SELECTION AND EVOLUTION

VARIATION

→ Differences between organisms of the same species.

→ Phenotypic variation is due to: genetic factors / environmental factors / combination of genetic and environmental.

① continuous
② discontinuous

Genetic variation

→ Differences in DNA base sequence within a species.

→ Causes

1) Independent assortment
2) Cross-over
3) Random fusion of gametes
4) Random mating
5) Mutation (of cells that form gametes) → creates a new allele

→ **Continuous Variation** (quantitative)

- → not discrete / categorical.
- → has normal distribution / bell-shaped curve / range of phenotypes.

genetic basis*

- → polygenic* / many genes involved.
- → environment has a large effect.

Discontinuous Variation (qualitative)

- → discrete / distinct categories / phenotypes.
- → no range of phenotypes / no intermediates / no normal distribution.
- → only one gene involved.
- ~~→ environment has a large affect~~
- → not affected by the environment.

Genetic Basis

a) *polygenes ⇒ many genes on diff locii affect the phenotype.
b) also, all the alleles have a small effect on phenotype.
c) environment has a large effect.

Genetic basis

a) one gene affects the phenotype.
b) alleles have a large effect on pheno.
c) not affected by the environment.

EVOLUTION

~~change in the characteristics of the species~~

→ Theory of evolution: a process leading to the formation of new species from pre-existing species over time, as a result of changes to gene pools from generation to generation.

↓

change in characteristics of the species due to changes in allele frequencies.

general theory of evolution: organisms have changed over time.

→ Change in allele frequency caused by:

1) Natural selection
2) Artificial selection
3) Genetic drift
4) Mutation
5) Non-random mating

NATURAL SELECTION

- occurs because populations have the capacity to produce many offspring that compete for resources.
- in the 'struggle for existence', individuals best adapted are most likely to survive to reproduce and pass on their alleles to next generation.

① Overproduction: producing more offspring than the environment can support.
② Genetic & phenotypic variation in population / offspring.
③ Environmental factors limit the population growth — selection pressures in environment. (affects / limits organisms' chances of survival & reproduction)
Selective advantage for a particular characteristic.
④ Organisms with this characteristic survive and reproduce.

⑤ Advantageous characteristics / alleles passed down to next generation offspring.

⑥ Allele frequency for that characteristic increased.

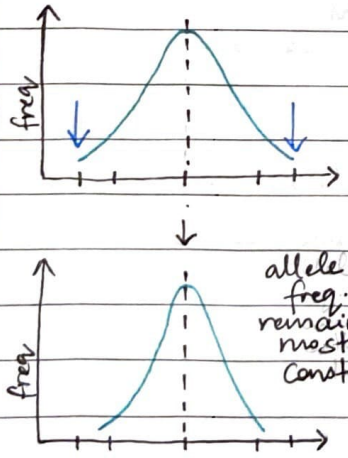
① overproduction → ② variation in offspring → ③ selection pressure → ④ survival and reproduction of fittest → ⑤ advantageous alleles passed down to next gen → ⑥ change in allele frequency

→ env. factors can act as stabilising, disruptive, directional forces of natural selection.

Natural Selection

Stabilising

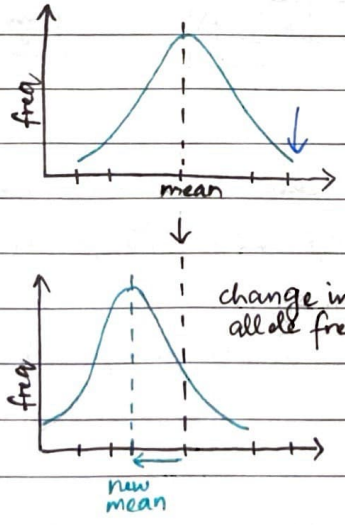
Selection pressure favours mean & acts against extremes.



allele freq. remains mostly constant

Directional

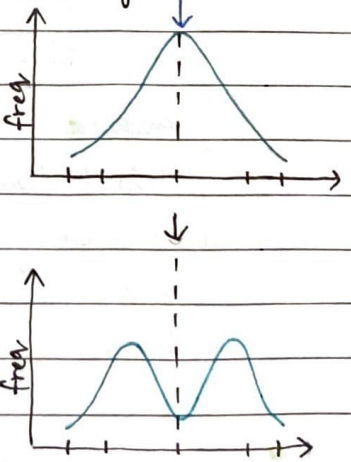
Selection pressure acts against one extreme.



change in allele freq.

Disruptive

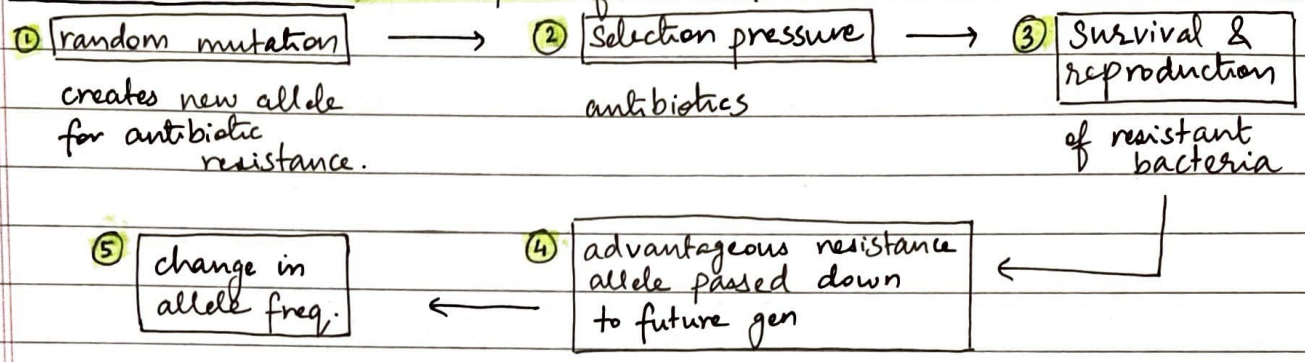
Selection pressure favours the extremes & acts against intermediates.



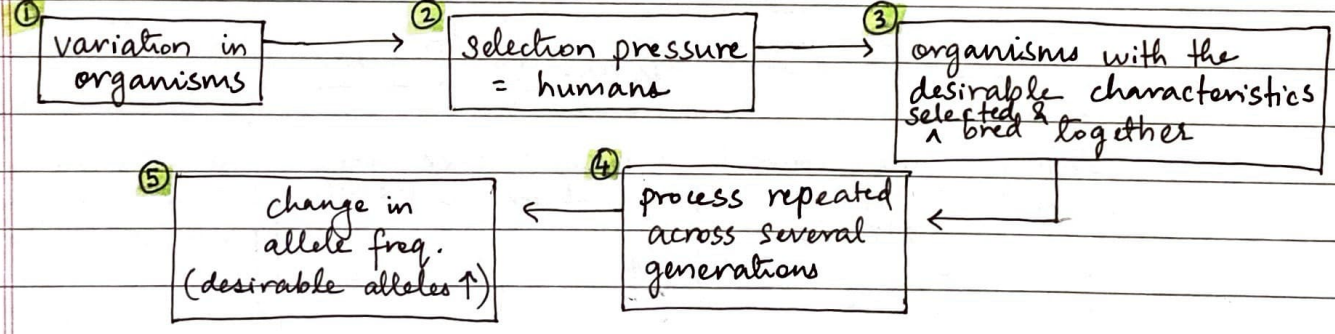
maintains 2 distinct phenotypes: polymorphism

→ ⇒ Selection pressure

Antibiotic Resistance - Example of Natural Selection



ARTIFICIAL SELECTION
(Selective Breeding)



Examples

a) Introduction of disease resistance to varieties of wheat and rice.

b) Inbreeding & hybridisation to produce vigorous, uniform varieties of maize.

c) Improving milk yield of dairy cattle.

a)
1- variation in organisms.
2- humans = selection pressure; expose to disease.
3- organisms with disease resistance chosen/ selected.
4- these organisms bred together.
5- process repeated ~~across~~ over few generations.
6- change in allele freq.; directional selection.

b) Inbreeding: breeding organisms with very similar genotypes.
→ as inbreeding is continued over generations, the plants become weaker = Inbreeding Depression.
(organisms become progressively weaker due to inbreeding).
→ possible explanation for inbreeding depression:
① mutation may give rise to harmful recessive alleles.
② inbreeding increases chances of passing down harmful recessive alleles.
③ harmful alleles can be expressed, causing organisms to become weaker.

Outbreeding: breeding organisms with less similar genotypes.
→ eg. homozygous dominant x homozygous recessive = heterozygous
→ organisms produced by outbreeding (although they have recessive allele) tend to be healthier & taller; they have hybrid vigour.
(mixed alleles; healthier, higher potential)

* Hybridisation is a type of outbreeding.

→ if outbreeding carried out completely randomly, too much variation produced btwn plants in one field.
→ uniformity is important when growing crops.
→ in order to achieve heterozygosity and uniformity, F1 hybrid seeds are developed by specialised companies.

c) → choose a cow with high milk yield, and breed it with a bull that is from a female with high milk yield.
→ down several generations, cow udders eventually get larger.
↳ advantage: higher milk yield.
↳ disadvantages: difficult for cows to walk, high chance of udder infection (mastitis) ∴ expensive to treat

GENETIC DRIFT

→ **Gene pool**: sum of all the genes and its alleles in one population.

→ **Genetic drift**: a change in allele frequency that happens randomly / by chance. (not due to natural / artificial selection)

can occur in 2 ways

Founder Effect	Bottleneck effect
→ a small population separates from the larger population, causing a change in allele frequency.	→ a drastic reduction in the population, causing a change in allele frequencies.
→ may lead to a smaller gene pool. ⇒ low genetic & phenotypic variation.	→ may lead to a smaller gene pool. ⇒ less genetic & phenotypic variation

↓

reduction in gene pool

↓

less genetic and phenotypic variation → less able to adapt to changing environments

HARDY-WEINBERG PRINCIPLE

$p + q = 1$

$p^2 + 2pq + q^2 = 1$

p = dominant allele freq.

q = recessive allele freq.

$p^2 = \frac{\text{no. of homozygous dominant}}{\text{total population}}$

$q^2 = \frac{\text{no. of homozygous recessive}}{\text{total population}}$

$2pq = \frac{\text{no. of heterozygous}}{\text{total population}}$

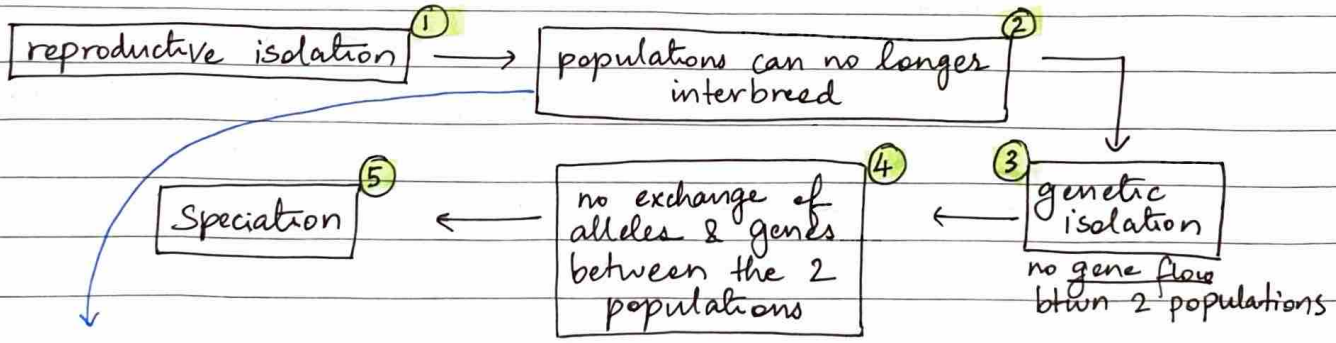
Conditions when Hard-Weinberg Principle can be applied:

1) Population is a large (reduces effect of genetic drift)
2) No natural selection (all genotypes have equal survival & reproductive success)
3) Random mating (no sexual selection/preference for particular genotypes)
4) No mutations (no new alleles introduced/existing alleles altered)
5) No migration (no gene flow into/out of population or genetic drift)

HW principle = equilibrium = no change in allele frequency.

SPECIATION

→ Process of forming a new species.
→ Evolution may eventually lead to formation of a new species.



Possible reasons:

1) → do not recognise each other as breeding partners.
   - ↳ diff appearance
   - ↳ diff mating rituals

2) → Sex organs are incompatible
   - ↳ do not fit
   - ↳ not complementary

3) → gametes are unable to fuse
4) → zygote may not be able to divide and become an embryo/offspring
5) → offspring is infertile

Speciation

Allopatric

- a new species forms
- due to geographical separation.

① geographical separation causes
② reproductive isolation
③ populations can no longer interbreed
④ genetic isolation: no gene flow btwn populations/ no exchange of alleles/genes
⑤ the 2 populations experience different mutations & selection pressures
⑥ change in allele frequencies
⑦ speciation - new species formed

Sympatric

- a new species forms
- without geographical separation.

① ecological separation (same area, diff env.)
└ populations subject to diff environmental factors.
(OR)
① behavioural separation (same area, diff behaviour)

② reproductive isolation
③ no interbreeding
④ genetic isolation
⑤ diff mutations & selection pressures
⑥ change in allele frequencies
⑦ speciation

IDENTIFYING EVOLUTIONARY RELATIONSHIPS

Compare base sequences of DNA
→ base sequence of nuclear DNA
→ base sequence of mitochondrial DNA (mtDNA)

- nuclear DNA of offspring different from that of parents due to cross-over, independent assortment, random fusion of gametes, mutation.
- mtDNA of offspring always identical to the female parent's. (unless mutation occurs)
  * mtDNA is inherited only from female parent.
    nuclear DNA is inherited from both parents.

a) **Base sequence of nuclear DNA**

- Compare genes that code for the same type of proteins.
- more similarities between base sequences ⇒ more closely related.
- if ~~all~~ individuals have the same gene ⇒ share a common ancestor. (recent common ancestor)

b) **Base sequence of mtDNA**

→ ~~what~~ Why mtDNA?

1) cell has hundreds of mitochondria, so mtDNA easily obtained.
2) mtDNA does not undergo crossover / random assortment.
3) mtDNA mutates at a fairly constant rate (molecular clock hypothesis).

→ mtDNA not enough proof to identify evolutionary relationships.
It has to be compared with fossil records, nuclear DNA, shape of organism, etc.

* For bacteria, compare circular DNA as they don't have mitochondria/nuclei