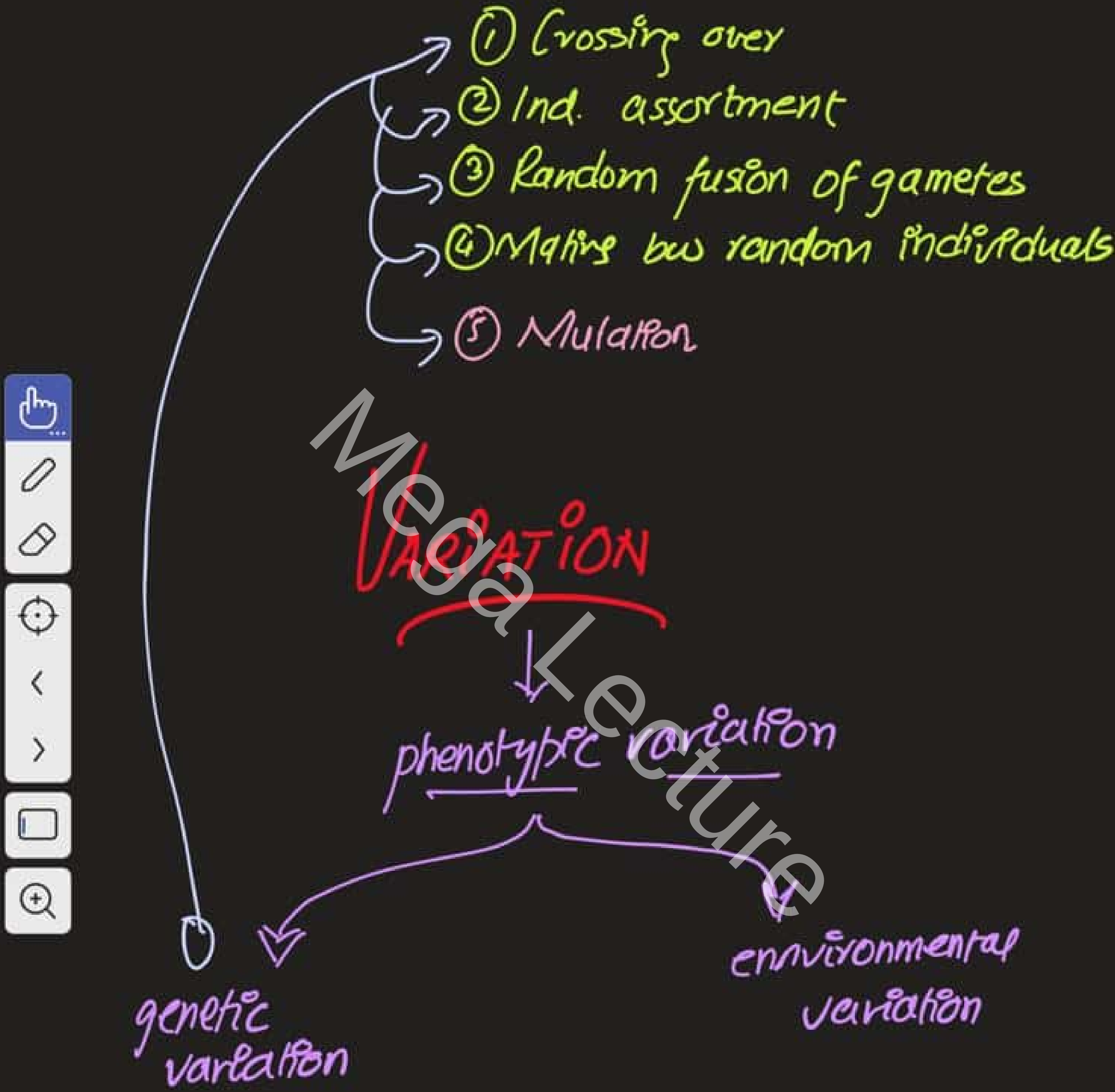
Selection & Evolution


① Crossing over
② Ind. assortment
③ Random fusion of gametes
④ Mating b/w random individuals
⑤ Mutation
VARIATION
phenotypic variation
genetic variation
environmental variation

$$V_P = V_G + V_E$$

Selection & Evolution

* Variation b/w living organisms exists due to genetic and environmental factors.

* Genetic variation results due to:

1) Crossing over
2) Independant Assortment
3) Random mating b/w individuals of a given species.
4) Random fusion of gametes during fertilisation.
5) Mutation

* The first four methods of genetic variation are responsible for reshuffling alleles in a population.

* Mutation, however, introduces new alleles in a population. Most of the time these alleles are disadvantageous and are not transmitted to the future generations.

Variation → Types

Continuous

eg. height, weight

- Quantitative
- Influenced by environmental factors
- Influenced by many genes
- Different alleles of a gene have a small effect on the phenotype

Discontinuous

eg. gender, blood groups

- Qualitative
- Not influenced by environmental factors
- Influenced by one or few genes
- Different alleles of a gene have a large effect on the phenotype

Continuous Variation

* Variation may be continuous or discontinuous

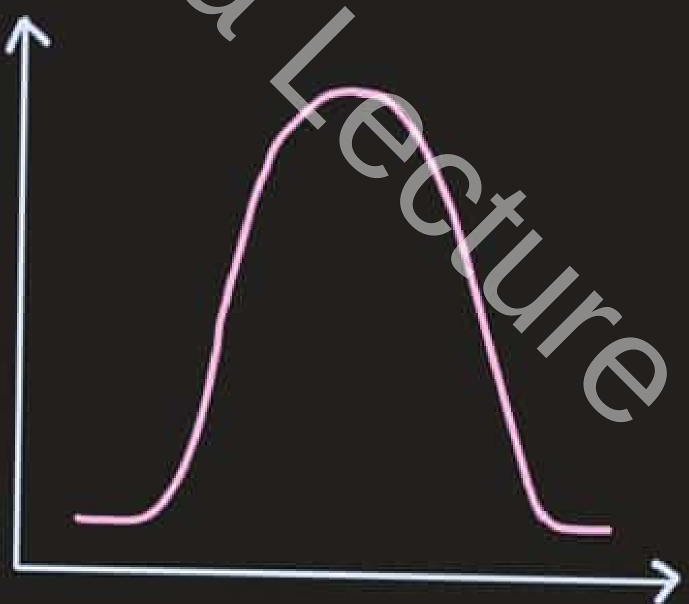
Continuous variation is shown by Traits that have a range of values, such as, the height & the weight.

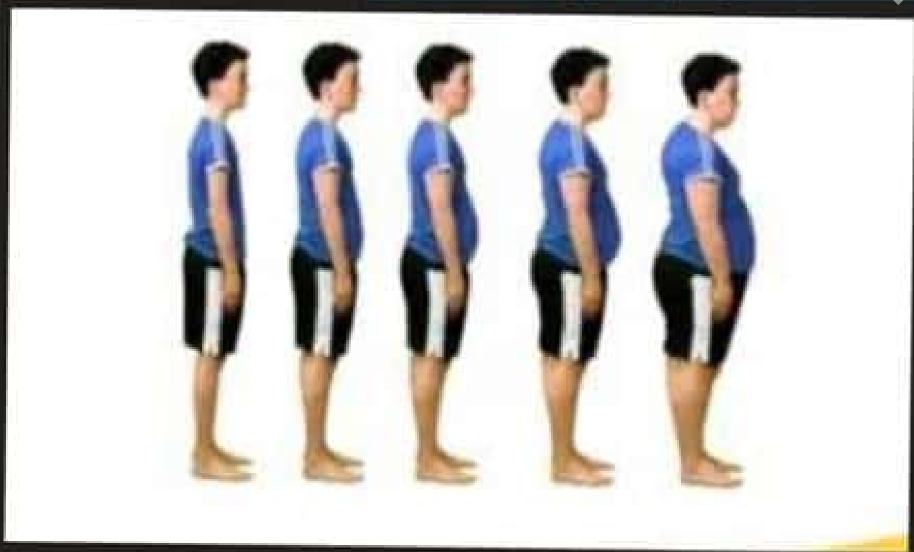
* Different alleles at a single gene locus have small effects on the phenotype.

* Different genes have the same, often additive effect on the phenotype.

* A large no. of genes may have a combined effect on a particular phenotypic trait, these genes are known as polygenes.

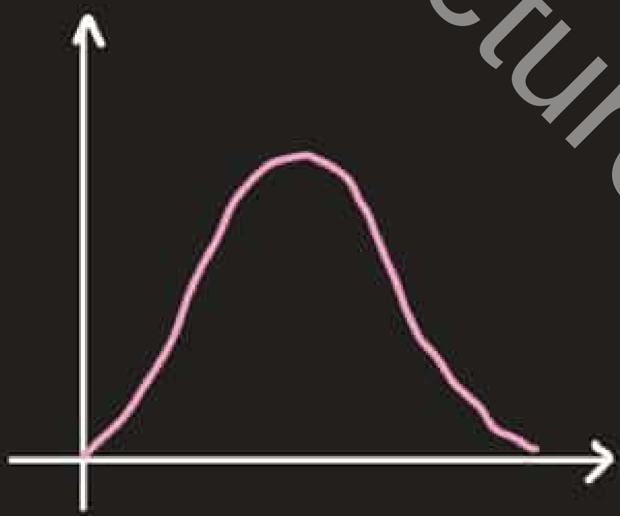
* Environment has a significant impact on the phenotype.





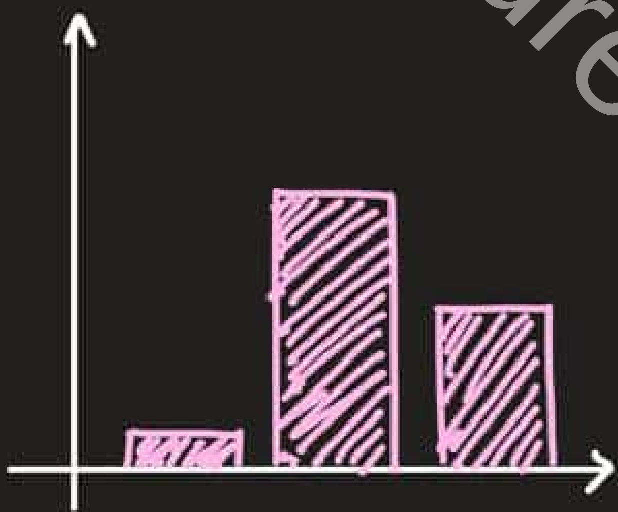
Continuous variation → Main features;

* No distinct categories
* Tends to be quantitative
* Controlled by many genes
* Strongly influenced by the environment.



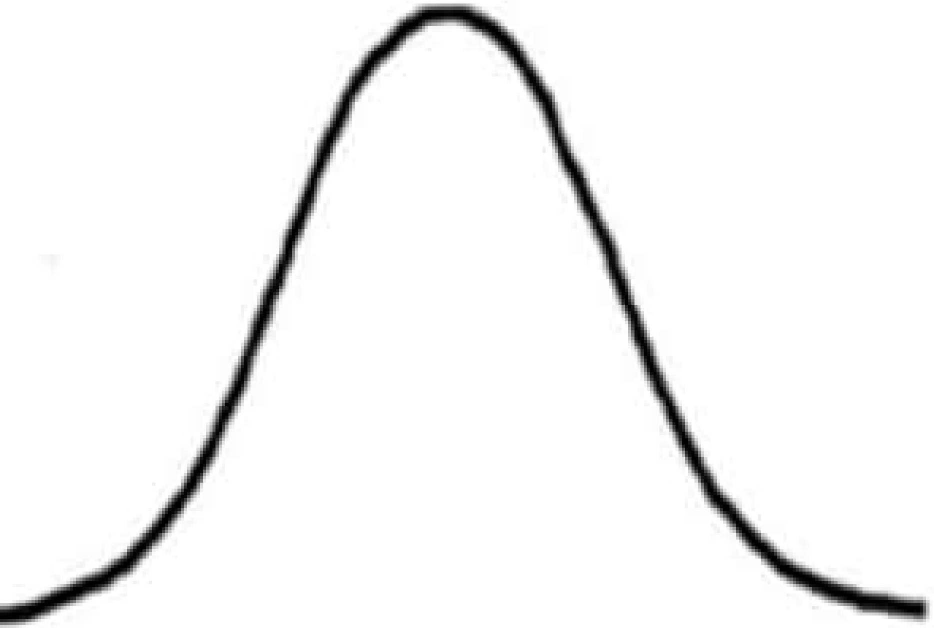
Discontinuous Variation

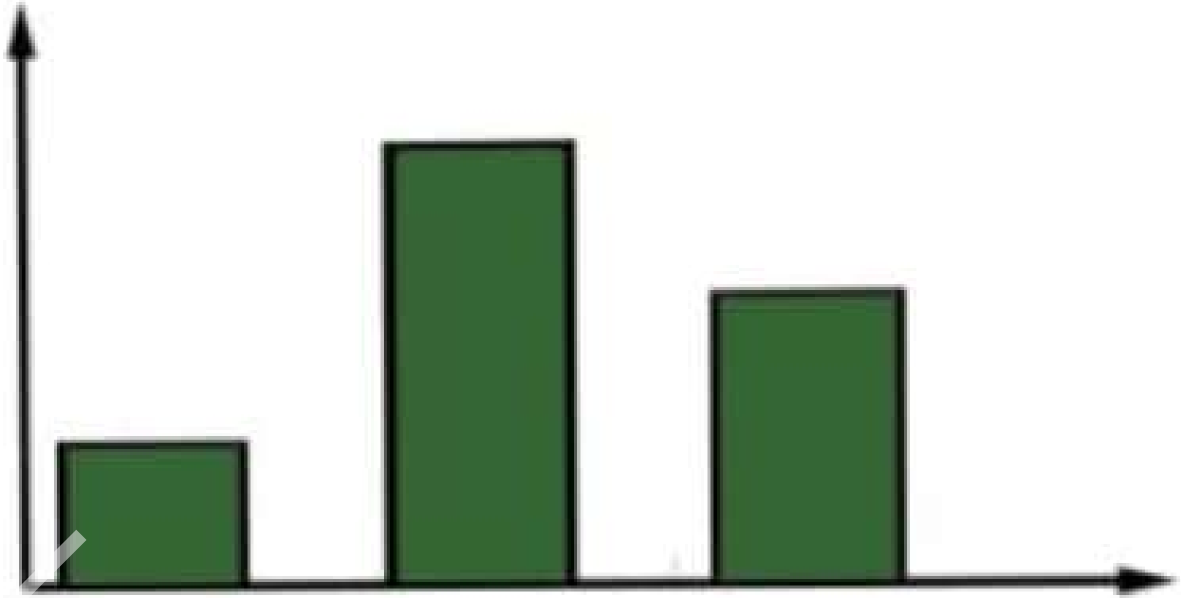
* Discontinuous Variation is shown by Traits that have discrete values with no intermediates
* Different alleles at a single gene locus have large effects on the phenotype.
* Controlled by a few genes.
* Unaffected by environment.



Discontinuous Variation → Main features;

* Distinct categories
* Tends to be qualitative
* Controlled by a few genes
* Unaffected by the environment.





Continuous Variation

- No distinct catagories
- Tends to be quantitative
- Controlled by a lot of genes
- Strongly influenced by the environment

Discontinuous Variation

- Distinct catagories
- Tends to be qualitative
- Controlled by a few genes
- Unaffected by the environment

Environmental impact on the phenotype

* environment affects the gene expression

↓

eventually affects the phenotype

$V_P = V_G + V_E$

* Examples:

1. Diet
2. low pO_2
3. pH of soil
4. phototropism / geotropism
5. dark extremities of Siamese cats and Himalayan rabbits

Environmental Impact on Phenotype

- Environmental factors are responsible for influencing the phenotype by altering the gene expression.
- Environment has a more significant impact on polygenetic traits.
- Variation in phenotype, therefore, results due to a complex interaction b/w the variation in genotype of the individuals & the variation in environment as shown by the expression below: $V_P = V_G + V_E$

Environmental Variation

* Examples of environmental variation include:

① A balanced diet affecting the height and weight of an individual in a population.

② Low partial pressure of oxygen causing acclimatisation which increases the no. of RBCs per mm^3 of blood.

③ The colour of the flowers of hydrangeas plant which alters with the pH of the soil. Acidic pH causes the flowers to become blue in colour, whereas alkaline pH of the soil water causes the flowers to become red or pink in colour. Change in pH alters the solubility of the Aluminium ions which, thereafter, influences a change in the colours of the flowers.

4) Darker fur colour of the extremities of the Siamese cat enables them to conserve heat. The heat loss through the extremities is significant due to high surface area to volume ratio.

5) The growing shoot of a plant grows towards light (phototropism)

* The growing roots of the plant grow towards gravity (geotropism)

pH of the soil will change the color of hydrangea flowers from blue to pink

- Environmental factors can influence the expression of genetic traits.

Example:

Siamese cats and Himalayan rabbits are darker in color where body heat is lost to the environment.

Darwin - Wallace

Theory of Natural Selection

Observations:

1. Organisms produce more offsprings than are needed to replace them
2. The population size is roughly stable
3. There are limited food sources
4. There exists genetic variation b/w the organisms of the same species
5. The genetic traits are heritable

Conclusions:

a. Competition for limited food resources

b. Organisms with favourable alleles are better adapted to survive and reproduce

Darwin-Wallace Theory of Natural Selection and Evolution

* Darwin & Wallace made important observations pertinent to natural selection & evolution. These observations were:

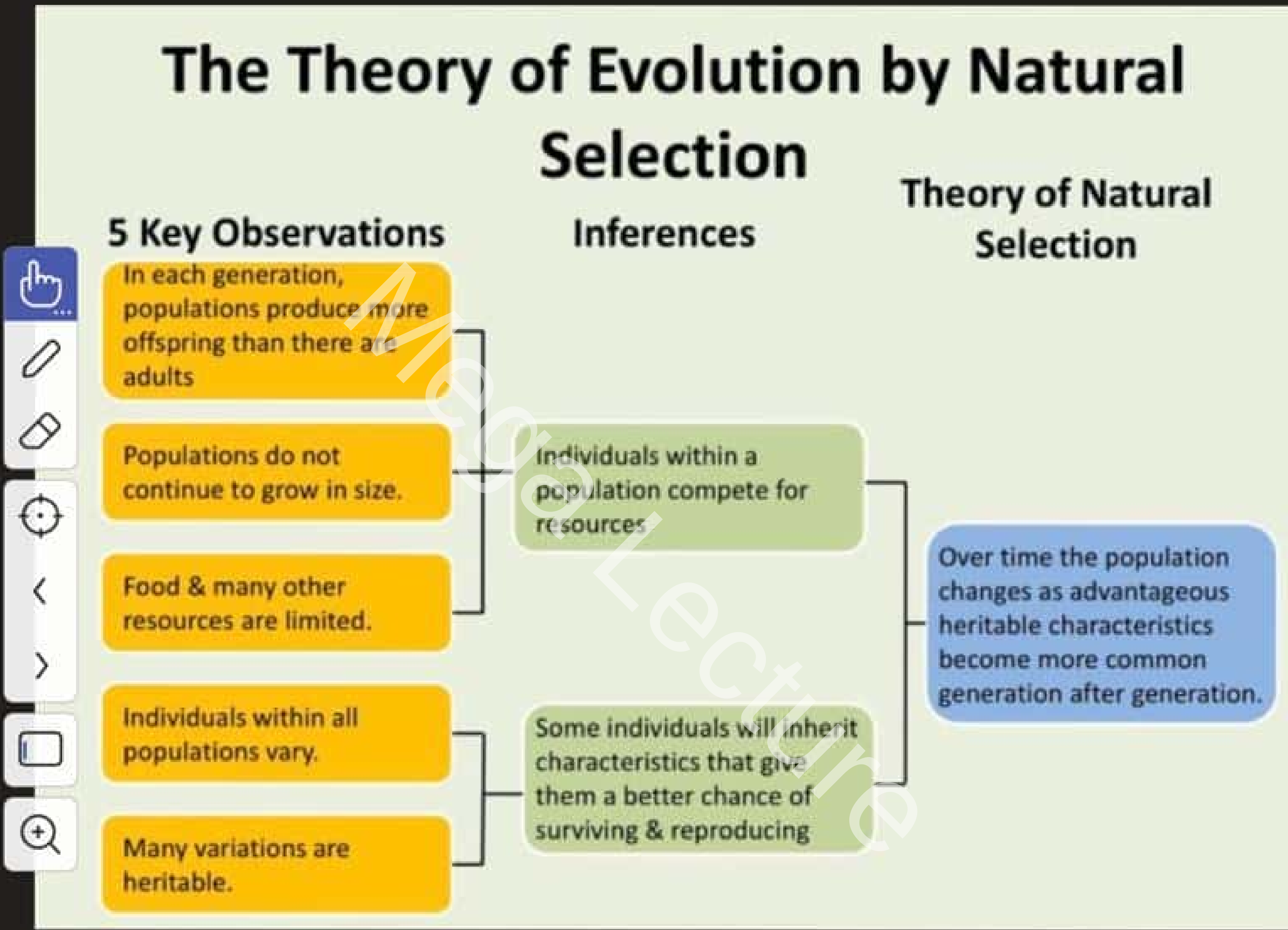
- Organisms produce more offspring than are needed to replace them.
- Natural populations, however, tend to remain stable in size.
- There exists genetic variation b/w organisms of the same species.

The following deductions were made using these observations:

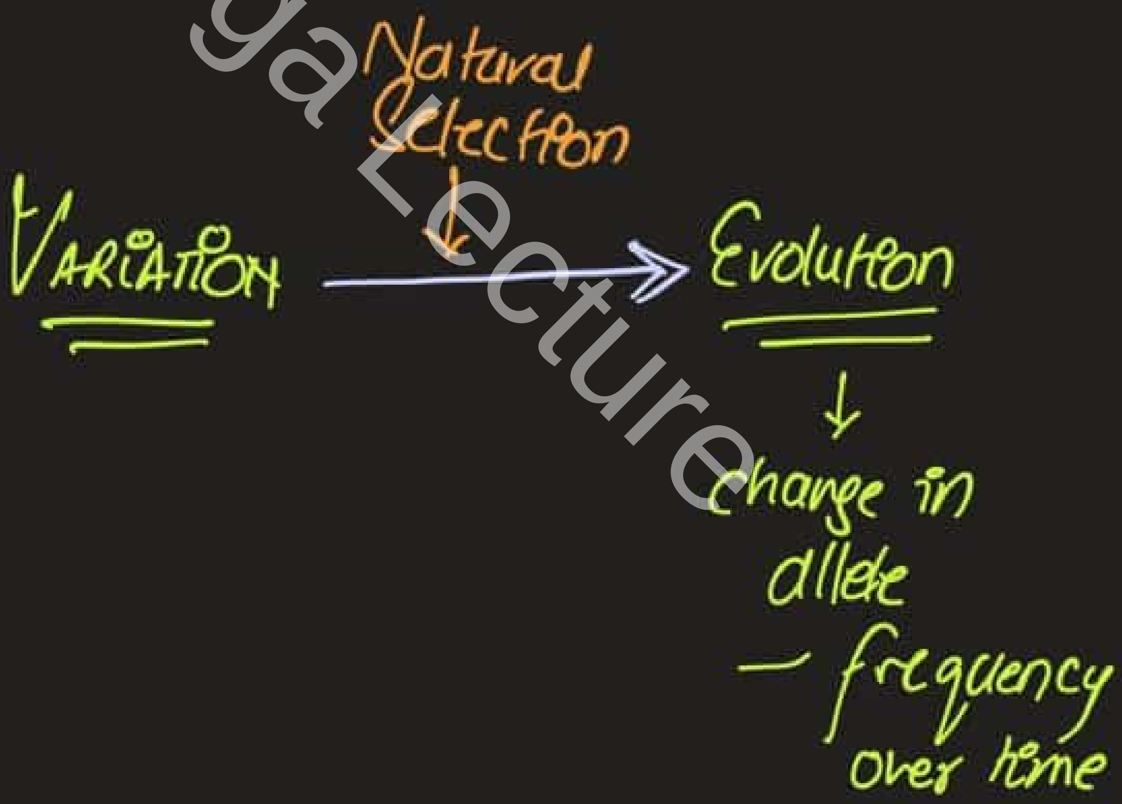
{ competition for resources }

- There is struggle for existence, which is why populations remain stable in size despite their potential to over reproduce.
- Natural selection acts on genetic variation to select for those organisms that have favourable characteristics.....

....Such organisms have advantageous alleles which enables them to adapt better to environmental conditions.


The Theory of Evolution by Natural Selection
5 Key Observations
Inferences
Theory of Natural Selection
In each generation, populations produce more offspring than there are adults
Populations do not continue to grow in size.
Food & many other resources are limited.
Individuals within all populations vary.
Many variations are heritable.
Individuals within a population compete for resources
Some individuals will inherit characteristics that give them a better chance of surviving & reproducing
Over time the population changes as advantageous heritable characteristics become more common generation after generation.

Role of natural selection in evolution



Outline The Role of Natural Selection in Evolution

* Natural Selection acts on variations b/w The organisms within a population.

* Despite The potential To overproduce, population of The organisms remains roughly constant.

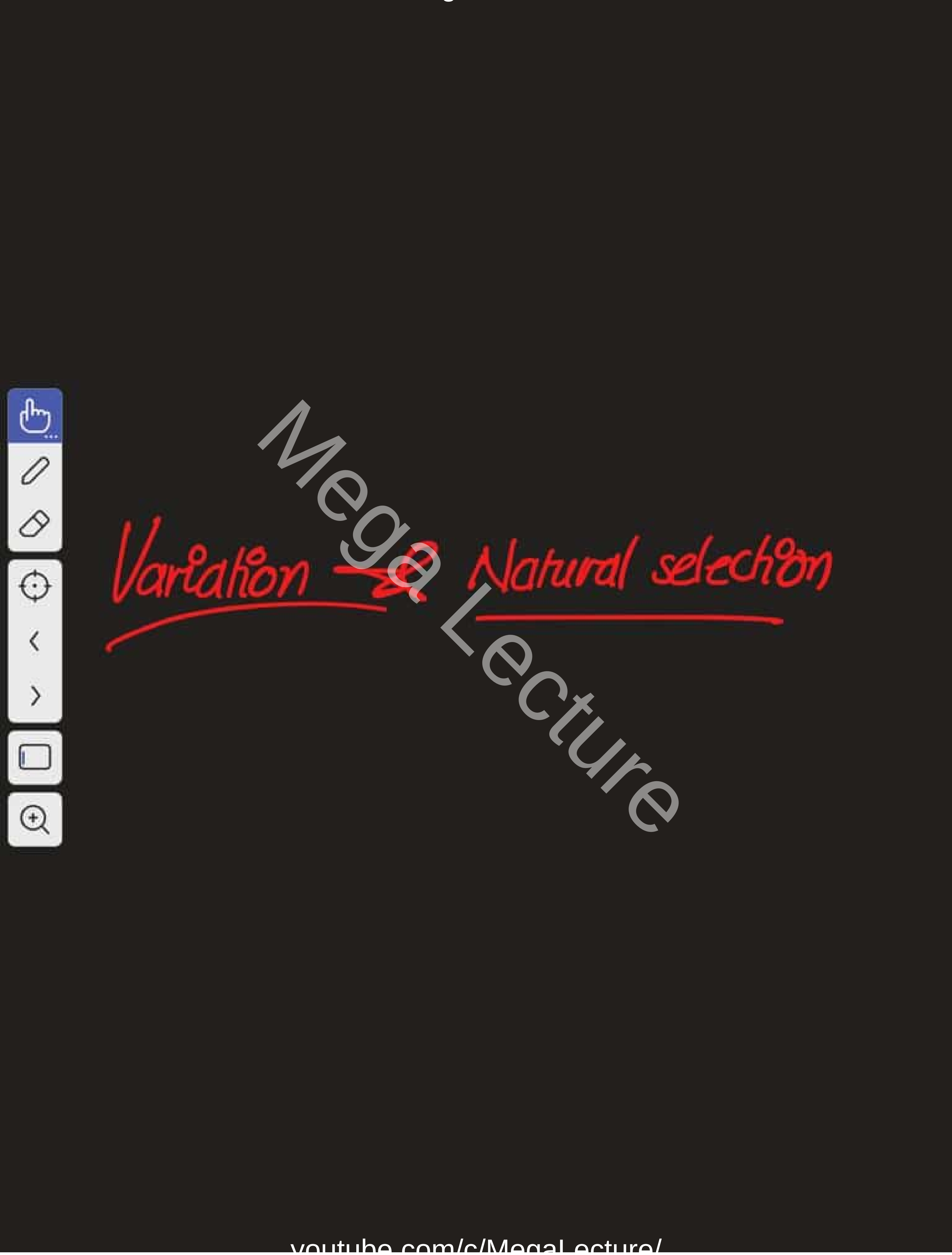
* Organisms that have advantageous alleles are better adapted To survive & reproduce.

* This leads To an increase in the frequency of the advantageous alleles.

* Selection of these advantageous alleles is due to selection pressures, such as, environmental factors.

* Organisms that have disadvantageous alleles fail to survive.

* Over time the change in allele frequency may lead to an evolutionary change & even formation of a new species (speciation).


Variation
Natural selection

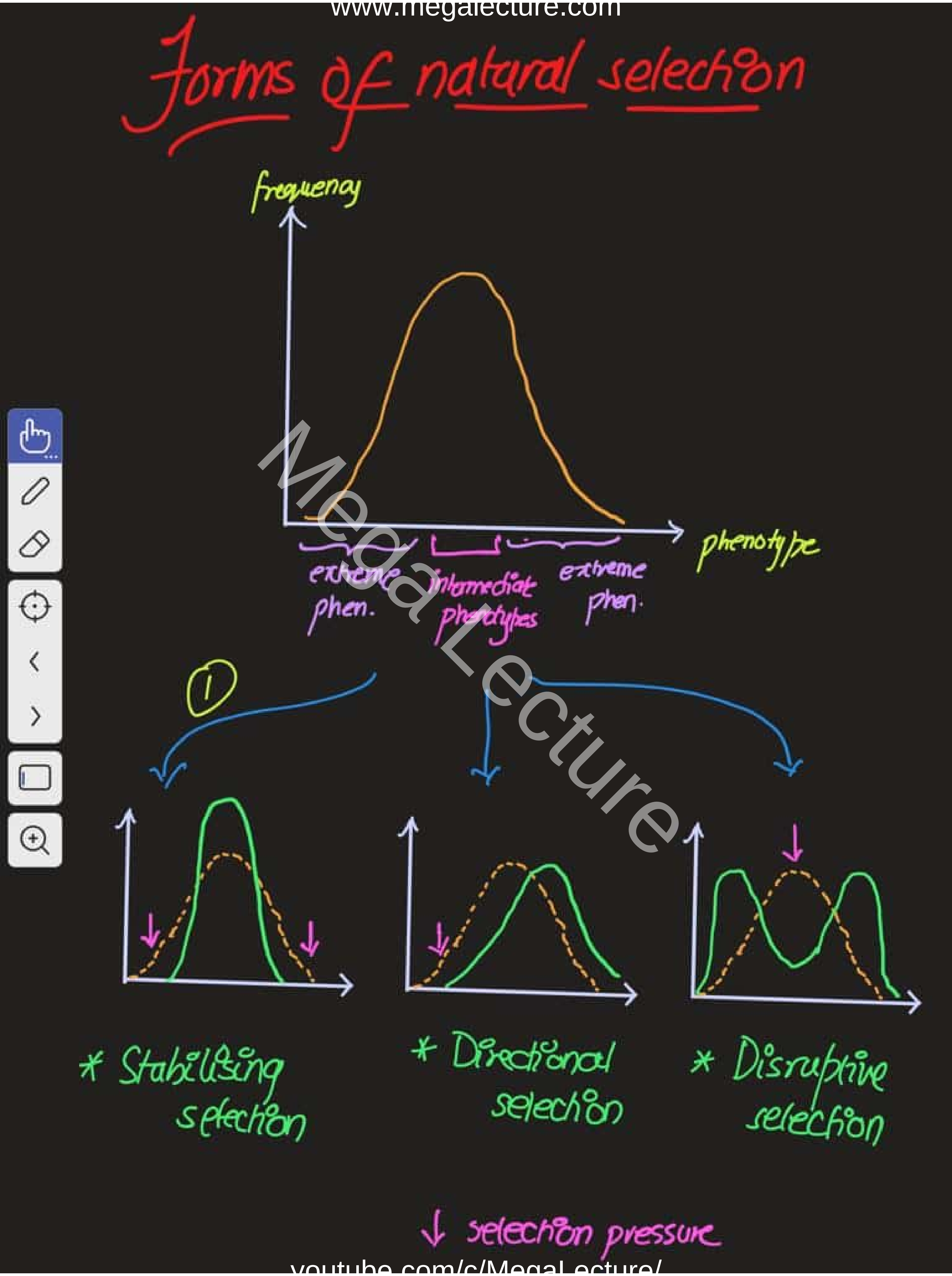
Outline why variation is important in natural selection

* Variation b/w organisms of a population results due to different alleles of the gene as well as environmental factors. It is due to complex interaction b/w the genotype of an individual & its environment. Variation in phenotype is given by the expression:

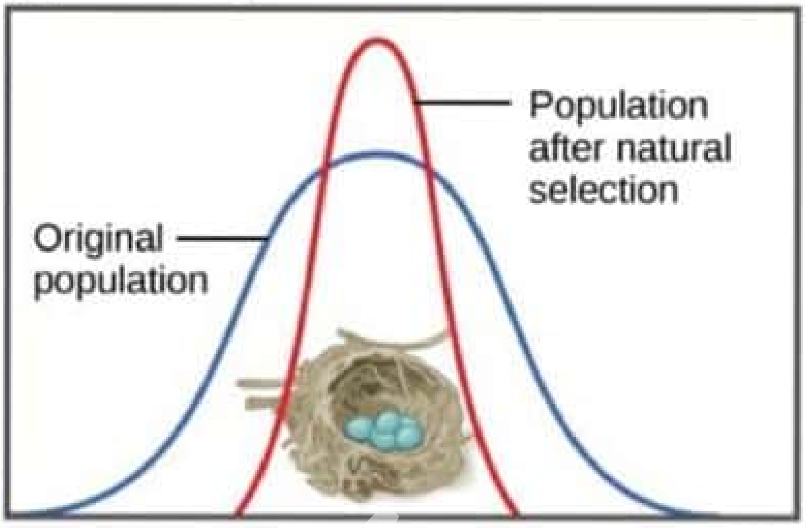
$$V_P = V_G + V_E$$

* Organisms that have a phenotype conferred by advantageous alleles are better able to survive following the struggle for existence

* Organisms that have a phenotype conferred by disadvantageous alleles are less likely to survive & therefore die.

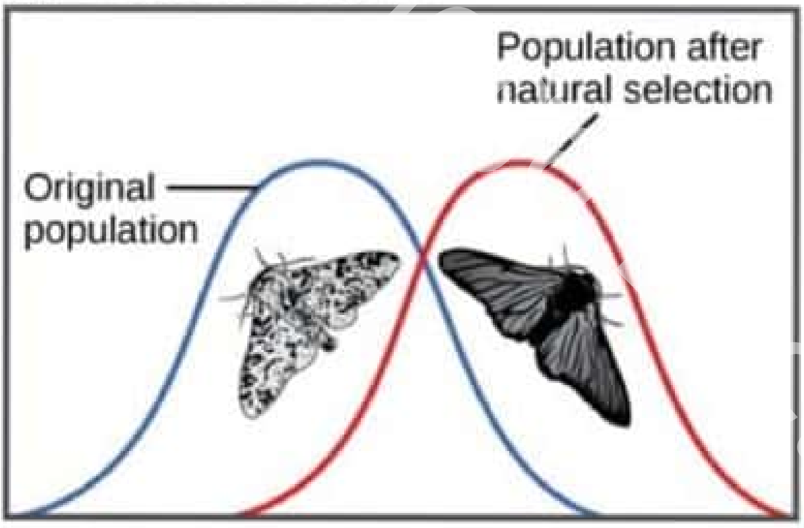

Forms of natural selection
frequency
phenotype
extreme phen.
intermediate phenotypes
extreme phen.
1
* Stabilising selection
* Directional selection
* Disruptive selection
↓ selection pressure

(a) **Stabilizing selection**



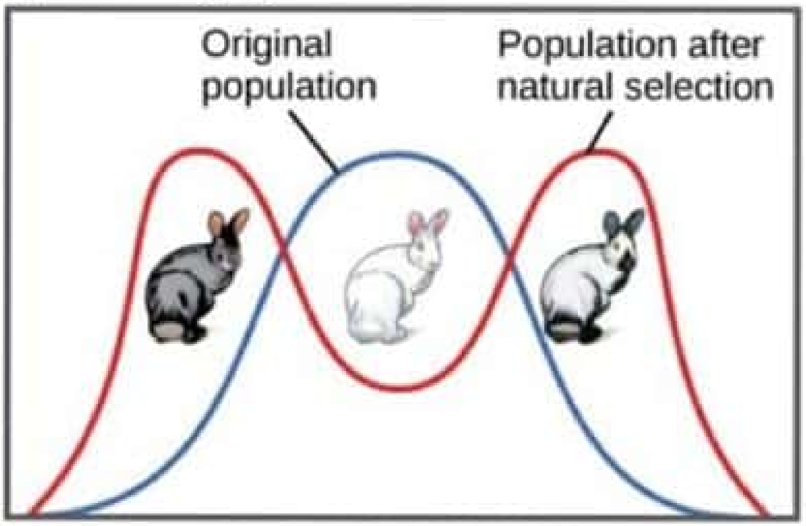
Robins typically lay four eggs, an example of stabilizing selection. Larger clutches may result in malnourished chicks, while smaller clutches may result in no viable offspring.

(b) **Directional selection**



Light-colored peppered moths are better camouflaged against a pristine environment; likewise, dark-colored peppered moths are better camouflaged against a sooty environment. Thus, as the Industrial Revolution progressed in nineteenth-century England, the color of the moth population shifted from light to dark, an example of directional selection.

(c) **Diversifying selection**

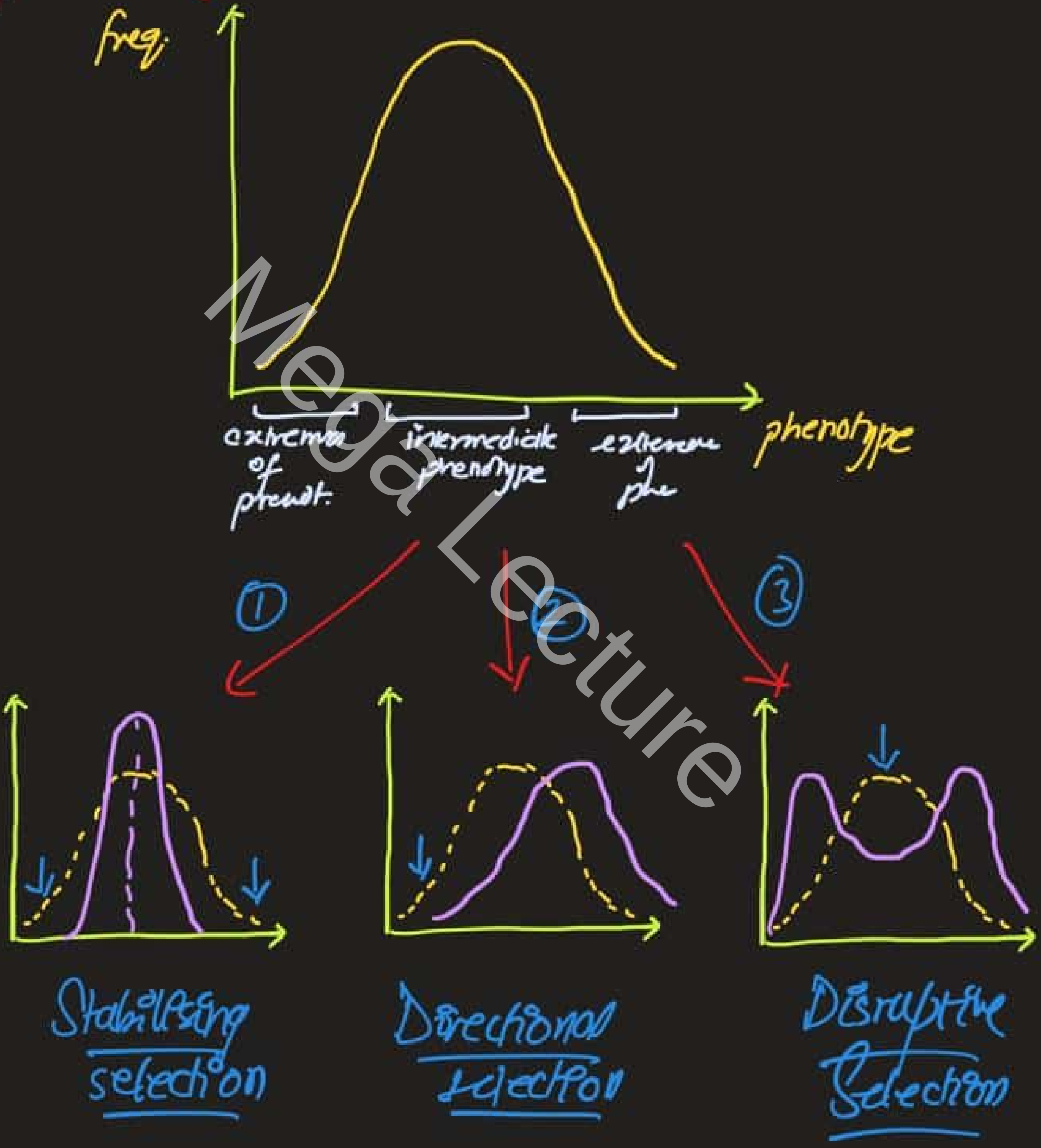


In a hyphothetical population, gray and Himalayan (gray and white) rabbits are better able to blend with a rocky environment than white rabbits, resulting in diversifying selection.

Selection & Evolution

Forms of Natural Selection

Forms of natural selection



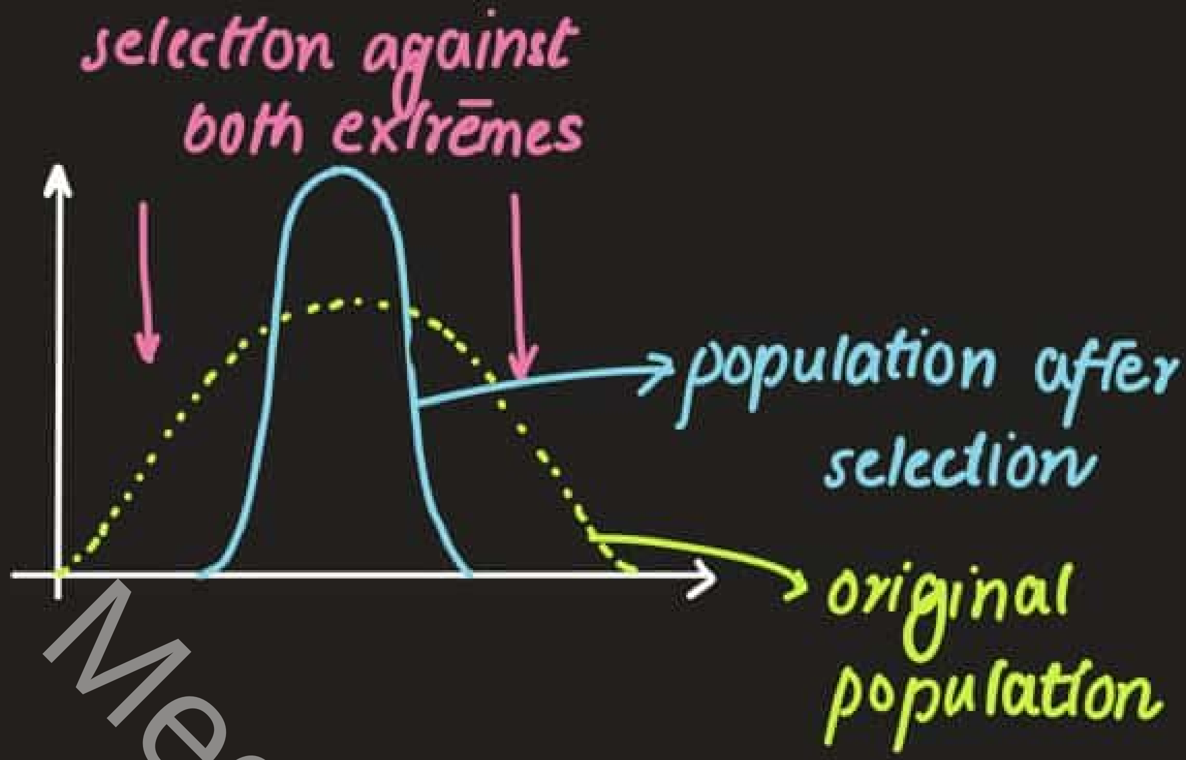
Forms of Natural Selection

- Stabilising Selection
- Directional Selection
- Disruptive Selection

Stabilising Selection

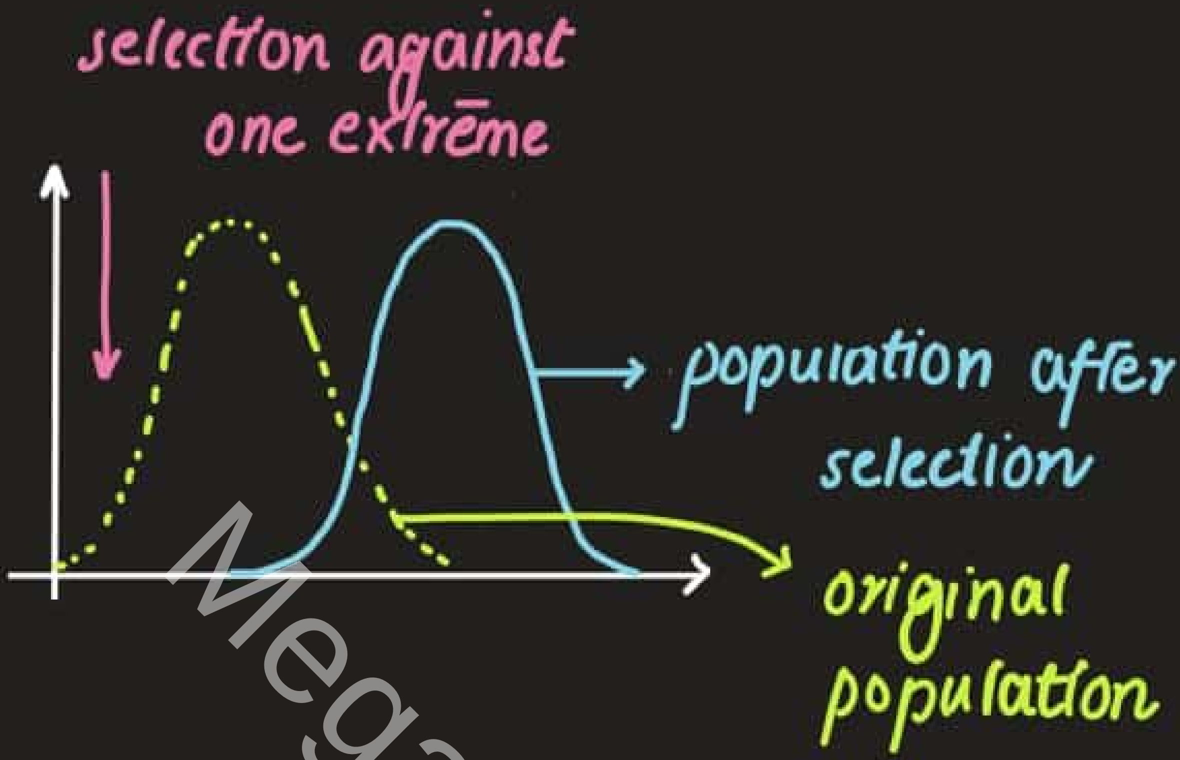
* A population experiences stabilising selection if the selection pressures act on the phenotypic extremes to make the intermediate phenotype more common.

* Examples of stabilising selection:
  - Birth weight in babies
  - Height of trees
  - Sickle cell anaemia


selection against
both extremes
population after
selection
original
population

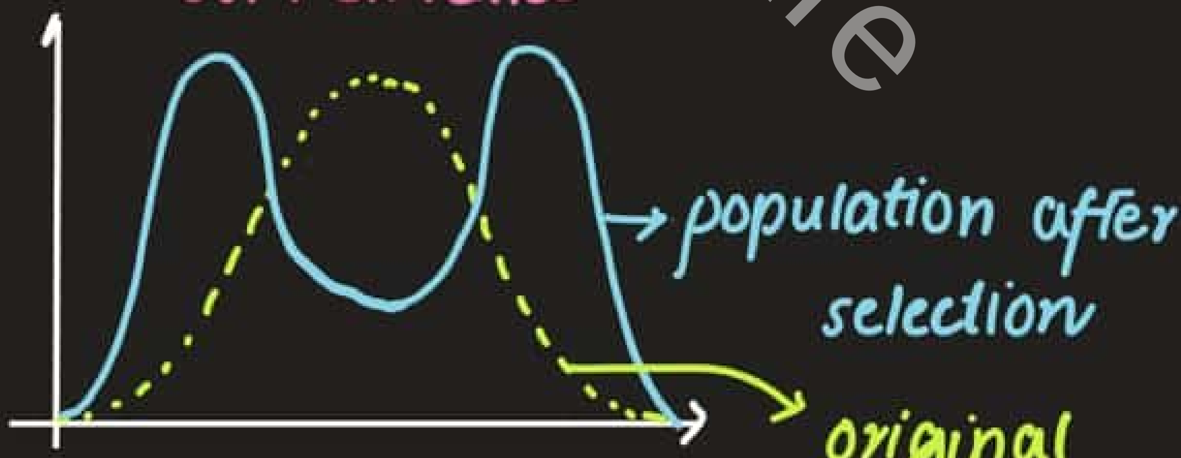
Directional Selection

* A population experiences directional selection if the selection pressure acts on one phenotypic extreme thereafter changing the most common phenotype.
* Directional selection occurs either due to an introduction of a new allele OR due to a new environmental factor.
* Examples of directional selection:
  - Antibiotic resistance (due to a new allele)
  - Industrial melanism (due to a new environmental factor)


selection against one extreme
population after selection
original population

Disruptive Selection

- A population experiences disruptive selection when the selection pressure acts on the intermediate phenotype to make the phenotypic extremes more common.
- Examples of disruptive selection are rare.



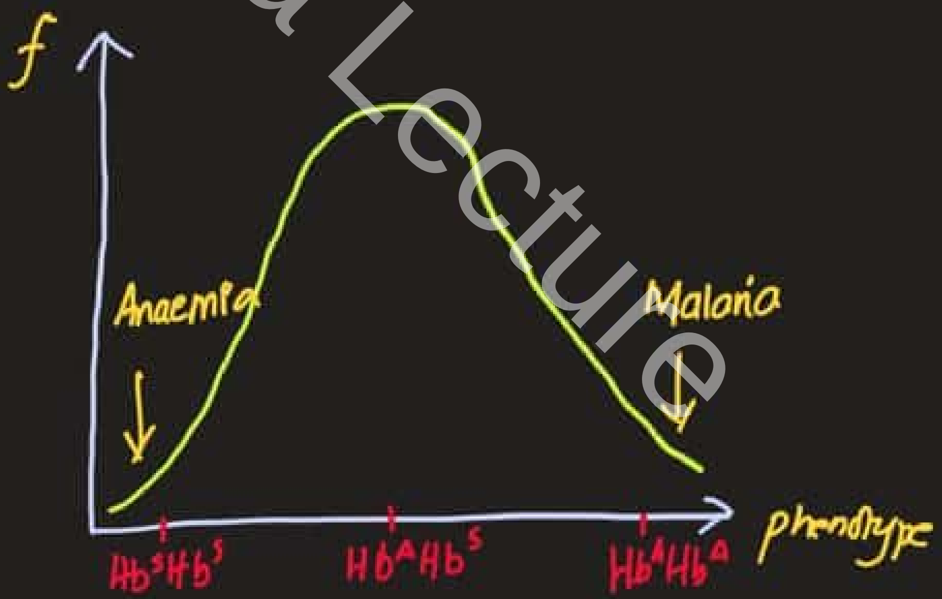
Examples

1. Sickle Cell Anaemia (stabilising)
2. Industrial Melanism (directional)
3. Antibiotic resistance (directional)

Sickle Cell Anaemia → a case of stabilising selection

↓

* applicable in parts of the world where malaria is endemic
* In regions where malaria is common, both Hb^A and Hb^S alleles exist



Sickle Cell Anaemia (Stabilising Selection)

- Frequency of this sickle cell allele is very high in some parts of the world e.g. East Africa.

- 50% carriers and 14% homozygous sickle cell allele.

- The parts of the world where malaria is found....

- People who are heterozygous for the sickle cell allele are less likely to suffer serious attack of malaria.

* In a study, 1 out of 100 children who died from malaria are normal homozygotes.

* There are two strong selection pressures acting on the sickle cell alleles;

- Selection against people who are homozygous for the sickle cell allele (die due to anaemia)

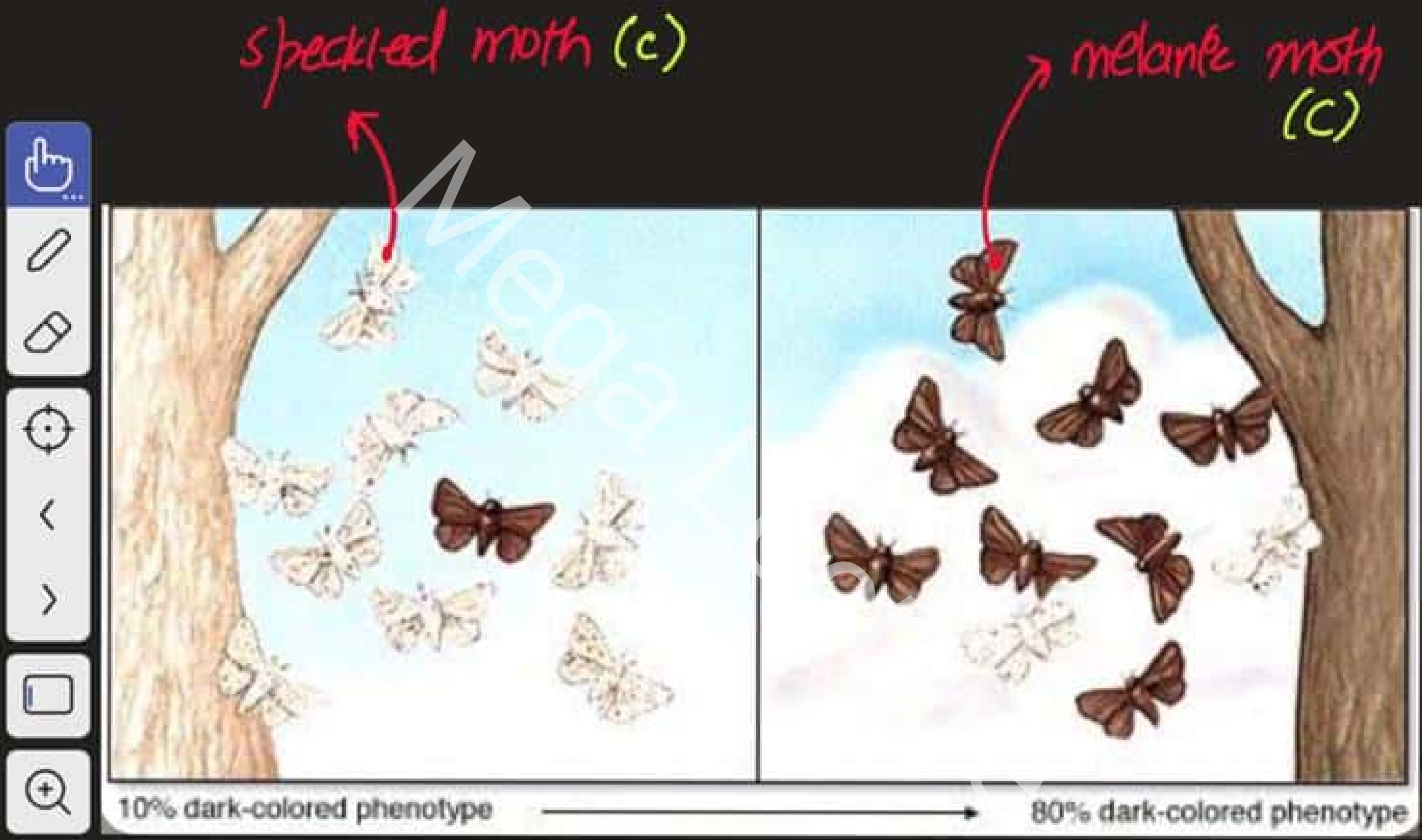
- Selection against those who are homozygous for the normal allele (die due to malaria)

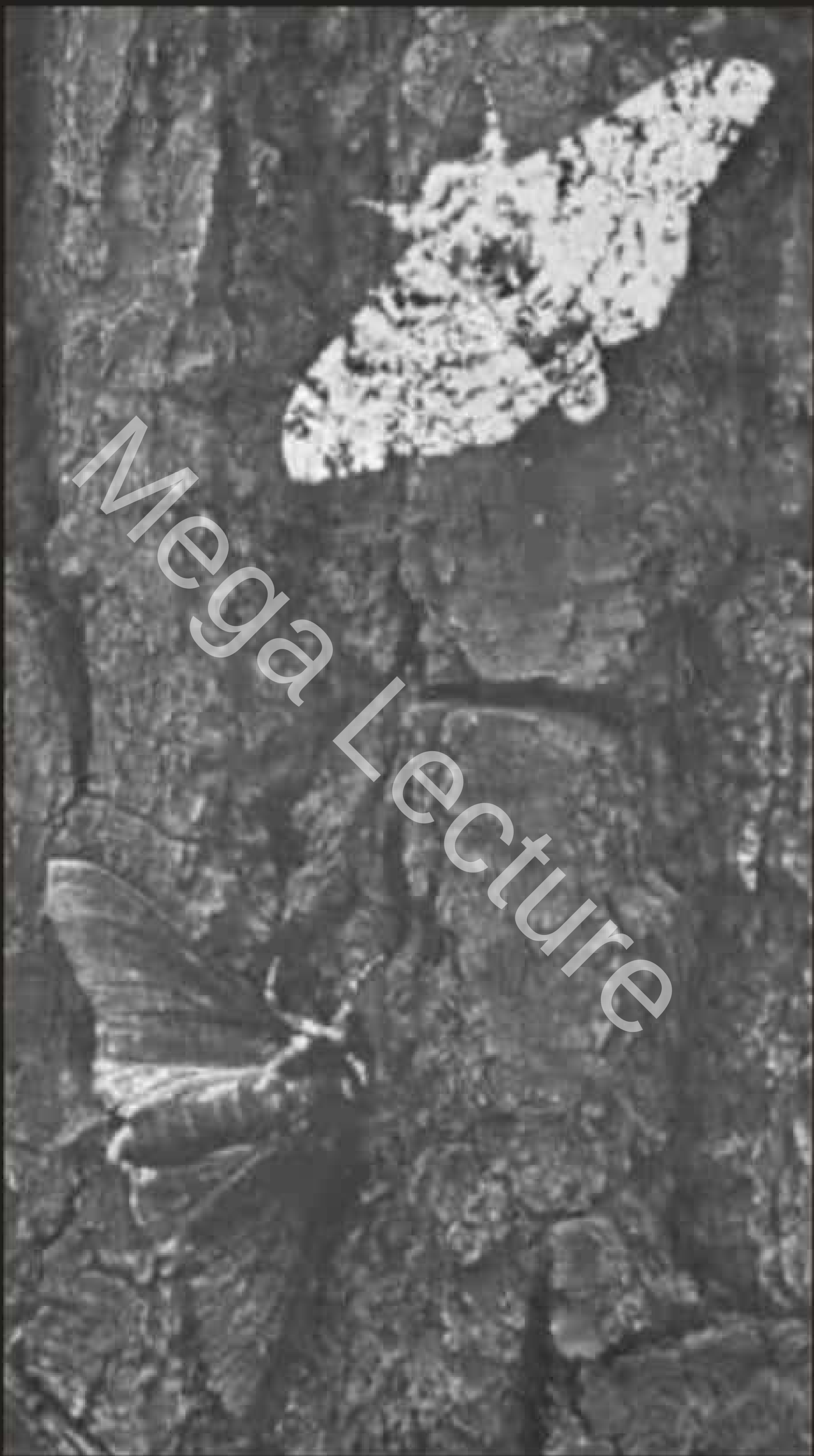
* Heterozygotes have a strong selective advantage

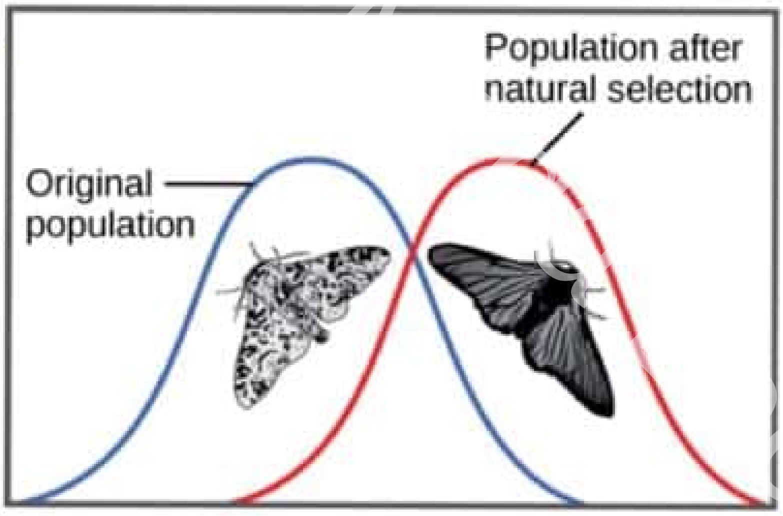
* Malaria is the environmental factor, causing both alleles to remain in the population.

* Places with no malaria only have selection against people with homozygous sickle cell allele, thus the Hb^S allele is almost removed from the population.

Industrial melanism → a case of directional selection


speckled moth (c)
melanic moth
(C)
10% dark-colored phenotype
80% dark-colored phenotype





Light-colored peppered moths are better camouflaged against a pristine environment; likewise, dark-colored peppered moths are better camouflaged against a sooty environment. Thus, as the Industrial Revolution progressed in nineteenth-century England, the color of the moth population shifted from light to dark, an example of directional selection.

Industrial Melanism (Directional Selection)

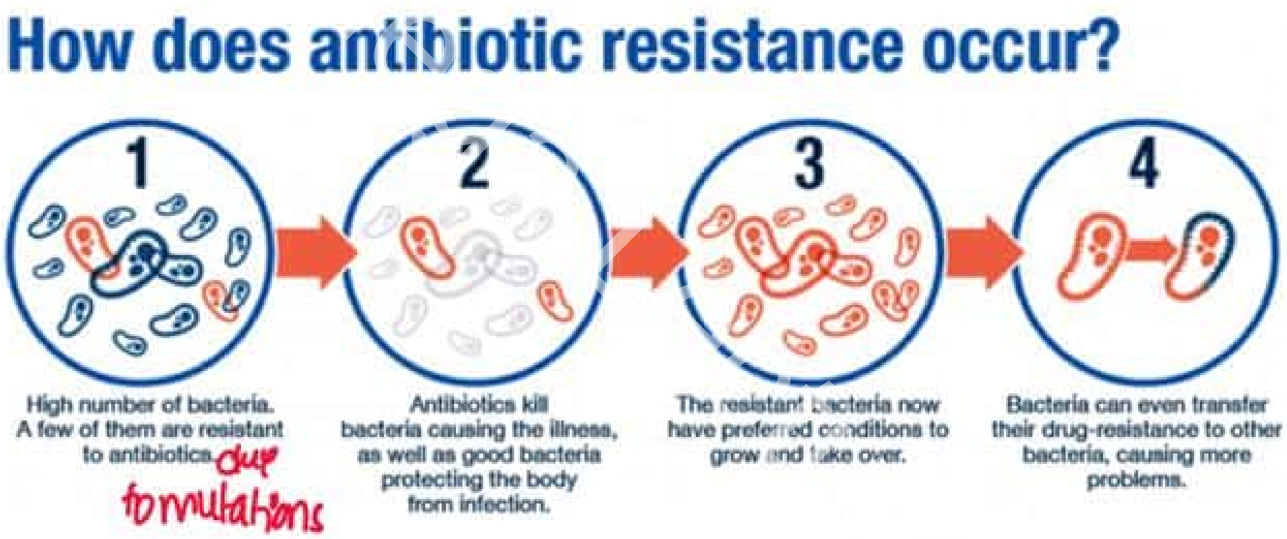
* Peppered moth Bislōn Betaluria is a night flying moth.
* It spends the day resting on the branches of trees, so it relies on camouflage to protect it from insect eating birds which hunt by sight.
* In UK, until the year 1849, all specimens of this moth collected are speckled moths (pale wings with dark markings)
* In 1849, a black (malanic) moth was caught near Manchester.

* The numbers of black moths increased dramatically in some areas.
* The speckled moth remains the more common in other parts of the country.
* The difference in black and speckled forms of the moth is caused by a single gene.
* The normal speckled colouring is produced a recessive allele of this gene, c, while the black colour is produced by the dominant allele C

* The selection pressure causing the change of allele frequency in industrial areas was predation by birds.
* Allele C (black) is more frequent near industrial areas.
* Allele c (speckled) is more common in non-industrial areas.
* In areas with unpolluted air, tree branches are often covered with grey-brown & green lichen (here speckled moths are very well camouflaged)

* However, lichens, fungus & green algae are very sensitive to pollutants such as sulfur dioxide.
* So trees in these (industrial) areas have less lichen.
* Hence the bark of these trees appear darker and here dark moths are better camouflaged
* Changes in environmental factors affect the likelihood of an allele surviving in a population.

Antibiotic resistance → a case of directional selection


How does antibiotic resistance occur?
1
2
3
4
High number of bacteria. A few of them are resistant to antibiotics.
due to mutations
Antibiotics kill bacteria causing the illness, as well as good bacteria protecting the body from infection.
The resistant bacteria now have preferred conditions to grow and take over.
Bacteria can even transfer their drug-resistance to other bacteria, causing more problems.

Antibiotic Resistance (Directional Selection)

* We will use penicillin as an example.
* If someone takes penicillin to treat bacterial infection, bacteria which are sensitive to penicillin die.
* There may be one or more individual bacteria with penicillin resistant allele.
* For e.g, Staphylococcus produce Penicillinase which inactivates Penicillin.

* Since bacteria have only one copy of each gene, so any bacterium possessing this allele will be resistant to penicillin.

* These individual bacteria will have a selective advantage.

* The bacteria without this allele will be killed.

* Those resistant to penicillin can survive & reproduce.

* By using antibiotics, we change the environmental factors that exert a selection pressure on bacteria.

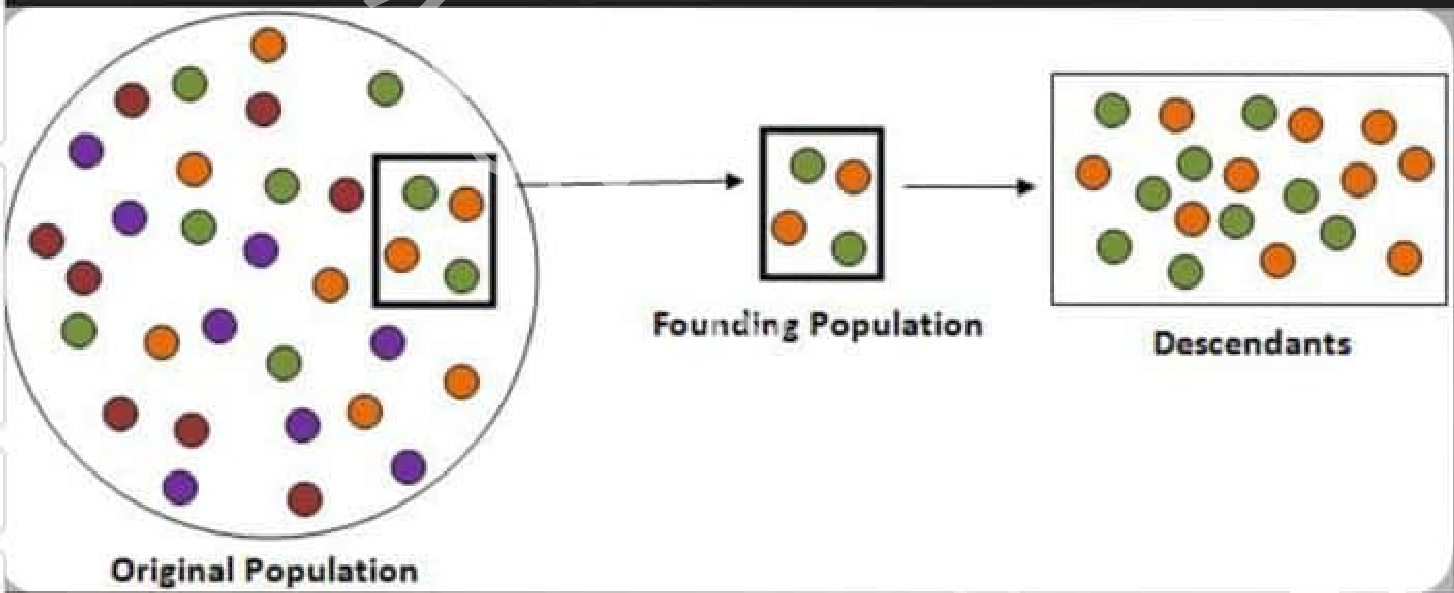
* Antibiotic resistant alleles often occur on plasmids.
* Plasmids can be transferred even to different species.

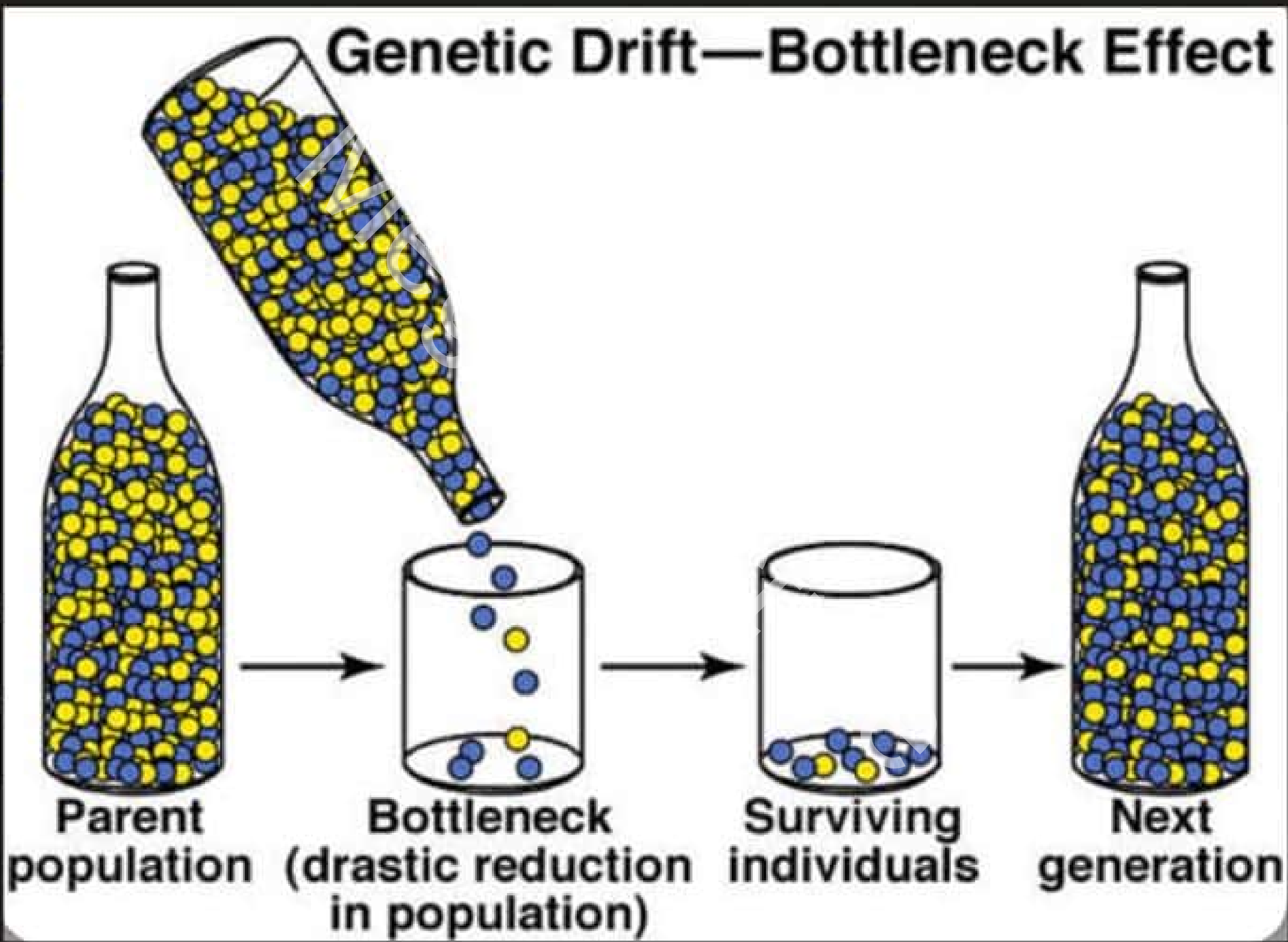
FOUNDER EFFECT → GENETIC DRIFT ← Bottleneck effect

GENETIC DRIFT

* change in allele frequency due to a CHANCE event.
* random process
* non-directional

GENETIC DRIFT ⇒ FOUNDER EFFECT




Genetic Drift—Bottleneck Effect
Parent population
Bottleneck (drastic reduction in population)
Surviving individuals
Next generation

GENETIC DRIFT :

- Genetic drift is defined as a change in allele frequency that occurs due to chance.
- Genetic drift usually occurs when a small group of organisms are segregated from a large population.
- This small group of organisms is more likely to have alleles which are different from a larger population.
- This change in allele frequency in a small isolated population is termed as Founder Effect.

* Genetic drift may also occur due to a bottle neck effect.

Founder Effect vs Bottleneck Effect

More Information Online WWW.DIFFERENCEBETWEEN.COM

	Founder Effect	Bottleneck Effect
DEFINITION	Founder effect is a phenomenon that causes genetic drift due to splitting off a small group from the main population to establish a colony	Bottleneck effect is a phenomenon that causes genetic drift due to the contraction of the population into a small size as a result of a natural disaster
CAUSE	Due to the separation of a small group of individuals from a larger population and colonization	Due to the destruction of most of the individuals of a population by natural disasters
INVOLVEMENT OF NATURAL DISASTERS	Not involved	Arises due to natural disasters

Natural Selection Vs Genetic Drift

Q: Compare & Contrast the processes of Natural Selection & Genetic Drift?

SIMILARITIES:

* Both involve a change in allele frequency
* Both may lead to evolutionary changes.

DIFFERENCES:

Natural Selection	Genetic Drift
• Natural selection operates to select for advantageous alleles	• Genetic drift may select for advantageous or disadvantageous alleles.
• Natural Selection is a directed & non-random process.	• Genetic drift is non-directional & random process
• Natural Selection involves adaptation	• Genetic drift does not involves adaptation.

ARTIFICIAL SELECTION

* selection pressure exerted by humans
* to select for traits that are of benefit to human.

Artificial Selection

* Artificial selection is a process in which humans exert the selection pressure to select for traits that are of benefits to humans.

Artificial selection involves selective breeding which can be summarised as below:

a) Parents with desirable traits are selected & interbred.

b) Offspring that have desirable features are again selected & interbred.

c) This is repeated over many generations to get organisms with favorable characteristics.

* Artificial selection has been commonly used to breed cattle to produce strains with:

a) Higher milk yields

b) Greater meat production

c) Higher Docility.

* Artificial selection is responsible for decreasing genetic variation, increasing homozygosity & inbreeding depression.

↳ decreased ability to survive due to reduced biological fitness.

Challenges faced by a selective breeder....

* The challenges that a selective breeder faces can be summarised as:

a) The slow growth rate of selectively bred organisms until they reach their mature size.

b) Long gestation periods.

c) The no. of organisms produced is small.

* Organisms that are better adapted to environmental conditions are selected for breeding. Genes that increase the stability of an organism to survive in given environmental conditions are known as the background genes.

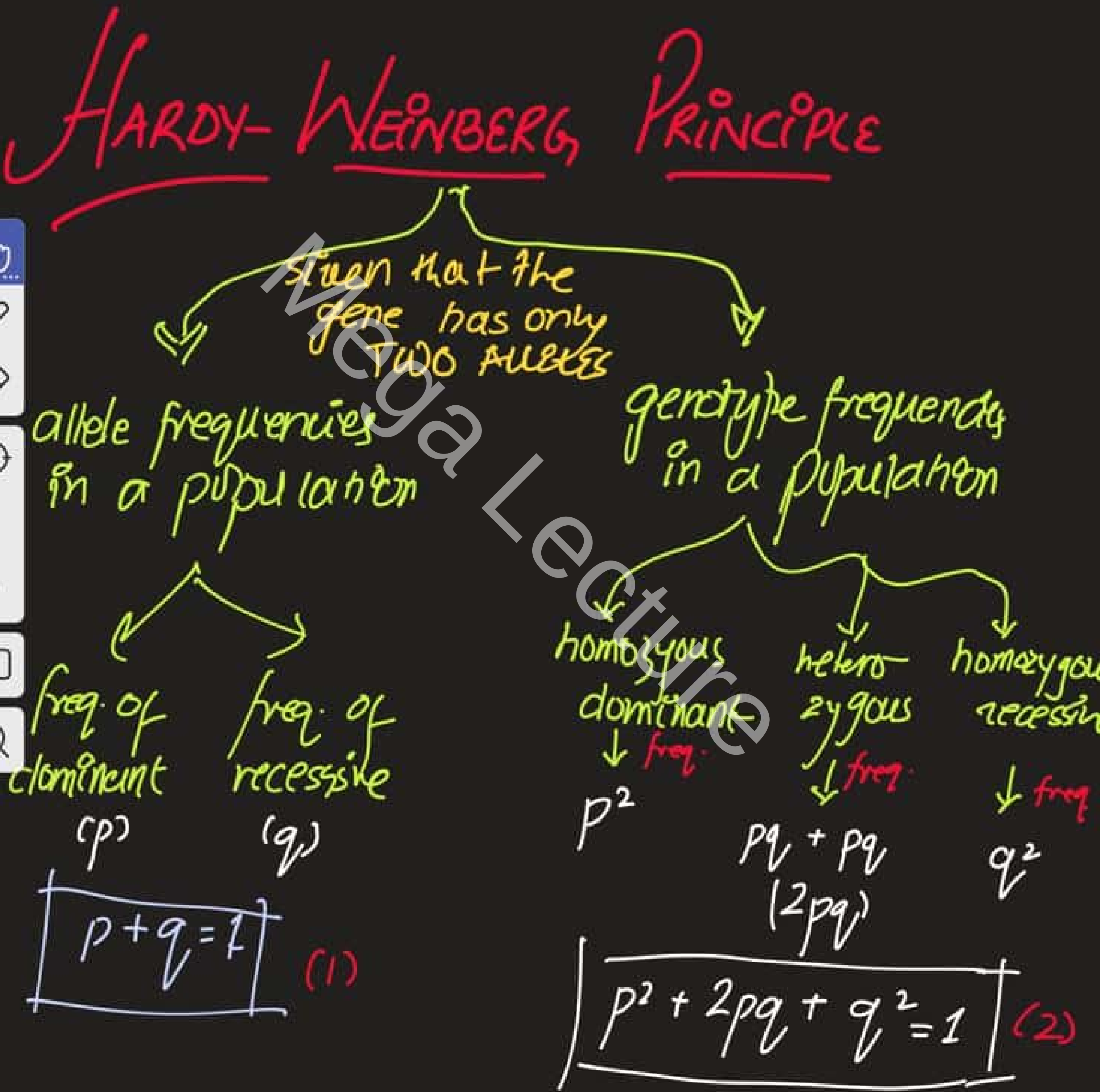
* Progeny testing refers to the testing of selectively bred offspring for sex-limited traits, such as, milk yield to select for the parent with the more desirable feature.

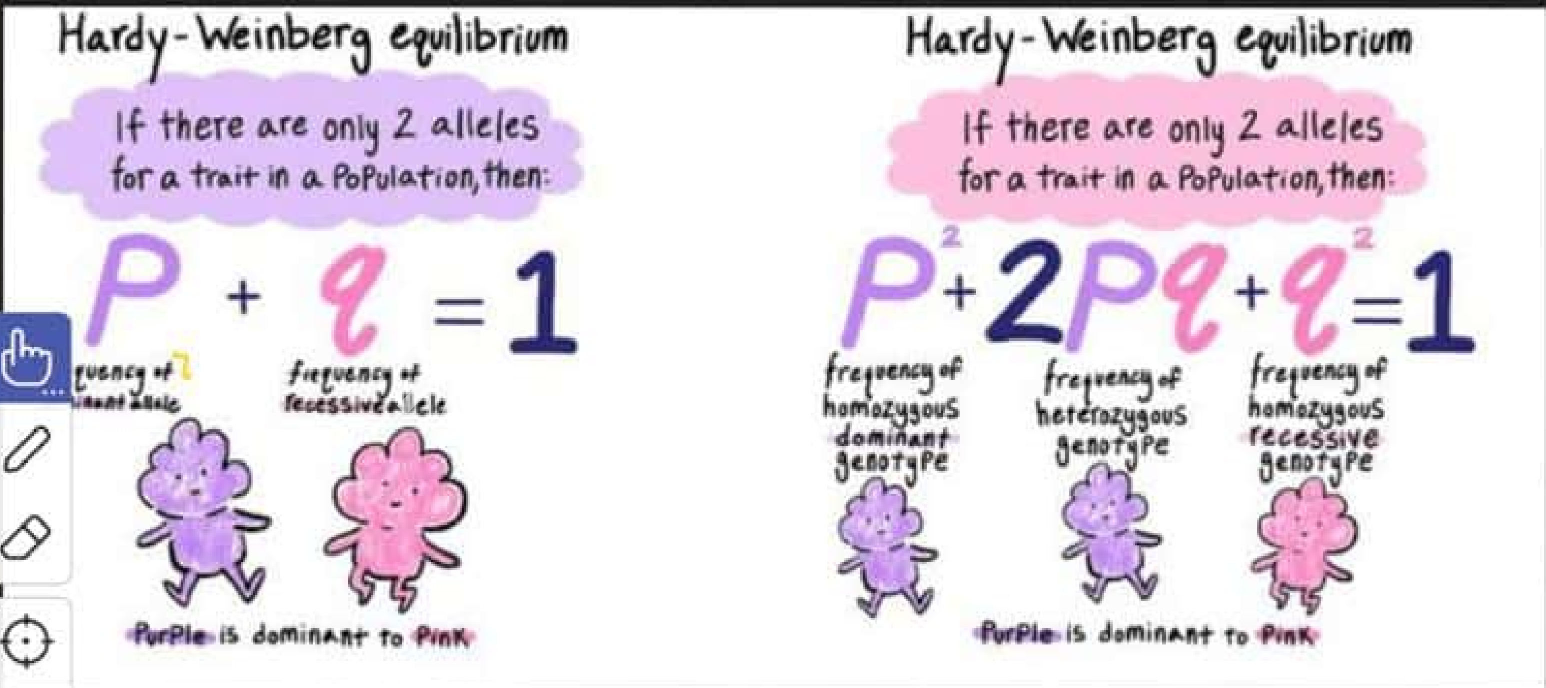
Natural Selection Vs Artificial Selection

Q: Enlist the differences b/w Natural Selection & Artificial Selection?

Natural Selection	Artificial Selection
• The selection pressure is exerted by the environment.	• The selection pressure is exerted by human beings.
• Selects for alleles that are of benefit to the organisms.	• Selects for alleles that are of benefit to humans.
• Slow process	• Fast process
• Increases genetic variation.	• Decreases genetic variation.
• Increases heterozygosity	• Decreases heterozygosity

Natural Selection	Artificial Selection
• Promotes outbreeding enhancement (Hybrid Vigor) - high growth rate & high reproductive rate.	• Promotes inbreeding depression.


HARDY-WEINBERG PRINCIPLE
given that the gene has only TWO ALLELES
allele frequencies in a population
genotype frequencies in a population
freq. of dominant (p)
freq. of recessive (q)
p+q=1
(1)
homozygous dominant
freq.
p²
hetero zygous
freq.
pq + pq
(2pq)
homozygous recessive
freq.
q²
p² + 2pq + q² = 1
(2)



Hardy Weinberg principle states:

$$p + q = 1$$

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

HARDY-WEINBERG PRINCIPLE

* The Hardy-Weinberg principle is used for calculating the genotype & allele frequencies in a large randomly mating population.

* Given that a phenotype trait is determined by two alleles, a dominant allele (B), and a recessive allele (b), the proportion of these alleles in a population will always add up to be 1.

* If the frequency of the dominant allele is given by p and the frequency of the recessive allele is given by q, $p+q=1$

* Given that a phenotype is only determined by a dominant & a recessive allele, the only possible genotypes in a population are:

a) BB – homozygous dominant

b) Bb – heterozygous

c) bb – homozygous recessive

* Proportion of individuals with the genotype BB will be equal to $p \times p = p^2$.

* Proportion of individuals with the genotype bb will be equal to $q \times q = q^2$.

* Proportion of individuals with the genotype Bb will be equal to $(p \times q) + (q \times p) = 2pq$.

(The value 2pq indicates that the dominant allele and recessive allele can be inherited from either parent)

* The proportion of all the genotypes in a population will add up to 1 as given by the following expression:

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

- The Hardy-Weinberg principle only applies if:

a) The population is large.

b) The mating is random.

- The frequency of alleles & the genotypes can be determined if the proportion of organisms with the recessive phenotype is given.

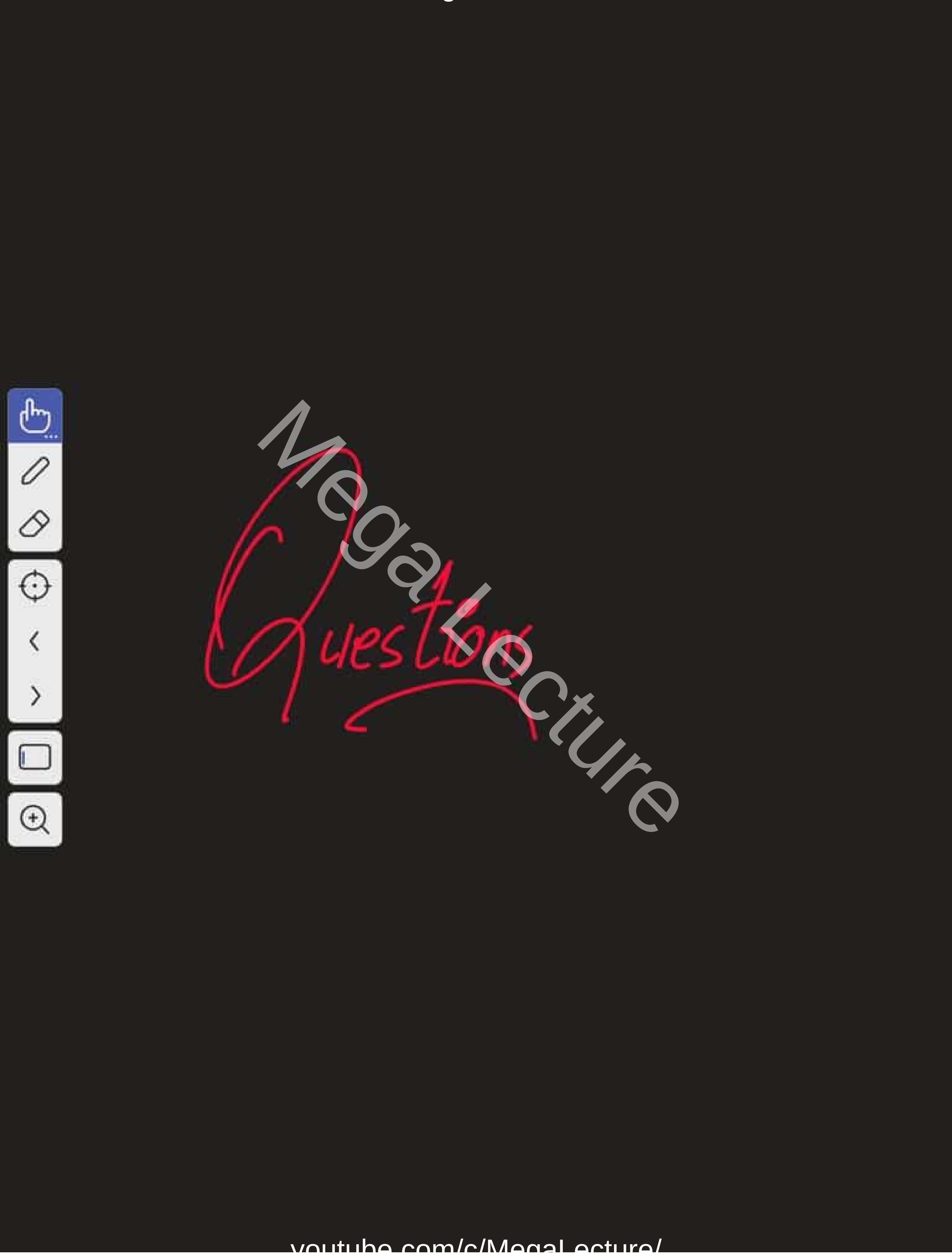
* The Hardy-Weinberg principle is not suitable if:

a) The population is small.

b) The mating is non-random

c) There is a migration of organisms into out of a population which may alter allele frequency.

d) If there is a selection pressure acting against a particular phenotype.


Questions

Q.

2 Scientists have found very little evolutionary change in populations of two Australian songbirds, the zebra finch, *Taeniopygia guttata castanotis*, and the budgerigar, *Melopsittacus undulatus*.

(a) Describe the process of evolution by natural selection.

* population shows genetic variation
* nature exerts selection pressure to select
* for organisms that have advantageous alleles
* these organism survive and reproduce
* thereby changing the allele frequency with time

[4]

(c) The Hardy–Weinberg principle is used to calculate allele, genotype and phenotype frequencies in populations.

- A breeder of birds keeps a population of 86 budgerigars in one enclosed area.
- Two distinct phenotypes are present, blue feathers and green feathers.
- Feather colour is controlled by one gene:
  - **G** is the allele for green feathers
  - **g** is the allele for blue feathers.
- Only 17 of the budgerigars have blue feathers.

(i) The Hardy–Weinberg equations are shown in Fig. 2.2.

$$p + q = 1$$

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

Fig. 2.2

Calculate the number of heterozygous individuals in the population.

Show your working.

$q^2 = 17/86 = 0.198$

$q = \sqrt{17/86} = 0.45$

$p + q = 1 \Rightarrow p = 1 - 0.45 = 0.55$

no. of heterozygous ind. = $2pq \times 86 = 2(0.55)(0.45) \times 86 =$

number = 42 [3]

(ii) The Hardy–Weinberg principle cannot be applied to all populations.

State **two** conditions when the Hardy–Weinberg principle **cannot** be applied.

1 small populations

2 non-random mating

[2]

3 An investigation was carried out into the population of a species of vole in one area of the USA. The population was sampled during the first two weeks of August between 1983 and 2004. Traps for catching small mammals were placed at equal distances along the same parallel line transects. Each year, the number of voles caught per 1000 traps was recorded.

Fig. 3.1 shows the results.

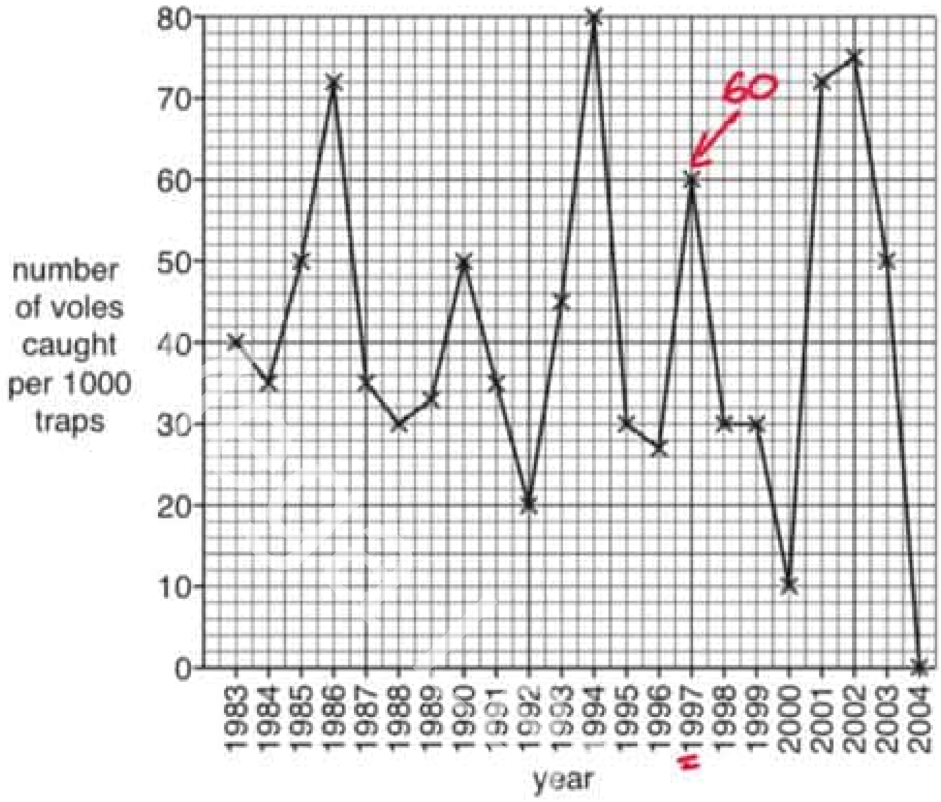


Fig. 3.1

(a) Identify three ways in which this investigation has been standardised.

1 Investigation was carried out at the same time each year in the first two weeks of August

2 traps were equally spaced along the transects

3 same number of traps were used

[3]

(b) Over the period of the study, it was found that 8 out of every 50 voles in this population had black fur, whilst all the other voles had brown fur.

Fur colour in voles is controlled by a single gene, **A/a**. Voles with black fur have the genotype **aa**.

The Hardy-Weinberg principle states that:
$p + q = 1$
$p^2 + 2pq + q^2 = 1$
p = the frequency of the dominant allele
q = the frequency of the recessive allele

Use the Hardy-Weinberg principle to calculate the expected number of voles heterozygous for fur colour that were recorded in 1997.

Give your answer to the nearest whole number.

$q^2 = 8/50 = 0.16$

$q = 0.4$

$p + q = 1 \Rightarrow p = 0.6$

no. of heterozygous voles $= 2pq \times 60$

$= 2(0.6)(0.4) \times 60$

number of voles per 1000 traps which are heterozygous for brown fur in 1997 = ...29.... [3]

SPECIATION

Speciation

Speciation refers to the evolution of new species resulting due to reproductive isolation.

Defining the term species.....

* Species is defined as a group of organisms that have similar morphological (1), physiological (2), biochemical (3) and behavioral (4) features & possess the ability to interbreed to produce fertile offsprings. All organisms of the same species are reproductively isolated.

* Morphological features refers to the structural or anatomical features of an organism. Morphological features are the easiest way of assessing similarities b/w organisms.

* Physiological features refers to the normal functioning of the body, for example, muscle contraction, enzyme catalysed reactions, nervous communications & hormonal systems are all part of the physiology of an organism.

* Biochemical features refer to the sequence of amino acids in polypeptides & the sequence of nucleotides in nucleic acid. Greater the similarity b/w the amino acid sequences &/or the nucleotide sequences the more recent are the ancestors of two or more species.

Behavioral features refer to their breeding seasons & mating behaviour.

* The most important feature which distinguishes organisms of different species is their failure to interbreed to produce fertile offspring. It is not easy, however, to determine if two organisms can interbreed to produce fertile offspring due to following reasons:

1) Organisms may be of the same sex.
2) They may be dead.
3) The male & female reproductive organs may be incompatible.
4) The biologists may not have time or resources to carry out interbreeding.

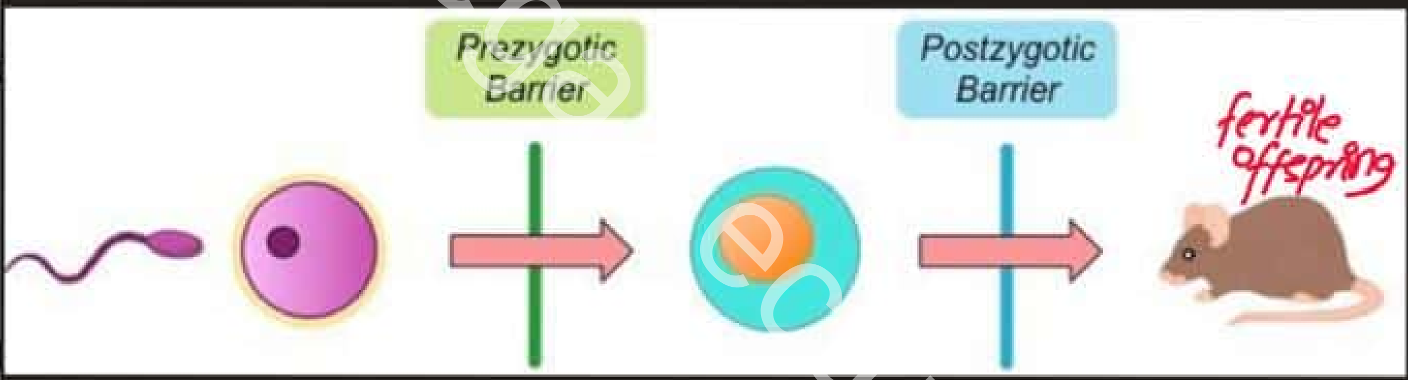
* Evolution of new species results due to reproductive isolation. Reproductive isolating mechanisms may be subdivided into two broad categories:

a) Pre-zygotic Isolating Mechanism

b) Post-zygotic Isolating Mechanism

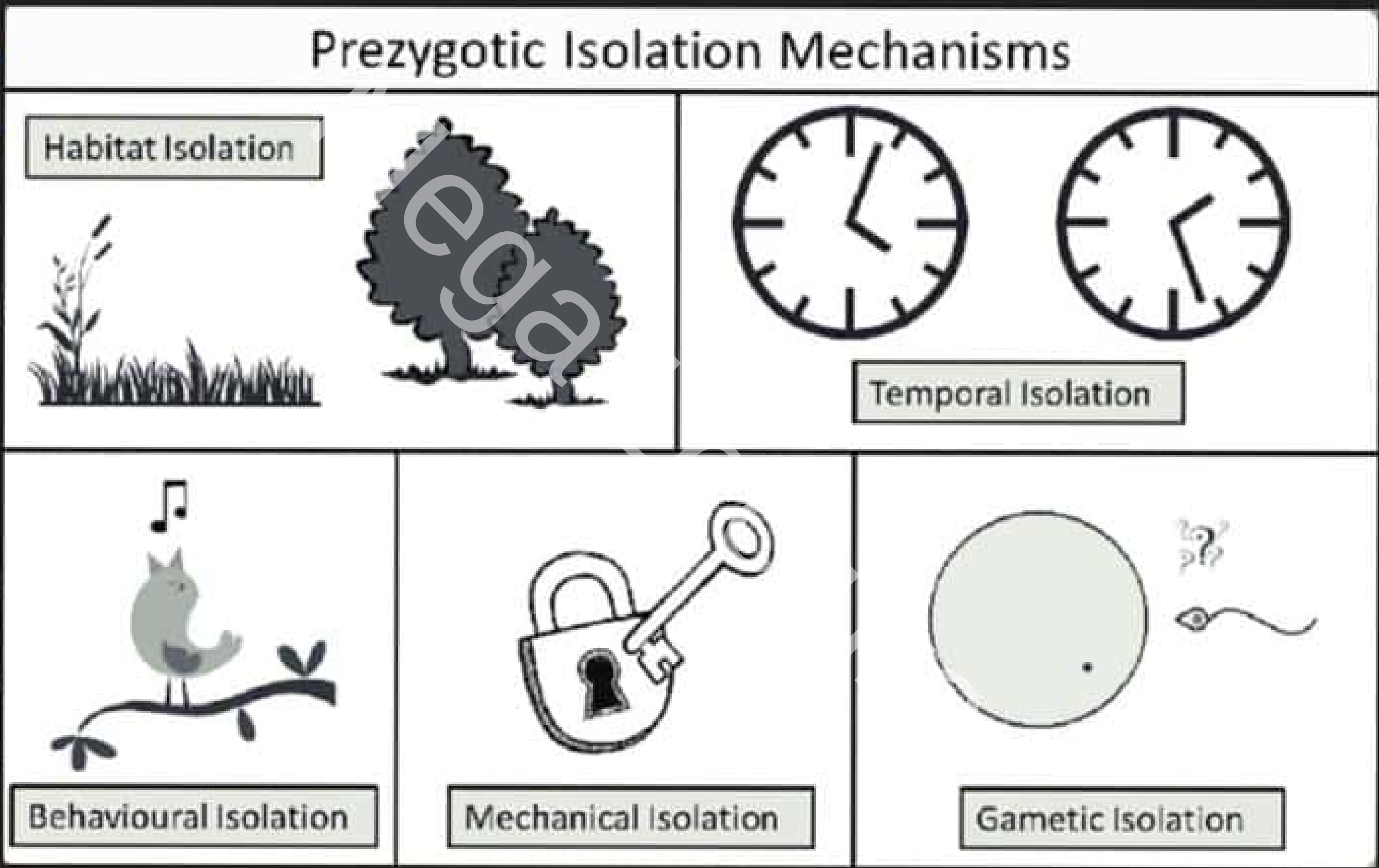
Isolating Mechanisms

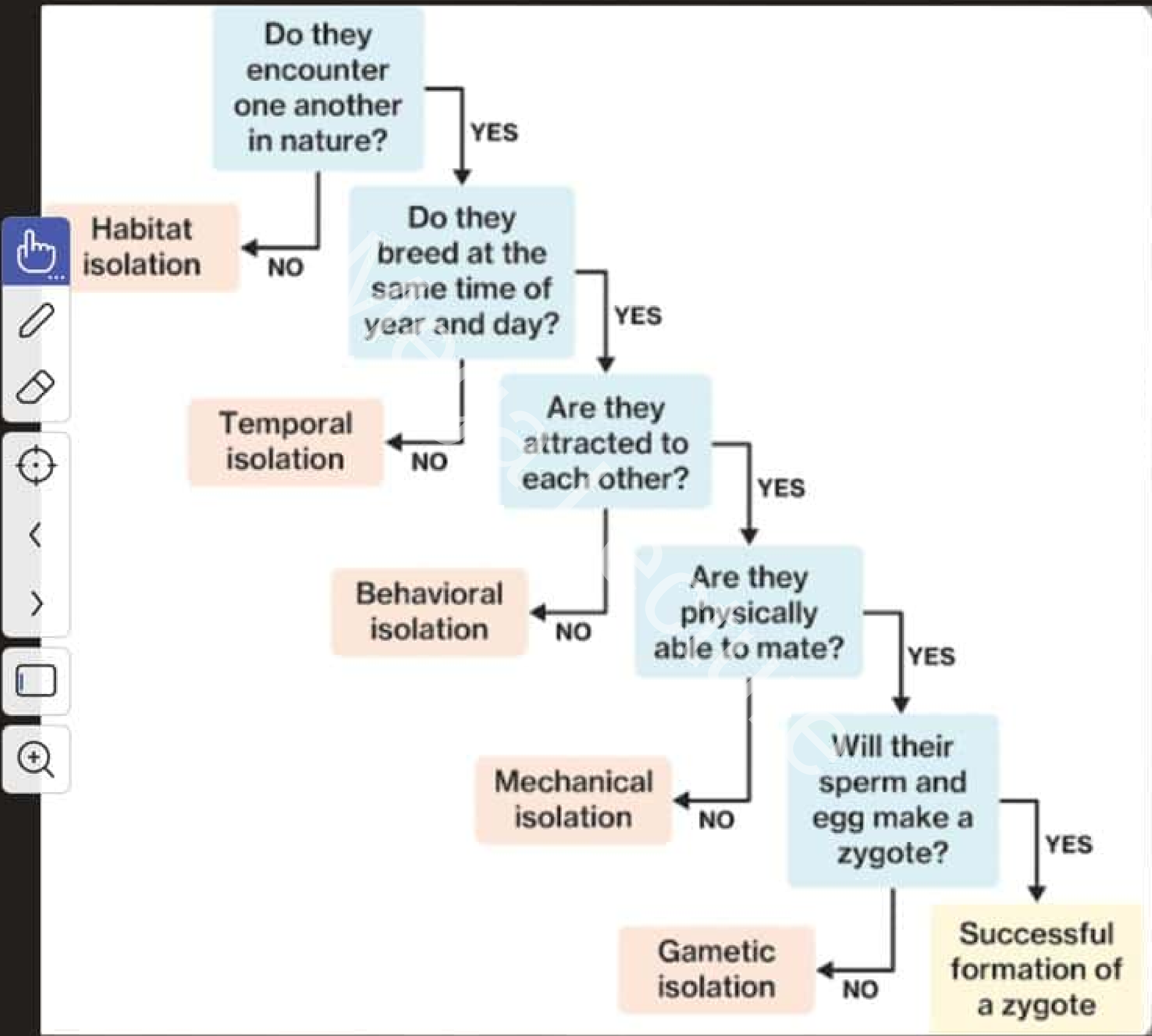
- Pre-zygotic
- Post-zygotic


Prezygotic
Barrier
Postzygotic
Barrier
fertile
offspring

Pre-zygotic

1. Geographical/habitat
2. Mechanical Isolation
3. Behavioural Isolation
4. Temporal Isolation


Prezygotic Isolation Mechanisms
Habitat Isolation
Temporal Isolation
Behavioural Isolation
Mechanical Isolation
Gametic Isolation


Do they encounter one another in nature?
YES
NO
Habitat isolation
Do they breed at the same time of year and day?
YES
NO
Temporal isolation
Are they attracted to each other?
YES
NO
Behavioral isolation
Are they physically able to mate?
YES
NO
Mechanical isolation
Will their sperm and egg make a zygote?
YES
NO
Gametic isolation
Successful formation of a zygote

a) Pre-zygotic Isolating Mechanism

* Pre-zygotic Isolating Mechanisms involve:

i) Behavioral Isolation – where organisms fail to interbreed due to differences in their mating behaviour. Organisms, such as, certain species of birds have courtship rituals which may alter leading to behavioral isolation.

ii) Temporal isolation – which refers to failure to interbreed due to different breeding seasons.

iii) Mechanical Isolation - which results due to incompatibility of male & female reproductive organs.

iv) Ecological or Habitat Isolation - which results due to differences in the environmental factors in which the two organisms survive.

Post-zygotic

1. failure of the zygote to divide by mitosis
2. Hybrid inviability
3. Hybrid sterility

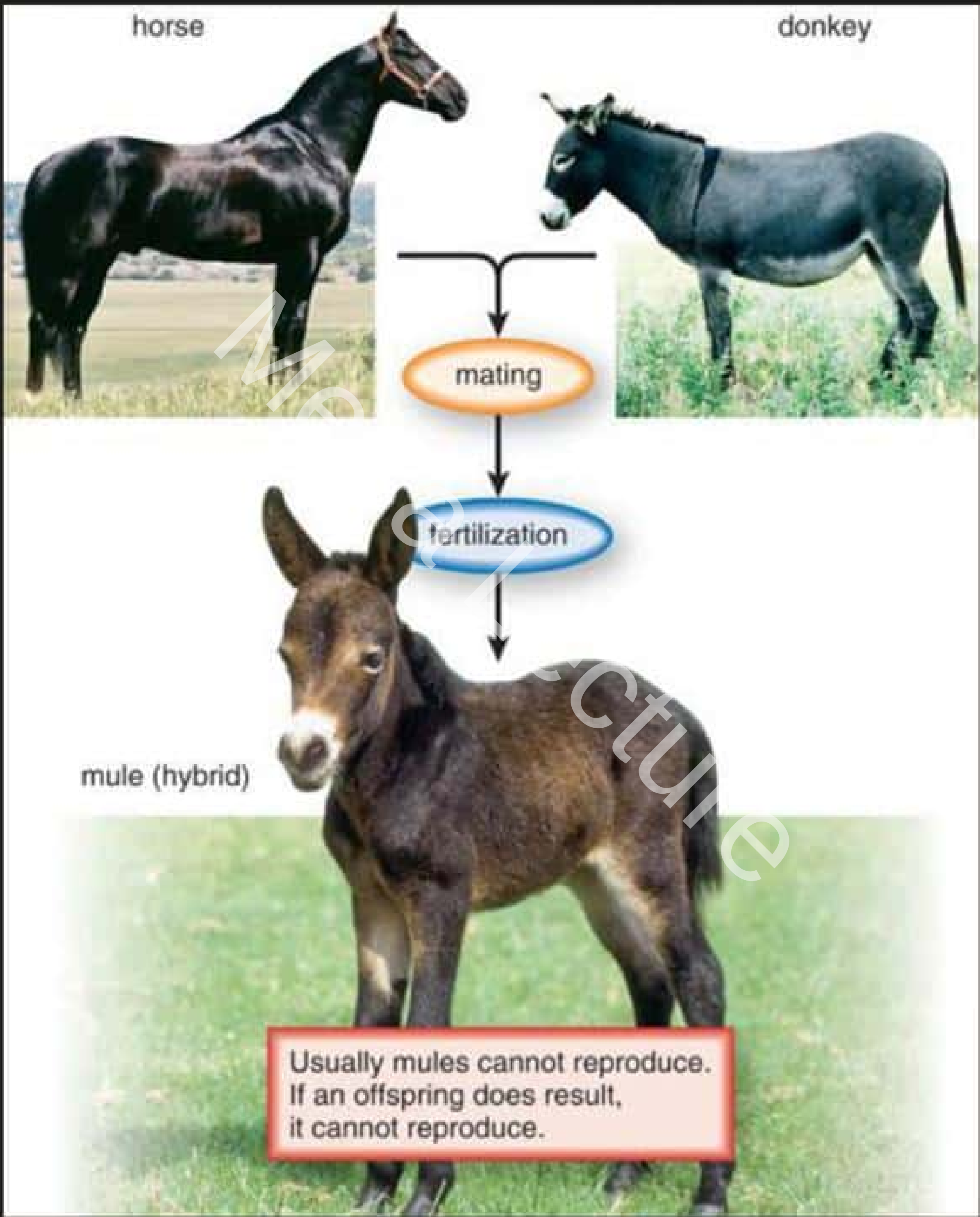
b) Post-zygotic Isolating Mechanism:

* Post-zygotic Isolating Mechanisms involve:

i) Failure of the zygote to divide by mitosis

ii) Hybrid Unviability – which refers to the inability of the hybrid to survive for too long

iii) Hybrid Sterility – which refers to hybrid being viable but unable to form gametes via meiosis.

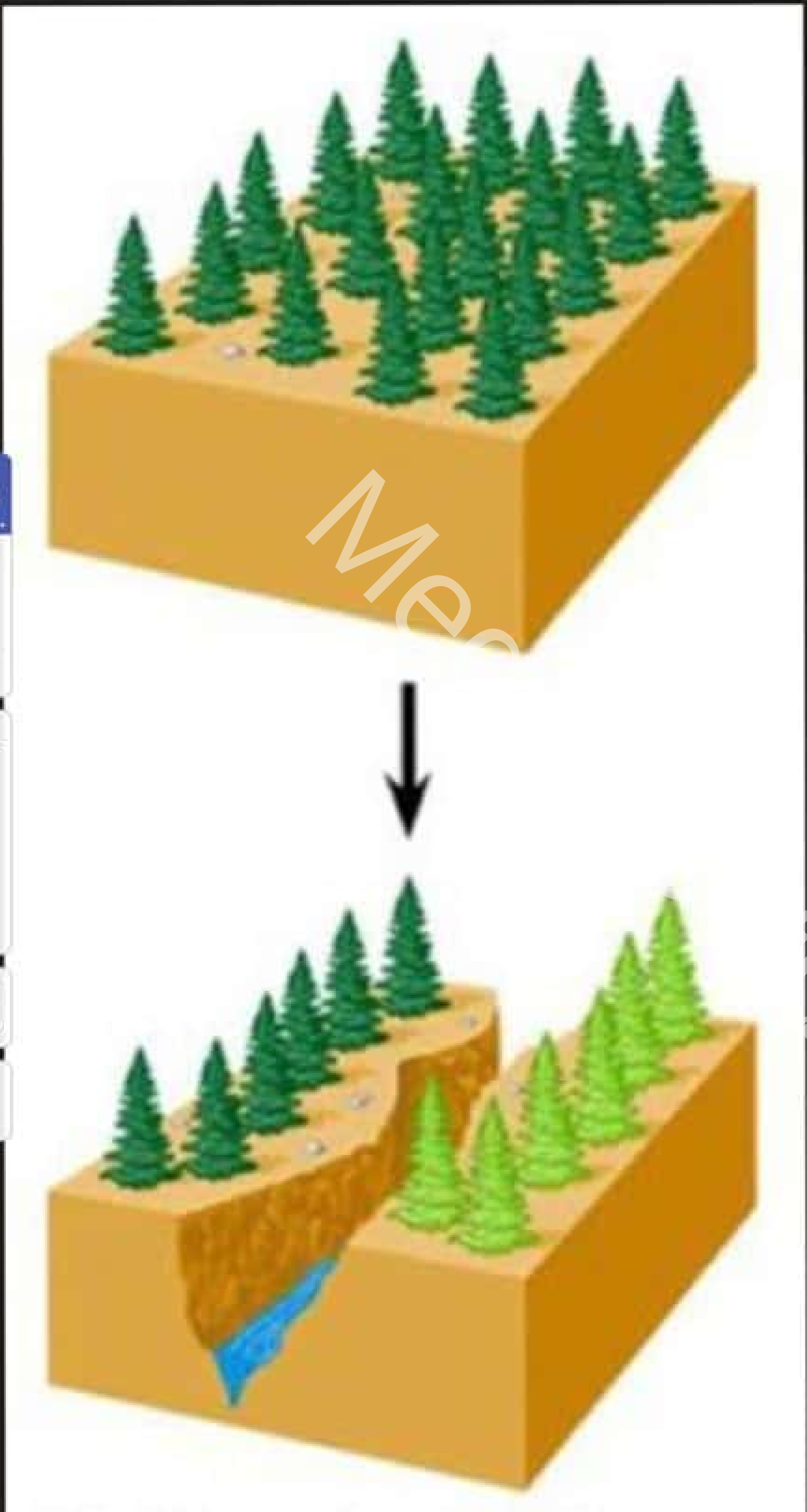

horse
donkey
mating
fertilization
mule (hybrid)
Usually mules cannot reproduce.
If an offspring does result,
it cannot reproduce.

* Pre-zygotic and/or Post-zygotic Isolating Mechanisms may lead to evolution of a new species from an original group of organisms within a population in the following two ways:

a) In the presence of a geographical barrier- a phenomenon termed as Allopatric Speciation

b) In the absence of a geographical barrier- a phenomenon termed as Sympatric Speciation.

Allopatric Speciation


Allopatric speciation

geographical barrier
↓
different environmental conditions
↓
different selection pressures
↓
no gene flow b/w the organisms
↓
evolutionary change
↓
speciation

Allopatric Speciation:

* Allopatric Speciation refers to evolution of new species in the presence of a geographical barrier, such as, a mountain or a river stream.

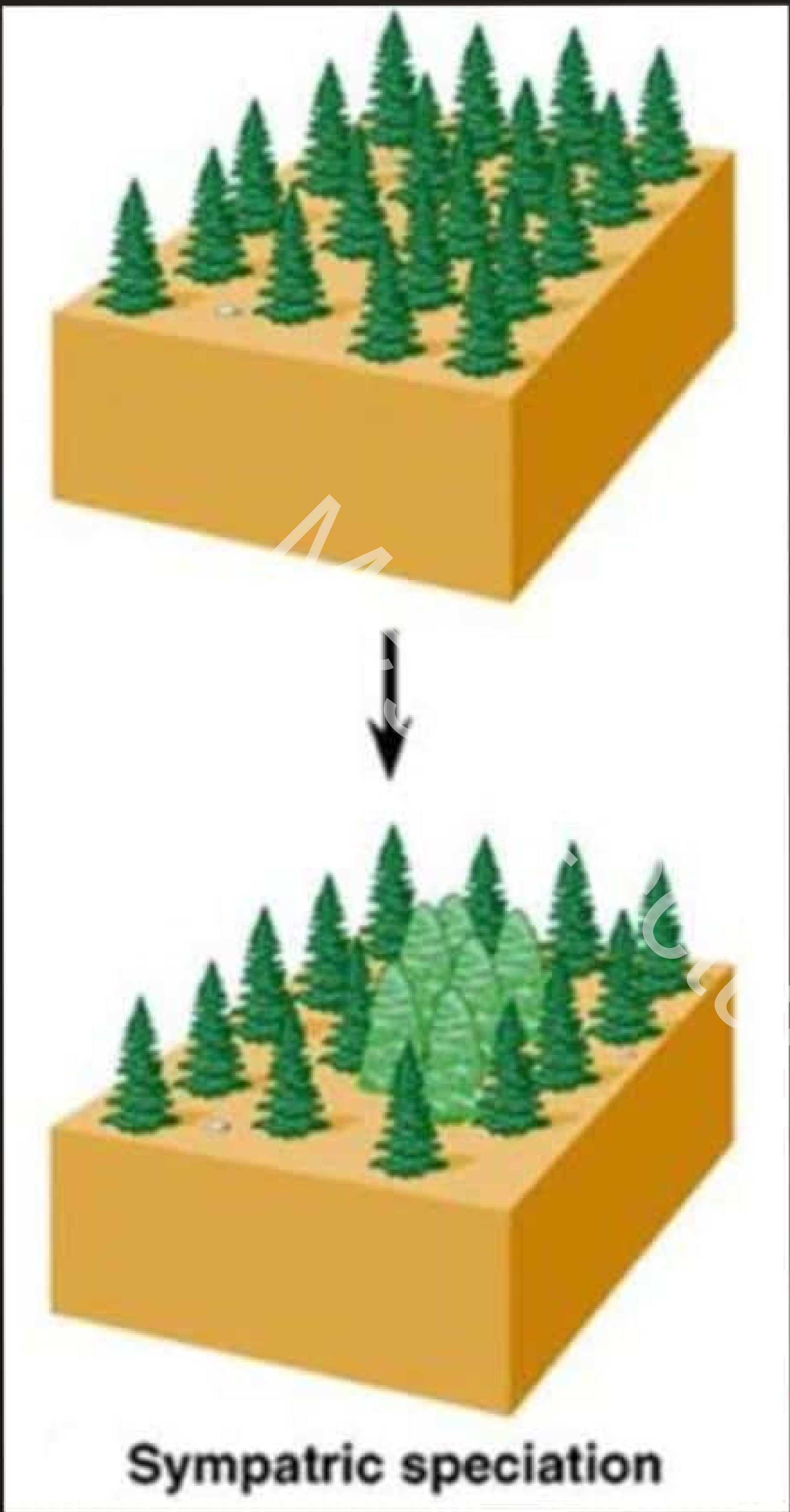
* Geographical barrier separates the organisms within a population such that these organisms are exposed to different environmental conditions.

* These environmental conditions exert different selection pressures which overtime leads to a significant change in the allele frequencies.

* There is no gene flow b/w these organisms separated by a geographical barrier.

* Overtime this can lead to evolution of new species due to failure of these organisms to interbreed to produce fertile offspring.

Sympatric Speciation



* NO geographical barrier
* Main mechanism
↓
Meiotic error (non-disjunction)
↓
leads to formation of POLYPLOIDS
(3n, 4n, 5n, 6n)

Autopolyploids | Allo-polyploids

Sympatric Speciation:

* Sympatric Speciation refers to the evolution of a new species in the absence of a geographical barrier.

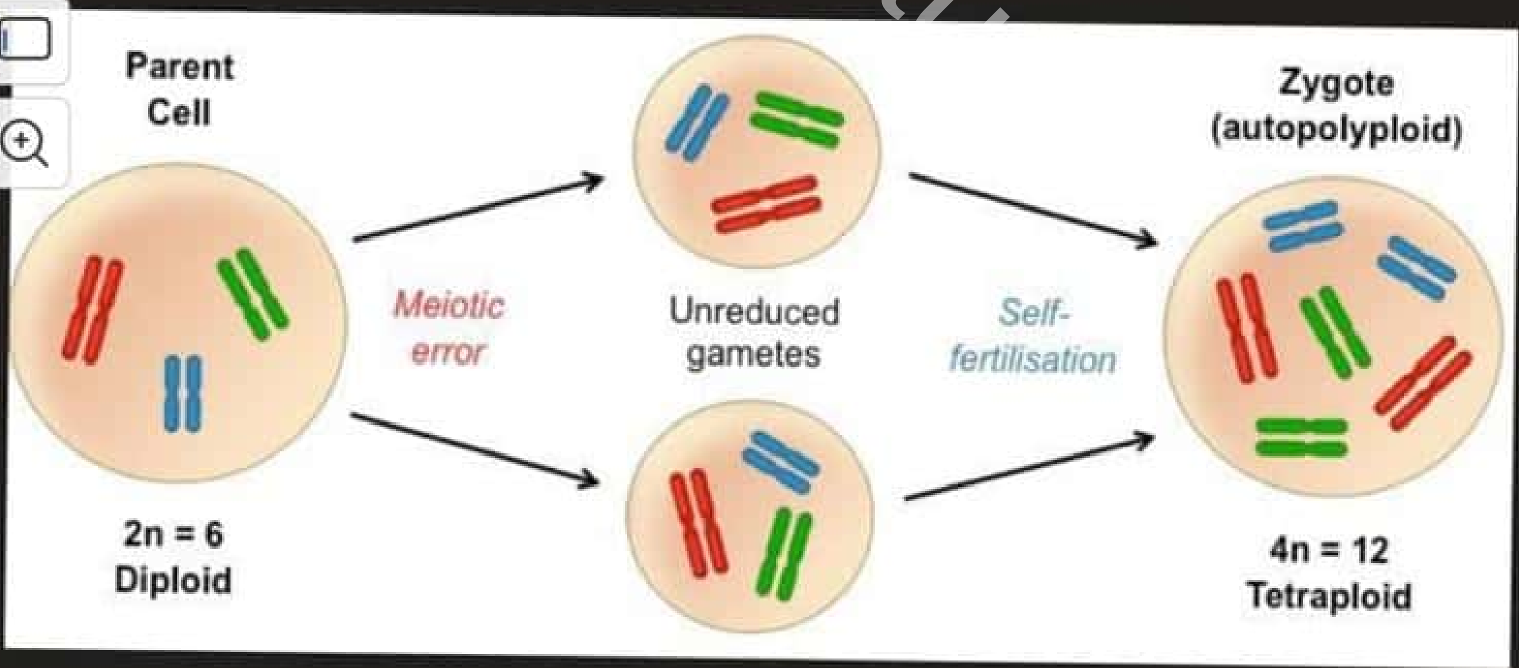
* Sympatric Speciation most commonly results due to polyploidy.

* Polyploidy is the phenomenon of having more than 2 sets of chromosomes within the cell, such as, 3n (Triploid) and 4n (Tetraploid).

* Polyploidy usually results due to meiotic errors, such as, non-disjunction.

* Polypoidy exists in two different forms:

a) Autopolyploid - in which the multiple sets of chromosomes are from the same species. Such a cell is termed as an autopolyploid cell. Autopolyploid organisms are sterile because the chromosomes fail to pair up during Prophase I of Meiosis I.

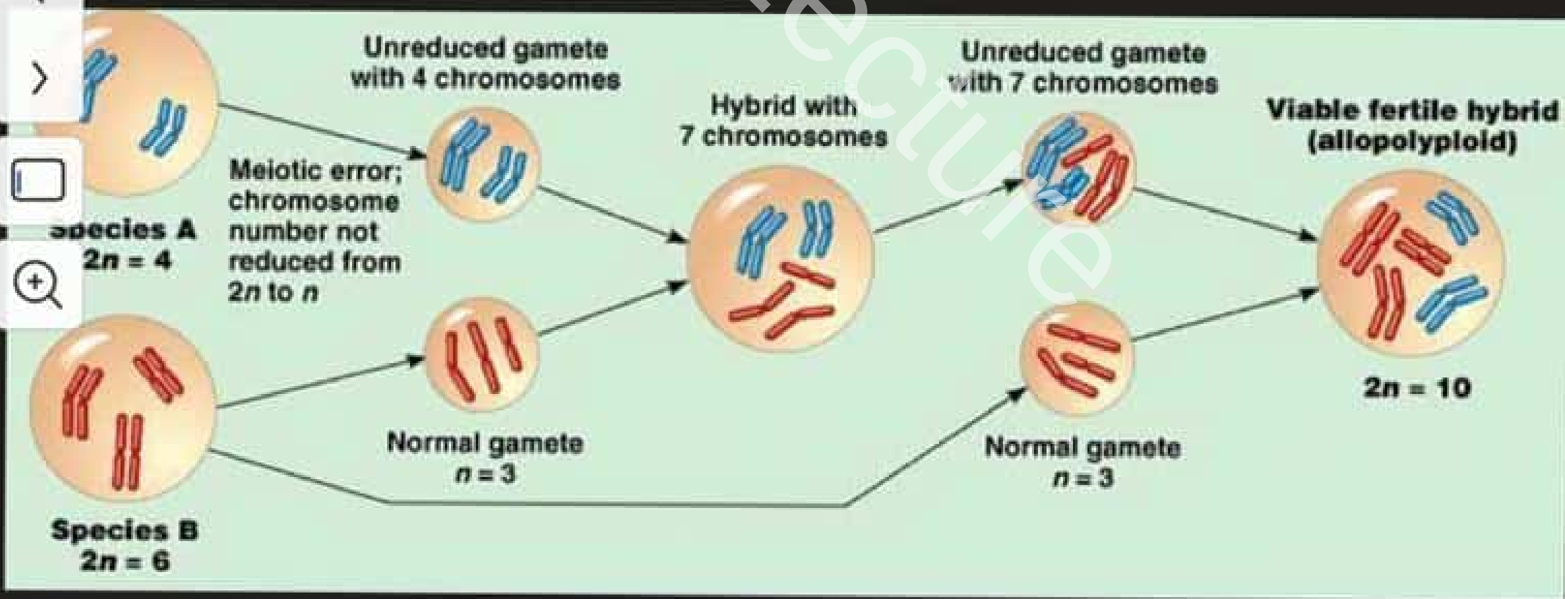


* A meiotic error in a diploid organism may lead to formation of diploid gametes rather than haploid gametes.

* If two such diploid gametes fuse during fertilisation, it may lead to formation of a tetraploid zygote which will eventually form a tetraploid organism.

* These tetraploids will not be able to interbreed with their diploid parents and thus form a new species of organisms.

b) Allopolyploid - in which the multiple sets of chromosomes come from two different species. Allopolyploids maybe fertile because the homologous chromosomes may pair up during Prophase I of Meiosis I.



Selection & Evolution

Molecular Comparison between species

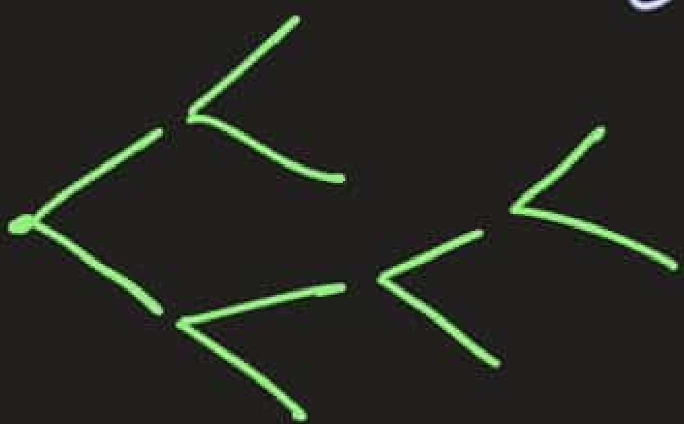
Comparison using amino acid sequence :

* Ancestral relationship of organisms of different species can be determined by looking at the amino acid sequences of important proteins, such as, cytochrome c.

* Cytochrome C is a mitochondrial protein present on the cristae of the mitochondria. This protein is used in oxidative phosphorylation & is therefore essential in the production of energy via aerobic respiration.

Molecular Differences Between Species

* Similarities in the amino acid sequences of proteins & the nucleotide sequences of DNA can be used to determine the ancestral relationship b/w organisms of different species.
* The greater the similarities b/w amino acid & nucleotide sequences b/w organisms of different species the more recent is their common ancestor and the more closely related they are.



* The amino acid sequence of Cytochrome C can be compared in humans, mice & rats to determine their ancestry.

* Results of the comparison are highlighted below:

a) The protein contains 104 amino acids in all three species.

b) Mice & rats have an exactly similar amino acid sequence.

c) Humans differ in 9 out of 104 amino acids.

d) These 9 amino acids, however, have R groups that are similar in nature to the R groups in mice and rats.

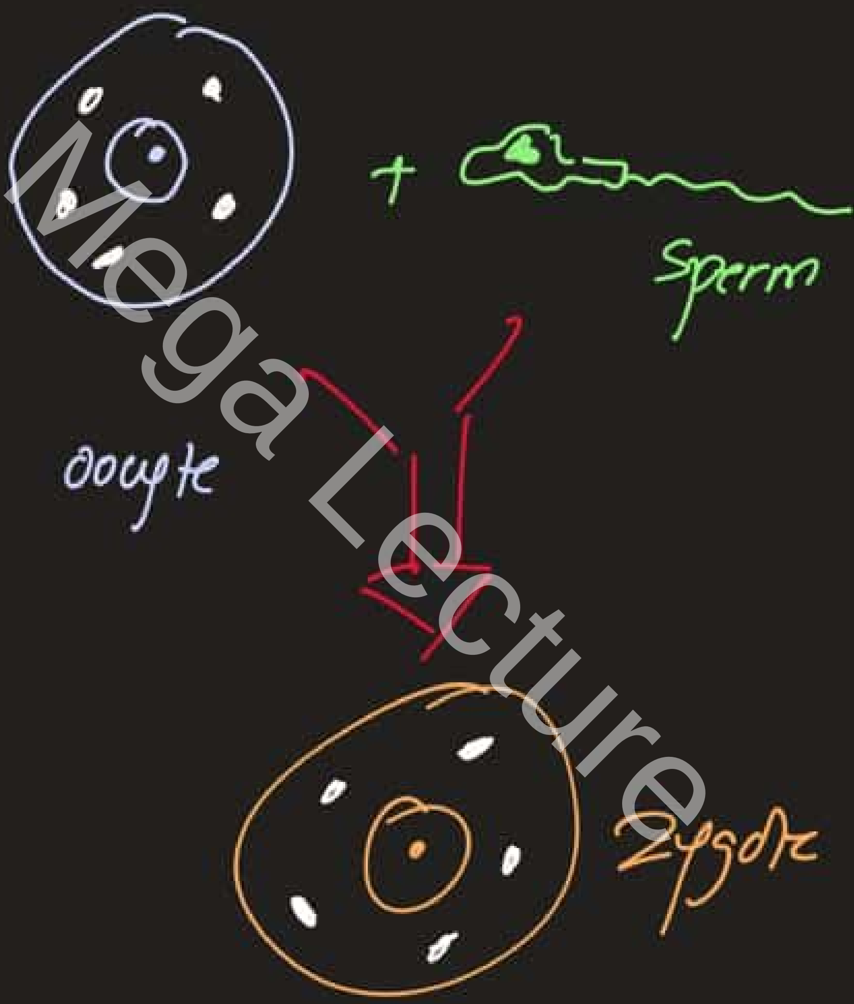
* Results of this comparison are therefore:

a) Mice and rats share a recent common ancestor.

b) Humans are more distantly related to mice & rats.

Mitochondrial DNA mutations to trace human ancestry

-



mitochondrial DNA sequence:

* Mitochondria are inherited from the mother.
* Mitochondrial DNA differs from nuclear DNA in the following aspects:

1) Mitochondrial DNA is circular.
2) Mitochondrial DNA is devoid of histone proteins & is therefore more prone to mutations

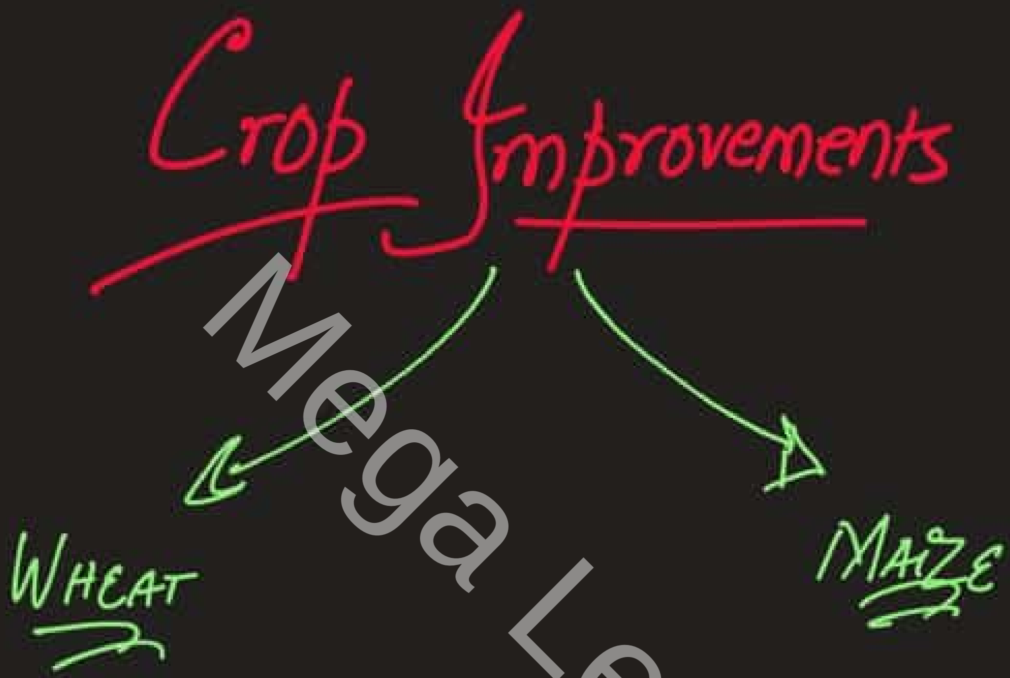
* Like nuclear DNA mitochondrial DNA is double stranded.
* Variations in mitochondrial DNA can only result due to mutations since circular DNA cannot undergo crossing over & independent assortment.

* Other than the absence of histone proteins which increase the likelihood of mitochondrial DNA mutation, production of reactive oxygen species within the mitochondria may also mutate mitochondrial DNA.

* The rate of mutation within mitochondrial DNA is assumed to be roughly constant.

* This phenomenon can be used to trace back the first human which gave rise to the evolution of the modern humans.

* This hypothesis of tracking back human ancestry based on mitochondrial DNA is the Molecular Clock Hypothesis


Crop Improvements
WHEAT
MAIZE

doubling of the chromosome (2)

* bread wheat = *Triticum aestivum* (6n)

wild hard grass (2n=14) AA → A

wild einkorn wheat (2n=14) BB → B

A × B → hybridisation*

sterile hybrid (2n=14)
AB

↓ doubling of the chromosome no. due to non-disjunction **

wild emmer wheat AABB (4n=28) × wild goat grass CC (2n=14)

AB × C → hybridisation*

sterile hybrid (3n=21)
ABC

↓ doubling of the chromosome no. **

BREAD WHEAT (6n=42)
AABBCC

Evolution of modern wheat

The following diagram summarises the evolution of modern bread wheat :

wild hard grass (*diploid*, $2n = 14$) x wild einkorn wheat (*diploid*, $2n = 14$)

↓

sterile hybrid (*diploid*, $2n = 14$)

chromosome number doubles ↓

wild emmer wheat (*tetraploid*, $4n = 28$) x wild goat grass (*diploid*, $2n = 14$)

↓

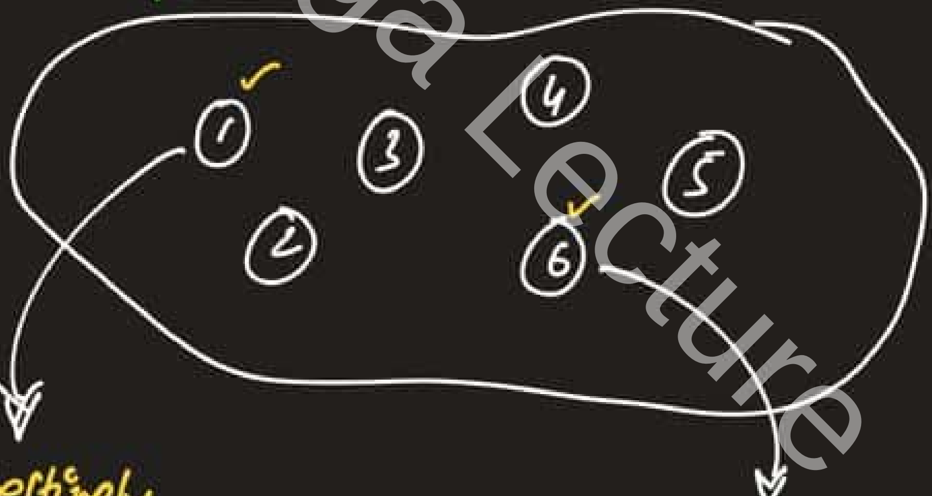
sterile hybrid (*triploid*, $2n = 21$)

chromosome number doubles ↓

bread wheat (*hexaploid*, $6n = 42$)

Evolution of maize through selective breeding and hybridisation

* high yield
* disease resistant
* plants should grow to the same height at the same time
* high quality and nutritional content of the kernels

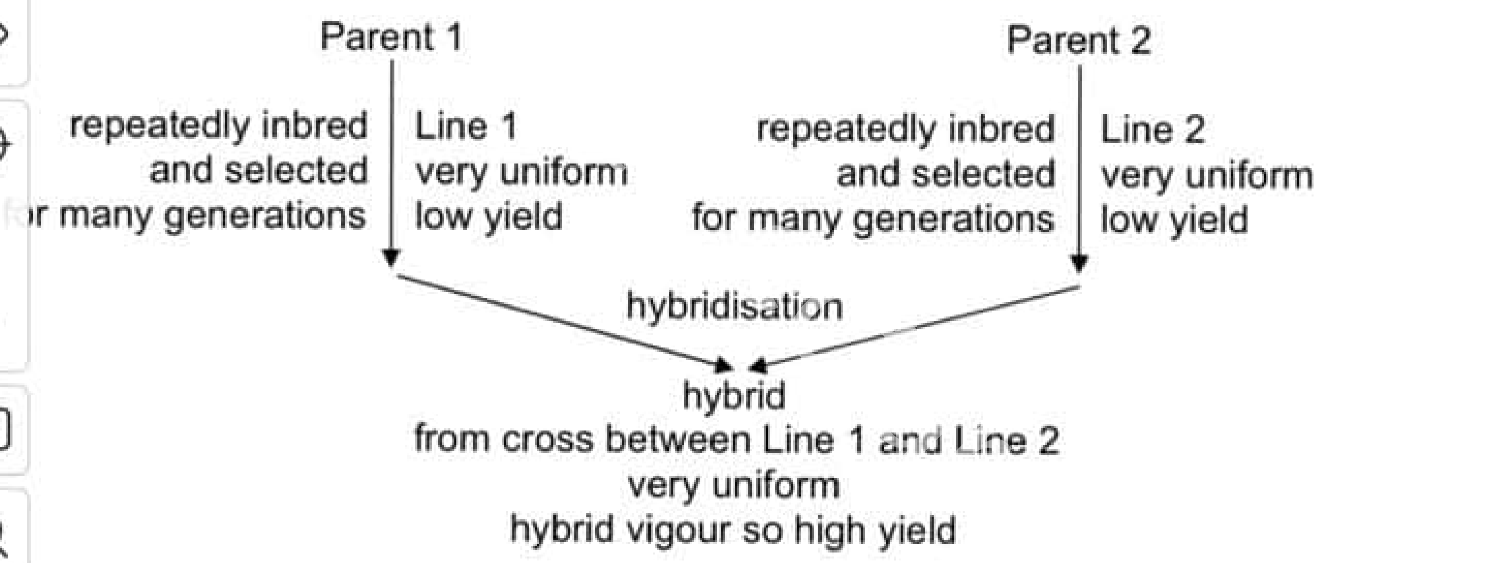


selectively breed these maize plants repeatedly over many generations

selectively breed these maize plants repeatedly over many generations

hybrid maize

Evolution of maize




Extinction

EXTINCTION

* Extinction refers to the absence of organisms from natural or artificial habitats.

* Mass extinction refers to eradication of organisms of multiple species at the same time.

* Extinction may result due to one or more of the following factors:

i) Climatic changes

ii) Competition with organisms that are better adapted to the environment.

iii) Human Activities, such as, Habitat Destruction resulting due to deforestation & land reclamation.

iv) Political reasons

v) Commercial reasons

vi) The unwillingness of the International Organizations to take measures to reduce illegal hunting (poaching) of endangered organisms.

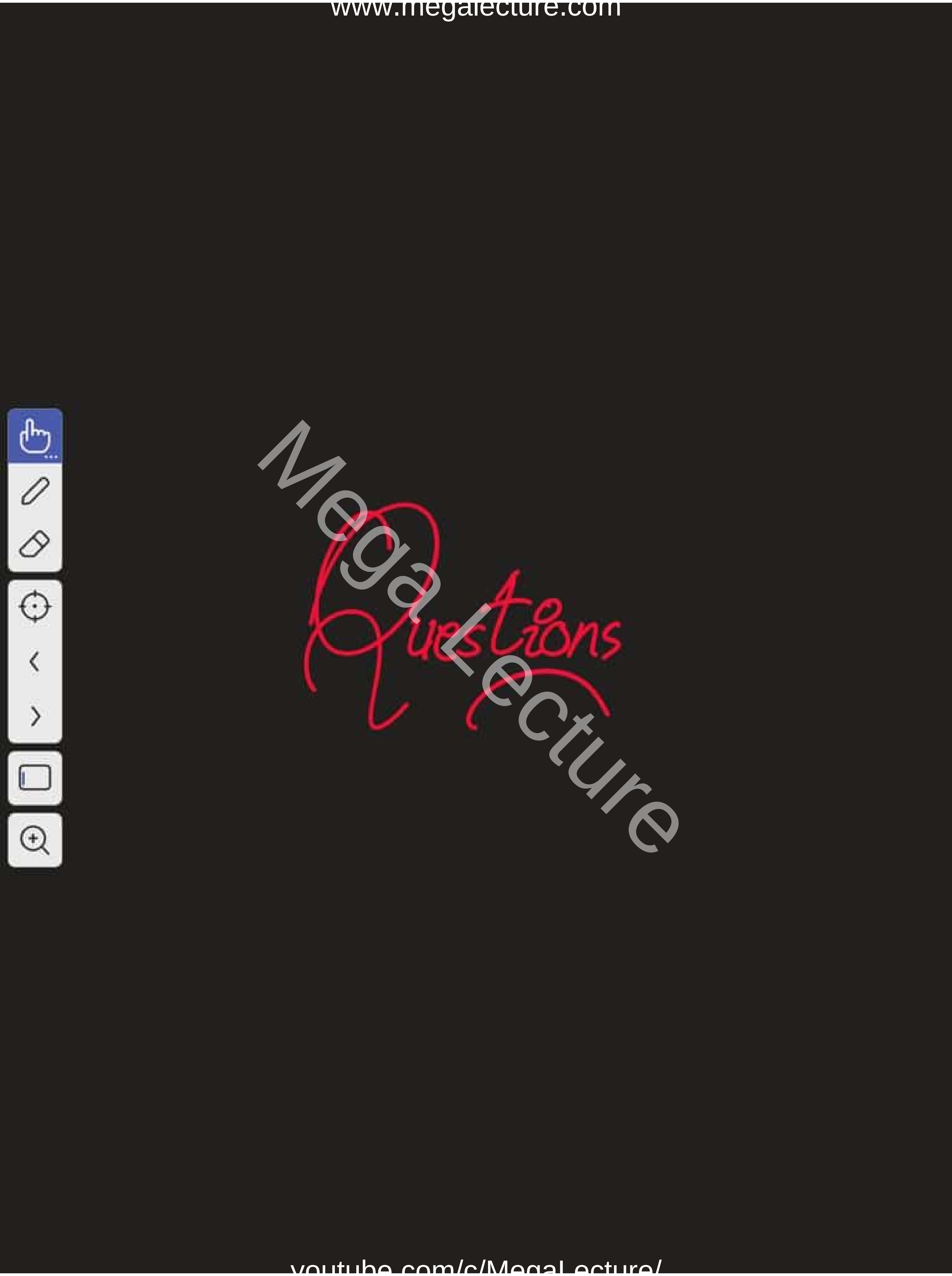
* The International Union for the Conservation of Nature (IUCN) has a Red List which includes all the extinct organisms. This Red List is growing day by day.

* Climatic changes & competition for survival were the main reasons for Mass extinctions in the past. Currently, human activities are the most significant reason which may lead to mass extinction in the future.

* High profile organism, such as, Giant Pandas & Black Rhinos are more difficult to

conserve due to political & commercial reasons. as compared to low profile organisms such as slugs.

* IUCN is therefore targeting its efforts to conserve low profile organisms which may have a greater success. Conservation of these low profile organisms is equally important in the conservation of the Ecosystem.


Questions

Q.

4 Maize is an important food crop that has been improved both by selective breeding and by genetic modification.

(a) Outline how selective breeding has been used to improve maize.

* maize plants with desirable features are selected and
* inbred repeatedly over many generations
* these plants have desirable features like high yield, good quality of kernel and disease resistance
* Two inbred varieties are hybridised to produce more vigorous maize plants

[4]

(b) Fig. 4.1 shows part of a maize cob. The cob is made up of many individual seeds called kernels. Each kernel results from a separate fertilisation of a male and a female gamete. Some kernels are yellow and some are purple.

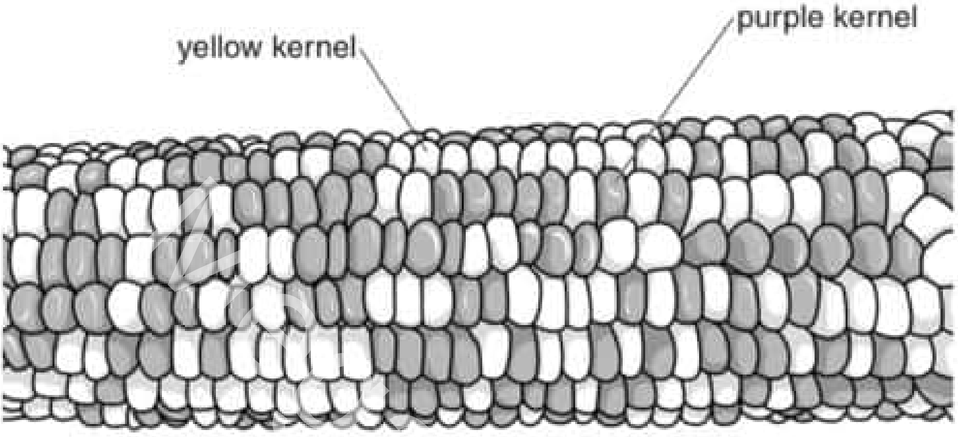


Fig. 4.1

Name the type of variation shown in Fig. 4.1. Suggest a genetic explanation for this pattern of variation in colour.

type of variation discontinuous variation

explanation the variation in colour is controlled by a single gene with two alleles.

[3]

Q.

4 Modern varieties of wheat have developed from numerous hybridisation events between different species of wild grasses. Fig. 4.1 shows some of the possible steps that are believed to have been involved in the development of bread wheat, *Triticum aestivum*.

The letters **A**, **B** and **C** represent three different sets of seven chromosomes.

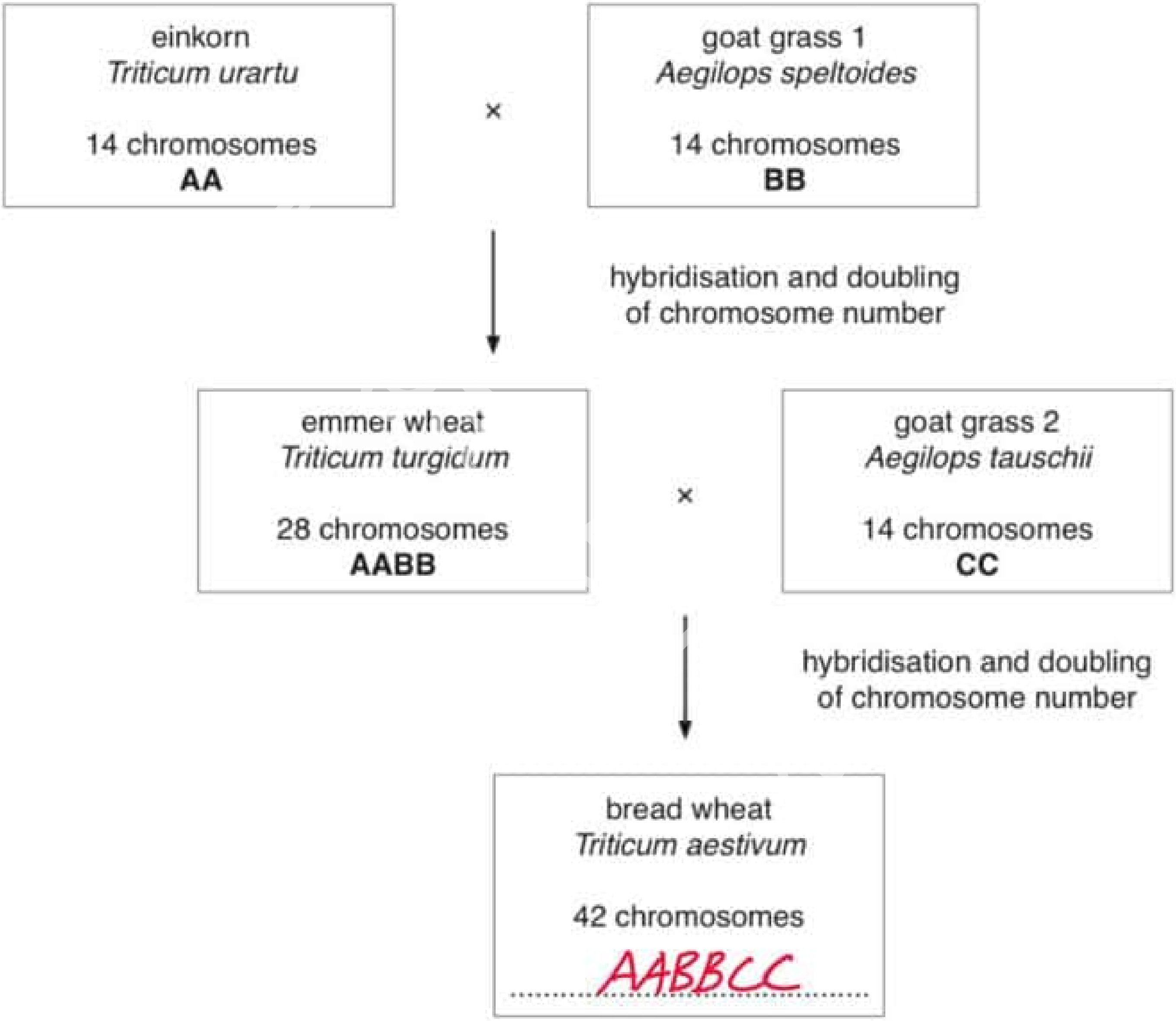


Fig. 4.1

(a) Complete Fig. 4.1 by writing letters to represent the sets of chromosomes in bread wheat.

Write your answer on Fig. 4.1. [1]

(b) Explain why hybridisation between emmer wheat and goat grass 2 would have produced a sterile hybrid, if doubling of chromosome number had **not** occurred.

* chromosomes would not be able to pair up
* during prophase I of meiosis I
* this is due to the non-homologous set of chromosome

[3]

(c) With reference to Fig. 4.1, suggest why *Triticum urartu* (2n) and *Triticum turgidum* (4n) are classified as different species.

* they will not be able to breed
* to produce fertile offspring

[2]

(d) *Triticum turgidum* emerged as a new species without being geographically isolated from *Triticum urartu*.

Outline how geographical isolation may result in speciation.

* species split into two groups by a geographical barrier
* different selection pressures due to different environmental conditions
* different alleles selected in the two regions
* change in allele frequency over time

[3]

[Total: 9]