## A. TYPES OF VARIATION

| CONTINUOUS | DISCONTINUOUS (DISCRETE) |
|---|---|
| Human **height**/**mass**/**intelligence** | **Blood group**/**tongue rolling**/**albinism** |
| Controlled by **two or more genes** (**polygenic**) and the **environment** | Controlled by **genes only** (usually one gene) with **little/no effect** from the **environment** |
| Individuals fit **within** a **range** of **two extreme** groups | Individuals fit **into one** of a number of **non-overlapping** groups |
| Results in a **range** of **phenotypes** between **two extremes** | Results in a **limited number** of **separate phenotypes** with **no intermediates** |
| Tend to be **quantitative** (can be measured with numbers) | Tend to be **qualitative** (cannot be measured with numbers) |
| Drawn as a **frequency histogram** | Drawn as a **bar chart** |

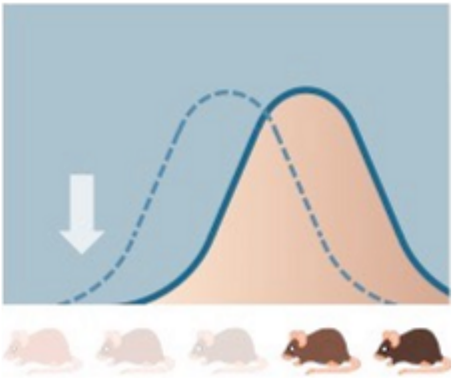
## B. GENE POOL

**All** the **genes** and their different **alleles**, present in an **interbreeding population**

## C. TYPES OF NATURAL SELECTION

### 1. Directional

- One extreme phenotype in the range is selected for.
- The other extreme phenotype is selected against.



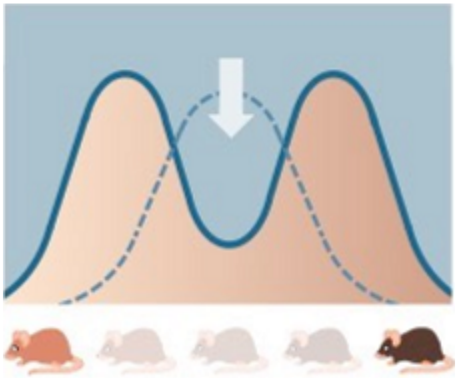
Favours one extreme

Shifts the distribution left or right

- Example: peppered moths (see SL notes).

### 2. Disruptive

- Extreme phenotype**s** are selected for.
- Intermediate phenotypes are selected against.

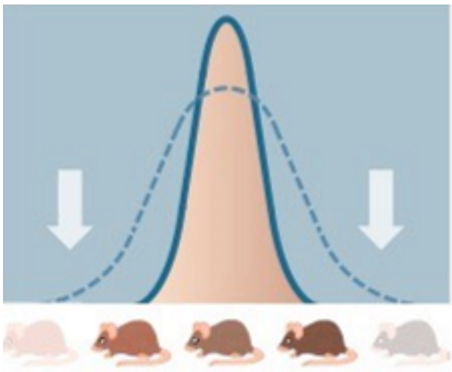


Favours both extreme phenotypes

- Example: Bird species *Passerina amoena*. 1 year-old males with the dullest and brightest feathers are better at securing high-quality territories than males with an intermediate feather colour. This allows them to pair with females and breed.

### 3. Stabilising

- Intermediate phenotypes are selected for.
- Extreme phenotypes are selected against.



Decreases extreme variations

Narrows the distribution

Example: sickle-cell anaemia in African populations.

- The $Hb^S$ allele for sickle-cell anaemia gives some protection against malaria.

| Genotype | Phenotype |
|---|---|
| $Hb^S\ Hb^S$ | Can die from sickle-cell anaemia |
| $Hb^S\ Hb^A$ | No sickle-cell anaemia **and** protected from malaria |
| $Hb^A\ Hb^A$ | Can die from malaria |

- **Heterozygous** individuals have a **selective advantage**.

## D. TYPES OF REPRODUCTIVE ISOLATION

- For **speciation**, **reproductive isolation** is needed, so that some individuals in a population are **prevented** from **interbreeding** with others.
- There are **three** types of **reproductive isolation**.

| Type | Description | Example |
|---|---|---|
| **Temporal Isolation** | Populations **breed at different times of the year**. | Some species of cicada insects breed every 13th year. |
| **Behavioural Isolation** | Populations have **behaviour** that prevents them from breeding. | Different mating calls, courtship dances or markings. |
| **Geographical Isolation** | Populations **live in different areas** or a **physical barrier separates** them in some way, such as a **river** or **mountain**. | Lava lizards migrate from island to island in the Galapagos islands, becoming reproductively isolated. |

## E. TYPES OF SPECIATION

- **Sympatric speciation** = population stays in the **same geographical area** (**temporal** and **behavioral** isolation)

- **Allopatric speciation** = population **separates** into **two new** populations by a **physical barrier** (**geographical** isolation)

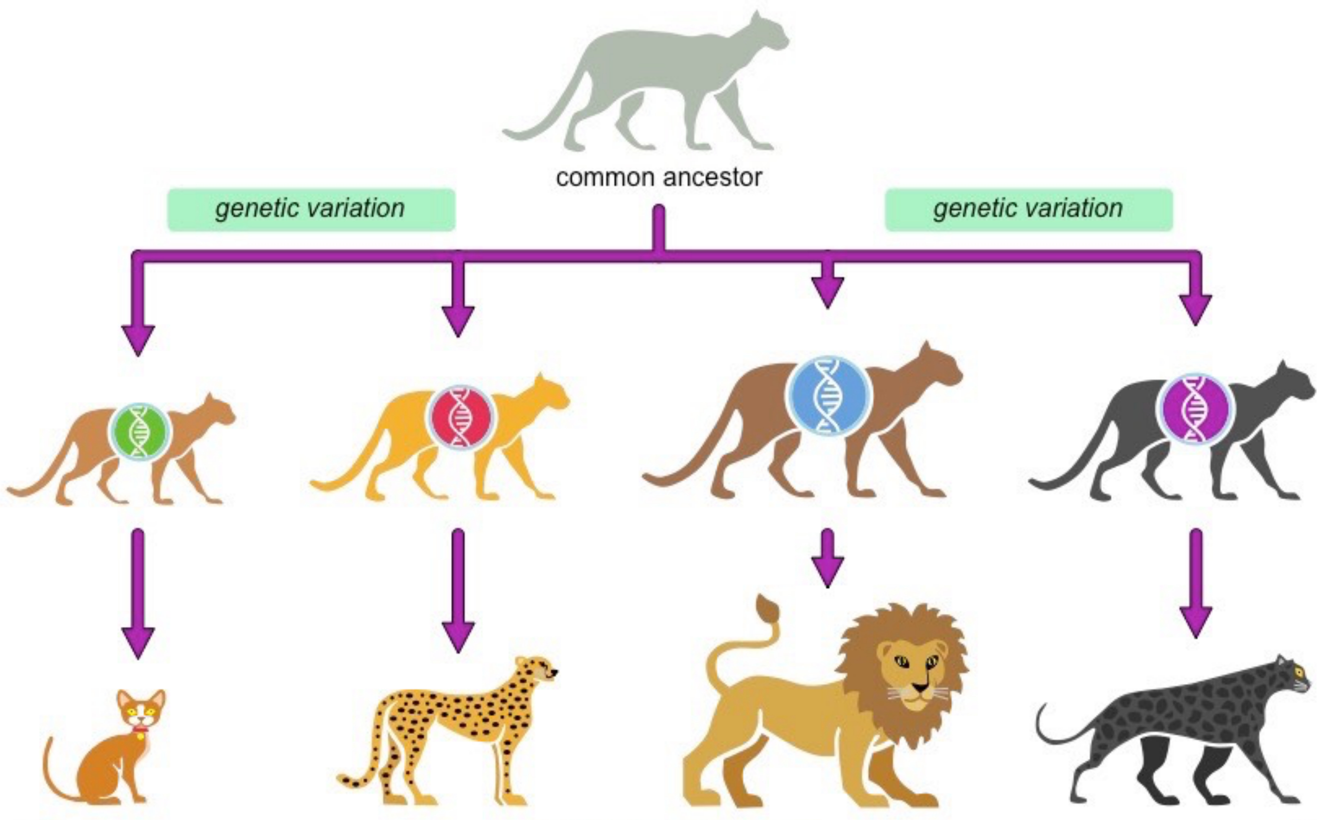
In terms of the **timescale**, speciation can occur in **two** ways:

| GRADUALISM | PUNCTUATED EQUILIBRIUM |
|---|---|
| Gradual cumulative changes over long periods of time | Sudden abrupt changes<br>Long periods without significant change and short periods of rapid change |

## F. SPECIATION

- This is the **formation** of a **new species** or the **splitting** of a **species**.

**Speciation = Reproductive Isolation + Natural Selection**



## The Process

- speciation is the formation of a new species/splitting of a species
- (populations become) reproductively isolated
- example given of temporal/behavioural/geographical isolation
- (so) no interbreeding / no gene flow (between the populations)
- different conditions/environment/selective pressures/natural selection for the two populations
- different features/adaptations are selected for / different individuals survive
- (over a long time) populations become genetically different / have different allele frequencies / different gene pools
- (so) unable to produce fertile offspring
- can happen by gradualism/changes accumulating over long periods
- can happen by punctuated equilibrium/sudden changes over a short period of time

## G. EXAM QUESTIONS ON SPECIATION

- You need to **read** the question **very carefully**. Consider the following two questions:

| **Explain how speciation occurs [8]** |
|---|

- This is what you have just read about above.

## Explain how natural selection can lead to speciation [8]

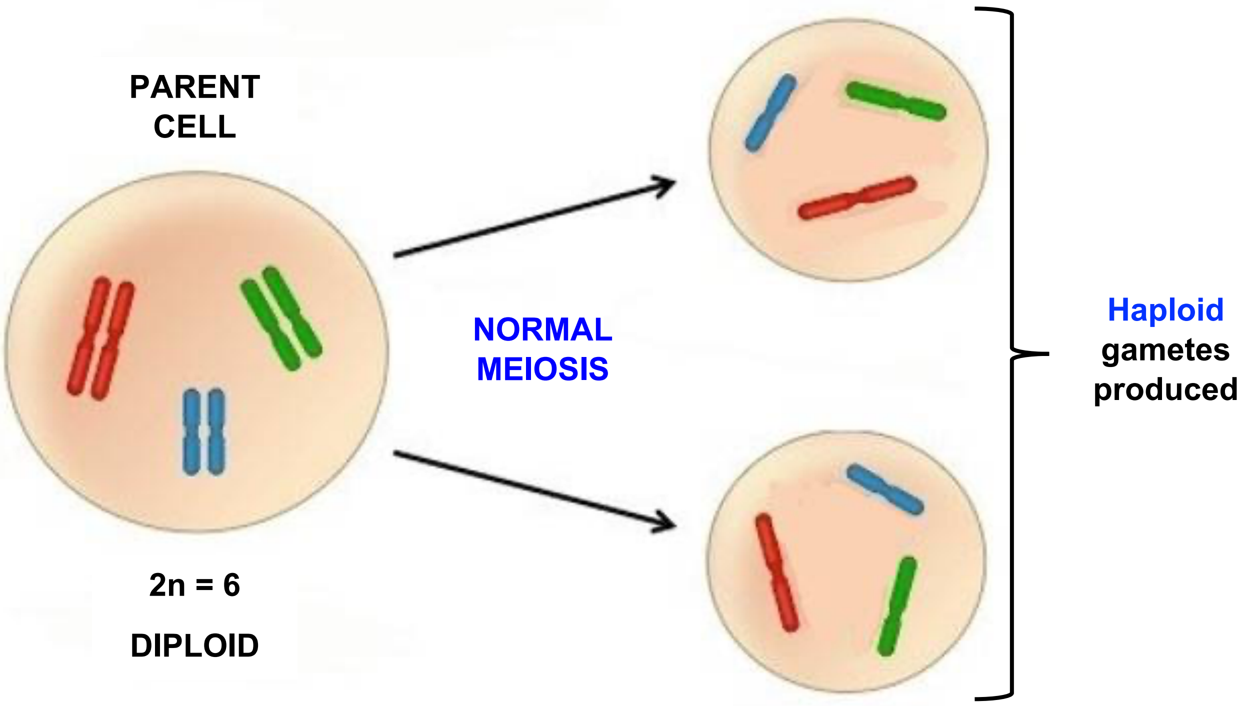
- Here, you need to also write in **more detail** about the whole process of **natural selection**, which will operate **differently** on **each population** after **reproductive isolation**.

- variation is required for natural selection in a species/population
- mutation/meiosis/sexual reproduction is a source of variation
- competition/more offspring produced than the environment can support
- adaptations make individuals suited to their environment
- better adapted individuals survive and reproduce
- (and) pass on useful alleles
- speciation is formation of a new species/splitting of a species
- reproductive isolation of separated populations
- geographic isolation «of populations can lead to speciation»
- temporal/behavioural isolation «of populations can lead to speciation»
- disruptive selection/differences in selection «between populations can lead to speciation»
- gradual divergence of populations due to natural selection/due to differences in environment
- changes in the gene pools «of separated populations»
- interbreeding becomes impossible/no fertile offspring produced «so speciation has happened»

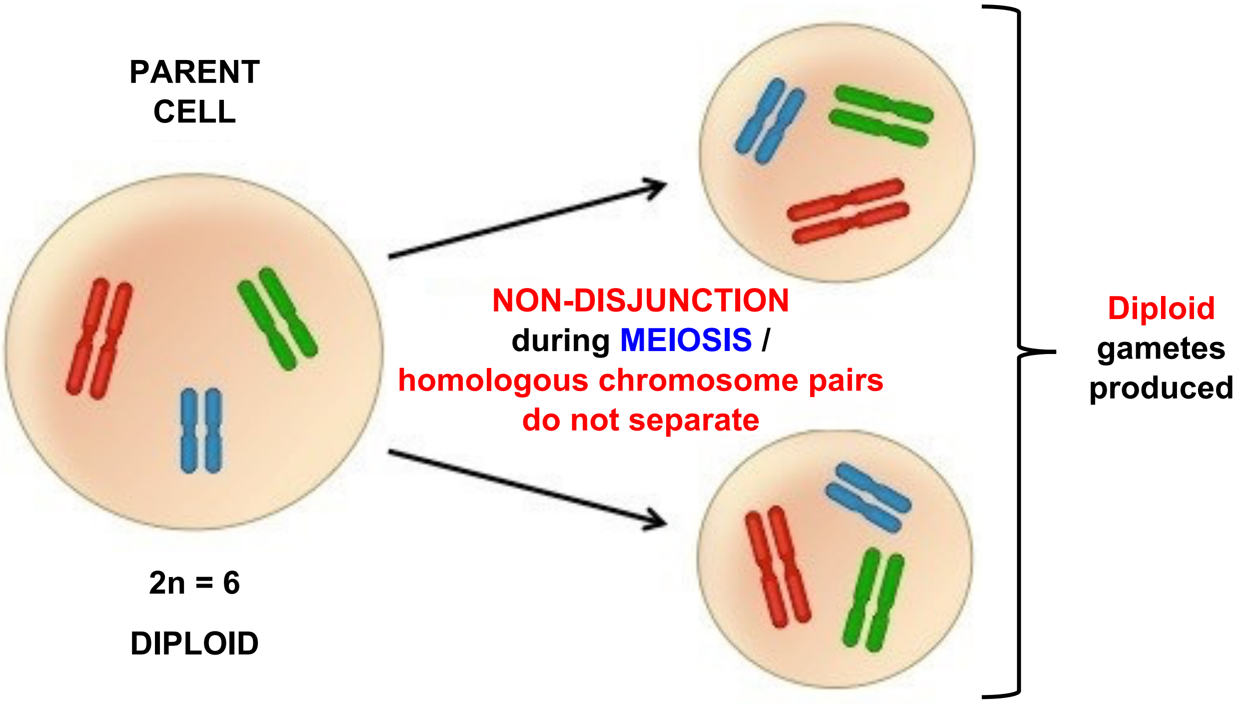
## H. POLYPLOIDY

- Polyploidy is having **more than two <u>sets</u>** of **homologous chromosomes**.
- Polyploid individuals are **<u>reproductively</u> isolated**
- Polyploidy can cause **instant/immediate speciation**.
- **Triploid** (**3n**) organisms have **3** sets of **homologous chromosomes**.
- **Tetraploid** (**4n**) organisms have **4** sets of **homologous chromosomes**.
- Polyploidy individuals tend to be **larger**.

### Normal Meiosis In Plants



## How polyploidy plants can be produced




- Joining of a **diploid** gamete with a (normal) **haploid** gamete produces a **triploid**.
- Joining **two diploid** gametes produces a **tetraploid** (plants can do self-fertilisation).
- **Meiosis** fails in **triploids** because **homologous chromosomes** **cannot pair up**.
- **Tetraploids** **cannot** cross/**produce** **fertile** **offspring** with **diploid** plants.
- **Tetraploids** **can** form a **new species** as they can **cross** with **each other**.
- **Speciation** by **polyploidy** is more common in **plants** than in animals as they may lack separate sexes or can reproduce asexually
- A good **example** of **polyploidy** in plants is the ***Allium*** genus (onion, garlic, chives, leeks).

## Speciation in Allium

- The genus ***Allium*** contains flowering plants and includes onions, garlic, chives and leeks.

- In many of these species **polyploidy** has occurred, resulting in **reproductively isolated** populations with their own **unique phenotypes**.

  Examples of polyploidy in Allium species include:

| Name of plant | Polyploidy | Number of chromosomes |
|---|---|---|
| Onion | Diploid (2n) | 16 |
| Keeled garlic | Triploid (3n) | 24 |
| Chinese chives | Tetraploid (4n) | 32 |
| Field garlic | Pentaploid (5n) | 40 |
| Blue chives | Octoploid (8n) | 66 |

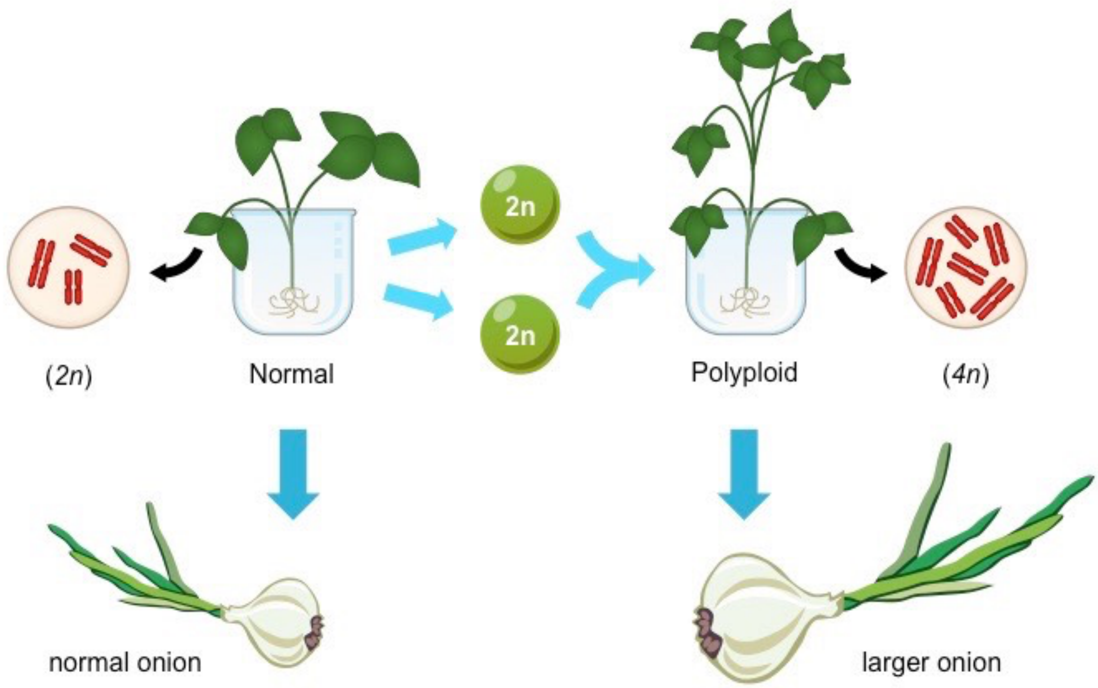
## How farmers can use polyploidy

- **Polyploid** crops may be particularly desirable to farmers for a number of reasons:

1. Allows for the production of **seedless fruits**
   e.g. **triploid** watermelons are **infertile** and hence **do not produce seeds**

2. Polyploid crops will typically **grow larger** and demonstrate **improved longevity** and **disease resistance** (known as “hybrid vigour”)

Consequently, farmers may **induce polyploidy** in certain plant species by treating plants with certain **drugs** (e.g. colchicine)



## I. HOMOLOGOUS v ANALAGOUS STRUCTURES

| HOMOLOGOUS STRUCTURES | ANALAGOUS STRUCTURES |
|---|---|
| **Same basic structure** but adapted for **different functions** | **Different structures** but used for the **same function** |
| e.g. **pentadactyl limb** | e.g. **eyes** of **humans** and **insects** |
| **Share** more recent common ancestor/ **same evolutionary origin** | **Do not share** (more) recent common ancestor/**different evolutionary origin** |
| Arise by **divergent** evolution/ **adaptive radiation** | Arise by **convergent** evolution |
| Used for **natural** classification | Used for **artificial** classification |
| Classification based on these **matches evolutionary history** | |