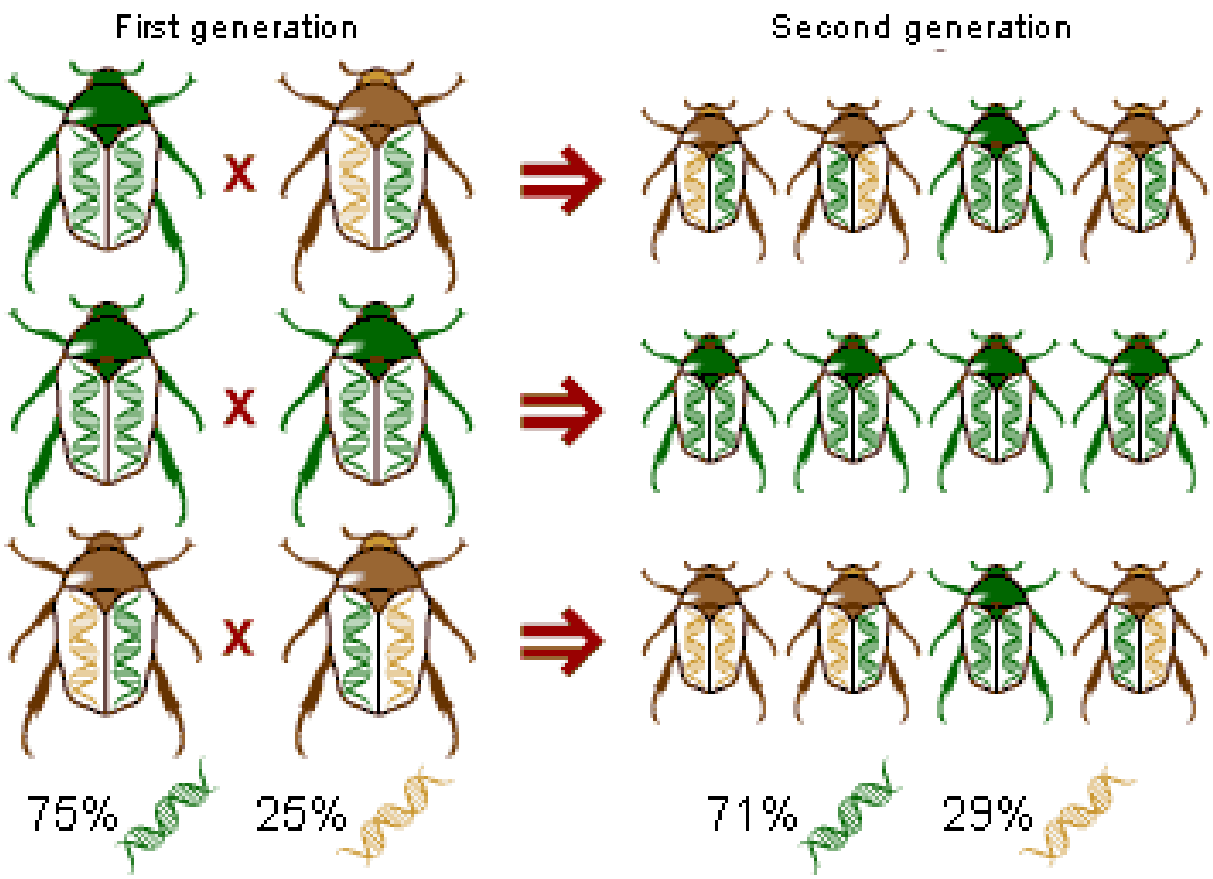




Intermediates
(always missing
or fictional)

Micro-evolution

- Small scale changes in allele frequencies from generation to generation



Macro-evolution

- Evolutionary changes on a grand-scale
- Encompasses
  - origin of new taxonomic groups
  - evolutionary trends
  - adaptive radiation
  - mass extinction

Genus,
Family,
Order
Class,
Phylum

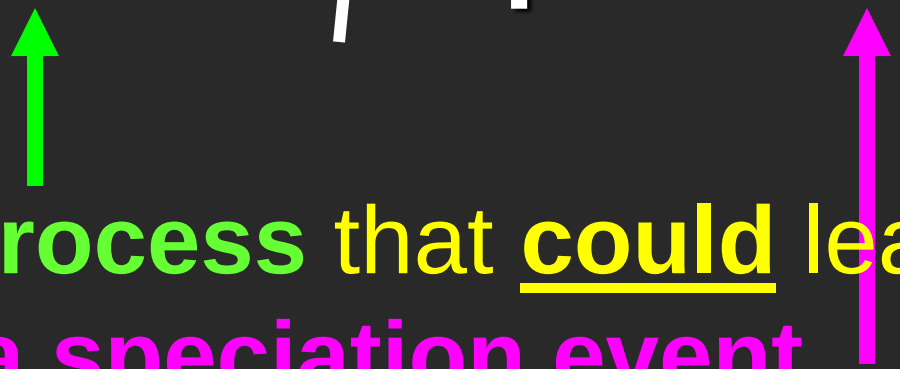
Jointed legs
Hard-shell eggs
Flight
Mammary glands

Link between Micro- and Macro-Evolution

Mutation
Gene Flow
Genetic Drift
Natural Selection
+ 3.8 billion years = Macroevolution

Both micro-evolution and macro-evolution are brought about by mutation, natural selection, gene flow and genetic drift.

Evolution ≠ Speciation



It is **a process** that **could** lead to **a speciation event**

THEORY OF EVOLUTION

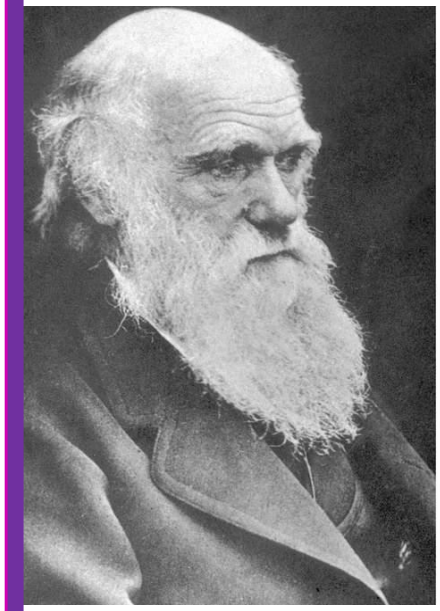
LAMARCK'S THEORY OF EVOLUTION

NEO-DARWINISM

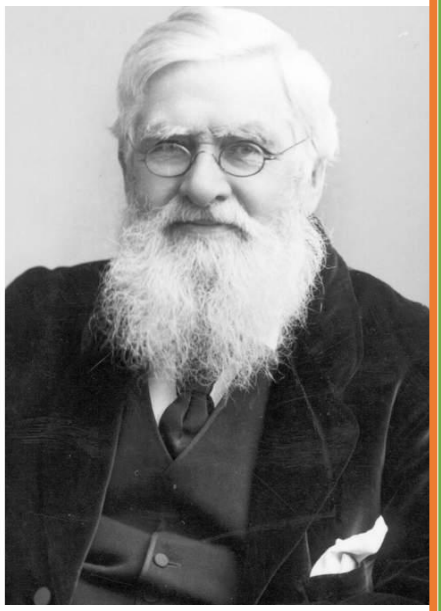
History of Evolution Theories

Jean-Baptiste Lamarck
(1744 – 1829)

Lamarck's Theory of Evolution
(Widely discredited)



Charles Darwin
(1802 - 1882)



Alfred Wallace
(1823 - 1913)

Theory of Evolution by Natural Selection
(most accepted model)

Gregor Mendel
(1822 - 1884)

Founder of modern genetics

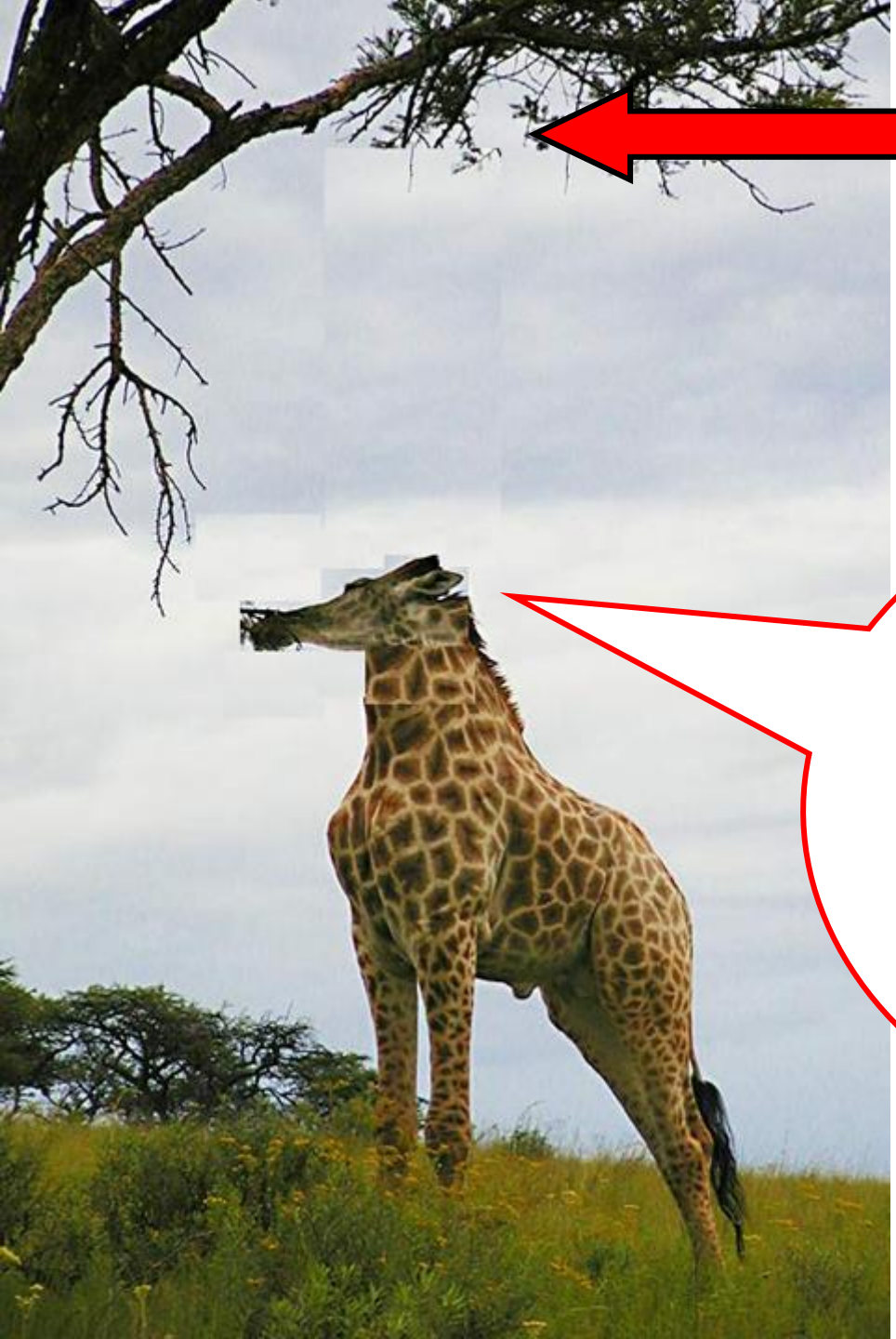
NEO-DARWINISM

Lamarck's theory of evolution

Idea 1: Use and disuse

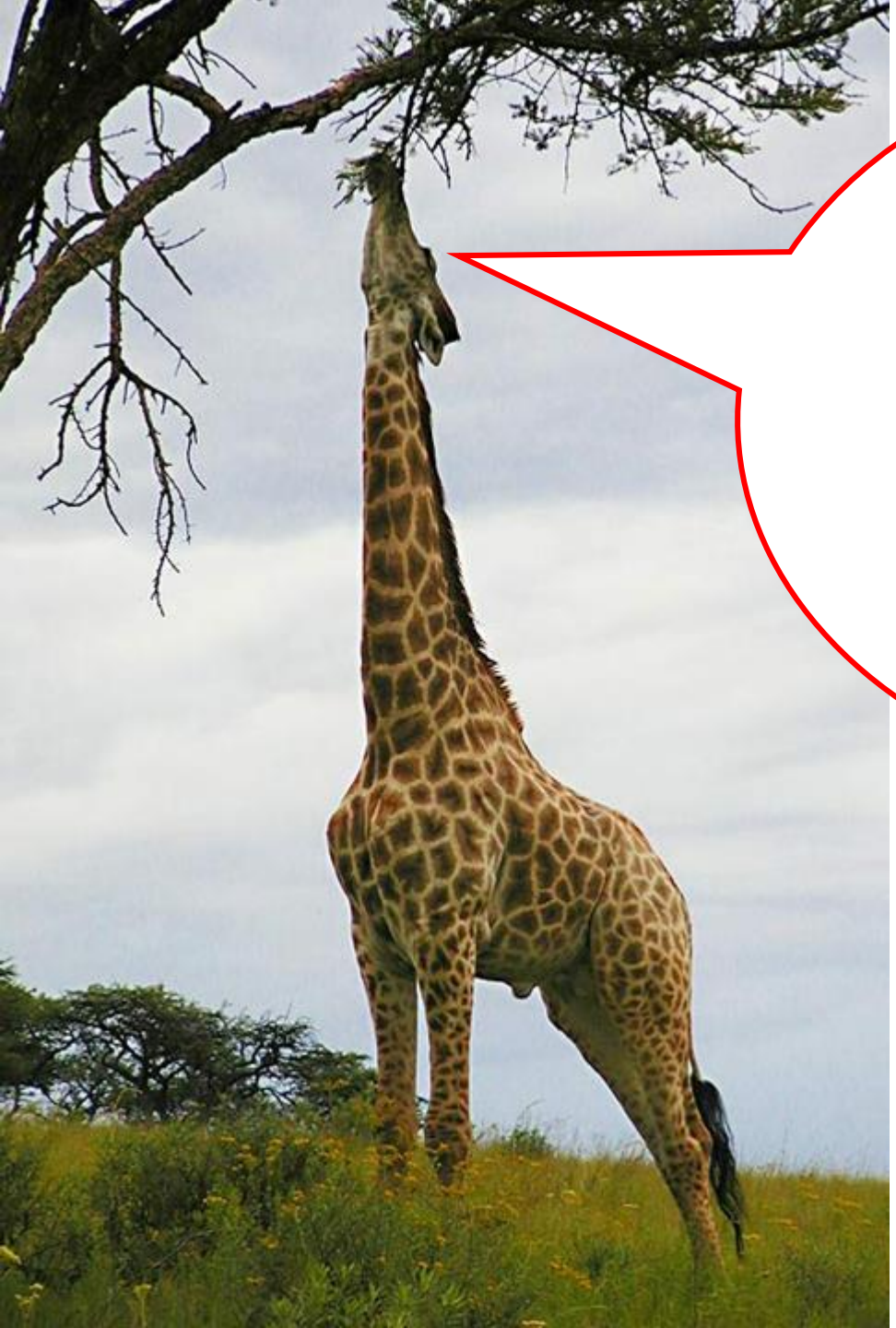
- When there is a **need** for a particular structure in an environment, the need **induced** the development of that structure in the organism.

→ Based on the observation that structures that are **often used** become **well-developed** whereas those **not used** tend to **degenerate.**



Yummy tender leaves

Sigh Wish I can reach those yummy tender leaves up there...


Grrrr….Yes!
Got it!
Huh? What
happen to my
neck??!

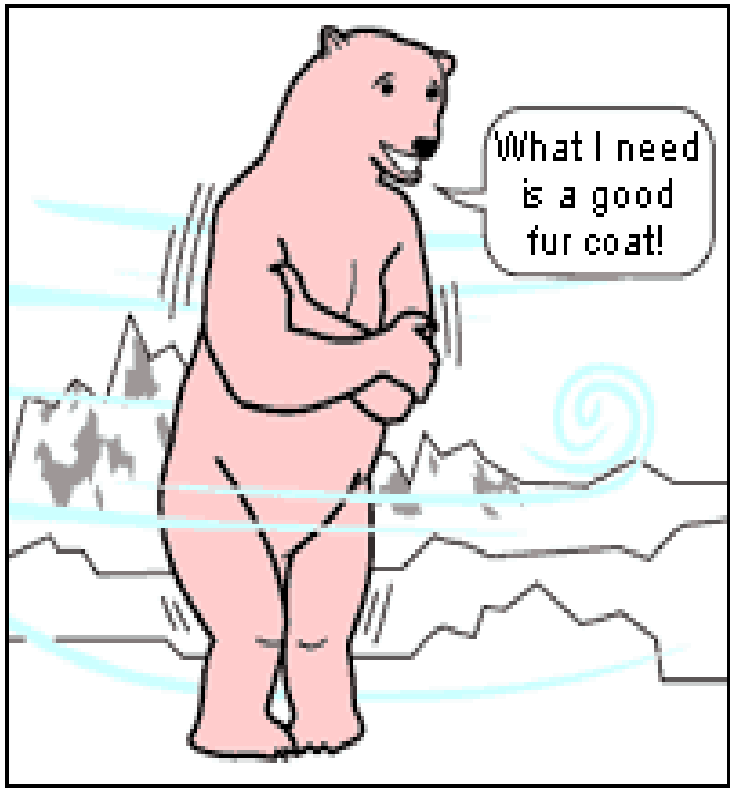
Lamarck's theory of evolution

Idea 2: Acquired characteristics can be inherited

- Beneficial characteristics, which were **acquired during the lifetime** of an individual, **could be inherited** by offspring.

Lamarck's theory of evolution

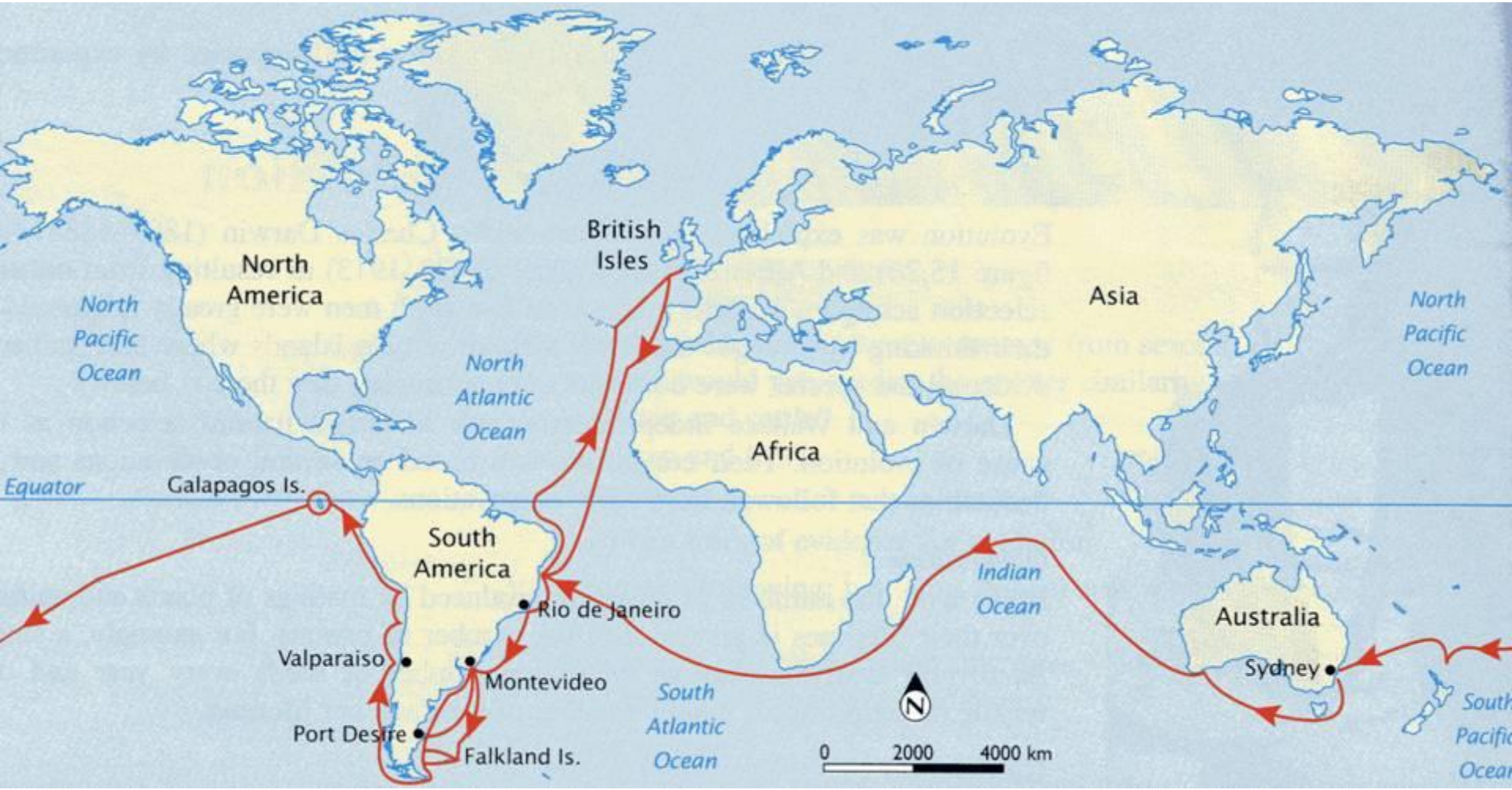
However, biologists **rejected Lamarck's theory** of evolution because it was not a reasonable proposition.



Evolution does not work this way.

Hi, I'm Charles!

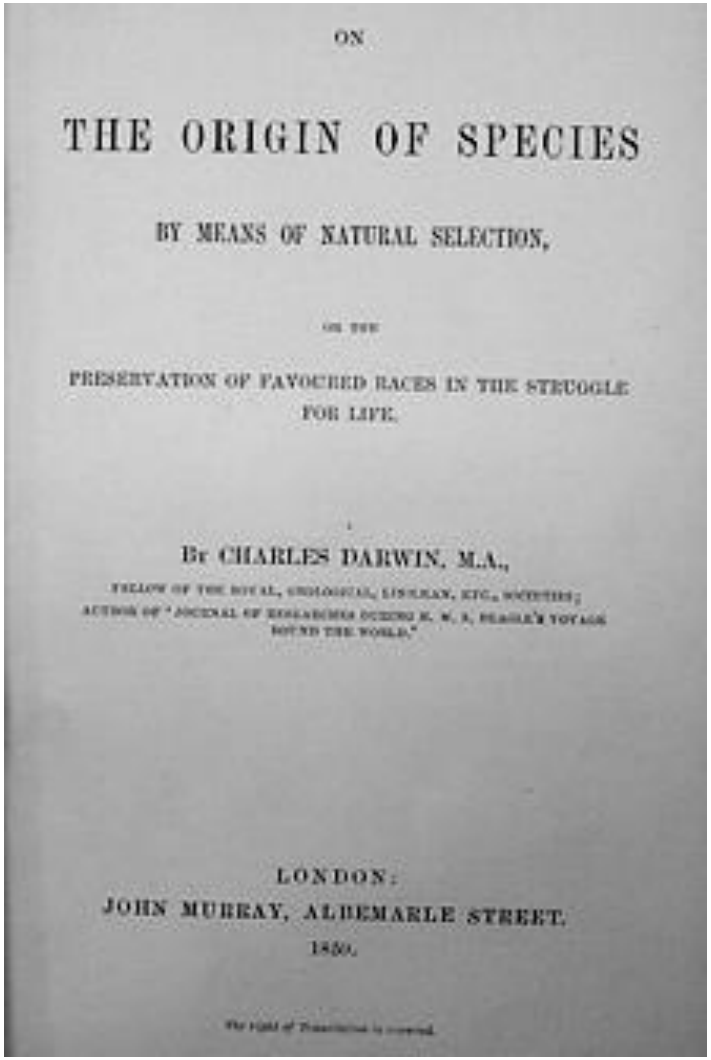
Charles Darwin's theory of Evolution by Natural Selection


North America
British Isles
Asia
North Pacific Ocean
North Atlantic Ocean
North Pacific Ocean
Africa
Equator
Galapagos Is.
South America
Rio de Janeiro
Indian Ocean
Australia
Valparaiso
Montevideo
Sydney
Port Desire
Falkland Is.
South Atlantic Ocean
South Pacific Ocean
N
0
2000
4000 km

Charles Darwin's Theory of Evolution

Darwin's four postulates:

1. Individuals in a population of a given species are **variable**.
2. Some of this variation is **heritable**.
3. In every generation, some individuals are more successful at **surviving to reproduce** than others.
4. Survival and reproduction are **not random**, but depend on individual heritable variation



ON

THE ORIGIN OF SPECIES

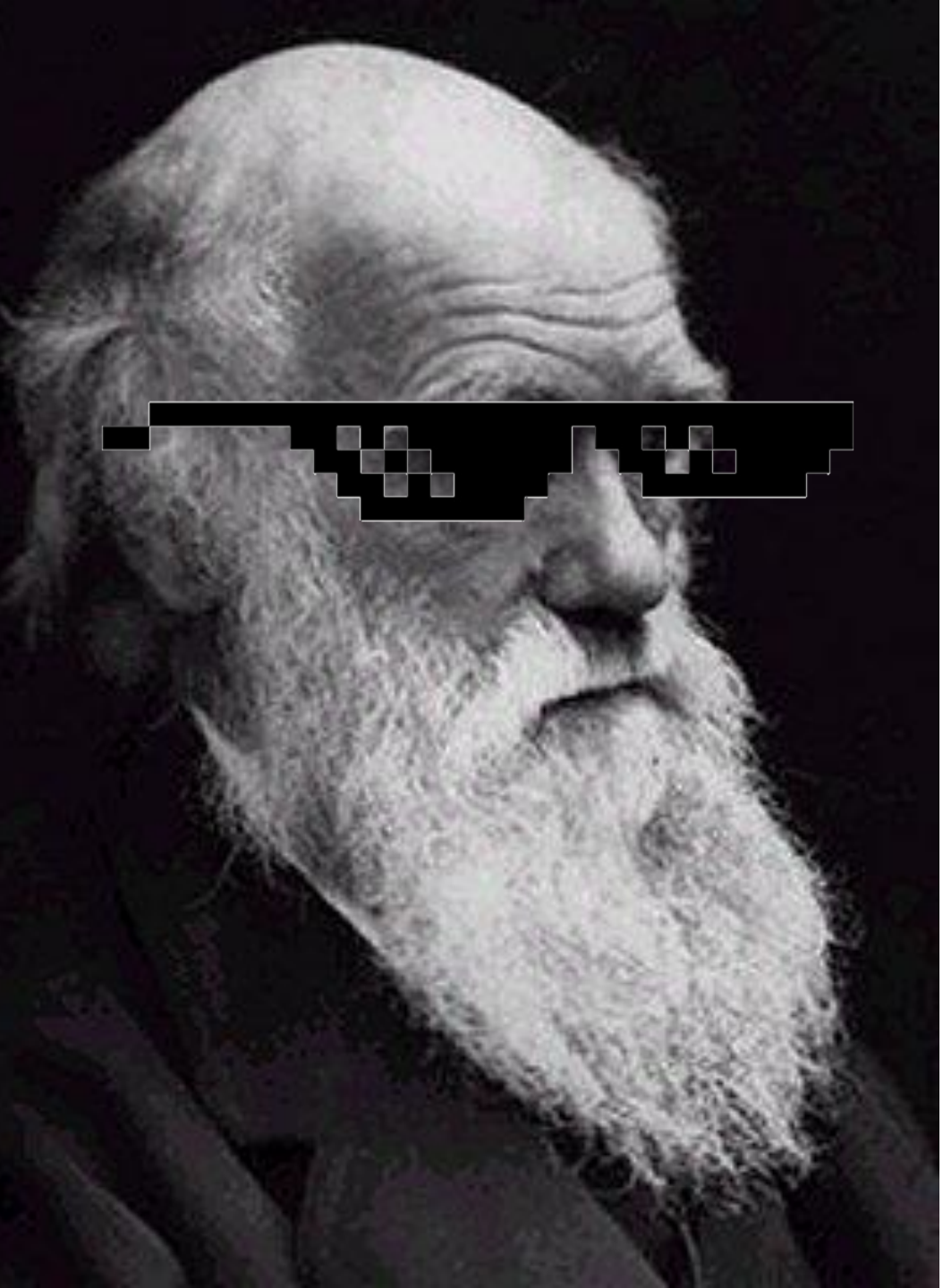
BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

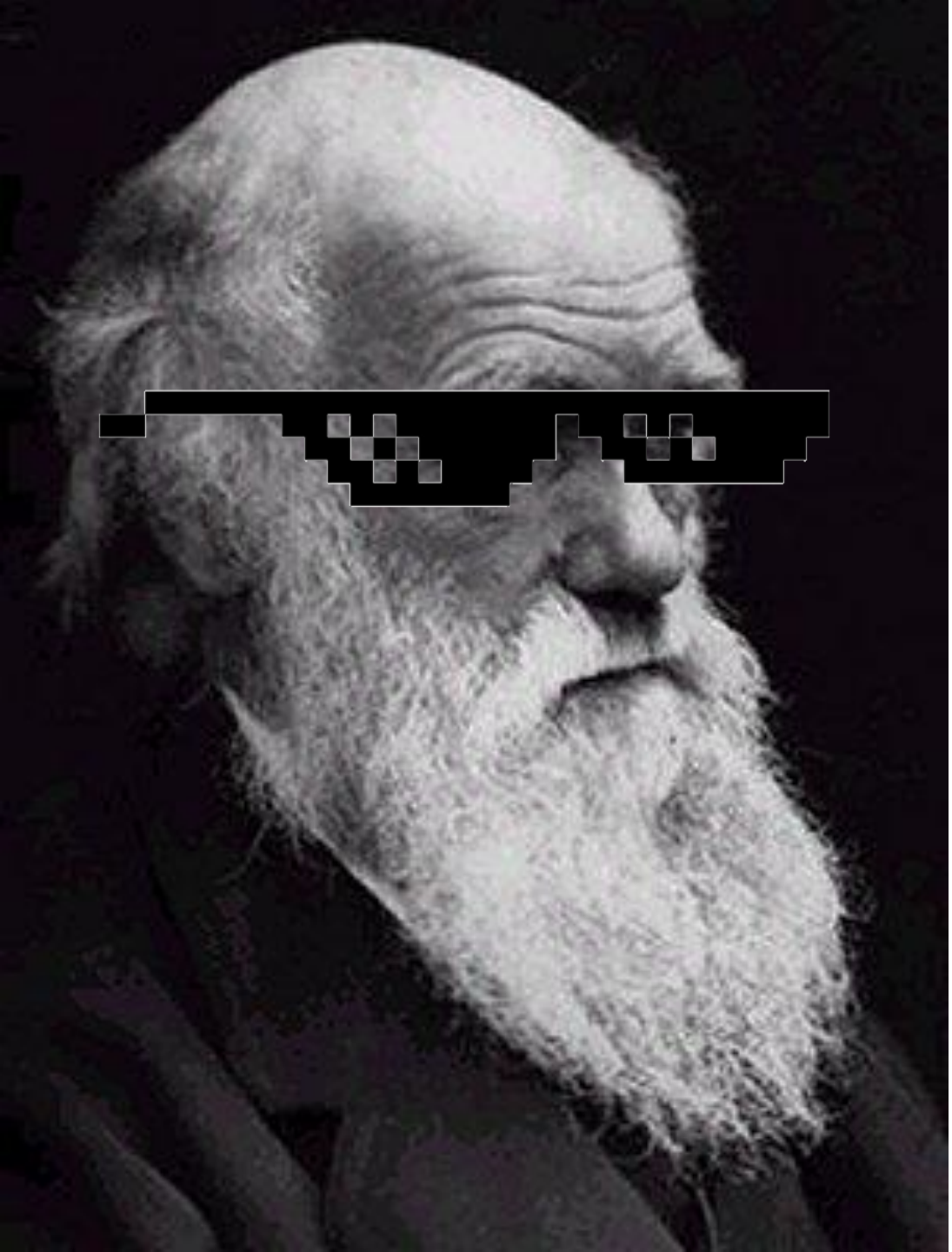
LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.



Neo-Darwinism

A modification of Charles Darwin's theory of evolution by natural selection as it **incorporates principles of genetics & molecular biology**

Natural selection as the main driving force of evolution



Neo-Darwinism

Explains that heritable traits are controlled by **genes**, and the inheritance of traits is through **alleles** passed down to offspring in gametes

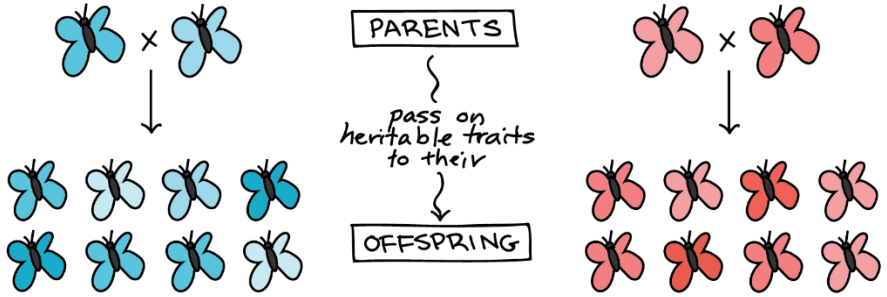
Features of Neo-Darwinism

1 Reproductive Potential

2 Genetic Variation

3 Survival of the fittest

4 Heritability



Features of Neo-Darwinism

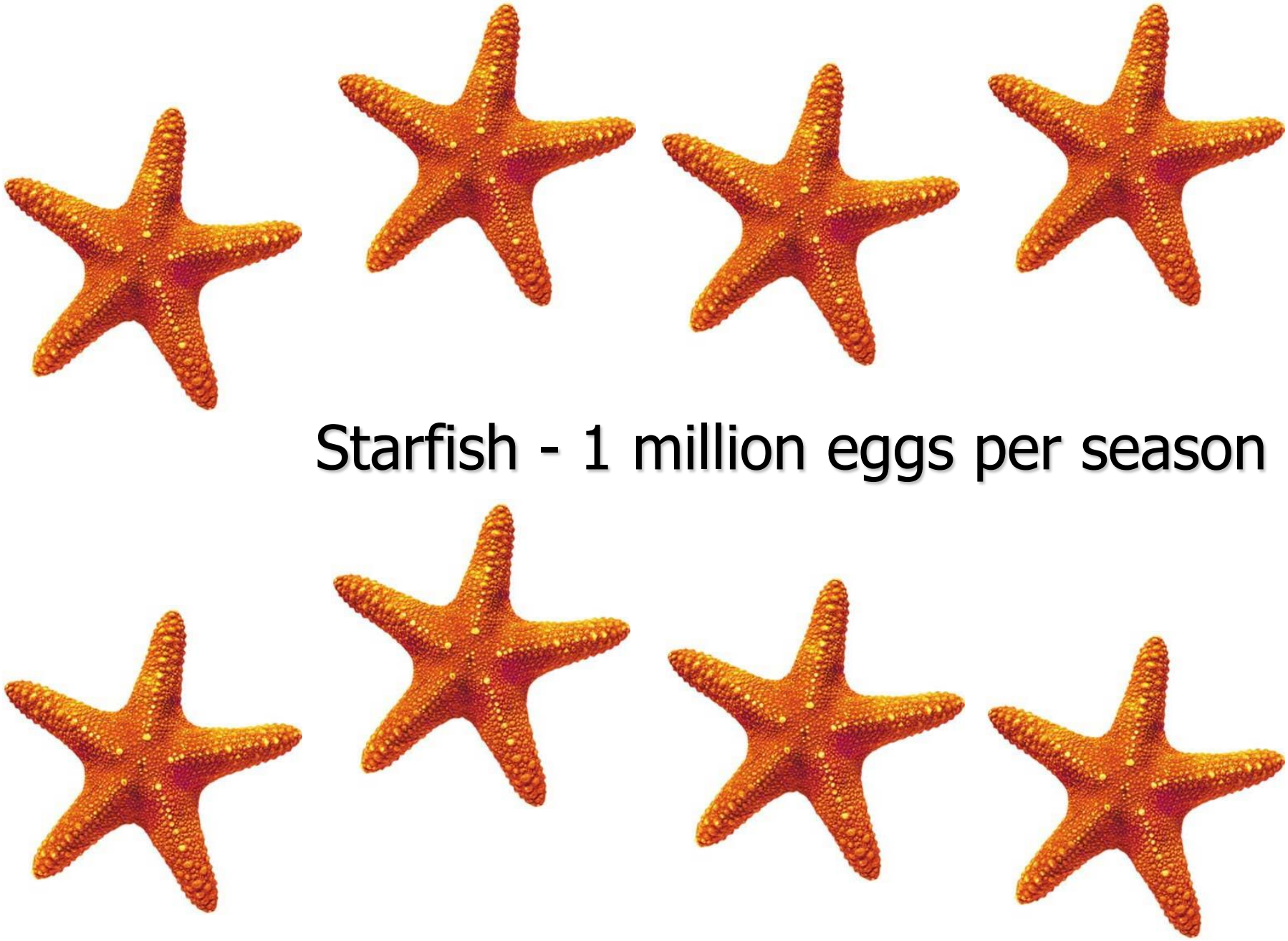
- Organisms have **great reproductive potential but** the offspring struggle for existence, giving rise to **constancy in numbers** in a given population.
  - Many fail to survive to reproduce in each generation due to environmental factors, intense competition for limited resources (e.g. food, shelter) and predation.

1 Reproductive Potential

Organisms have **great reproductive potential**

- The population size would increase rapidly and exponentially if all the individuals born reproduced.

Frogs - 20,000 eggs annually



Starfish - 1 million eggs per season

Giant puff balls produces 7×10^{11} spores

Features of Neo-Darwinism

- Individuals in a population are **genetically different** from each other
- These variations **arise spontaneously** before a change in the environment.

Not in response to the needs of individual due to a change in environment

Sources of variation:

a. spontaneous mutation
b. meiosis (crossing over and independent assortment)
c. random fusion of gametes

2 Genetic Variation

Features of Neo-Darwinism

- The environment exerts **selection pressure**
  - **Selective Advantage** - Individuals with genotypes (hence phenotypes) **best adapted** to the new environment are more likely to **survive till maturity** and **reproduce to pass down their alleles** to their offspring.

3 Survival of the fittest

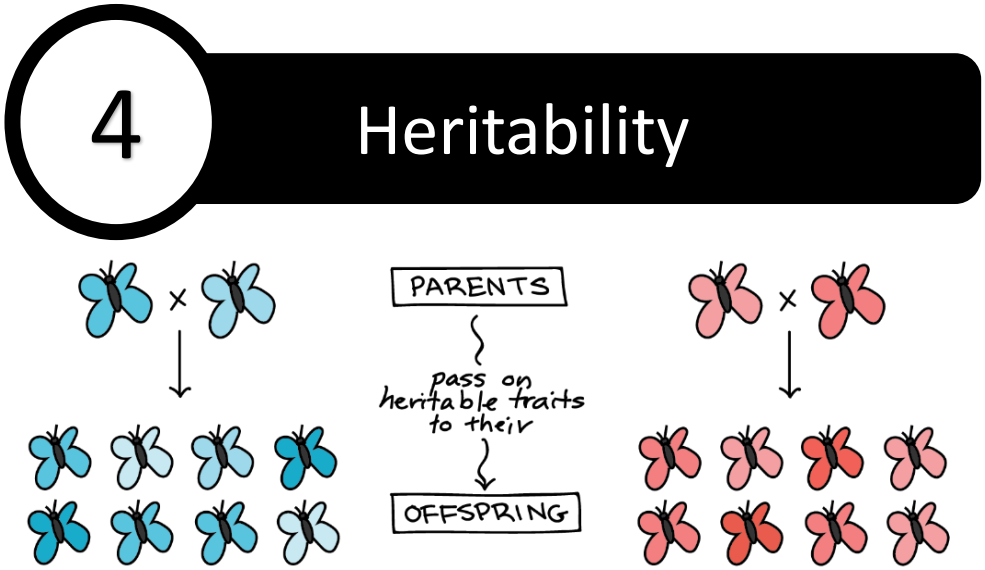
Features of Neo-Darwinism

- The environment exerts **selection pressure**
  - **Selective Disadvantage** - individuals with ***alleles coding for traits*** that are unable to withstand the environmental pressure **die before reaching reproductive age.**

3 Survival of the fittest

Features of Neo-Darwinism

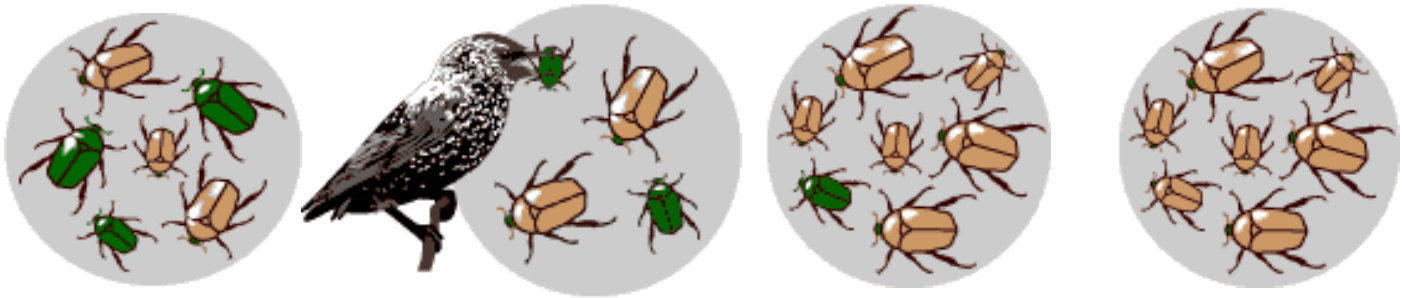
- Individuals produce **similar offspring** → beneficial characteristics are likely to be passed down.
- With each generation, the proportion of individuals who are at **selective advantage increases** while that at **selective disadvantage decreases**.



Features of Neo-Darwinism

- **Accumulation of favourable alleles** in the population over time
- → **changes in allele frequency** in a population.
- ***Certain advantageous* alleles becoming fixed *in the population over time.***

When only one allele of a gene remains in the gene pool



5 Changes in allele frequency

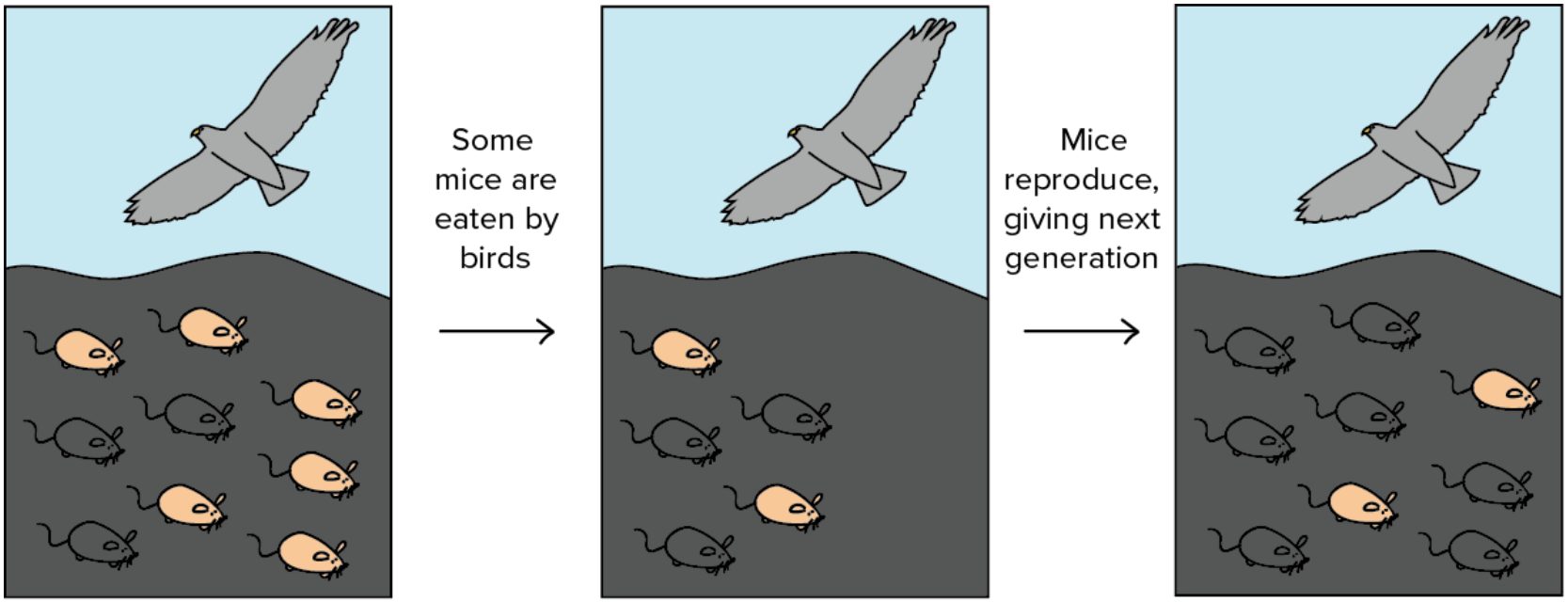
NATURAL SELECTION

PROCESS

MODES – STABILISING, DIRECTIONAL

Natural Selection

- **Definition** - Natural selection is a process whereby organisms **better adapted** to their environment **tend to survive** and **reproduce more offspring**.

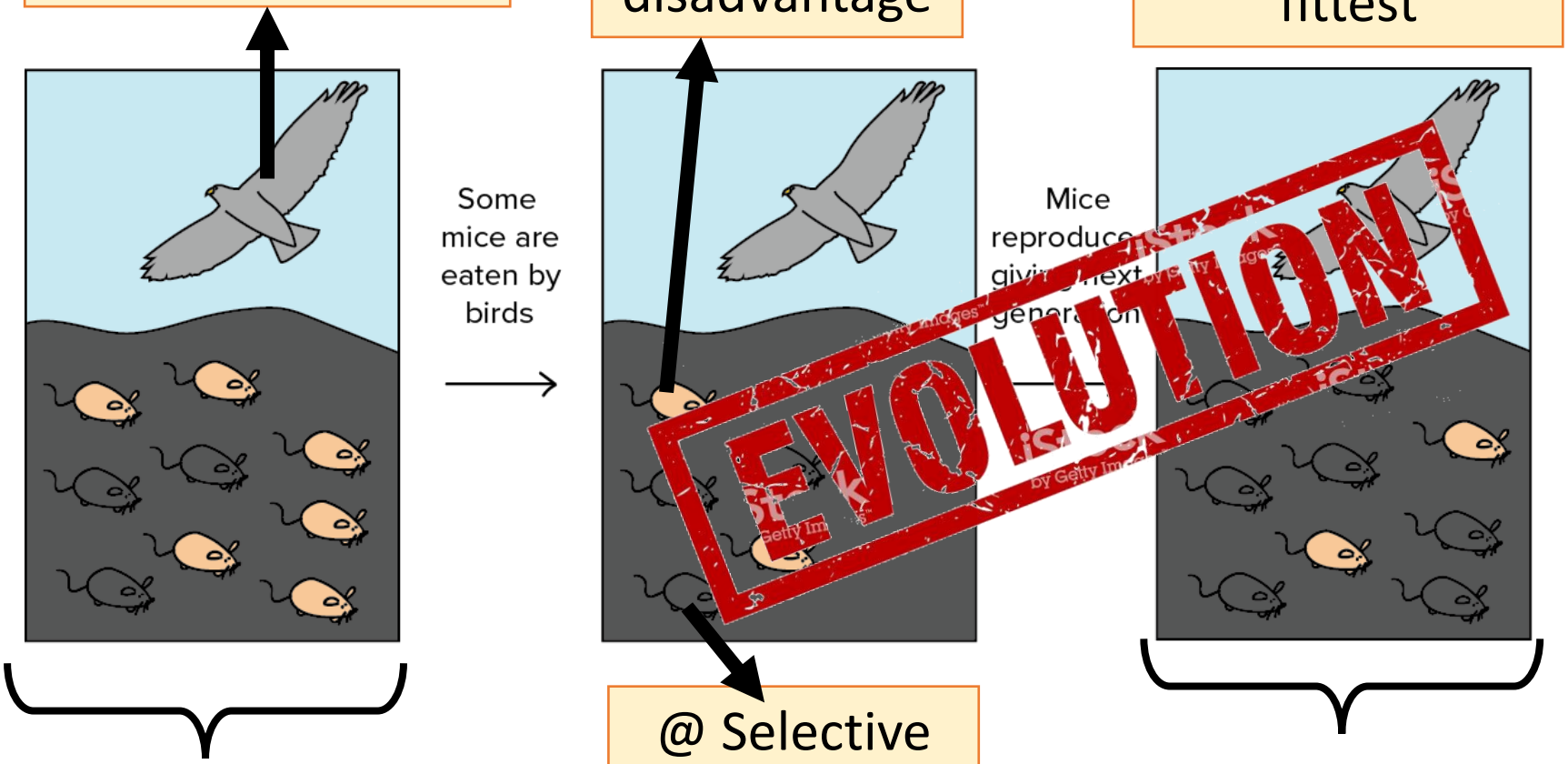


Natural Selection

Selection pressure

@ Selective disadvantage

Survival of the fittest



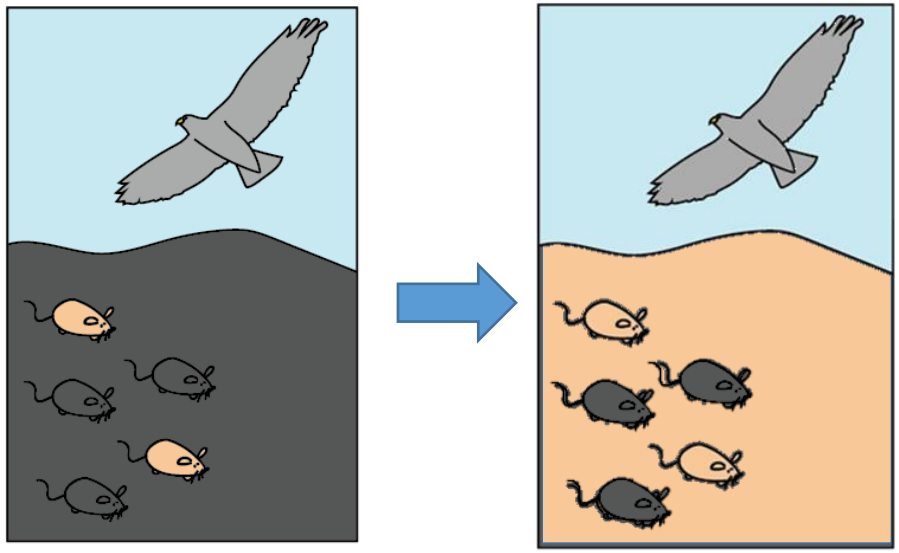
Variation

@ Selective advantage

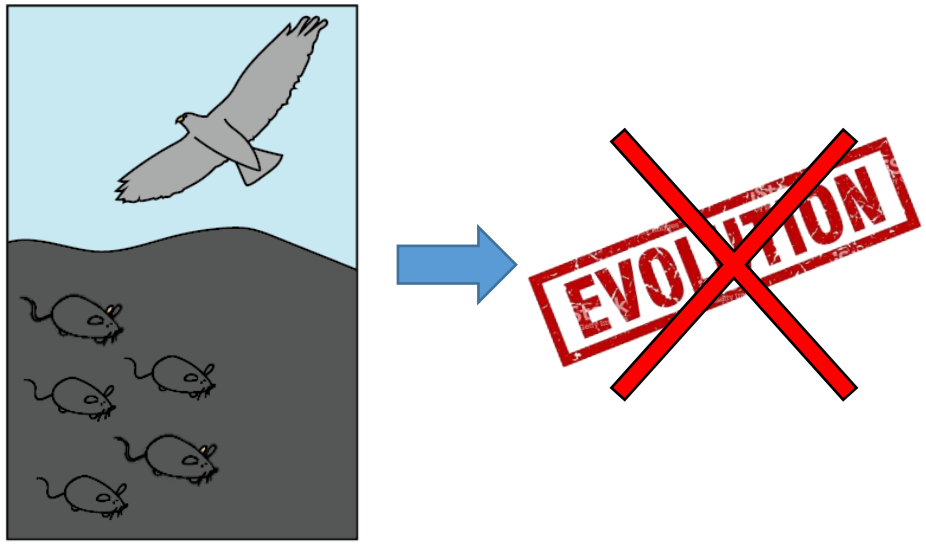
Allele frequency changed

Natural Selection

- Points to note:
  - Selective advantage or selective disadvantage **relates to one specific environment** and one specific time only



  - If all the individuals in a population **are genetically identical** for a heritable trait, evolution by **natural selection cannot occur.**



Read: page 10, dotted box

Role of natural selection on speciation

- Speciation: when one species diverges into two or more new species
- Speciation involves natural selection and requires a lot of other conditions to occur
  - e.g. Reproductive isolation (not in H1 syllabus)

What is natural selection?

NOTE:
Natural selection is a non-random process. Selection favored variants that were better able to survive and reproduce.

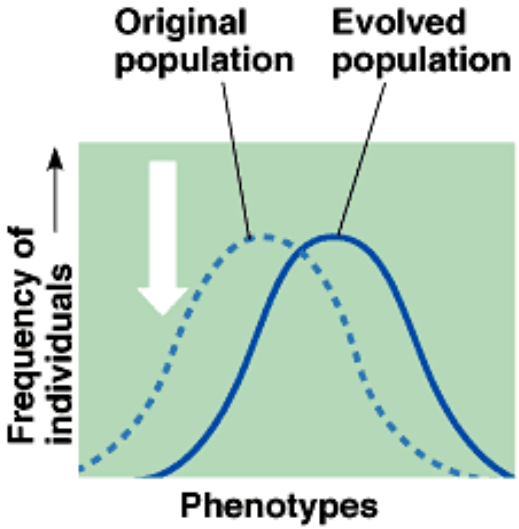
Recall…

"What is Evolution?"

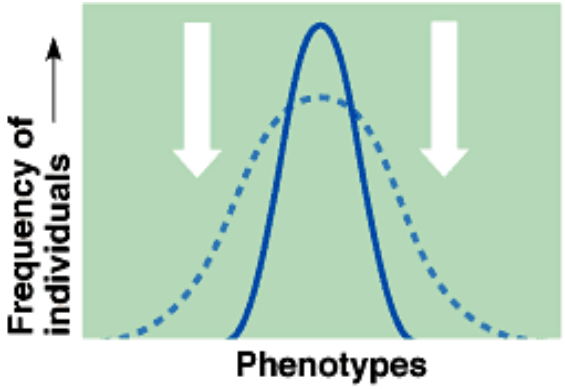
- **Changes in gene frequencies** that occur **in a gene pool over time.**

Modes of Natural Selection

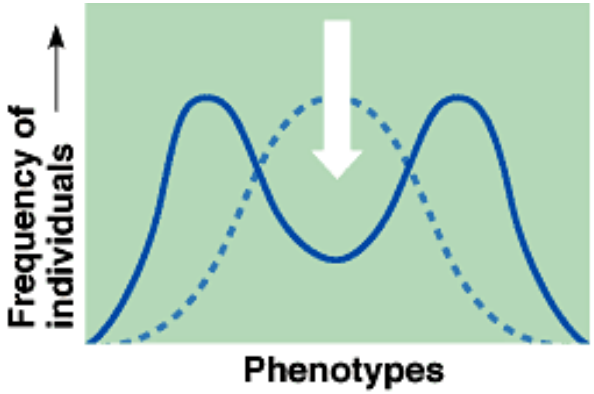
1 Directional selection



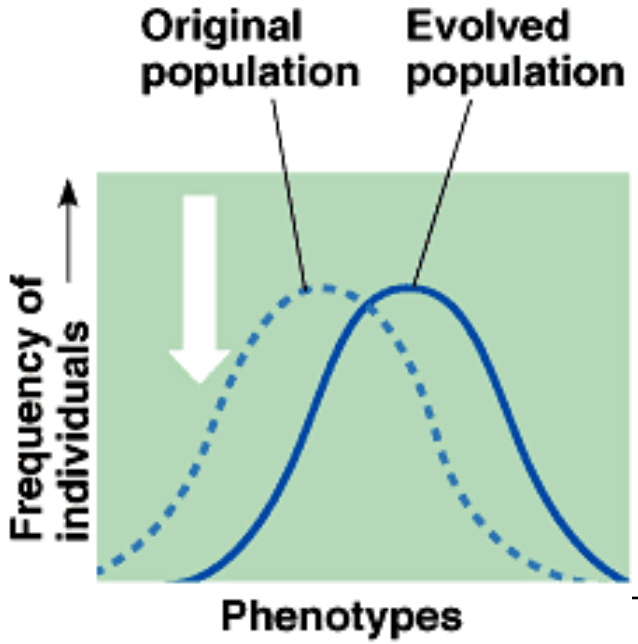
2 Stabilising selection



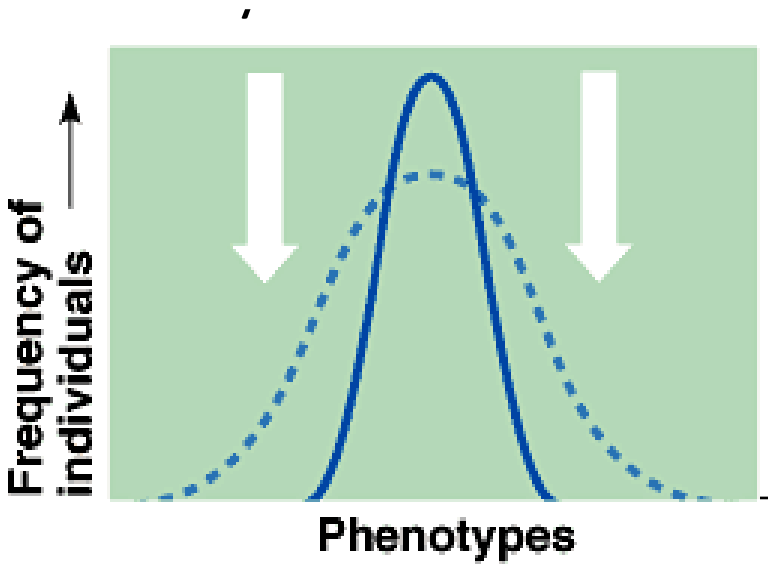
3 Disruptive selection



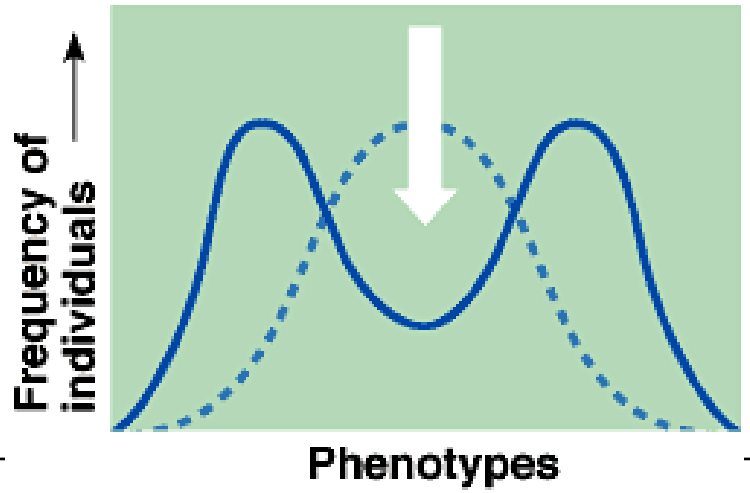
Modes of Natural Selection

Mode of Selection	Effects
1. Directional selection • •	• • 

Modes of Natural Selection

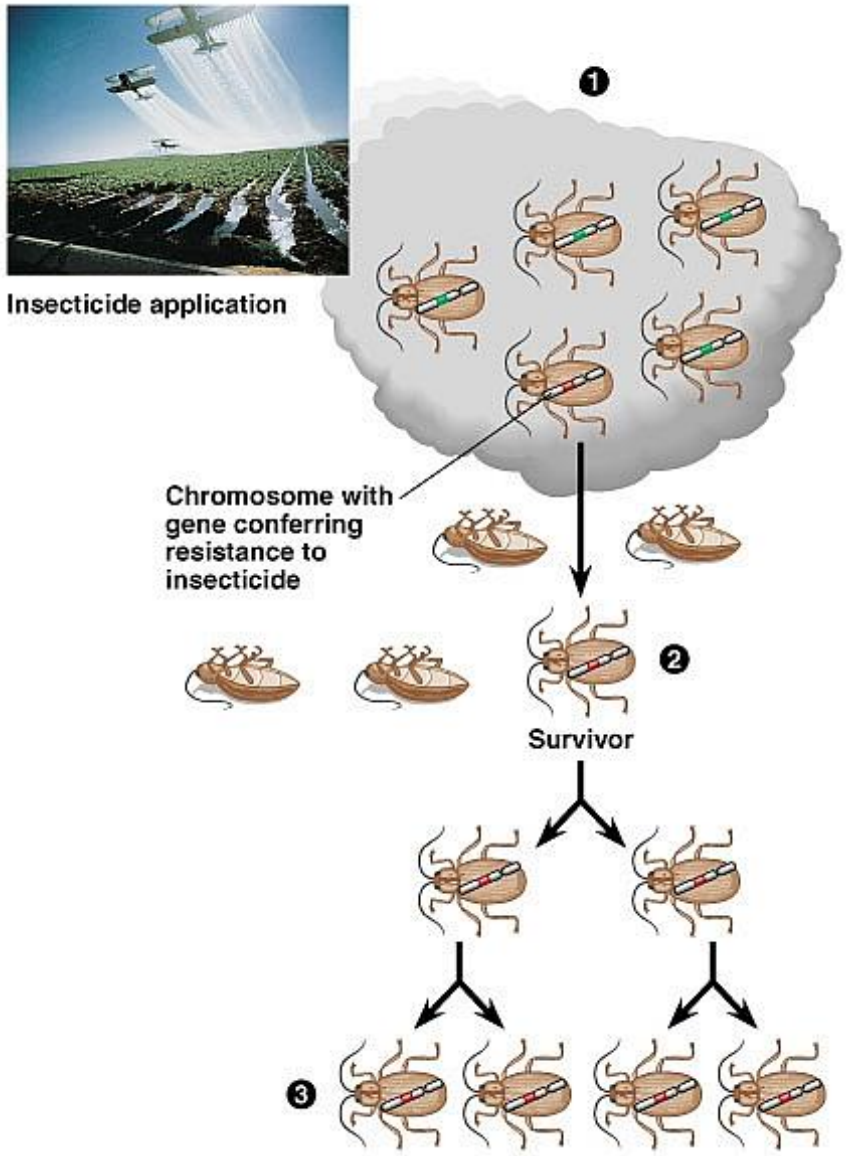
Mode of Selection	Effects
2. Stabilizing selection • •	• • 

Modes of Natural Selection

Mode of Selection	Effects
3. Disruptive / Diversifying selection • •	• • 

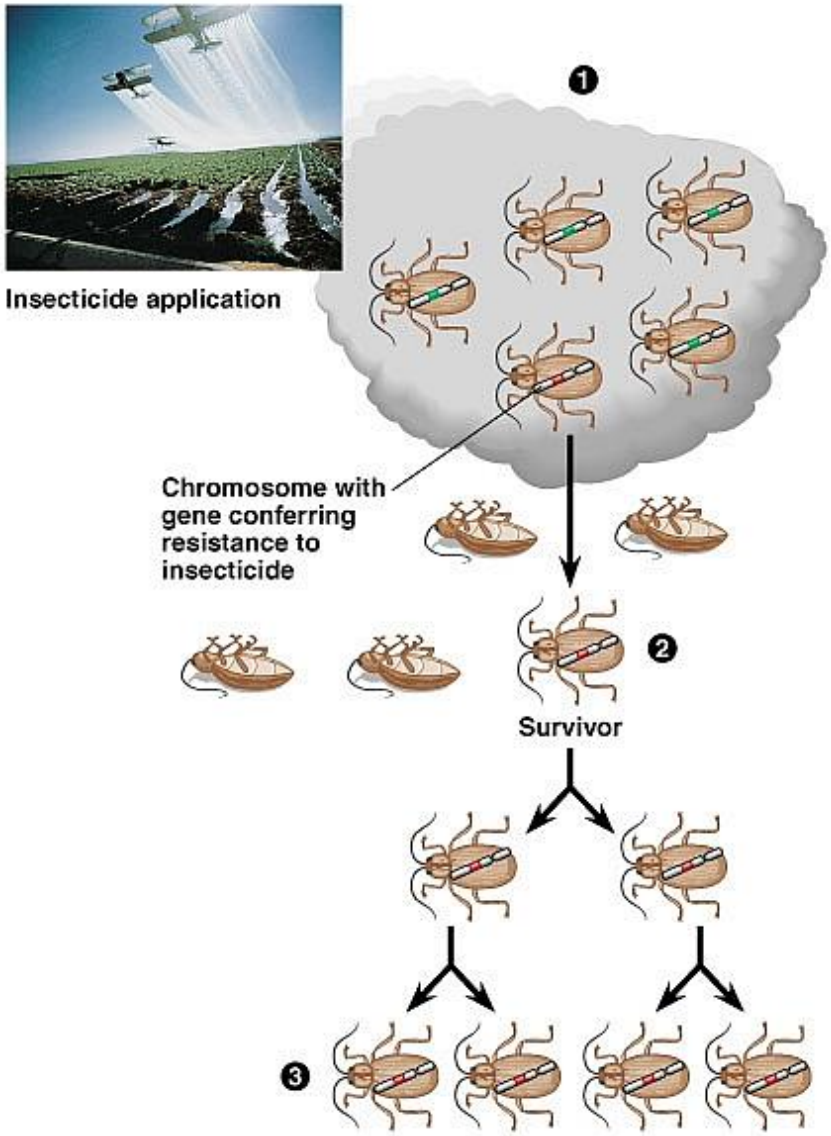
Directional Selection – Resistance to Pesticides

- Widespread use of chemical pesticides in agriculture results in directional selection.
- Initial applications kill most of the insects or other pests, but some individuals managed to **survive**.
- *Some aspect of their structure, physiology, or behaviours helps them resist the chemical effects.*



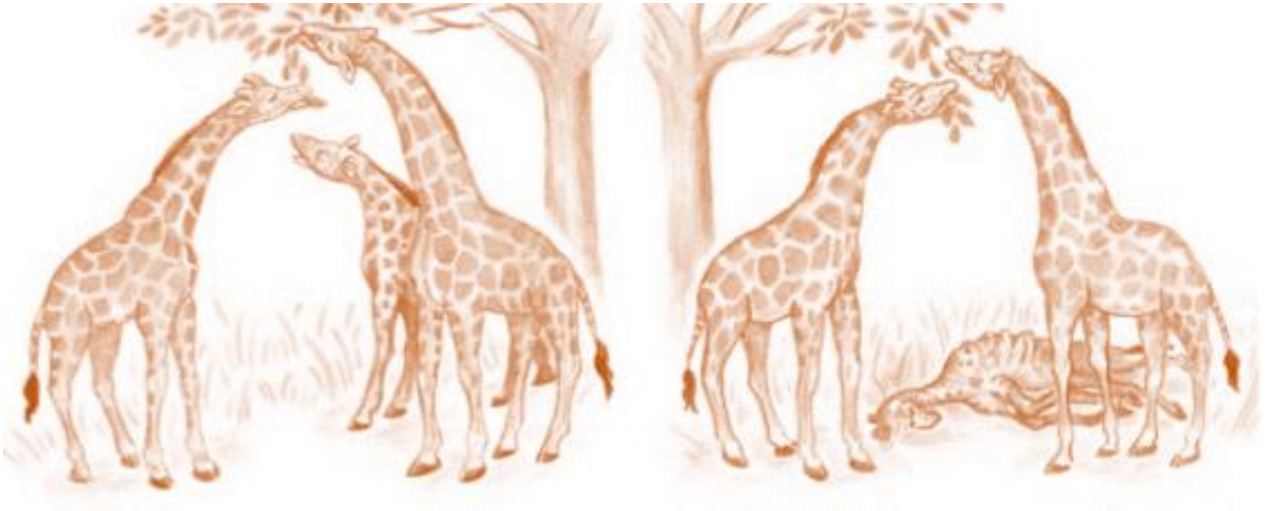
Directional Selection – Resistance to Pesticides

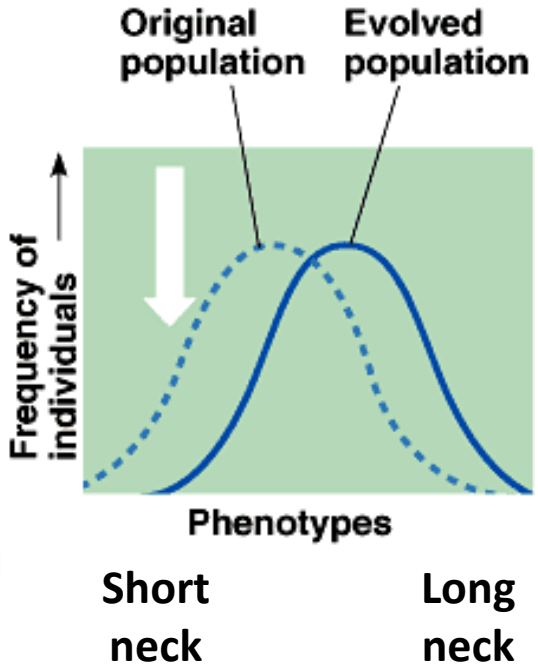
- When the resistance has a heritable basis, it becomes more common in each new generation.
- The **use of the pesticides** act as agents of selection that favor the most resistant forms.



Directional Selection – Giraffes' neck length

- Ancestors of the giraffes had shorter necks
- Still there was some variation in the neck lengths of the giraffes
- As giraffes fed on tall acacia tree (selection pressure), the relatively **longer necks giraffes had a selective advantage**.
- Over generations, it caused a directional selection towards longer neck giraffes.





Stabilising Selection – Gall making flies

Golden rod gall fly → Tumour formed around the larvae in goldenrod plant stem

SELECTION

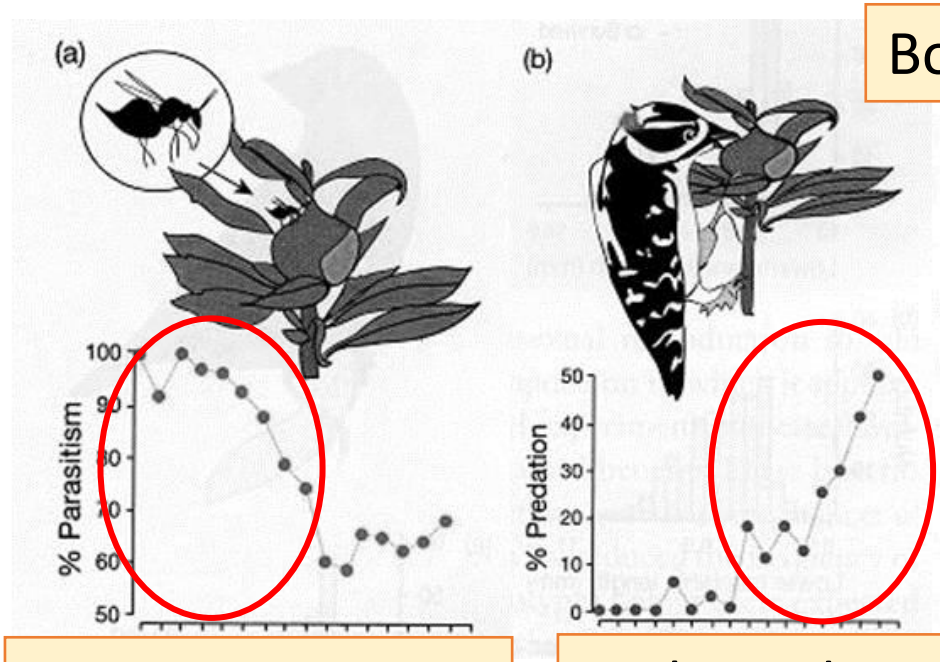
Parasites – **Wasps** lay their own eggs by penetrating thin walls of **small galls**

PRESSURES

Predators - **Downy woodpeckers** chisel into **large galls** to eat the larvae

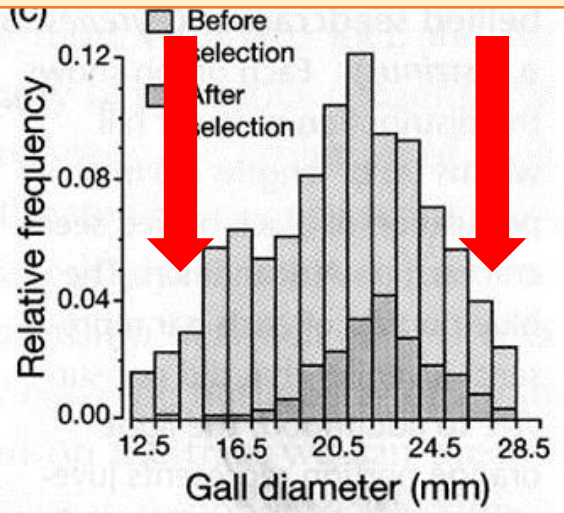
Stabilising Selection – Gall making flies

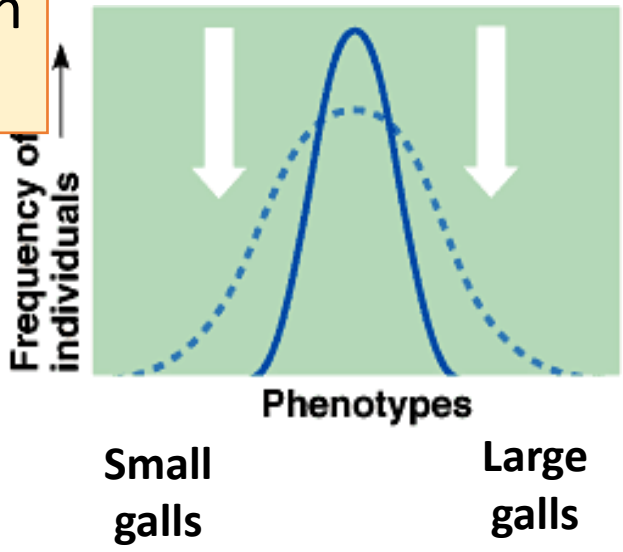
Both sizes are selected against



High parasitism in smaller gall sizes

High predation in larger gall sizes

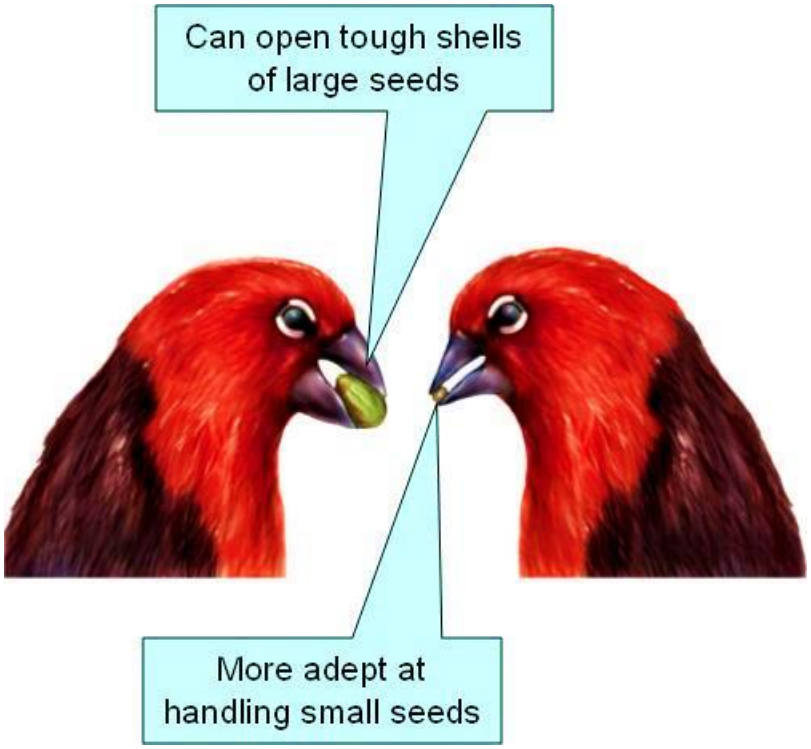


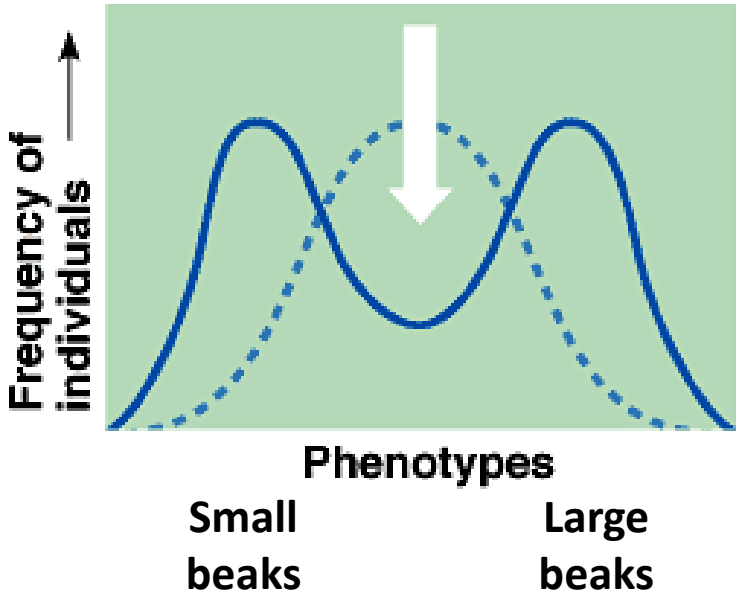


Disruptive Selection – African finches' beaks

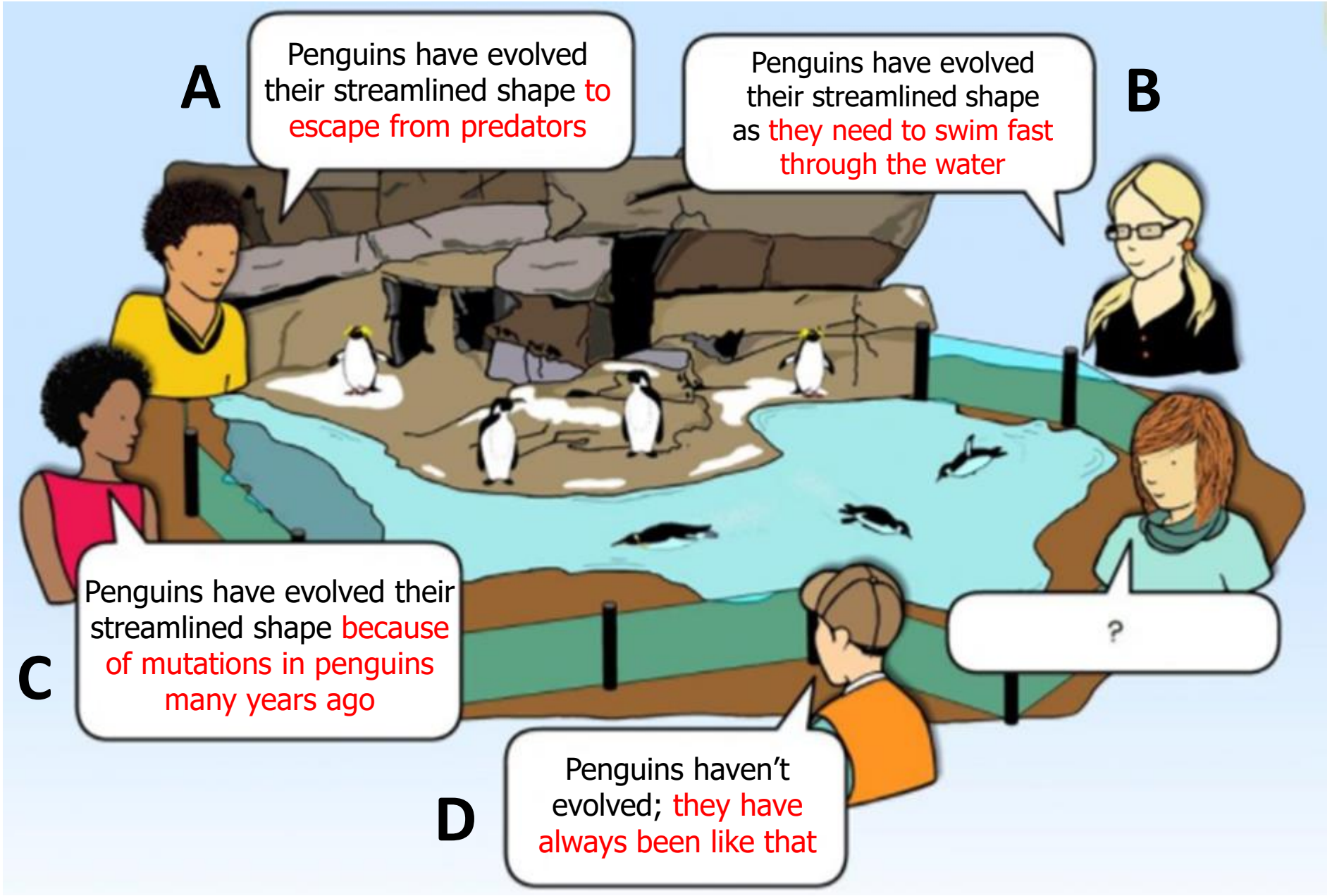
- Black bellied seed cracker finches (exclusively) feed on sedge plants' seeds
- Two species of sedge plants dominate the habitat → one with **hard large seeds and one with small soft seeds**

Disruptive Selection – African finches' beaks





- Selection pressure → ***Limited types of seeds available*** (only large/hard and small/soft) select **against birds with intermediate beak size** as it would crack both classes of seeds relatively inefficiently.



Why do penguins have streamlined bodies?

VARIATION within populations

- SOURCES
- IMPORTANCE
- PRESERVING GENETIC VARIATION - Diploidy, Heterozygote advantage, Frequency-dependent selection

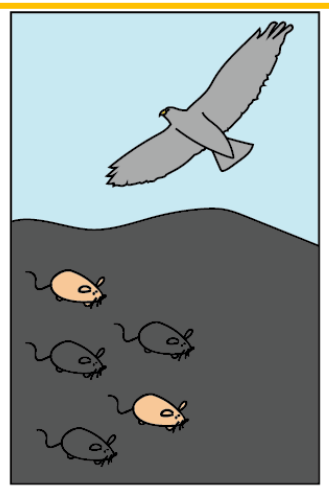
Sources of Variation (Recap from previous topics)

- **Mutation**: ….. result in the **formation of new alleles**. The acquisition of new alleles increases the gene pool for natural selection to operate.
- **Crossing over**: ….. results in the formation of new combinations of alleles on the chromosomes of the gametes.
- **Independent assortment**: …. results in **different combinations** of maternal and paternal chromosomes in the gametes
- **Random fusion** of gametes: …. results in **new combination of alleles** in the offspring

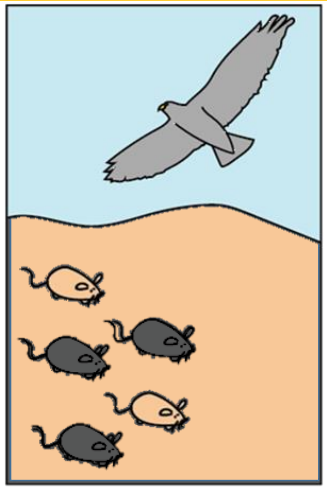
Importance of Variation in Evolution

- Variations are a **pre-requisite for evolution by natural selection**.
- As the environment is always changing, a diverse gene pool is important for the long-term survival of a species.
- … **populations with considerable genetic variations** are generally **better adapted** to respond to changes in environment

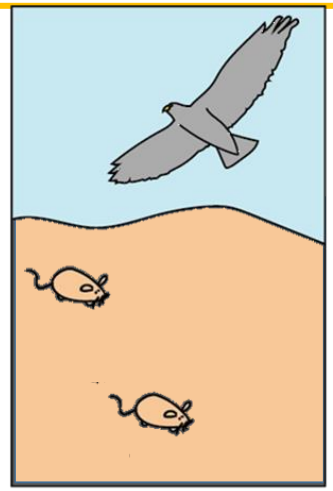
Importance of Variation in Evolution



Some variation in mice coat colour

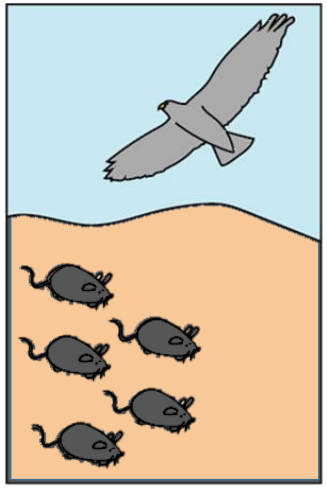


Change in environment

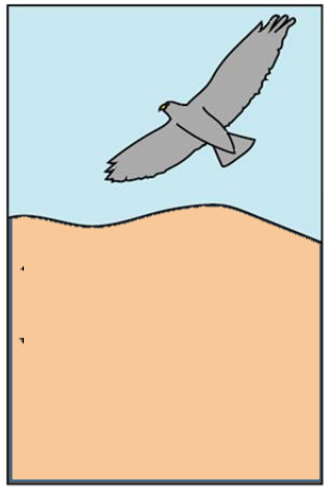


Some members survived → population was better adapted

No variation in mice coat colour



Change in environment



Whole population wiped out

Importance of Variation in Evolution

(terms & conditions)

- **Mutation** → new alleles → **increase in gene pool** for natural selection to operate on
- Mutation must have occurred **during gamete formation** to be passed down

Importance of Variation in Evolution

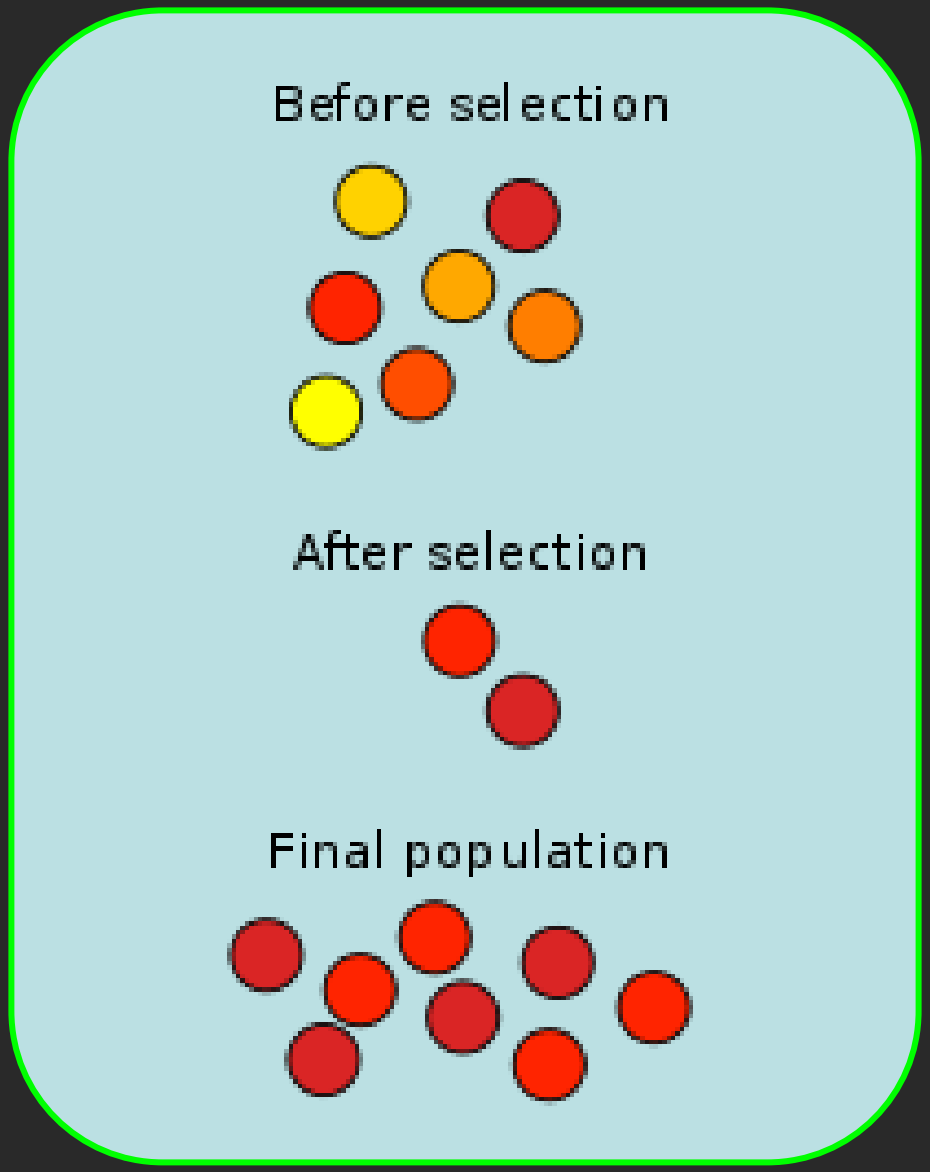
- Advantageous characteristics increase the individuals' fitness which are then passed to their offspring, thus giving the offspring the same advantageous characteristics.

- **Fitness**: a measure of evolutionary success as indicated by the number of surviving offspring left to produce the next generation.
- A genotype's fitness includes its **ability to survive, find a mate, produce offspring** and ultimately **pass on its genes to the next generation**.

Why is variation important in selection?

- The advantage comes in the form of survival and reproductive success.

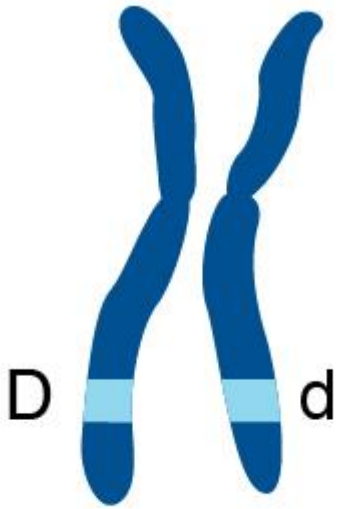
→ more likely to survive till reproductive age and pass on their genes to offspring.



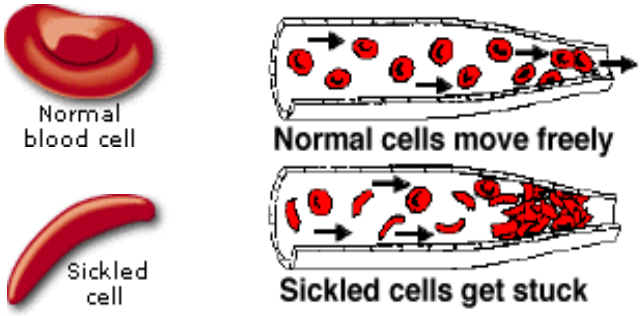
Variation hence allows natural selection to operate.

Preserving Genetic Variation

1. Diploidy
2. Heterozygote advantage
3. Frequency Dependent Selection

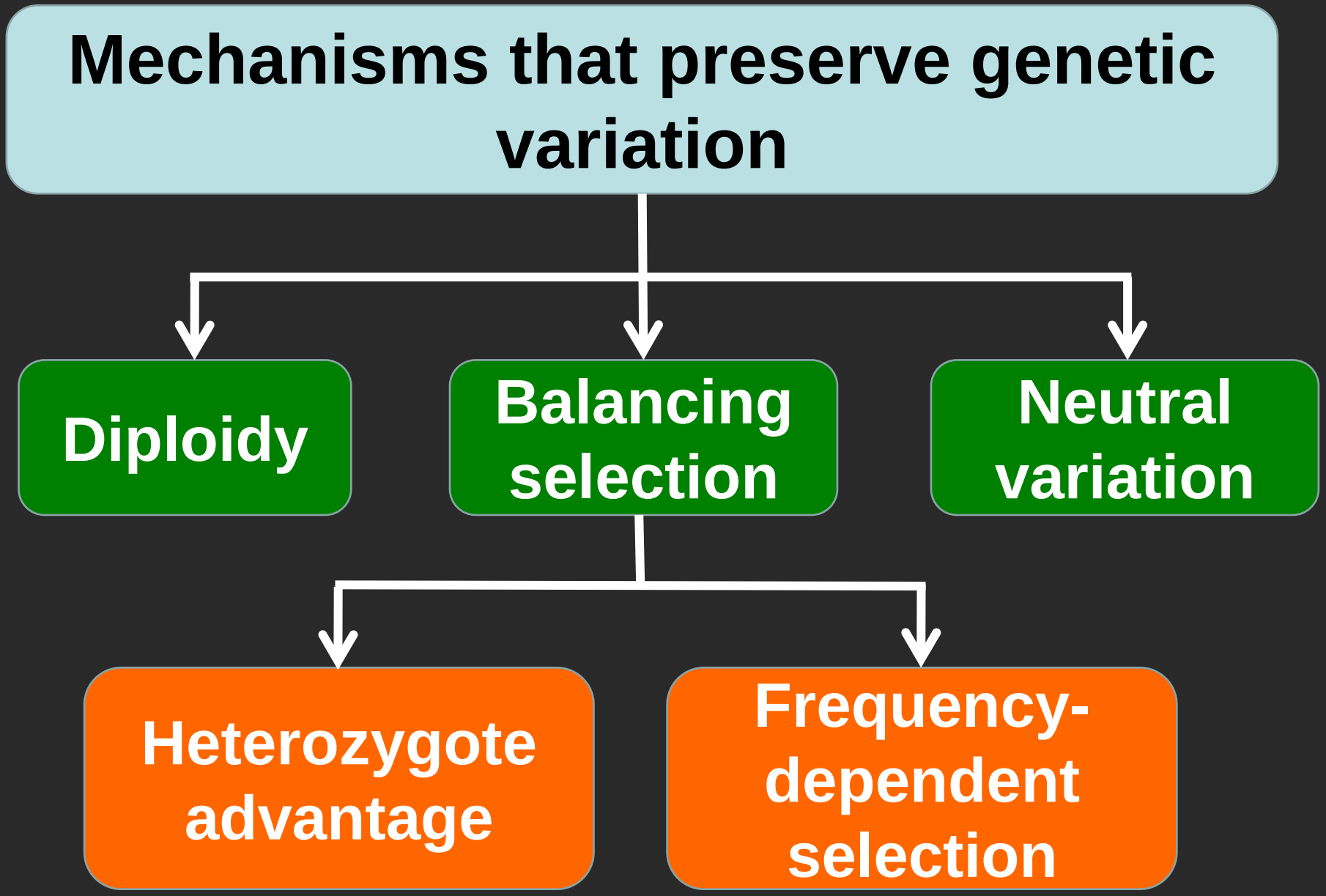


Recessive alleles in eukaryotes



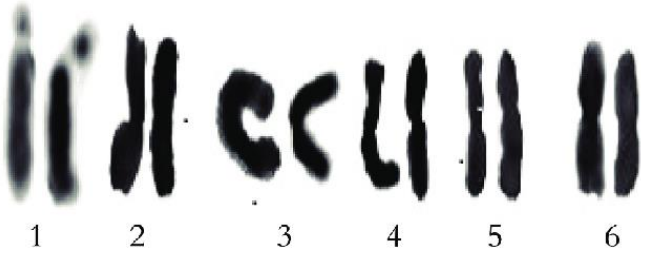
Heterozygous advantage of sickle-cell anaemia in malaria infected regions

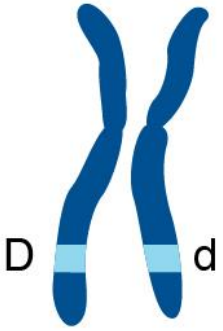
Scale-eating cichlid fish

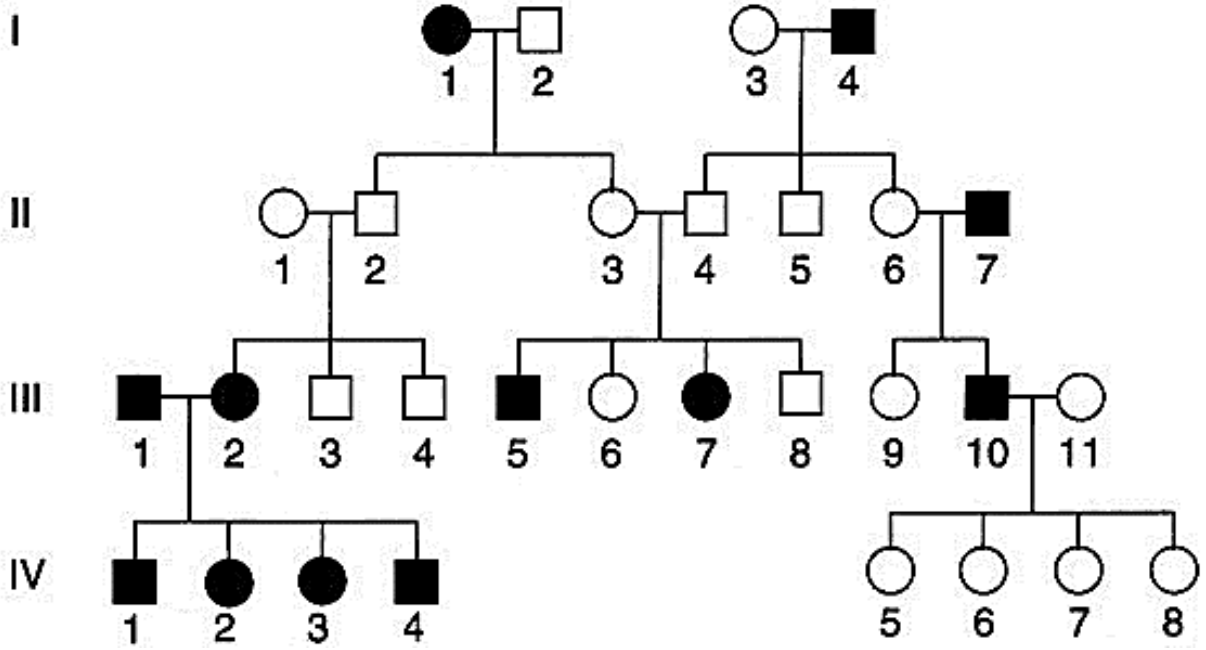

Mechanisms that preserve genetic variation
Diploidy
Balancing selection
Neutral variation
Heterozygote advantage
Frequency-dependent selection

Diploidy

- Genetic variation is **hidden from selection** in the form of **recessive alleles**
- Less favourable recessive alleles **propagated in heterozygous individuals.**







Diploidy

- Heterozygote containing the recessive allele is able to **survive and reproduce** → passed down to the offspring → preserved in the population.
- Heterozygote protection maintains a huge pool of alleles that might not be favoured under present conditions but some **could bring new benefits when the environment changes.**

Recall: Selective advantage and disadvantage of an allele is dependent on the environment

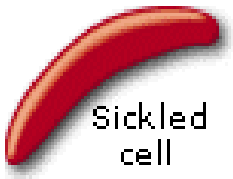
Balancing Selection

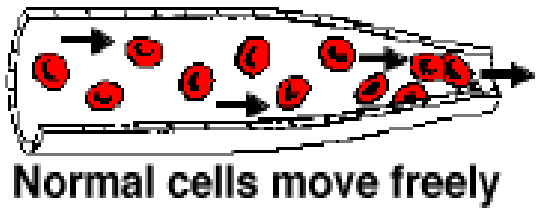
- Balancing selection occurs when natural selection maintains **stable frequencies** of two or more phenotypic forms in a population
- This type of selection includes
  1. **Heterozygous advantage**
  2. **Frequency-dependent selection**

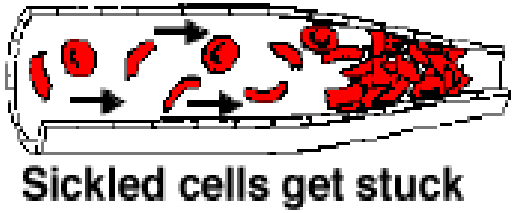
Heterozygote advantage

- If individuals who are **heterozygous at a particular locus have greater fitness** than those who are homozygous at that loci.
- Natural selection will **maintain two or more alleles** at that locus.
- CASE STUDY – Sickle-Cell allele in West Africa

#TB to topic on gene mutations to recap the genetic cause of sickle cell anaemia!

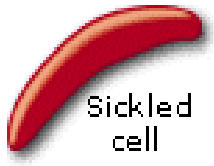


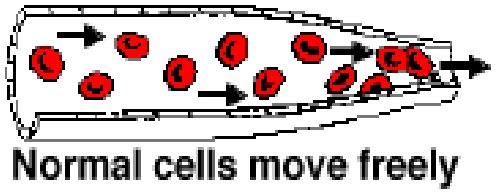


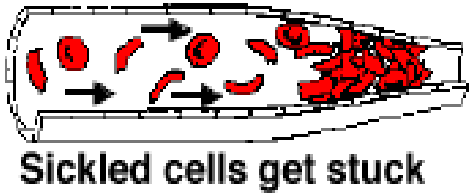


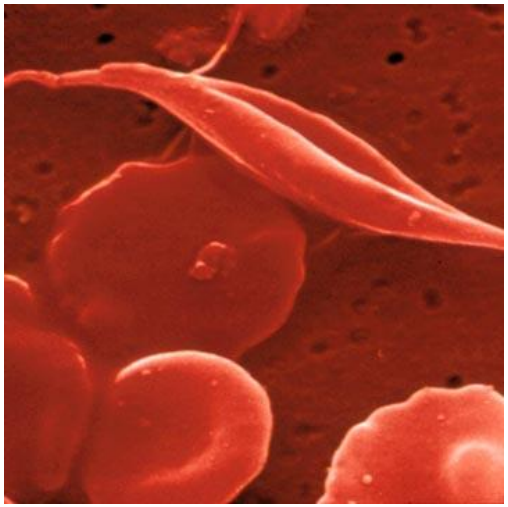
Heterozygote advantage – Sickle Cell in Africa

- Homozygous Hb^SHb^S → Hb^A with a point mutation
  - Suffer from sickle cell anaemia
- Heterozygous Hb^AHb^S
  - Suffer from the sickle cell trait
  - Hb^A and Hb^S alleles are co-dominant → produce both normal and abnormal haemoglobin
  - usually healthy but **RBCs can sickle due to low oxygen concentrations**







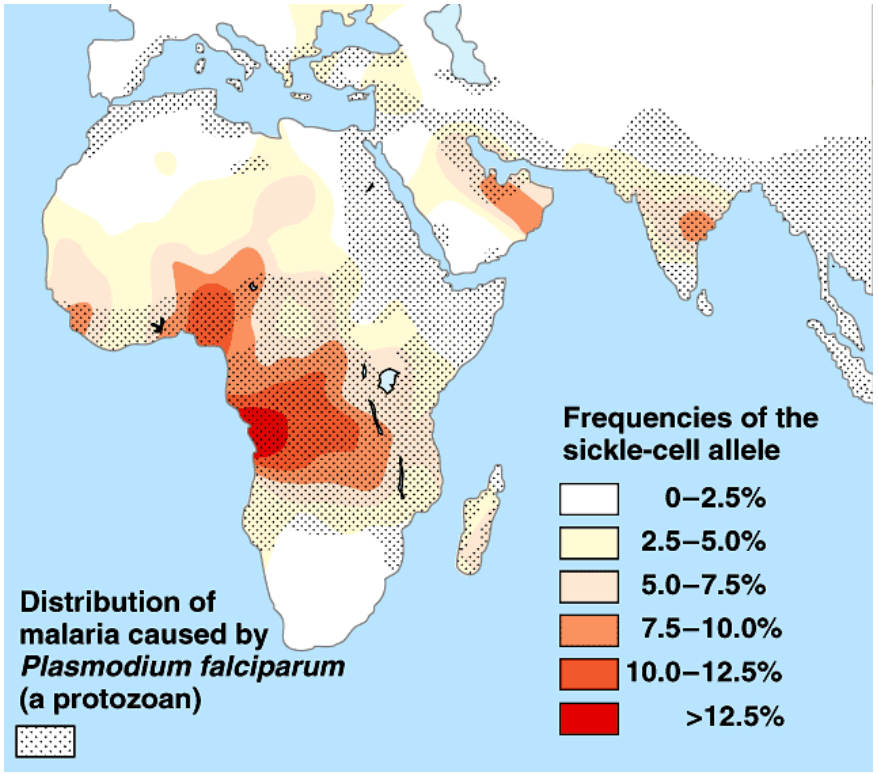


Heterozygote advantage – Sickle Cell in Africa

Why is the genotype Hb^AHb^S maintained at such high frequency in West Africa?

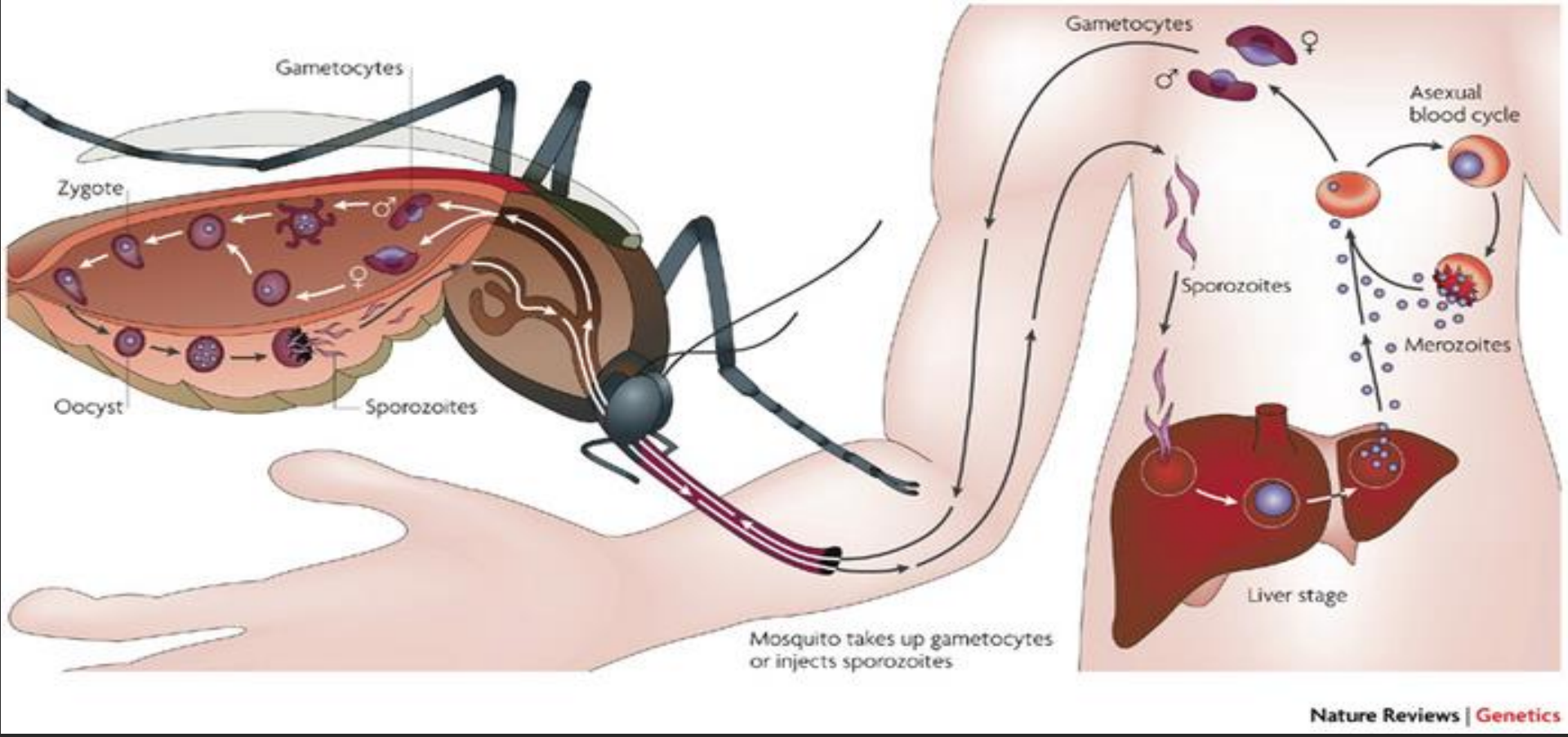
Because of MALARIA!

- (Anopheles) Mosquito transmits *Plasmodium falciparum*, the malaria parasite, to humans.
- The malaria **parasite infects red blood cells leading to hypoxia** i.e. low oxygen concentration.



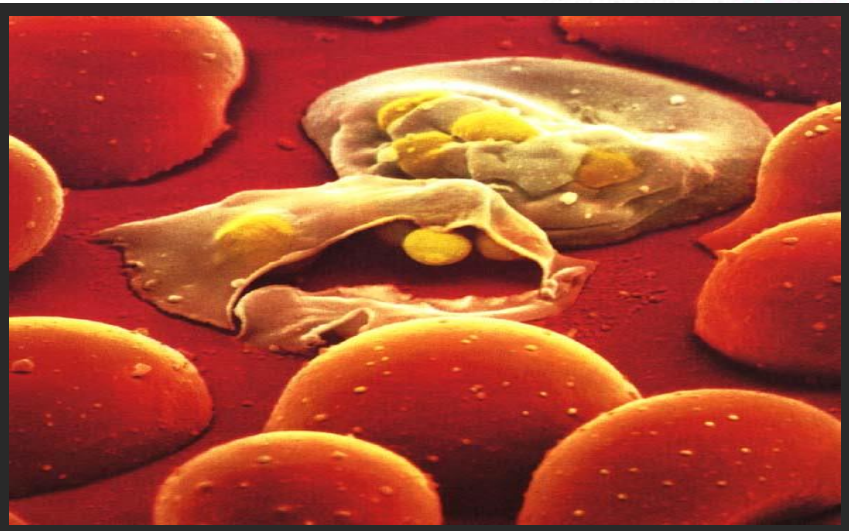
Not in Notes

A female *Anopheles* mosquito transmits *Plasmodium*, the malaria parasite to humans.



The malaria parasite spends part of its life cycle in red blood cells

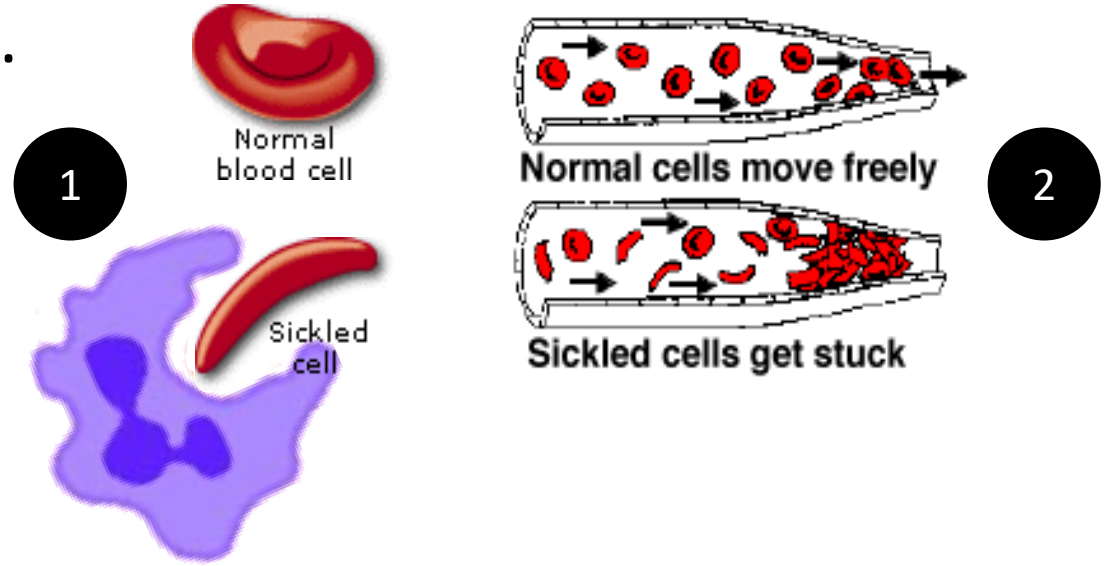
Not in Notes



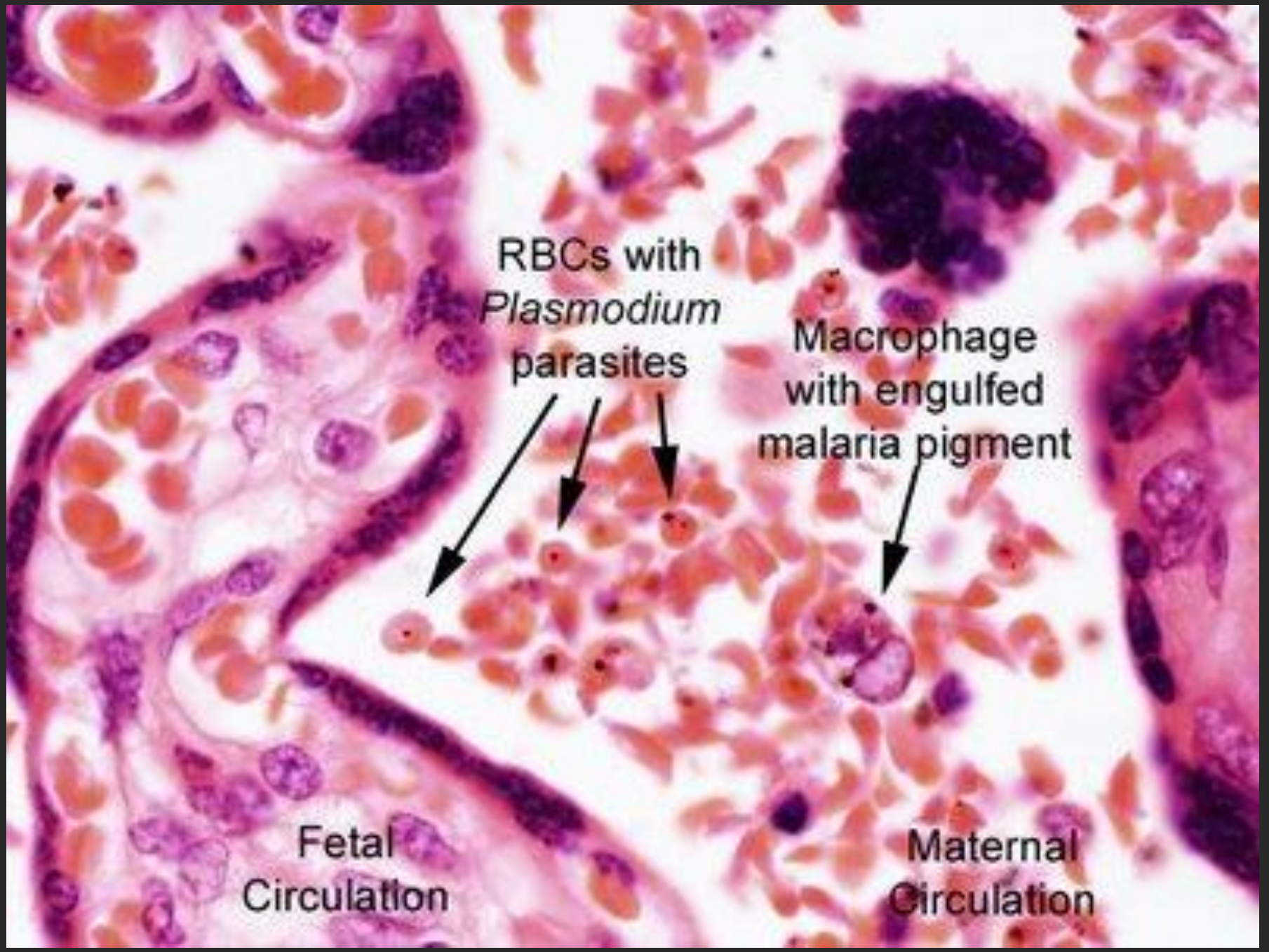
Heterozygote advantage – Sickle Cell in Africa

1. RBCs of heterozygotes **readily sickle** → eliminated by the WBCs → **malarial parasites inside the RBC are eliminated along with it.**

2. **Slowdown in blood flow** due to **blocked blood vessels** → hampers the parasite's ability to travel and rapidly infect new cells.

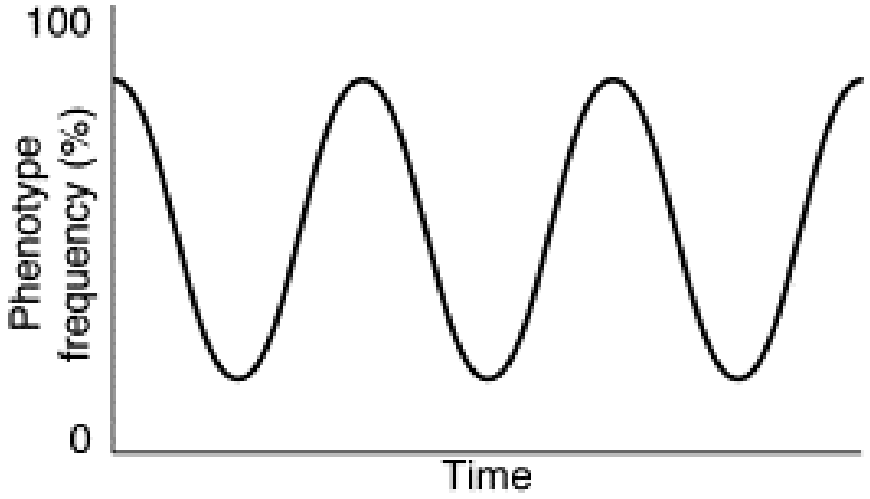


Hb^AHb^S individuals are a selective advantage (over Hb^AHb^A) → survive and reproduce in malaria-infected areas


RBCs with
Plasmodium
parasites
Macrophage
with engulfed
malaria pigment
Fetal
Circulation
Maternal
Circulation

Frequency-Dependent Selection

- The fitness of a phenotype depends on **how common it is in the population** i.e. its frequency relative to other phenotypes in a given population.
- In frequency-dependent selection, **the fitness of any form declines if it becomes too common** in the population.

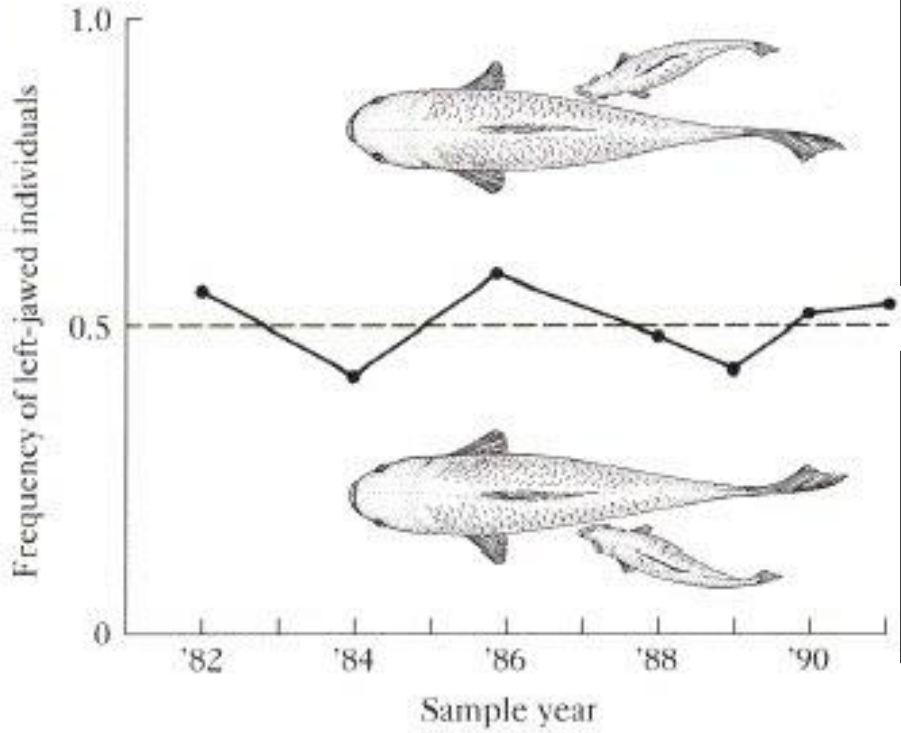


Frequency-Dependent Selection – Scale eating cichlid fish

- Scale eating cichlid fish attacks other fishes from behind, darting in to **remove a few scales from the side** of their prey.

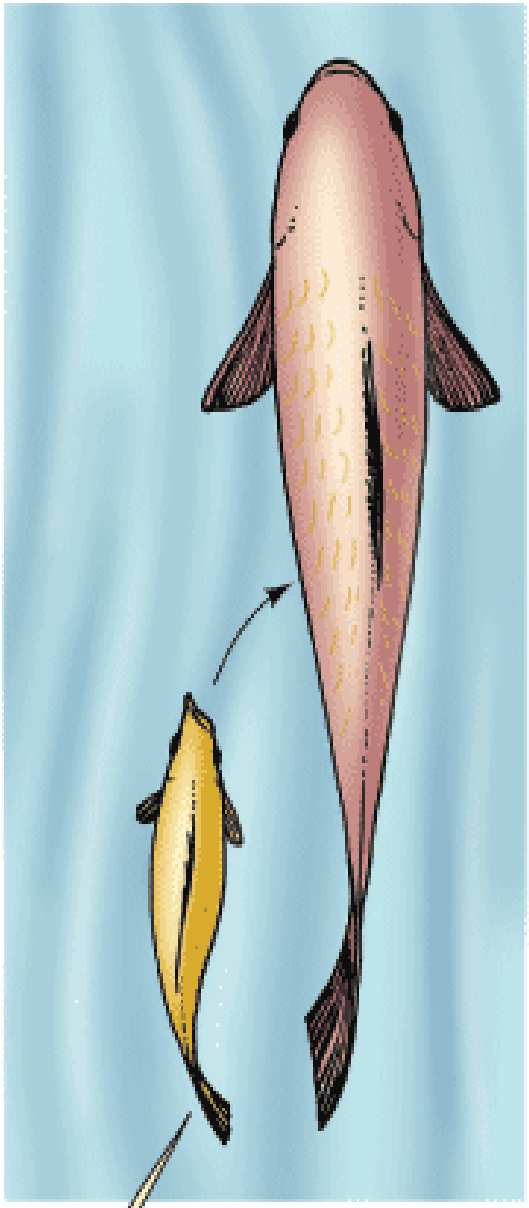
Right-mouthed

Left-mouthed

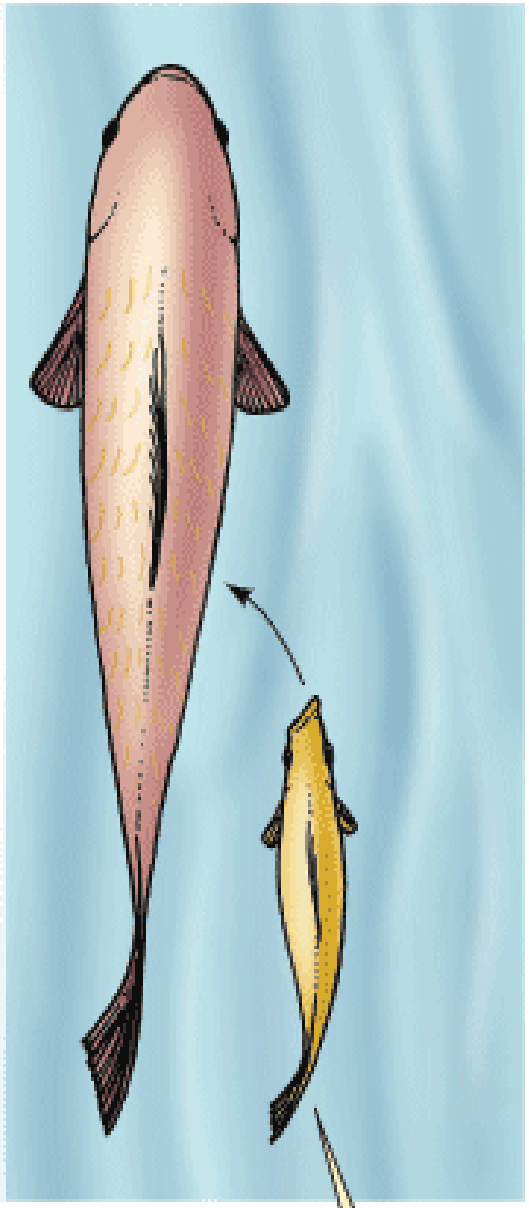


Left-mouthed attack on the right side of the prey

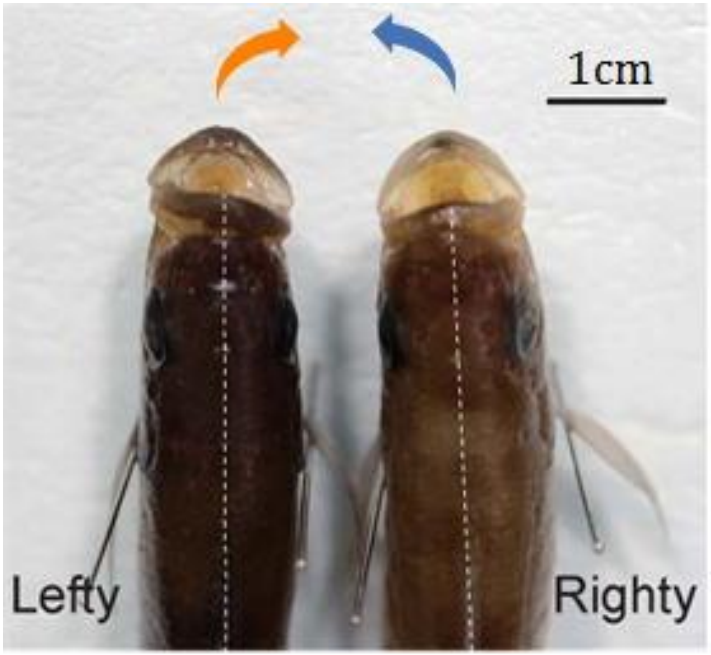
Right-mouthed attack on the left side of the prey



"Right-mouthed" *Perissodus* attack prey from the left rear side.

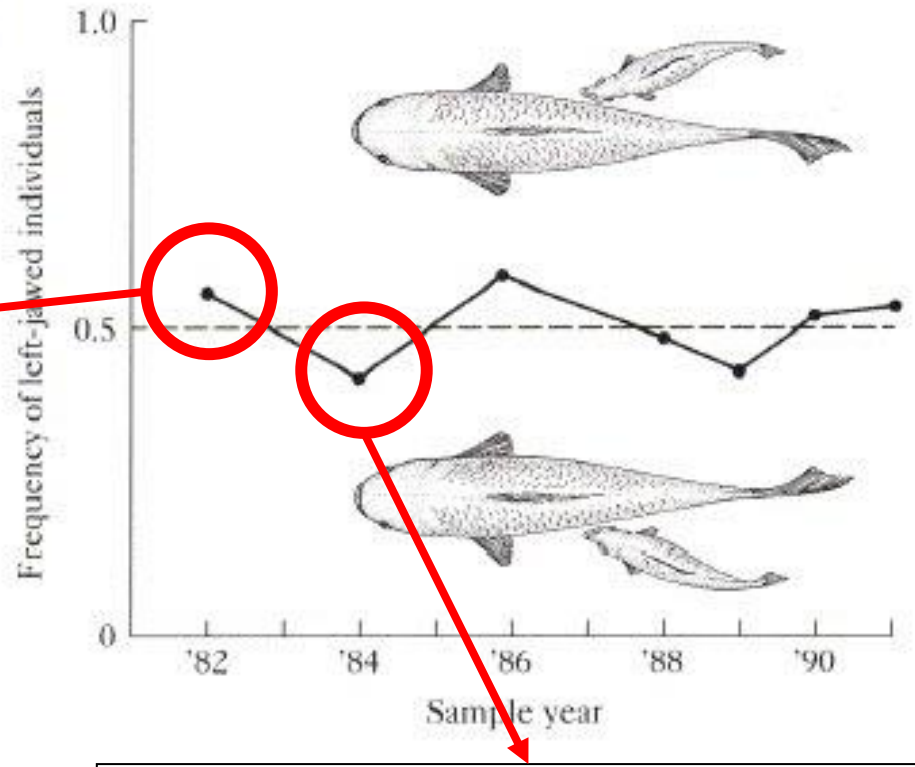


"Left-mouthed" *Perissodus* attack prey from the right rear side.



Frequency-Dependent Selection – Scale eating cichlid fish

Prey species started **guarding more against the left-mouthed** ones as they were more common →
Left-mouthed predators could feed and reproduce lesser → selective disadvantage



Lower guard against right-mouthed ones →
Minority phenotype will be able to eat more scales and reproduce more → selective advantage

Reverse occurred when right-mouthed ones became too common.

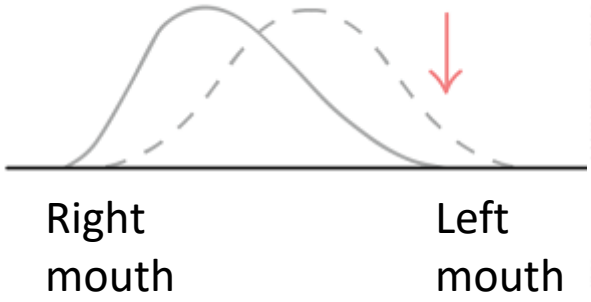
Frequency maintained close to 50%

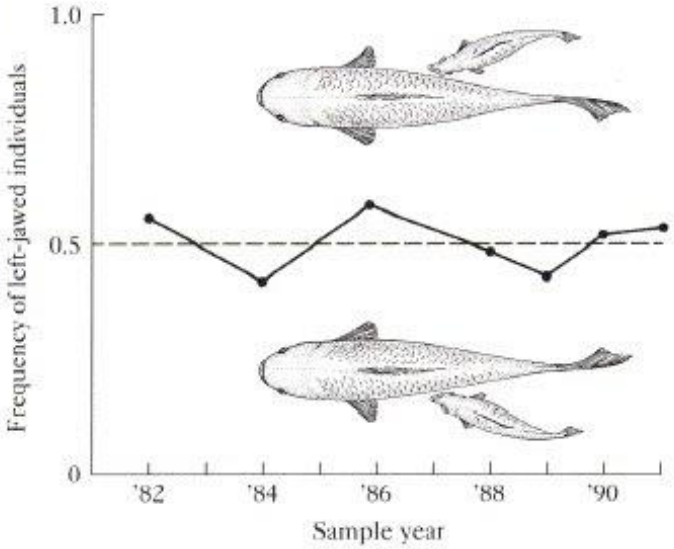
Clarifications on Balancing Selection

Student X – Is frequency dependent selection just directional selection going back and forth?

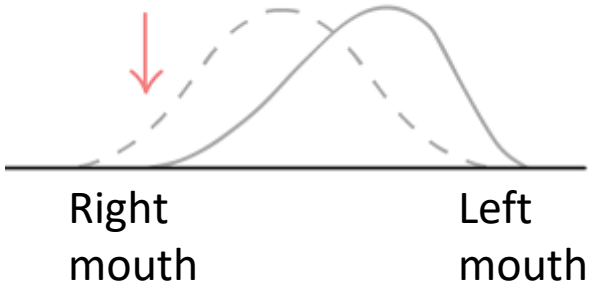
YES!

When frequency of left-mouthed fish increases





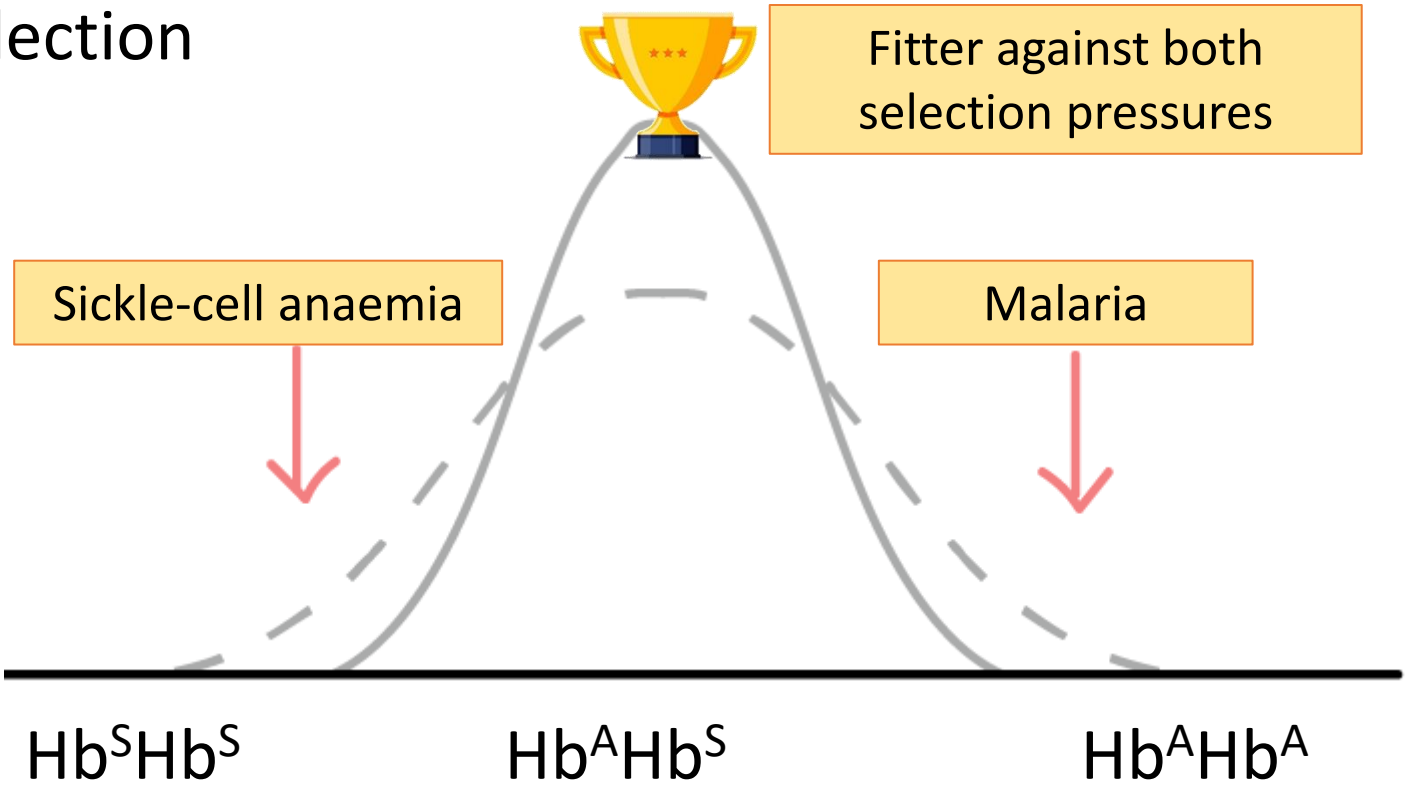
When frequency of right-mouthed fish increases



Clarifications on Balancing Selection

- ***Student Y – Why isn't balancing selection considered a mode of natural selection?***

- Heterozygote advantage is a form of stabilising selection



Selection pressures

Selection Pressures

- An **environmental force** that acts on the population to select for or against individuals of a particular phenotype.

↑ selection pressures → Makes organisms **more specialized**

↓ selection pressures → Makes organisms **more diverse**

Examples:

1. *Predators*
2. *Climatic factors – Temperature, pH, salinity, light intensity*
3. *Antibiotics (affecting bacteria only)*
4. *Competition for space and nutrients*
5. *Pathogens & parasites*

1. Predators - Polymorphism in Land Snail

- Land grove snail shows **polymorphism** of its shell
- Various morphs arose by spontaneous **mutations**.

In colours

In banding patterns

- Habitat → Woodlands or Grasslands
- Hunted by **predatory birds** that hunt by sight

2. Predators - Polymorphism in Land Snail

In grasslands,

Yellow unbanded snails are at a selective advantage as they are well-camouflaged

In woodlands,

Brown banded snails are at a selective advantage as they are well-camouflaged

2. Light Intensity - Polymorphism in land snail

In sunny mountain areas,

- **Brown banded snails are at a selective disadvantage** as they absorb more heat → die of overheating

- **Yellow unbanded snails are at a selective advantage** → survive, reproduce and pass on favourable trait to offsprings

3. Antibiotics – Resistance in *Staphylococcus aureus*

- *Staphylococcus aureus* (*S. aureus*) causes skin infections and more infections like infecting blood, lungs, urinary tract and surgical wounds

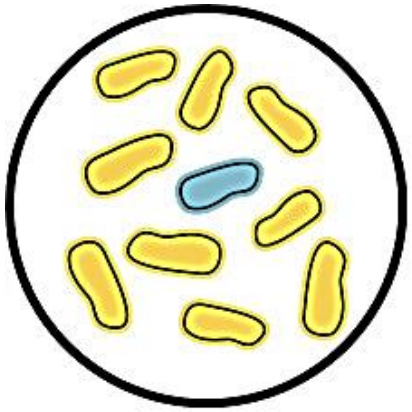
Releases toxins that are super-antigens i.e. cause excessive stimulation of immune system

- **Treated with antibiotics** such as penicilin & methicilin.
- strains of *S. aureus* **resistant to antibiotics** began to show up.

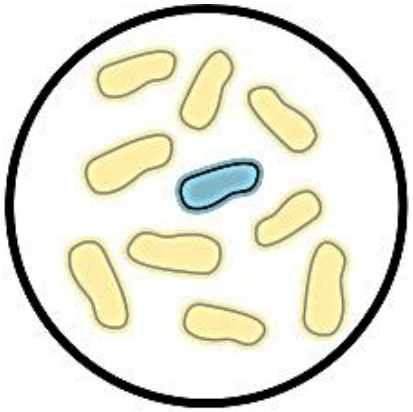
3. Antibiotics – Resistance in *Staphylococcus aureus*

Did the use of antibiotics make the bacteria antibiotic resistant?

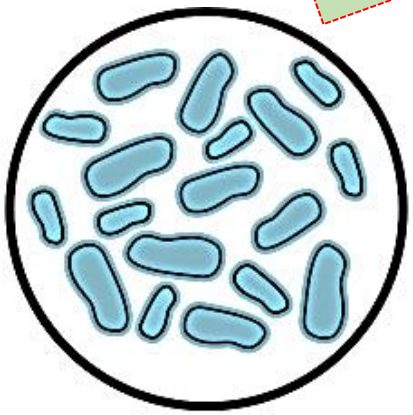
NO!!



Population of *S. aureus* with **variation in antibiotic resistance**



Antibiotics act as a **selection pressure** killing non-resistant bacteria



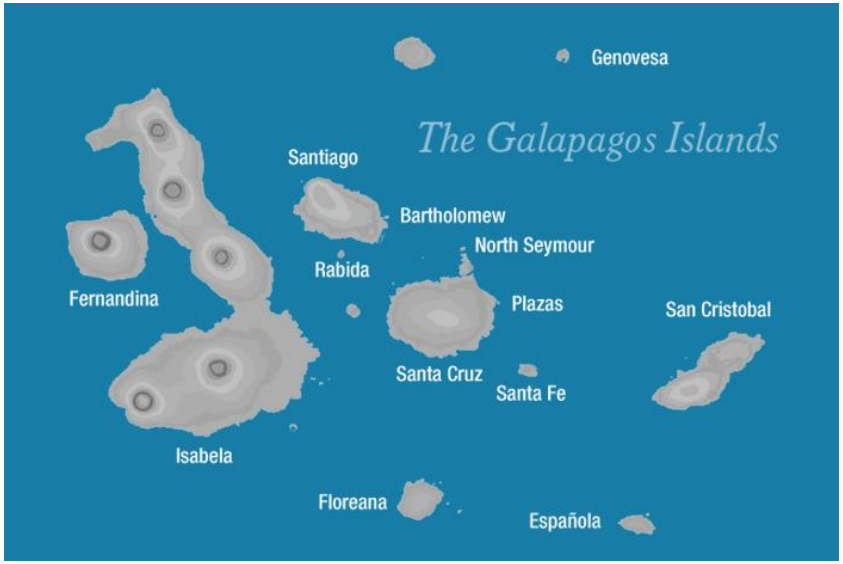
Resistant bacteria survive & multiple increasing frequency of antibiotic resistance allele

4. Competition for Space & Nutrients – Darwin's Finches

Credits: Biointeractive Youtube channel https://www.youtube.com/watch?v=mcM23M-CCog

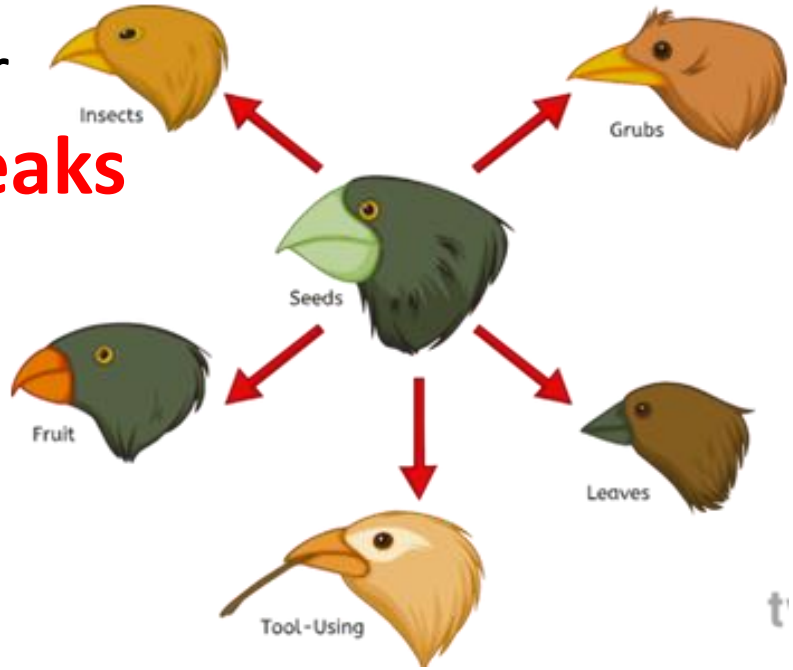
4. Competition for Space & Nutrients – Darwin's Finches

- Galapagos Islands - 14 species of closely related finches on the islands
- Most striking difference **- beaks,** which **vary in the shape and size, adapted for specific diets.**
- Ancestral finches that ate seeds migrated and occupied different islands that had different food sources available due to geographical differences.



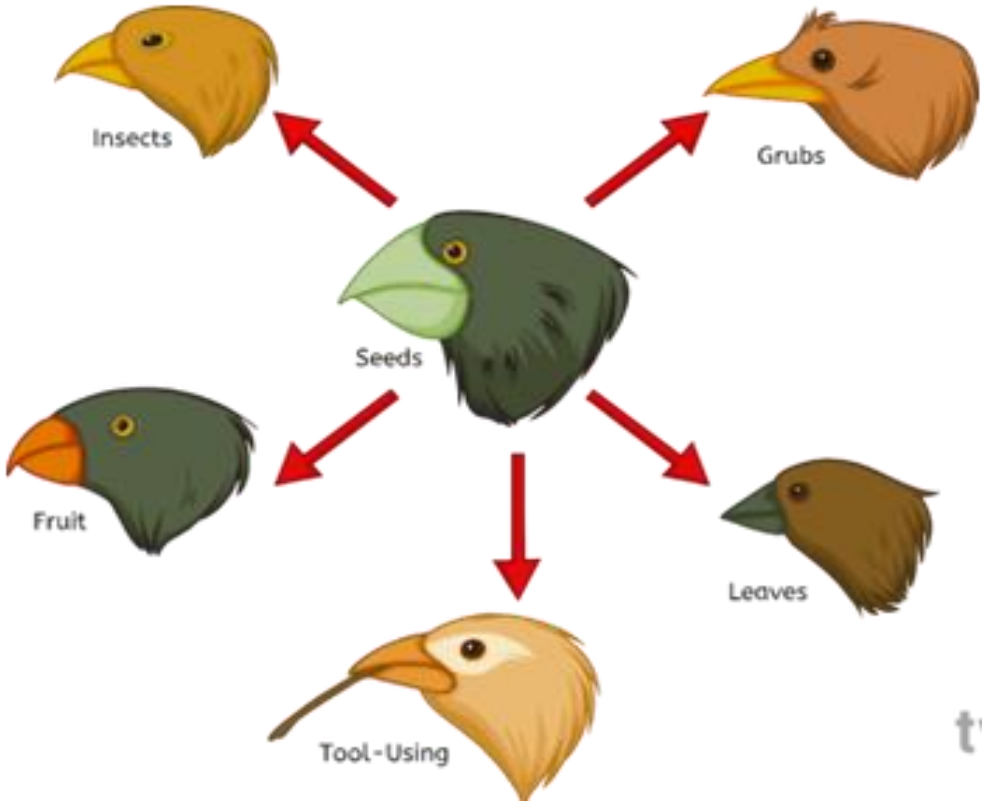
4. Competition for Space & Nutrients – Darwin's Finches

- The variation in beak forms within each population **EXISTED** due to spontaneous mutations
- Type of food source available acted as selection pressure:
  - In islands with **large seeds** → **large sturdy beaks** had a selective advantage.
  - In islands with higher number of **insects** →**thin, sharp beaks** had a selective advantage.



4. Competition for Space & Nutrients – Darwin's Finches

- Individuals that were selected for → survived → reproduced → passed on advantageous alleles (for the best beak shape)

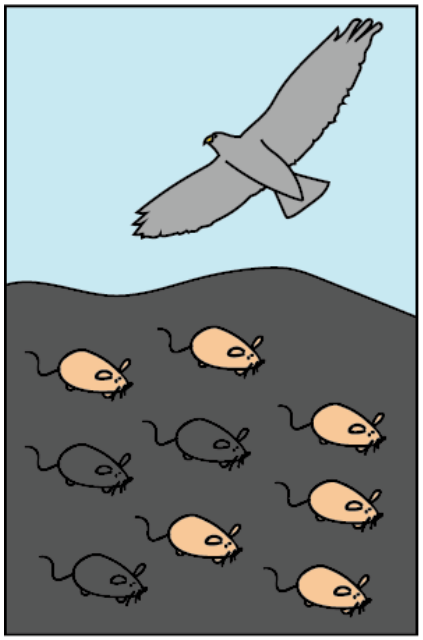


POPULATION IS THE SMALLEST UNIT OF EVOLUTION

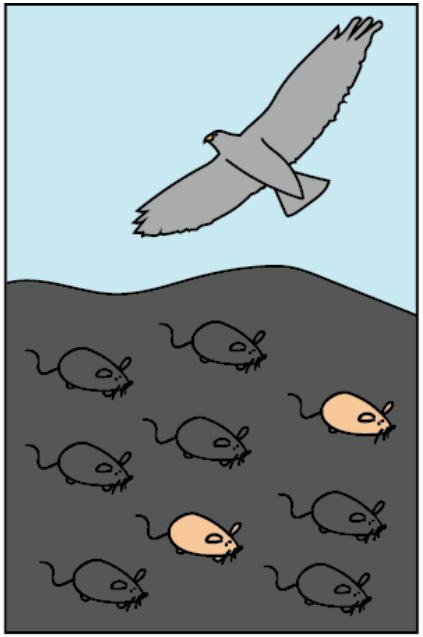
What is a population?

Population refers to a group of **interbreeding individuals** belonging to a particular **species** that share a common **geographical area.**

Do individuals evolve?



Population evolved to have better camouflage



But did the **individuals evolve** to have better camouflage?

Individuals do not evolve

- **Individuals cannot change their genotype** (or alleles) in response to environmental changes

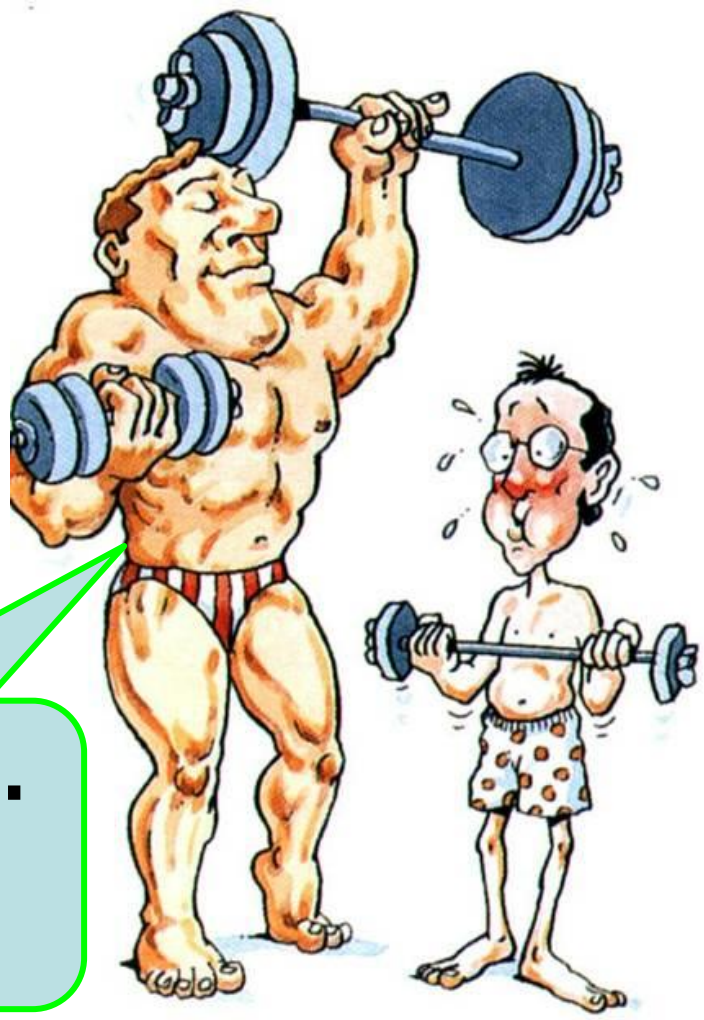
- Any phenotypic changes an individual acquired during its lifetime is **not passed on to its offspring**, hence the **allele frequency of the gene pool to which the individual belongs is unchanged**

#TBT to pg 15 → Mutations only play an important role in evolution if they occur during gamete formation

Individuals do not evolve

Distinction between…

Adaptations that an organism acquires during its lifetime VS Inherited adaptations that accumulate in a population as a result of natural selection



Populations evolve

- Populations can evolve
  - because **variations exist** between individuals.
  - Some individuals to be **selected for or against** in an environment by natural selection.
  - As such, the **favourable alleles become more common** one generation to the next and vice versa.
  - This **change in allele frequency** **in a population is evolution**.

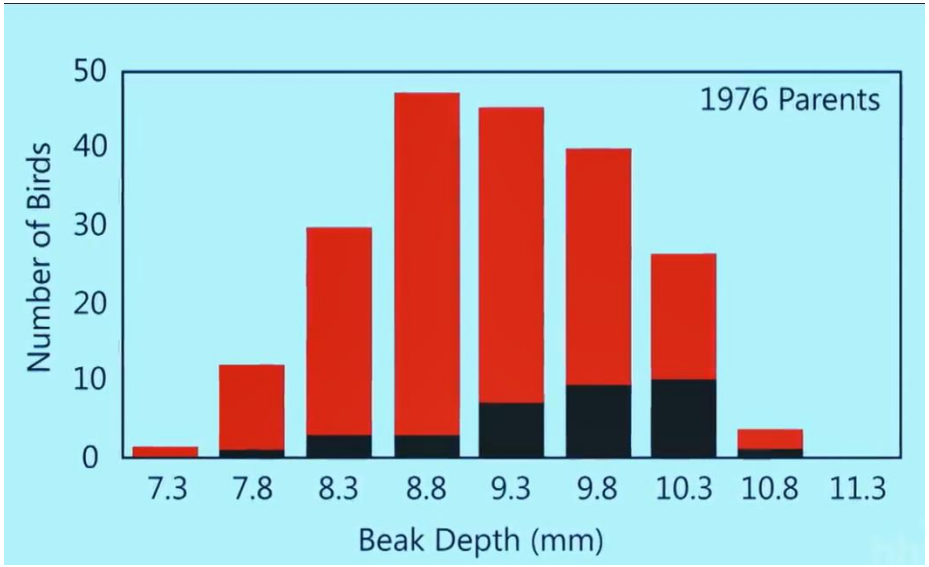
Galapagos finches after the 1977 drought

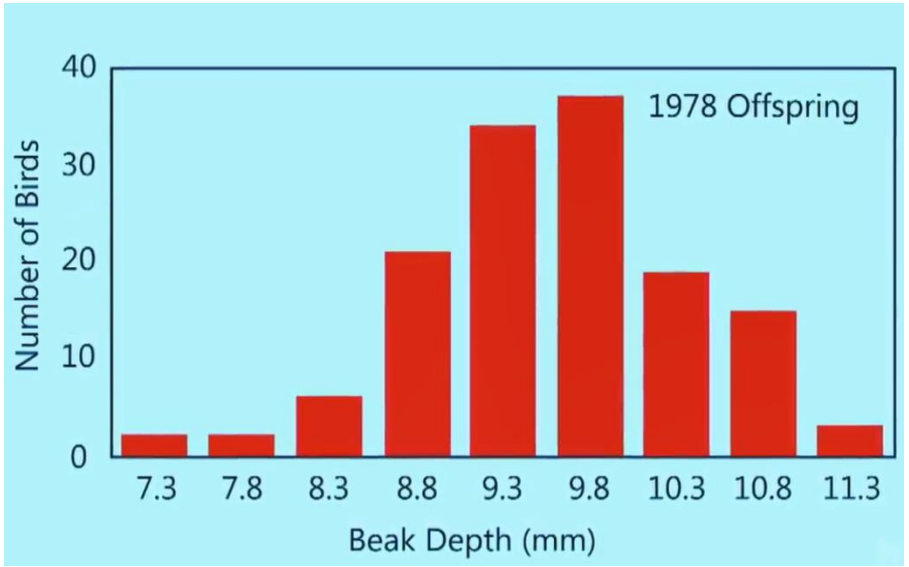
- 1977 drought on Galapagos islands
  - Only **harder seeds** available as food

  - Individual medium ground finch's **beak did not grow larger** to break open the harder seeds.

Galapagos finches after the 1977 drought

- 1977 drought on Galapagos islands
  - Rather, the **population evolved to have a larger proportion of finches with larger beaks** because these finches were at a selective advantage over finches with small beaks.





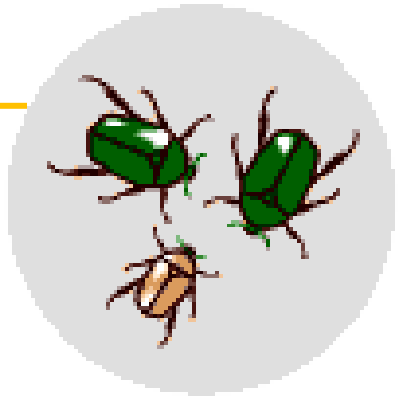
FORCES OF EVOLUTION

1. Mutations
2. Natural Selection
3. Genetic Drift
4. Gene Flow

What is a Force of Evolution?

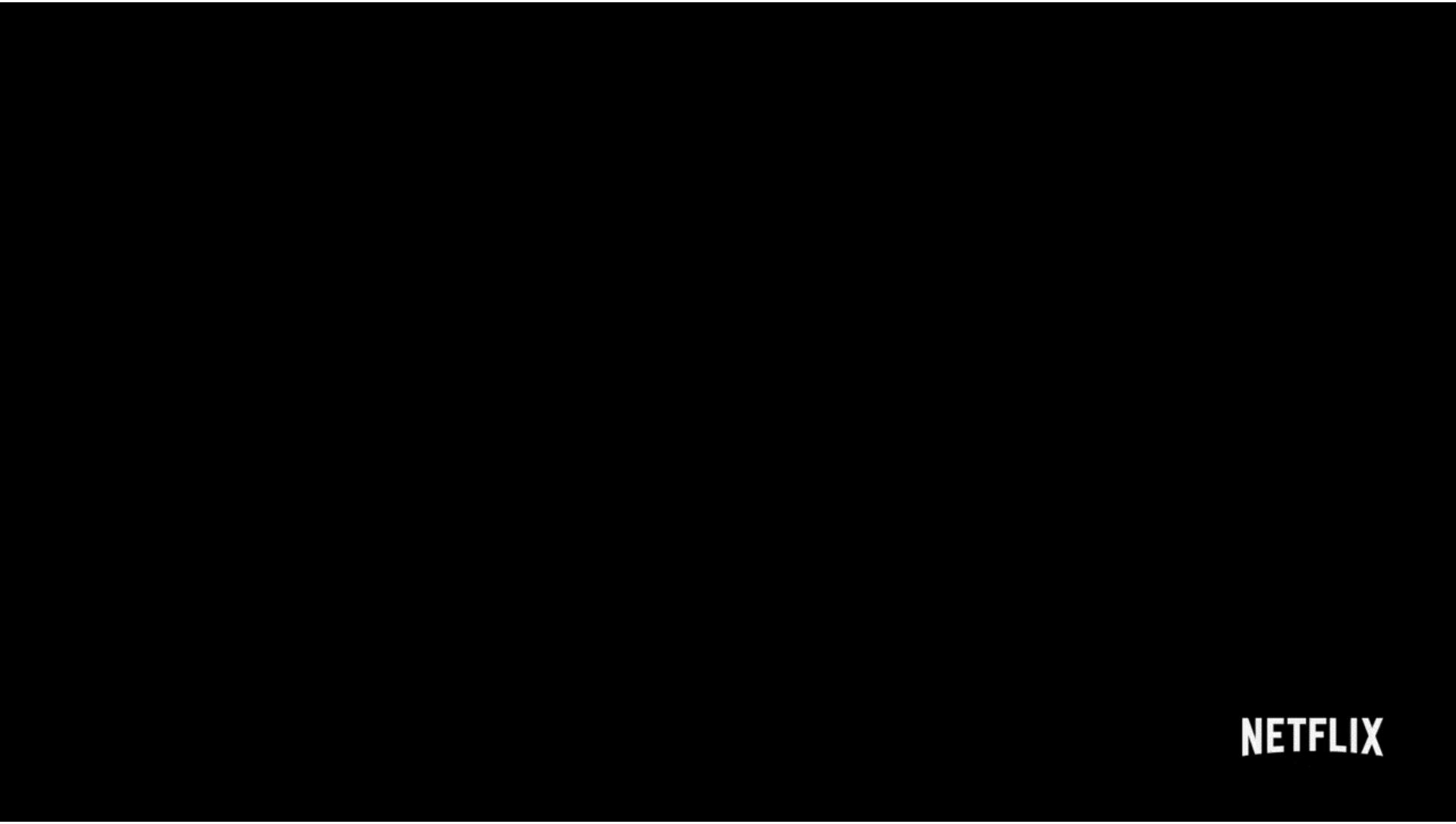
- Processes that **cause change in allele frequencies of a population** over time
- Broadly classified into:
  1. Mutations
  2. Natural Selection
  3. Genetic Drift – Bottleneck effect & Founder effect
  4. Migration results in gene flow

1. Mutations



- Source of all **new alleles**
- Results from
  - changes in the nucleotide base pairs of a gene
  - rearrangement of genes within chromosomes so that their interactions produce different effects
  - change in the chromosome structure
- Mutations from one allele to another → **changes the frequency of alleles and gene pool** of a population
- But individual mutations occur so rarely that mutation alone **does not change allele frequency much.**
- Nonetheless beneficial mutation is the **ultimate source of genetic variation** that makes evolution possible.

2. Natural Selection – Sexual Selection



Credits: Our Planet | Birds Of Paradise | Exclusive Clip | Netflix
https://www.youtube.com/watch?v=rX40mBb8bkU

2. Natural Selection – Sexual Selection

- Individuals with certain **inherited characteristics** are more likely than other individuals to obtain mates.

(1) **Choice of mate** by members of one sex (usually females) on the basis of physical characteristics e.g., the attractive plumage of male birds

(2) **Competition among members** of one sex (usually males) for access to members of the other sex, e.g., male competition can take the form of direct fighting (intra-sexual selection)

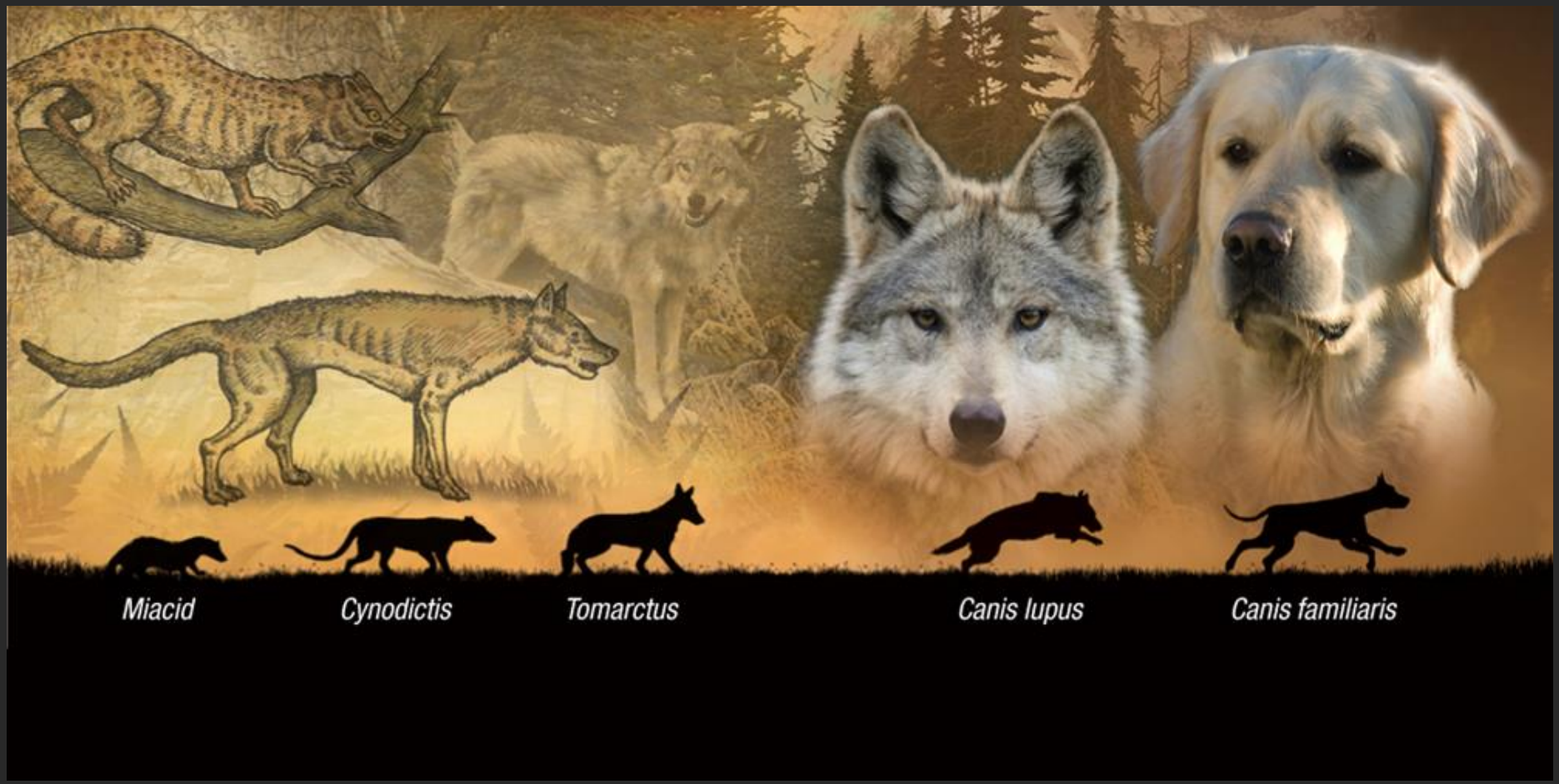
2. Artificial Selection (Not-so-Natural Selection)

- **Non-random selective breeding** process as only individuals with traits **desirable to humans** are selected for breeding. i.e. man exerts a directional selection.
- One example is the domestication of dogs from wolves.

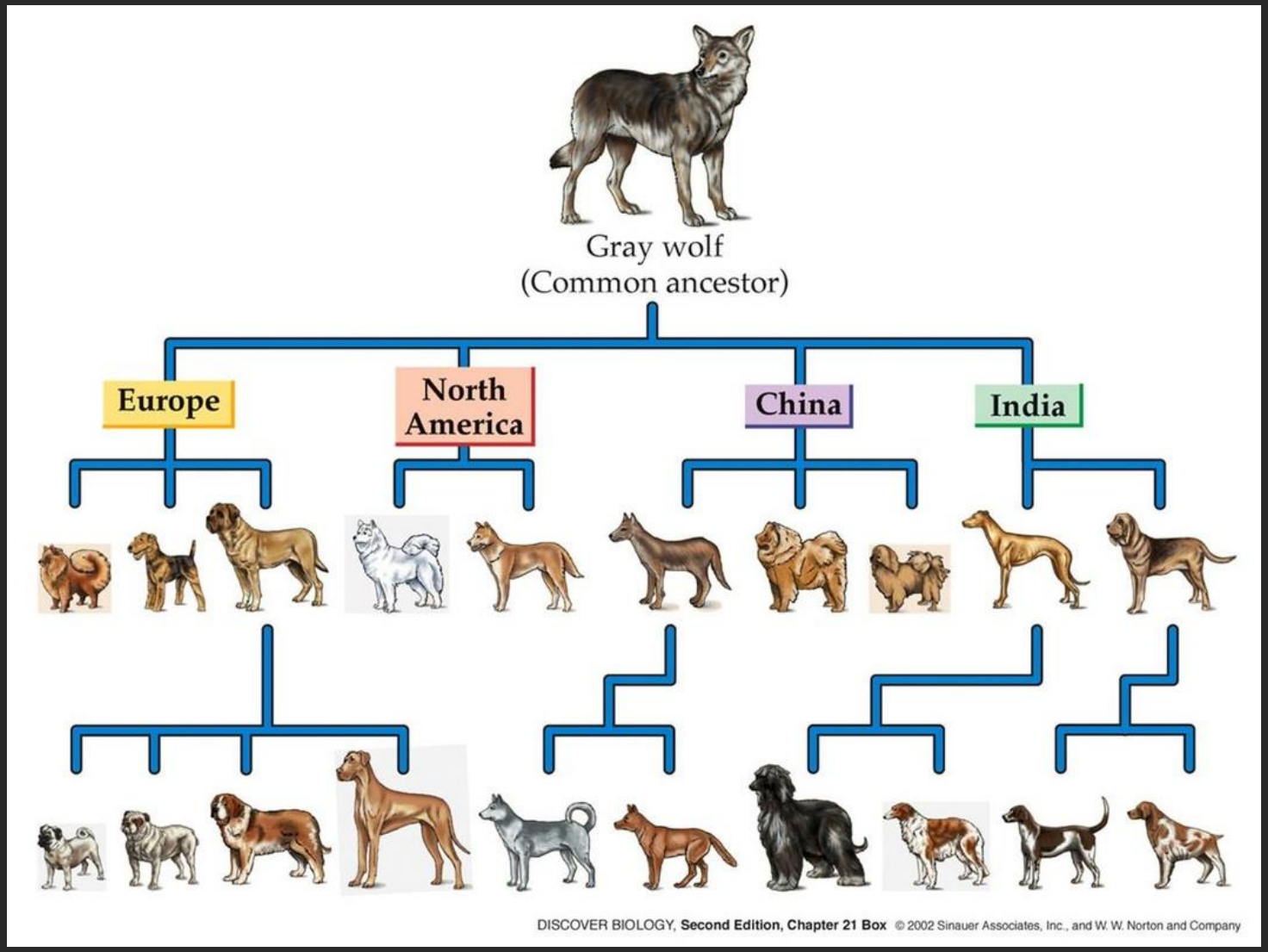
Refer to page 28 to read about it!

- Artificial selection in domesticated animals and plants demonstrates the ability to **change the gene pool in a small amount of time if the selection pressure is strong.**

Domestication of Dogs



Domestication of Dogs



Non-random mating / artificial selection

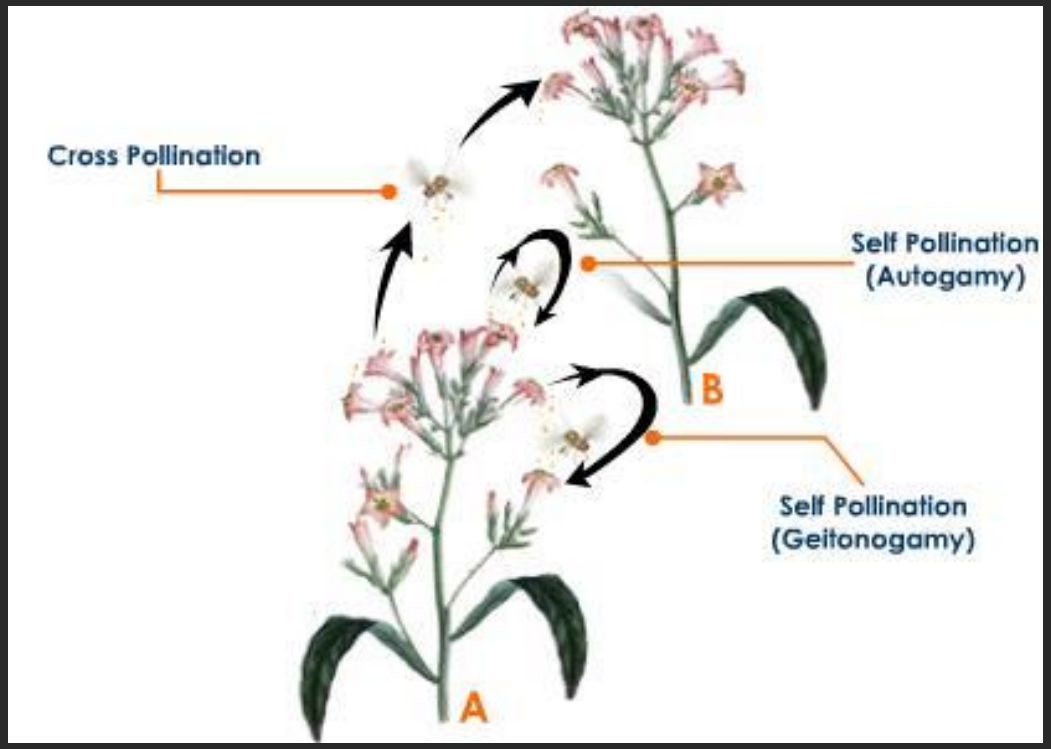
as an evolutionary agent

- Two types of artificial selection:

Inbreeding and **Outbreeding**

Inbreeding

- Involves breeding of closely related individuals e.g. sibling mating or self-fertilisation.



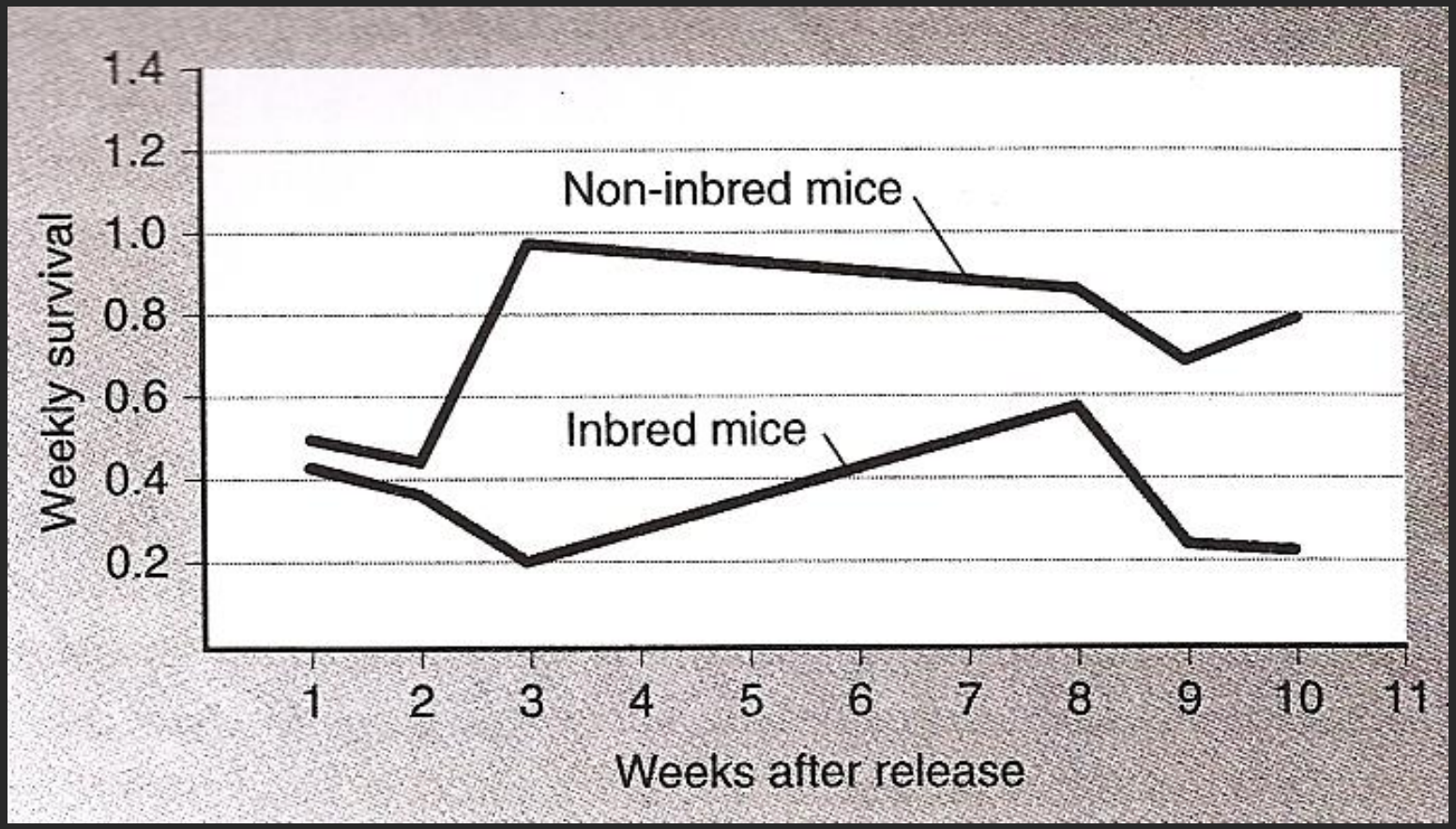
Inbreeding

- Increases the proportions of homozygous individuals with uniformity in characteristics, however at the expense of genetic diversity.

Inbreeding

- Complete homozygosity in plants e.g. wheat => all the plants being killed when exposed to environmental changes / diseases and there are no other alleles to produce genetically different individuals.

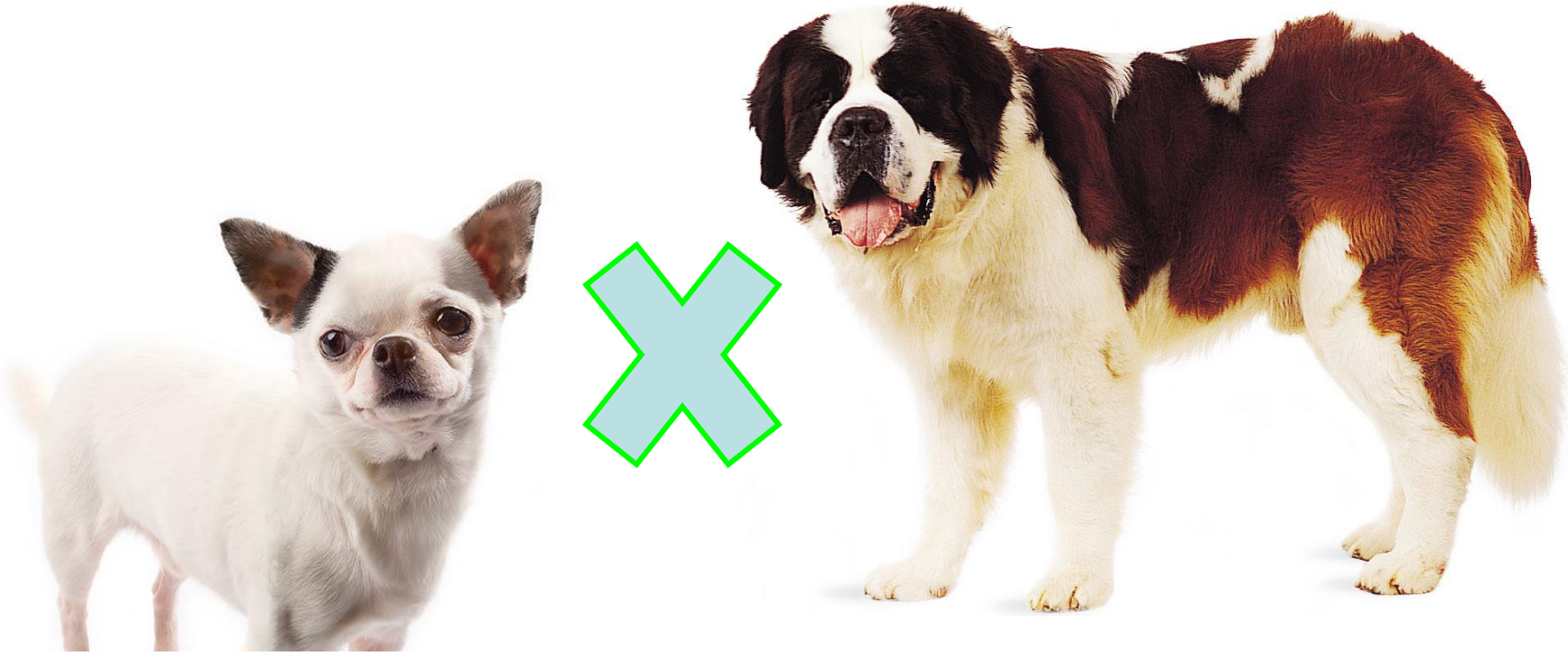
Inbreeding



Survival of inbred and non-inbred mice over 10-week period.

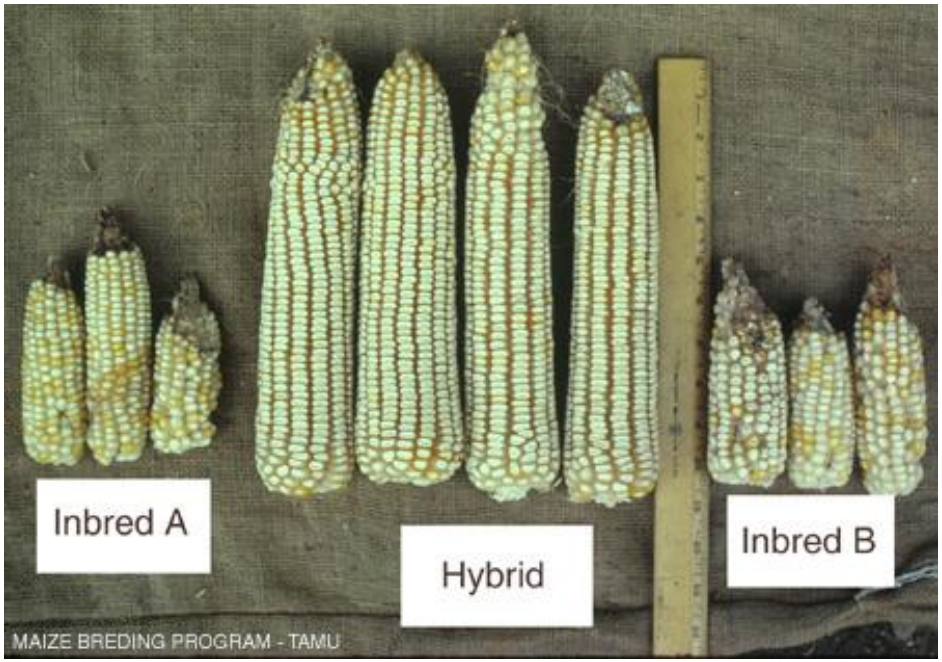
Outbreeding

- Involves crossing individuals from genetically distinct strains.



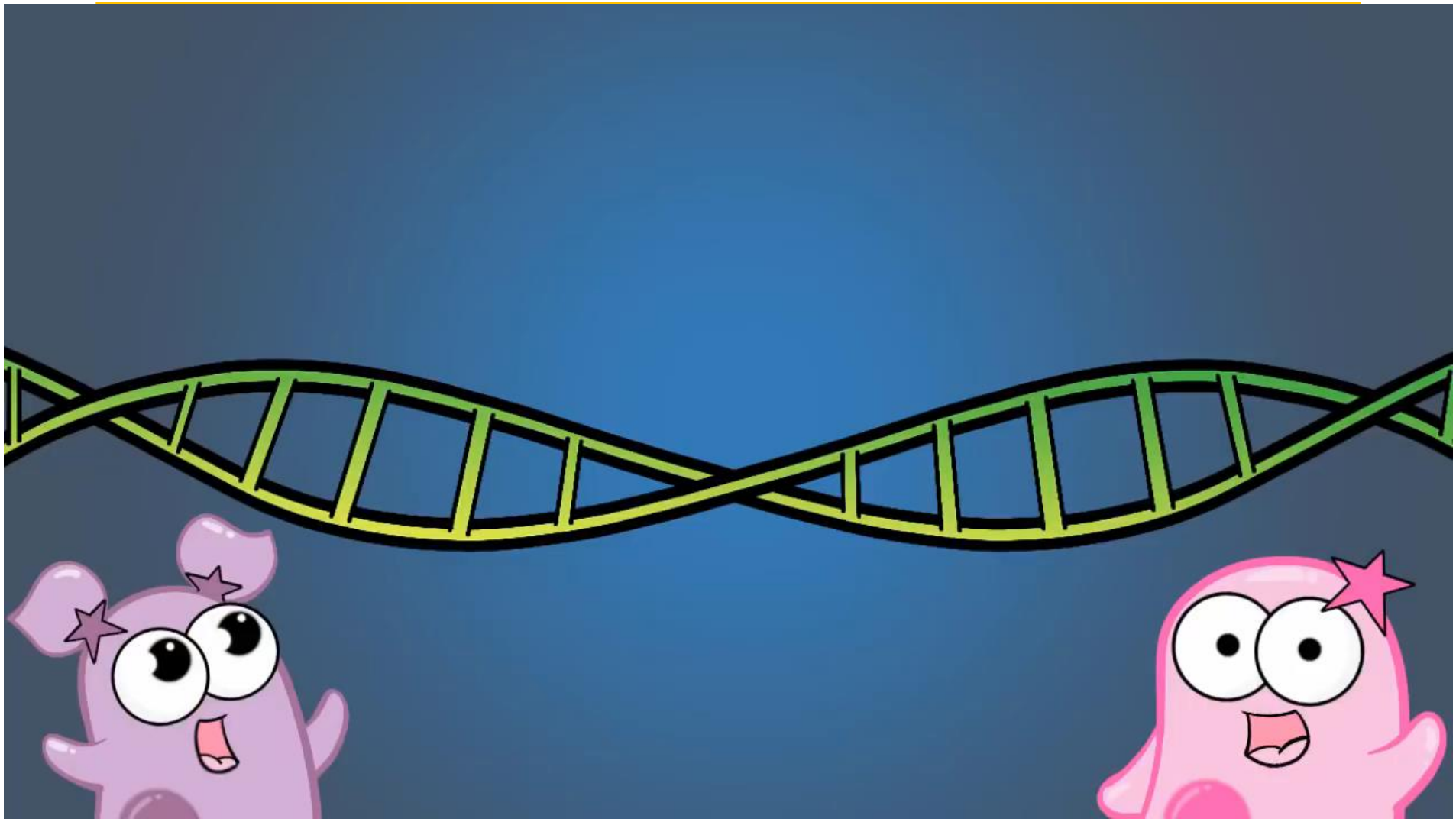
Outbreeding

- Offspring derived are known as hybrids.
- Hybrids often have characters which are superior to that of each parent => hybrid vigor
- May have arisen from an increase in heterozygosity from the mixing of alleles.



Heritage Quiz!

3. Genetic Drift – Overview



Credits: Amoeba sisters Youtube https://www.youtube.com/watch?v=W0TM4LQmoZY

Genetic Drift - Overview

- **Definition: Genetic drift** is defined as **a change in allele frequencies of a small population** (small gene pool) from one generation to the next **due to chance** events alone.
- Through genetic drift, certain alleles may **be over-represented, under-represented, lost or become fixed** in the gene pool.
- Little impact in large populations
- Large impact on genetic variation in small populations.

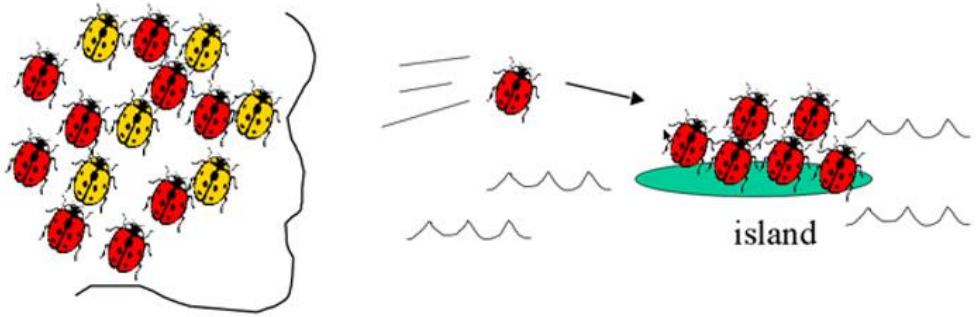
Genetic Drift - Overview

- Main features of genetic drift are:
  1. Change in allele frequencies
  2. A loss of genetic variation results within populations
  3. Results in genetic divergences between populations
  4. Results in evolution

3. Genetic Drift

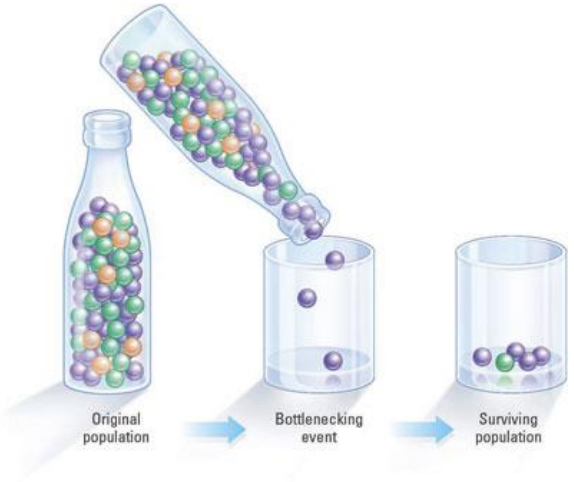
1 Founder Effect

Few individuals get isolated from the original population on a new habitat



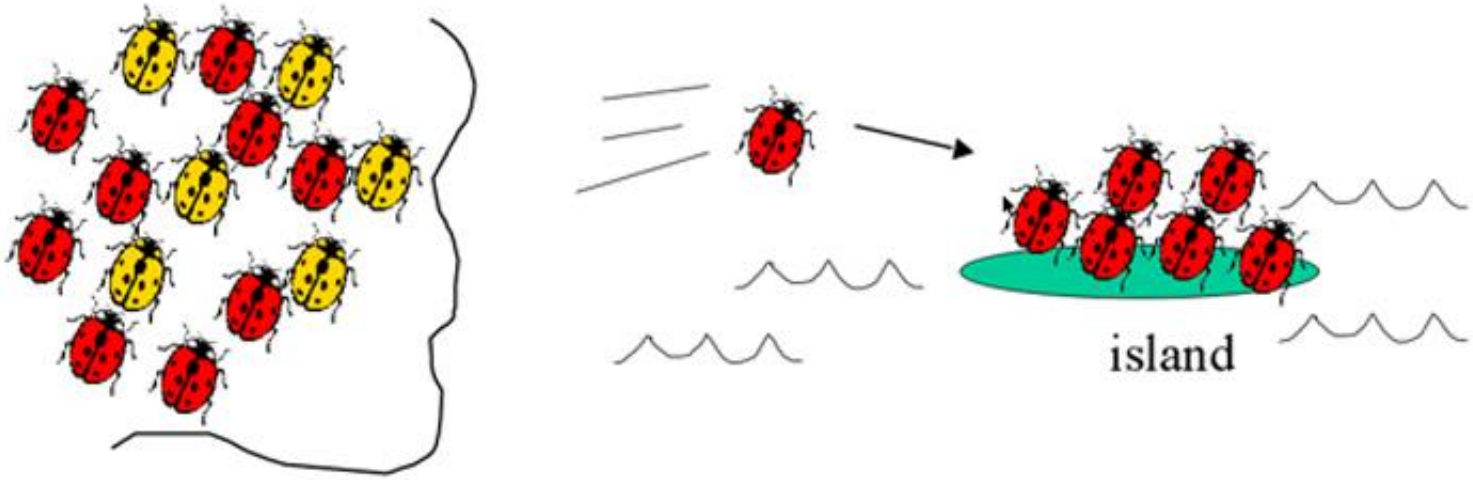
2 Bottleneck Effect

Few individuals survive after a natural disaster



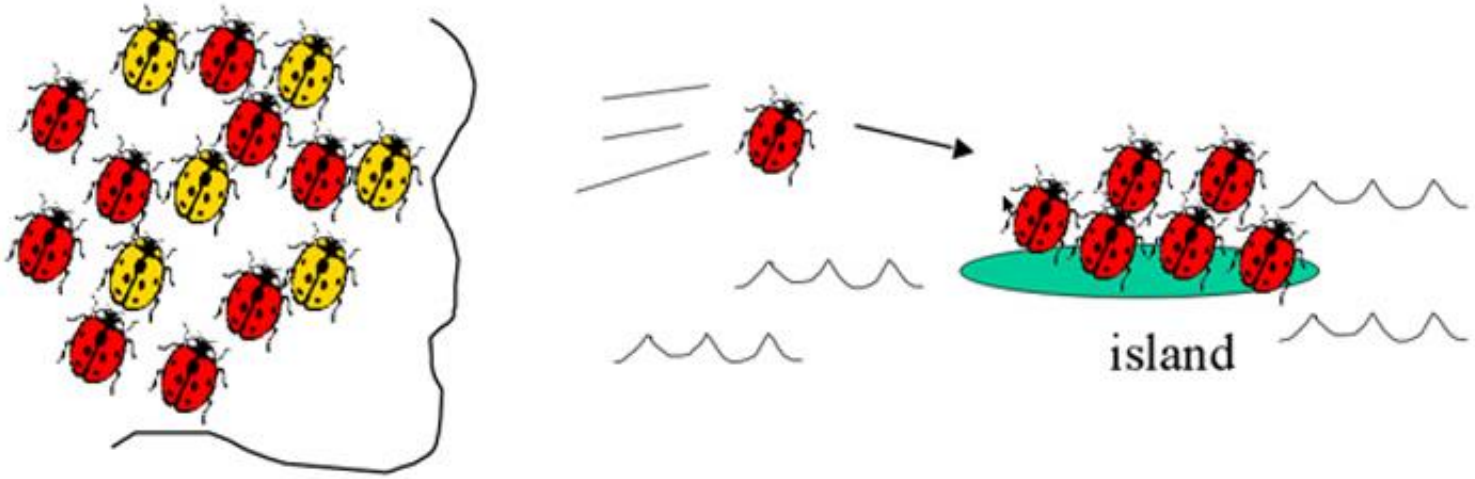
3.1 Founder Effect

- **Few individuals get isolated** from a larger population → colonise an isolated area away from their place of origin.



3.1 Founder Effect

- The founder population's **gene pool will be different** from the original population as it represents a random small portion of the original gene pool.
- By chance certain alleles may be over-represented, under-represented, lost or become fixed in the gene pool of the founder population.



The Founder Effect

- **Example among human populations**

carry unusual concentrations of mutations that cause a number of rare inherited disorders, including the Ellis-van Crevald syndrome.

The founder effect

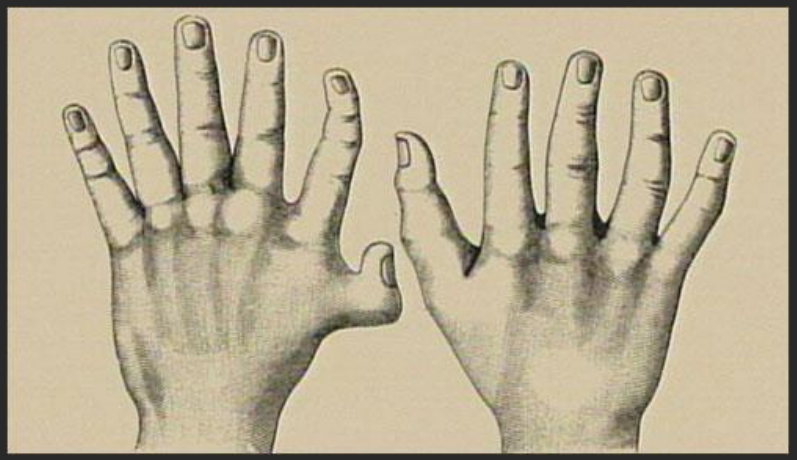
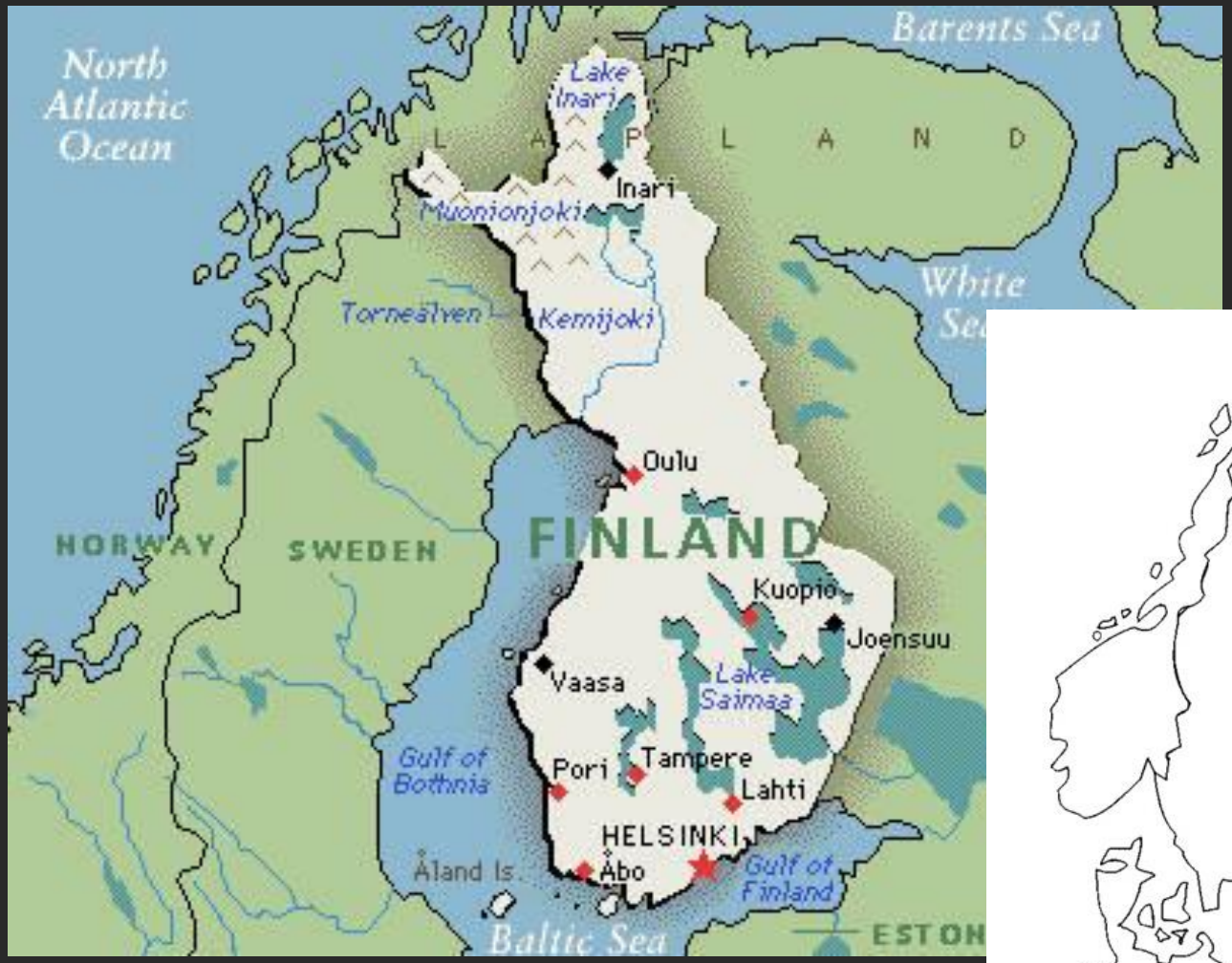


Figure 38-12 AN AMISH CHILD WITH ELLIS–VAN CREVELD SYNDROME.
The child has shortened limbs and six fingers on each hand. All the Amish with this syndrome are descendants of a single couple that helped found the Amish community in Lancaster County, Pennsylvania, in 1744. Because of inbreeding in the isolated community, the recessive trait is now common.


North Atlantic Ocean
Barents Sea
White Sea
Lake Inari
LAPLAND
Inari
Muonionjoki
Torneälven
Kemijoki
Oulu
NORWAY
SWEDEN
FINLAND
Kuopio
Joensuu
Vaasa
Lake Saimaa
Gulf of Bothnia
Pori
Tampere
Lahti
HELSINKI
Åland Is.
Åbo
Gulf of Finland
Baltic Sea
ESTON

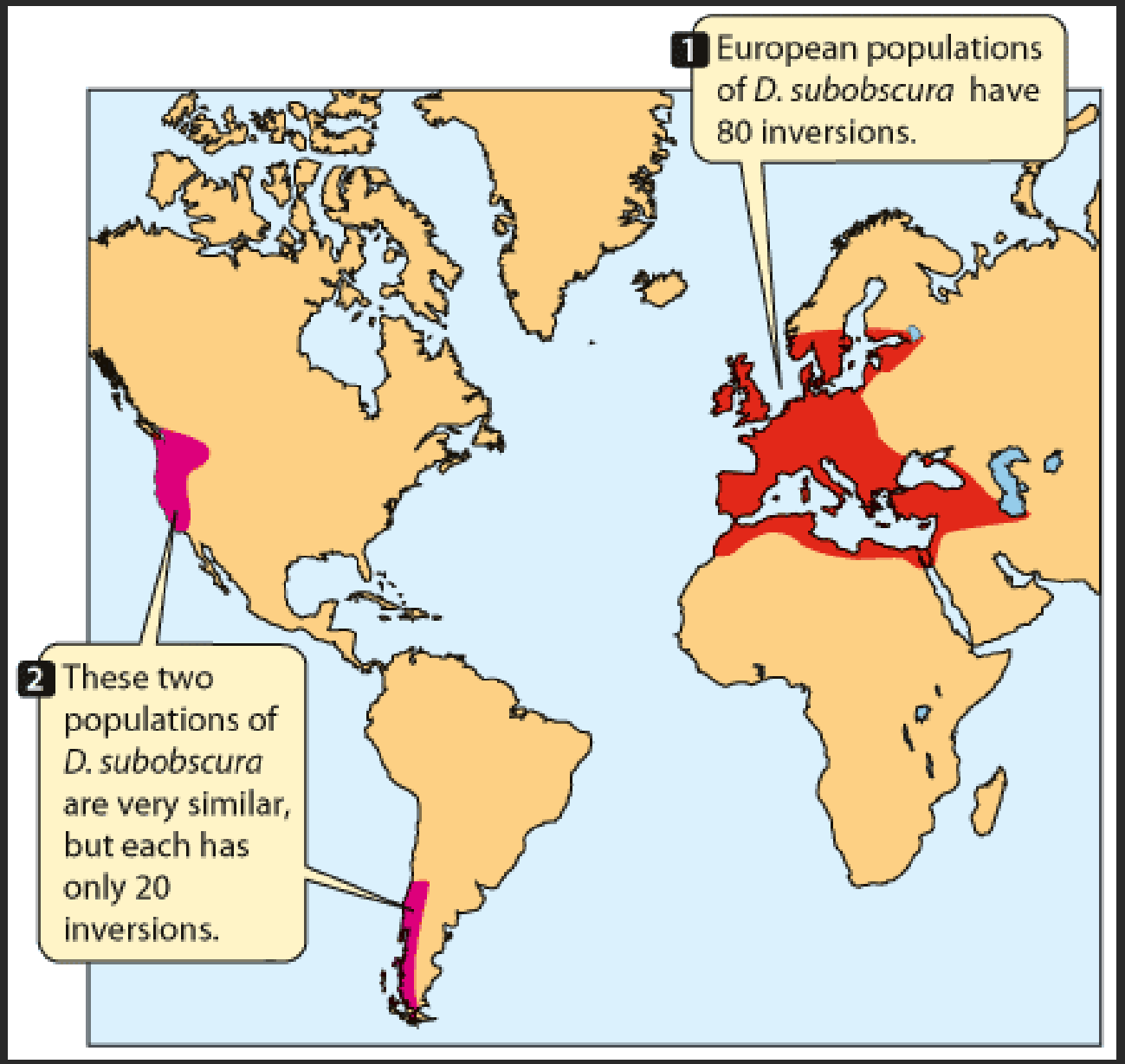

Finland
South-Russia
Central Europe

The Finns

The Founder Effect

- **Case Study: Among fruit fly populations**

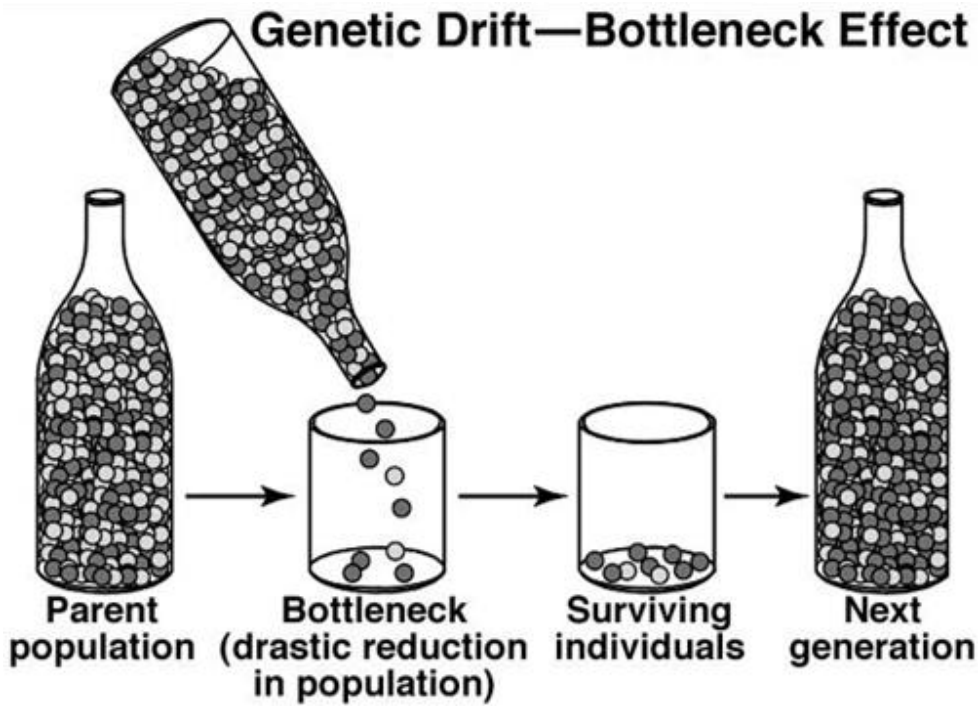
The founder effect



3.2 Bottleneck Effect

- **Drastic reduction** in the size of the population caused by natural disasters, disease or predators (by chance) which results in the survivors representing a **random small portion of the original gene pool.**

- By chance, certain alleles may be over represented, under-represented or eliminated from the gene pool of the survivors.
- those that survive do so primarily **by chance**



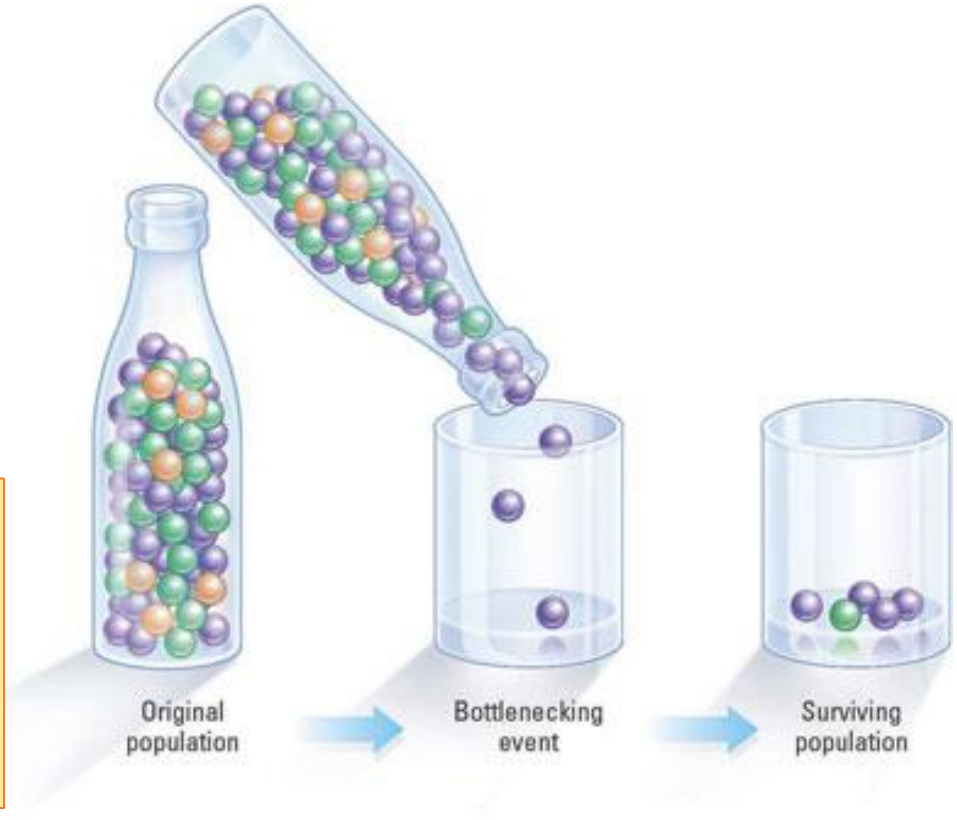
3.2 Bottleneck Effect

- Even when the population of survivors increases to its original size, a portion of its **original genetic diversity remains lost.**

Due to inbreeding!

- This leads to **reduction in genetic variability**, which may explain the problem with many endangered species.

#TBT to pg 15
Lesser genetic variation
→ population less fit for survival during natural selection



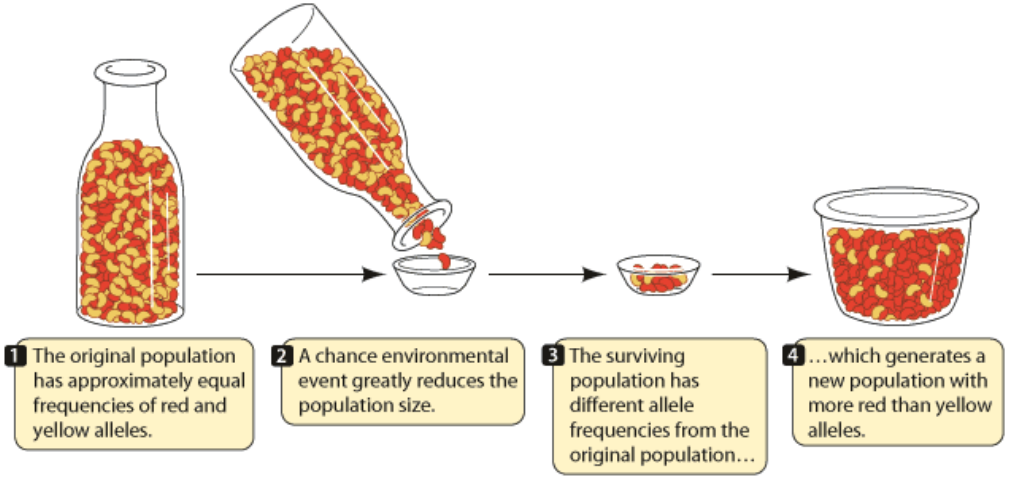
3.2 Bottleneck Effect

- Alternatively, a population may crash due to an infectious disease, **where selection will favour individuals** with specific genetic variants of their immune system.

Natural Selection

Reduction in popn size

- Whatever the cause, **genetic bottlenecks always reduce the amount of variation in a population.**



Bottleneck Effect

- **Case Study: Northern elephant seals**

The Bottleneck effect

- **Case Study: Cheetahs**

The Bottleneck effect

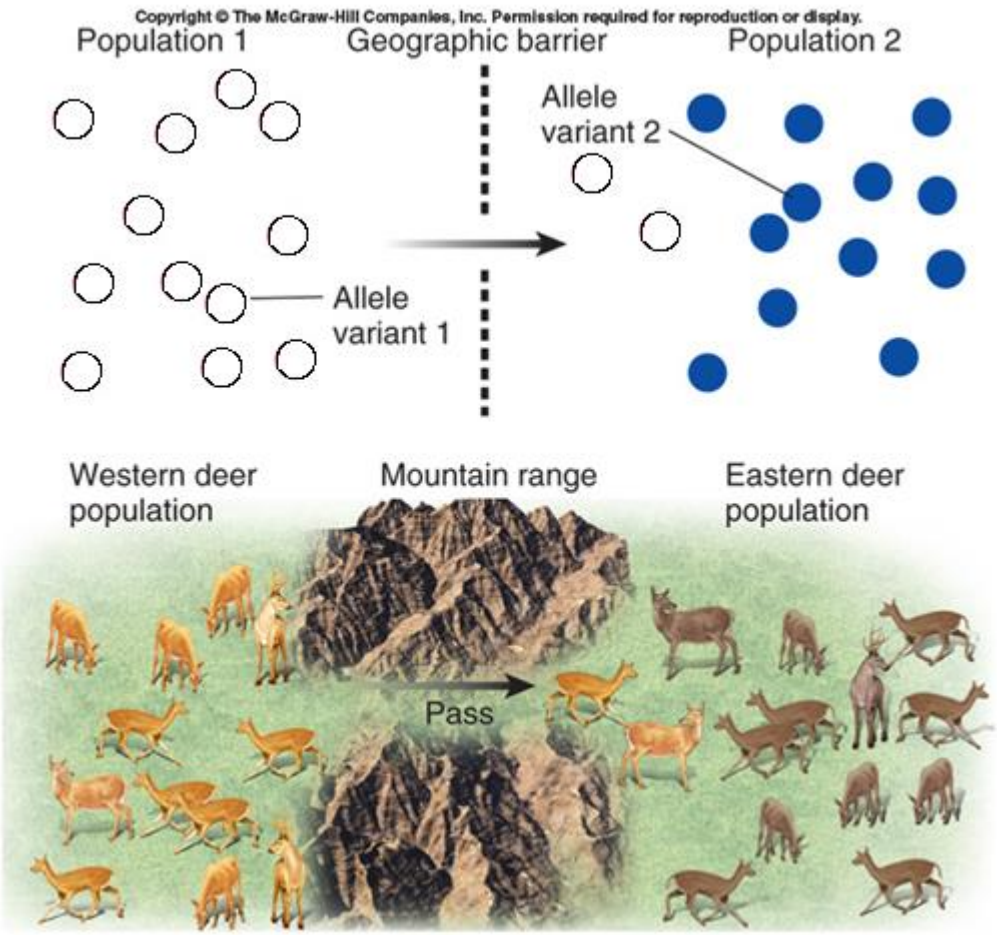
- **Case Study: Illinois prairie chickens**

3.4 Migration resulting in Gene Flow

- Gene flow is defined as the movement of genes from one population to another

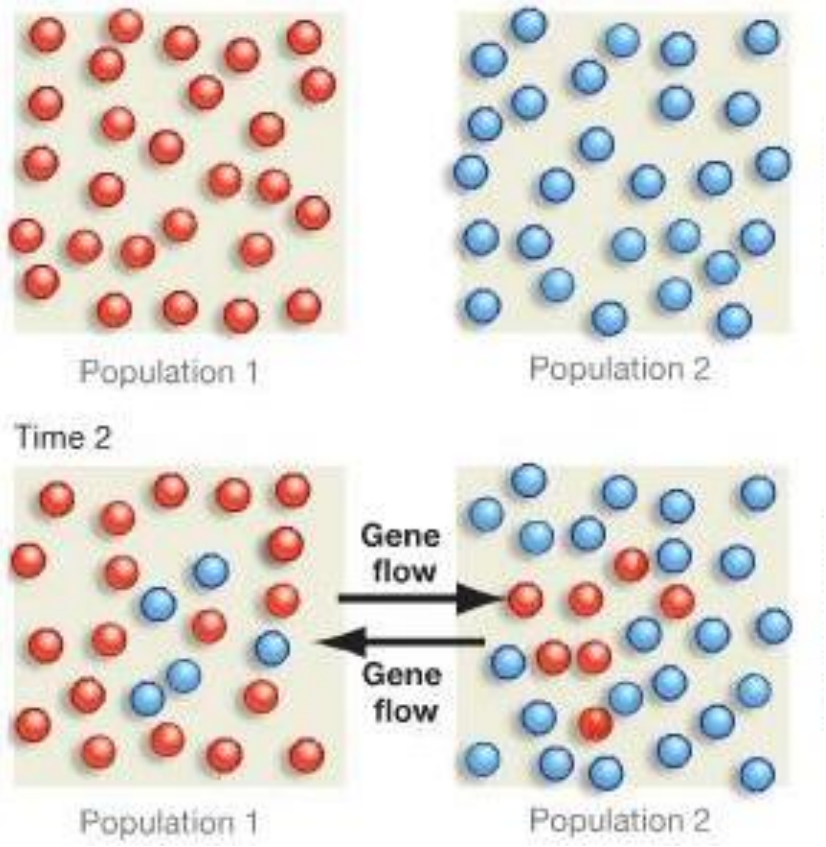
Changes allele frequencies in both populations

- This may be achieved by the **migration of fertile individuals or the transfer of gametes**.



3.4 Migration resulting in Gene Flow

- **Reduce genetic differences** that have accumulated between populations as a result of natural selection or genetic drift.
- **Maintenance** of organisms over a large area **as one species.**
- If migrants carry genes back and forth between populations, the populations will never develop large differences.



Explain, with examples, how environmental factors act as forces of natural selection?

Framework to answer question

Explain, with examples, how environmental factors act as forces of natural selection?

*Framework to answer question

1. Genetic variation exists in population. Eg.
2. Selection pressure. Eg.
3. Selective advantage. Eg.
4. Selective disadvantage. Eg.

Not in notes, copy it down

Explain, with examples, how environmental factors act as forces of natural selection?

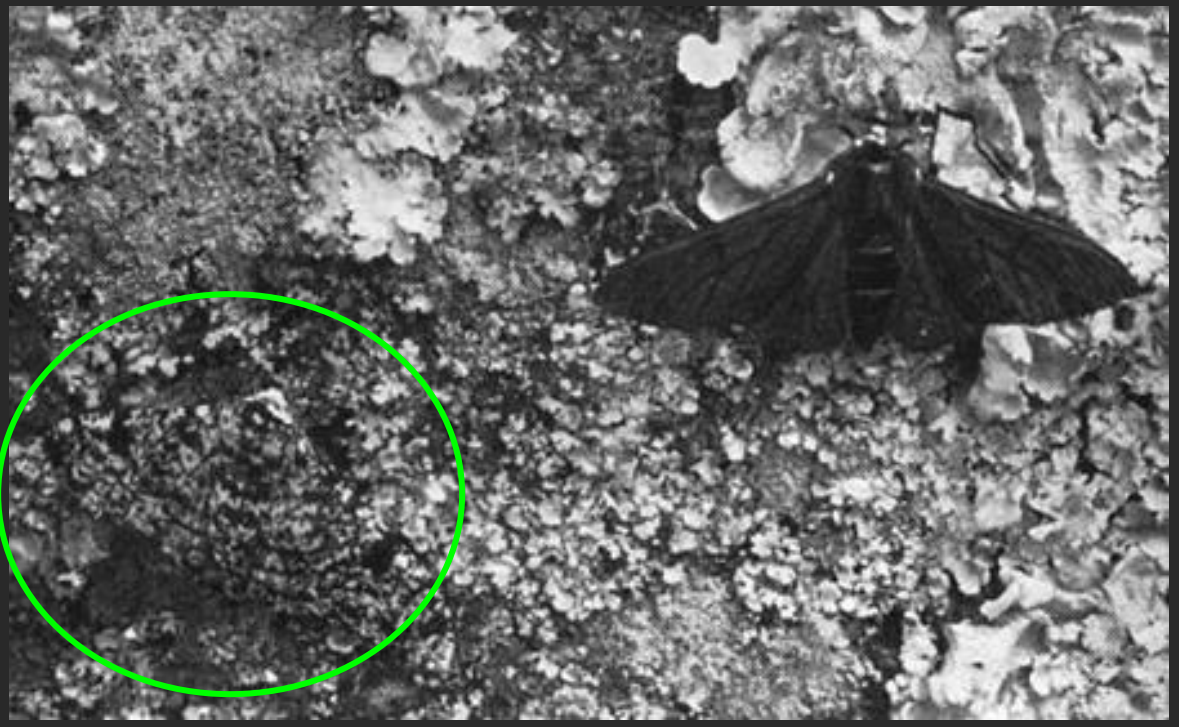
5. Outcome. Eg.
6. Survival and reproductive success. More *(list advantageous phenotype)* survive to reproductive age and produce viable, fertile offspring. Their alleles would hence be passed down to subsequent generations.
7. Change in allele frequencies. E.g. Selection of *(list the advantageous phenotype)* lead to change in frequency of alleles responsible for *(list phenotype).*

Not in notes, copy it down

The Truth behind Peppered Moths

- Before 1848, the lighter coloured moths had a selective advantage / were well-camouflaged from predators (birds) on light coloured, lichen-covered tree barks

Can you find it?

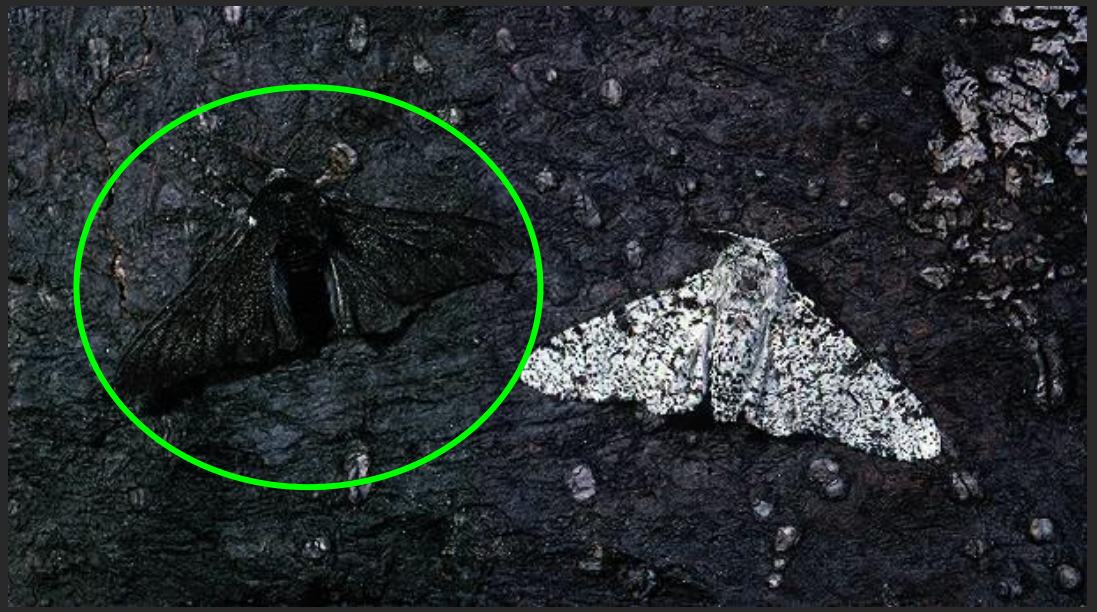


The Truth behind Peppered Moths

- With the industrial revolution, lichens on bark of trees were killed and barks were covered with soot & thus appeared darker.
- Lighter coloured moths were selected against

=> Easy prey to birds.

Can you find it?

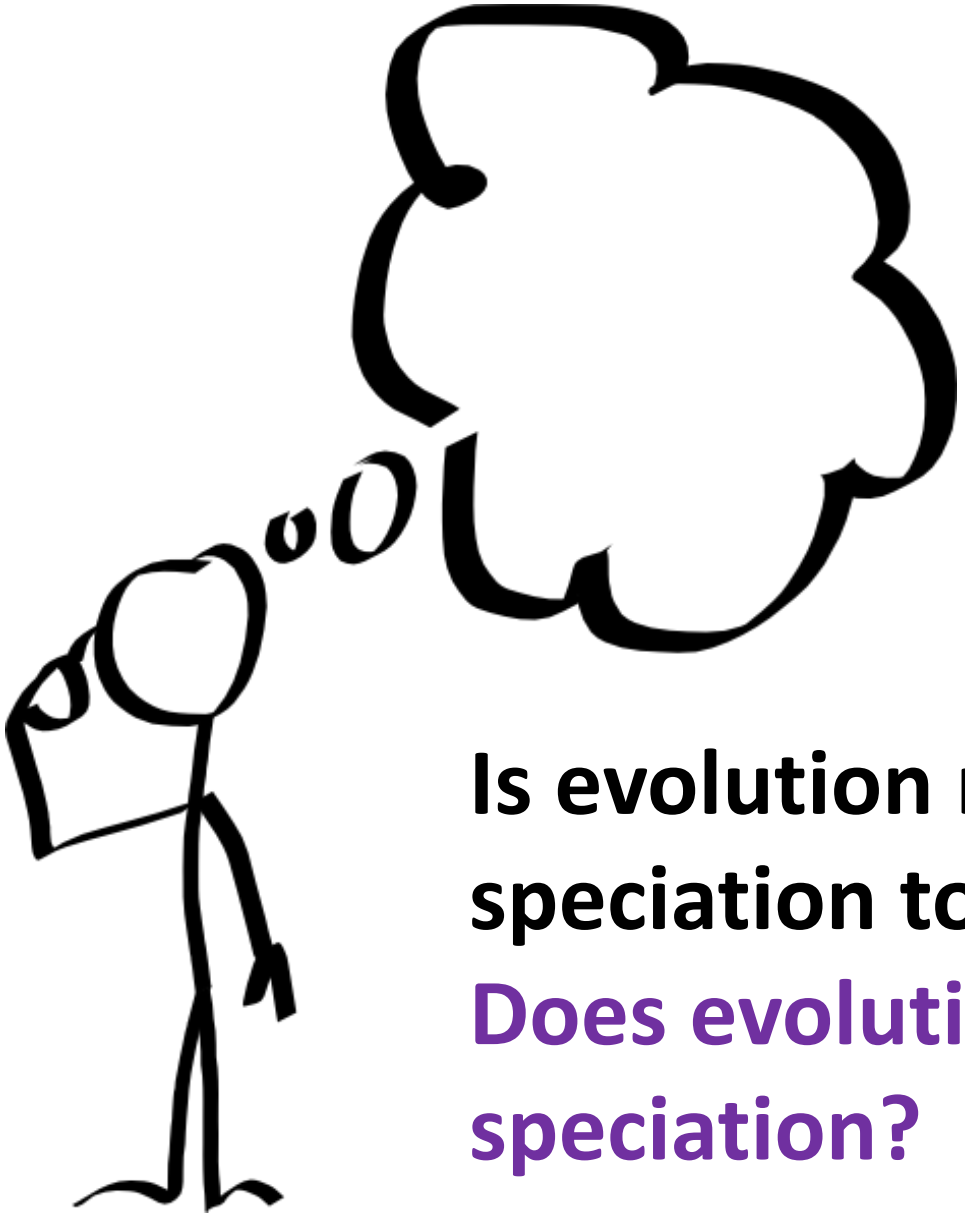


The Truth behind Peppered Moths

- Neither dark nor light moths ever spend their days on exposed tree trunks or rocks! Moths prefer to settle in locations higher in the tree.
- Textbook photos were faked
  => Dead moths glued to tree trunks!!
- Kettlewell placed the moths on tree trunks, two to four specimens per tree (much higher concentrations than other times), and exposed them during the day

  => More **easily predated** by the birds!

Extra



Is evolution required for speciation to occur?

Does evolution always lead to speciation?

Extra

Evolution & Speciation

- Evolution is **required for speciation** to occur BUT Evolution **does not always lead to speciation**!

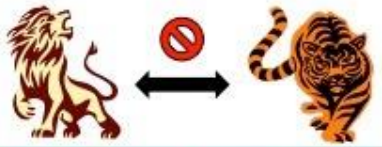
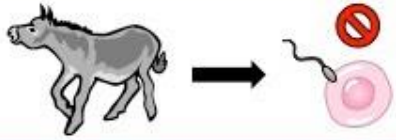
- In order for speciation to occur,
  - Individuals from one species must differ from each other (there **must be a change in allele frequency** that occur in a gene pool over time = evolution must have occurred).

AND

  - The populations must be **reproductively isolated.**

Extra

Reproductive isolation

Pre-zygotic Isolating Mechanisms		Example	
Temporal	Occurs when two species mate at different times of year	Frogs live in same pond but breed during different seasons (summer vs spring)	
Ecological	Occurs when two species occupy different habitats	Lions and tigers can potentially interbreed, but usually occupy different habitats	
Behavioural	Occurs when two species have different courtship behaviours	Certain groups of birds will only respond to species-specific mating calls	
Mechanical	Occurs when physical differences prevent copulation / pollination	Certain breeds of dog are morphologically incapable of mating due to size	
Post-zygotic Isolating Mechanisms		**Examples**	
Hybrid Inviability	Hybrids are produced but fail to develop to reproductive maturity	Certain types of frogs form hybrid tadpoles that die before they can become a frog	
Hybrid Infertility	Hybrids fail to produce functional gametes (sterility)	Mules are sterile hybrids resulting from mating between a horse and a donkey	
Hybrid Breakdown	F_1 hybrids are fertile, but F_2 generation fails to develop properly	The offspring of hybrid copepods have less potential for survival or reproduction