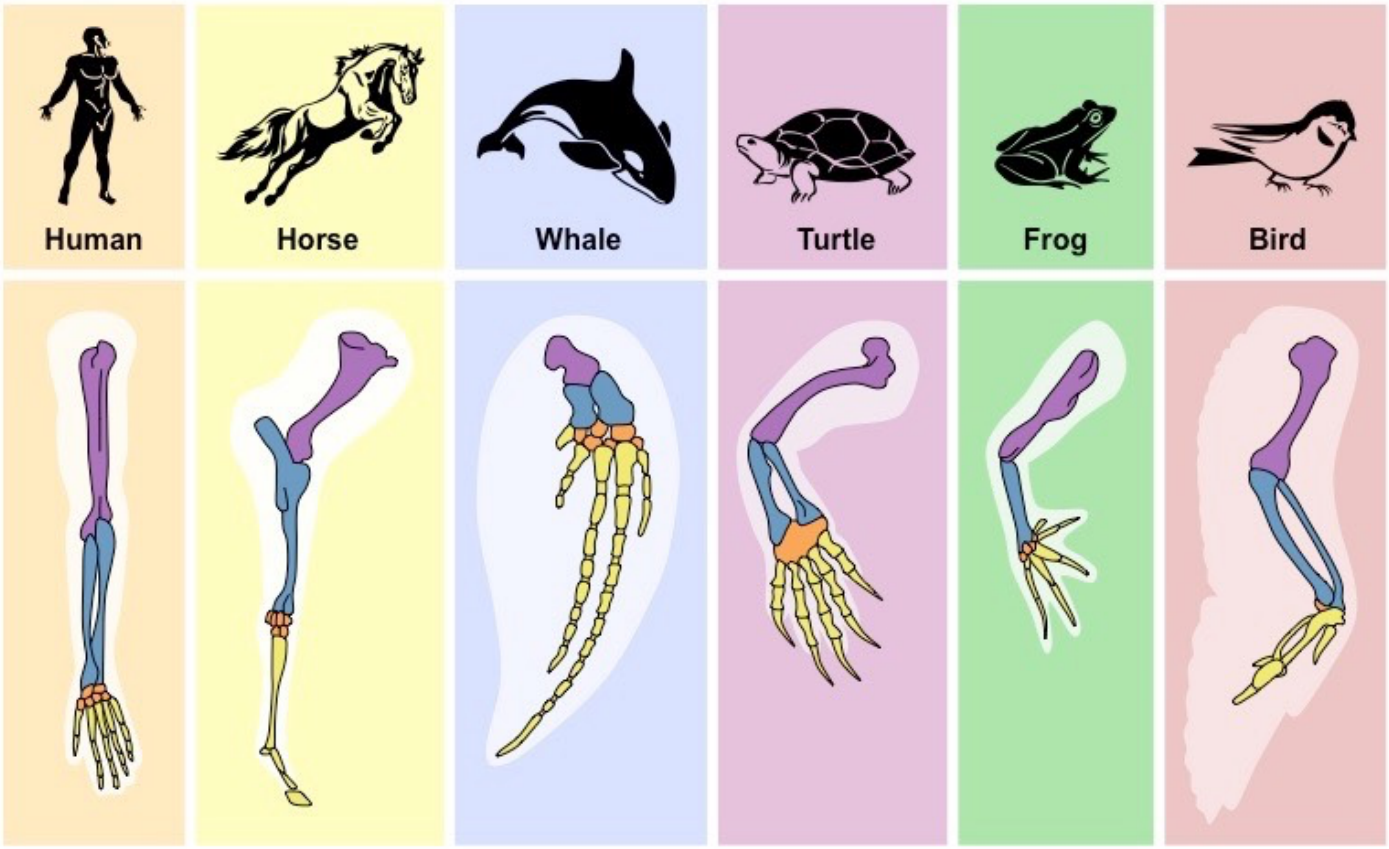
A. DEFINITION

Evolution is the **gradual cumulative changes** in the **heritable** (inherited) **characteristics** of a **species**

B. EVIDENCE FOR EVOLUTION

1. Homologous structures

- Mammals, birds, amphibians and reptiles all share a similar **arrangement of bones** based on a **five-digit (pentadactyl) limb**



tool manipulation	galloping	swimming	swimming	jumping	flying

- Evidence that they **evolved** from a **common ancestor**.
- The pentadactyl limb has the **same basic bone structure**.
- However, it has evolved to have **different functions**.
- This is an example of **adaptive radiation**, which produces organisms, who have **different adaptations** but **common ancestry**. It happens due to **different environments** or **different selective pressures** acting on a population.

Gradual changes in inherited characteristics over time accumulate to give large changes in the phenotype

2. Selective Breeding

Wild pig

Domestic pig

- This is **artificial selection** in which animals with **desirable features** are bred together.
- **Crop plants** and **domesticated animals** are **produced** by **selective breeding**.
- Domestic **pigs** have been **selectively bred** from **wild pigs** for **desirable characteristics**.
- Domestic **dogs** have been selectively bred from **wolves**.
- Selective breeding can cause **rapid change** over time from the **original wild species**
- This is evidence that **species can evolve rapidly** by **artificial selection (=selective breeding)** from the **original species.**
- **Changes** due to **selective breeding** show that **natural selection** can cause **change/evolution** in a **species**.
- Shows that:

Gradual changes in inherited characteristics over time accumulate to give large changes in the phenotype

3. Speciation

- Populations in the same species are **reproductively isolated** so they **cannot breed** with each other.
- Each population will be exposed to **different environmental conditions** and **different selective pressures**.
- **Natural selection** will be **different** for each population and **different adaptations** will be **selected for** in each population.
- Over thousands of years, the two populations may become **so genetically different** that they are **unable to breed** to **produce fertile offspring**, even if they could meet.
- This **would** be **expected** if populations evolve into **separate species**.
- It does **not support** the idea of separate species simply being **created** and **not evolving**.

Gradual changes in inherited characteristics over time accumulate to give large changes in the phenotype

EXAM TIP!

Explain how natural selection leads to speciation

- Here, you need to mention **both** natural selection and speciation in **detail**.

4. Fossil record

- Fossils have been found for many **different types** of **organism** that **do not exist** today.
- Usually, **fossils have not been found** for **organisms** that **do exist** today.
- Shows how **different species** have **changed over time**.
- They **evolved** from a **common ancestor**.
- It suggests that:

Gradual changes in inherited characteristics over time accumulate to give large changes in the phenotype

- **Carbon dating** has shown that:
  - the **order** in which organisms **appeared** on **Earth** matches how **complex** they are

    bacteria + algae **then** fungi + worms **then** land vertebrates

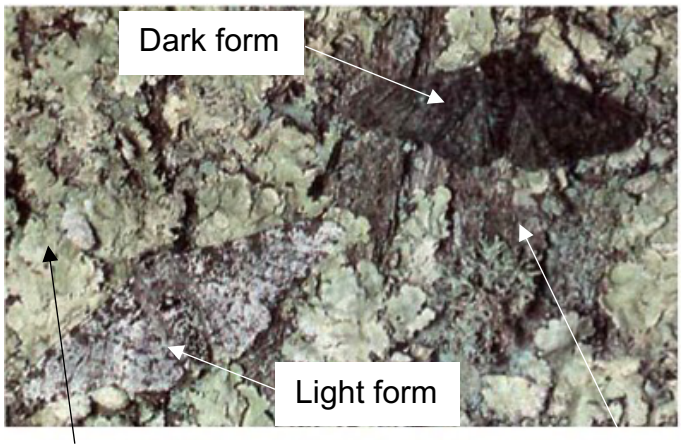
C. NATURAL SELECTION (CHARLES DARWIN)

- **Mutation** causes **variation** in a population
- **Meiosis** and **sexual reproduction** also cause **variation** in a population
- **More** offspring are **produced** than can **survive**
- Due to **competition** for resources
- Some individuals are **better adapted** and have a **selective advantage** over others
- These individuals will **survive**, **reproduce** and **pass** on their **useful alleles** to offspring
- The **frequency** of this **allele** will **increase** in the population
- The **proportion** of the **population** carrying this useful **allele** will **increase**

Example 1: Peppered moths

- There are two types of peppered moth: **light** and **dark** (melanic).

Unpolluted environment



Pale lichen growing on tree bark

Tree bark

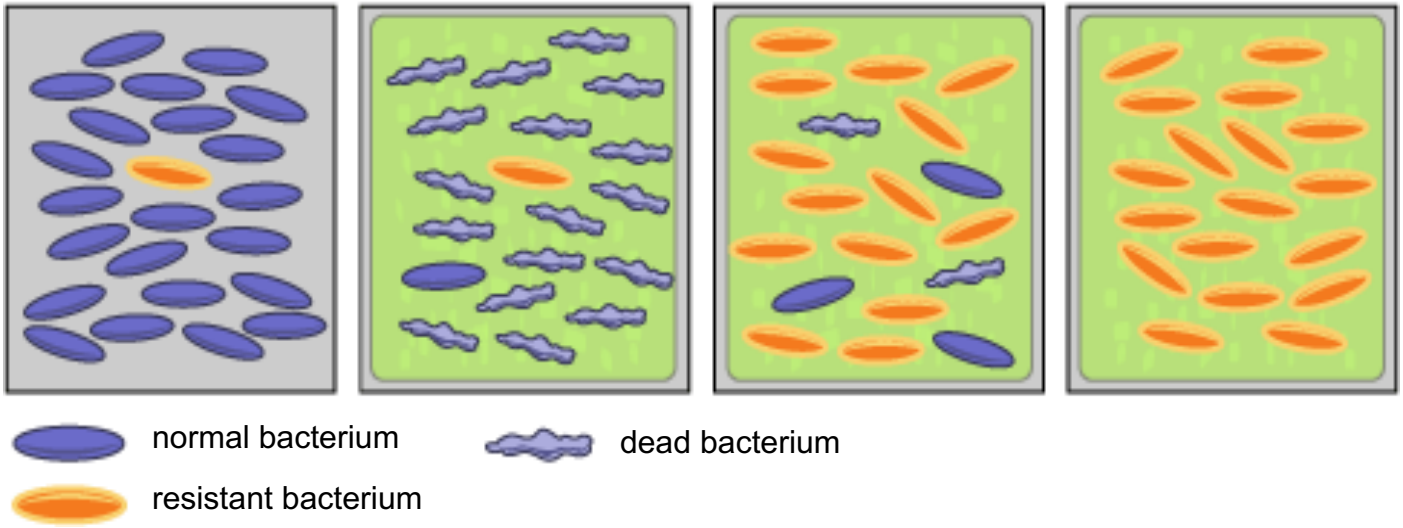
Polluted environment

Unpolluted environment	Polluted environment
Before the industrial revolution	**After** the industrial revolution
Trees covered by pale **lichens**	**Sulphur dioxide killed** pale **lichens**
No soot on tree bark	**Soot blackens** tree bark
Light form has a **selective advantage**	**Dark** form has a **selective advantage**
It is **camouflaged** from predators (birds)	It is **camouflaged** from predators (birds)
Light form **survives** and **reproduces**	**Dark** form **survives** and **reproduces**
Passes on **alleles** to offspring	**Passes** on **alleles** to offspring
Frequency of **allele** for **light** form **increases** in the **population**	**Frequency** of **allele** for **dark** form **increases** in the **population**

Example 2: Antibiotic resistance in bacteria

- Antibiotics are chemicals used to treat bacterial infections.
- Bacteria can pass on **antibiotic resistance genes** on **plasmids** by **conjugation**, even to **different species** of bacteria.
- Bacteria can also pass on **antibiotic resistance genes** by **binary fission**.

Variation exists in the **population** of bacteria, making some **resistant** to a specific **antibiotic** This variation arises from a **mutation**	The **antibiotic** is a **selective pressure** that **kills normal** bacteria but **resistant** bacteria have a **selective advantage** and **survive**	**Resistant** bacteria **reproduce** and **pass on** the **resistance allele** to offspring	**Frequency** of **resistance allele increases** in the **population** Soon, population will be **mainly** made up of **antibiotic resistant** bacteria

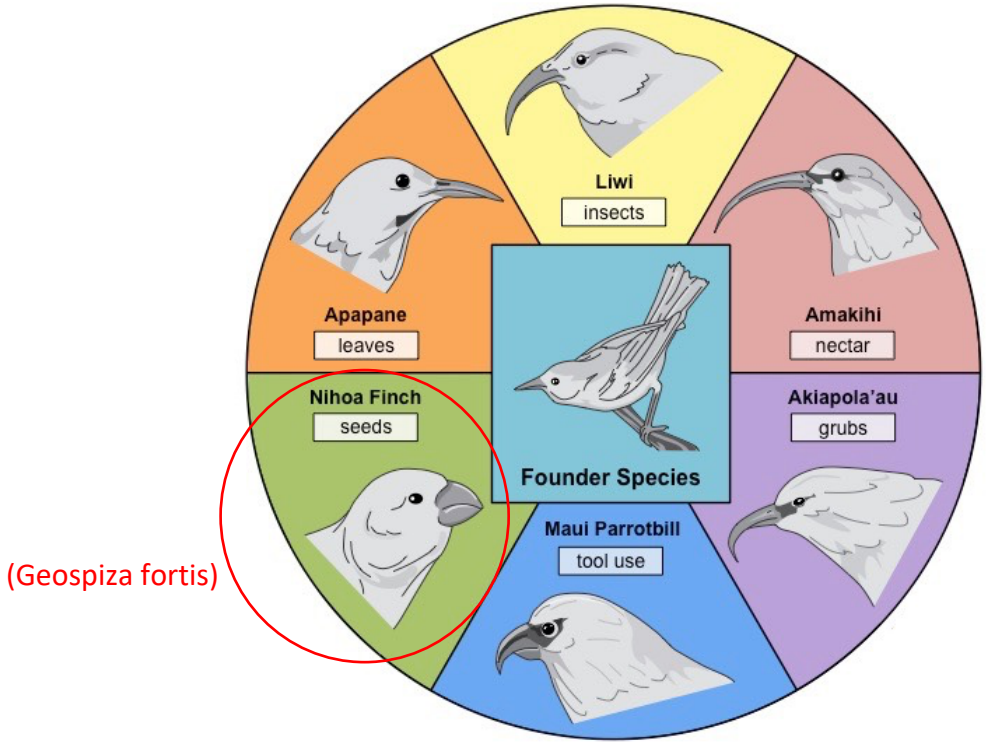


- The **problem** results from:
  - **excessive** use of antibiotics by **doctors**;
  - **low doses** of antibiotics taken by **patients** due to **not finishing** the full course
- The **more** an antibiotic is **used**, the **more** antibiotic-resistant bacteria there will be.
- Doctors need to use a **different antibiotic,** but **resistance** can develop to this too.
- Bacteria can evolve that are **resistant** to **multiple antibiotics**.
- This is an example of **natural selection**.

Example 3: Darwin's Finches On The Galapagos Islands

- A **basic structure** that **evolved** from a **common ancestor** has developed **different functions** in different organisms through **evolution** due to **different selective pressures**.

- Darwin's finches demonstrate **adaptive radiation** and show marked **variation** in **beak size** and **shape** according to **diet**.



"Homing In" On *Geospiza fortis* – one specific species of finch

Finches that feed on seeds (*G. fortis*) possess compact, powerful beaks –
with larger beaks better equipped to crack open larger seed cases
and smaller beaks better equipped to crack open smaller seed cases

- *Geospiza fortis* finches still show **variation** in **beak size**

- There was an **extended drought** from 1973-1977 on a Galapagos Island called ***Daphne Major***.

- **Dry** conditions result in plants producing **larger seeds** with **tougher coats**.

- Between 1976 and 1978 there was an **increase** in the **mean beak size** (depth) within the *Geospiza fortis* population.

- Finches with **larger beaks** were **better adapted** to feed on the **larger seeds.**

- They **survived**, **reproduced**, **passed on** their **useful alleles**, **increasing** the **frequency** of these **alleles**, producing **more offspring** with **larger beaks**.

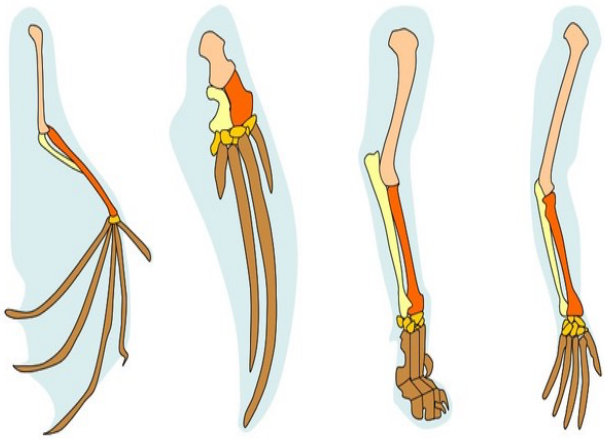
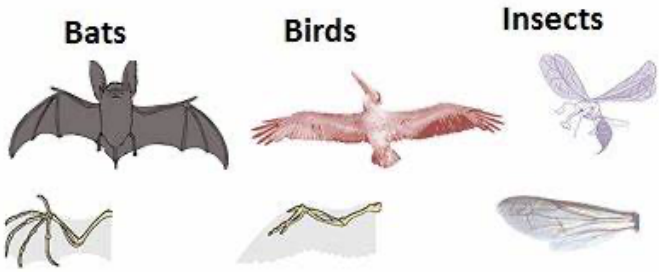
D. CAUSES OF VARIATION

- **Mutation**, **meiosis** and **sexual reproduction** cause **variation** between individuals in a species.

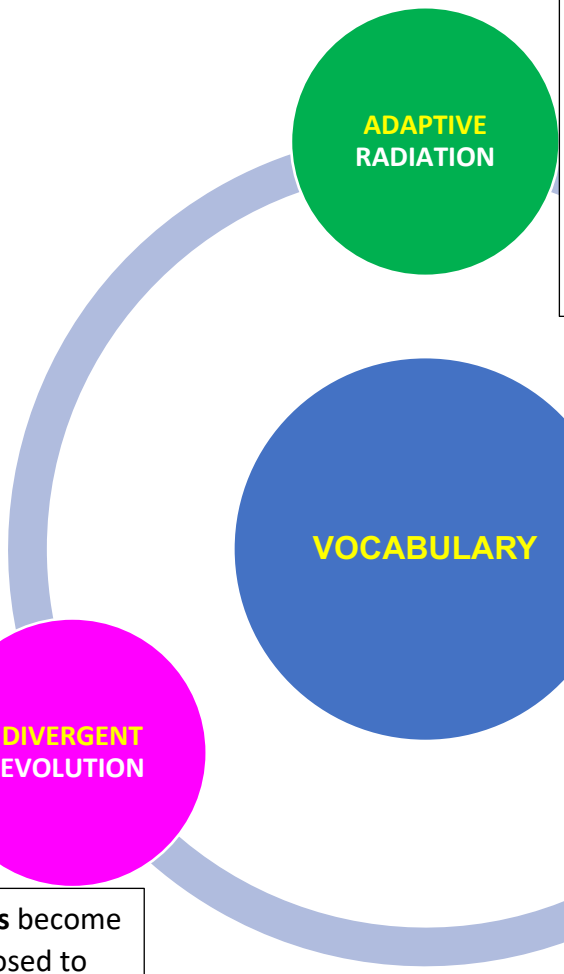
Natural selection does not cause variation.

It reduces variation by selecting for individuals that have a selective advantage.

E. HOMOLOGOUS STRUCTURES v ANALOGOUS STRUCTURES

Homologous Structures	Analogous Structures
Same basic structure but **adapted** for **different functions**	**Different basic** structure but **same function**
Share a more **recent** common ancestor/ **same evolutionary origin**	**Share a** more **distant** common ancestor/ **different evolutionary origin**
Example: **Pentadactyl limb** in vertebrates  **Tailbone** of mammals	Example: **Wings** of bats, birds and insects  **Eyes** of humans and insects
Share a more **recent** common ancestor/ **same evolutionary origin**	**Share a** more **distant** common ancestor/ **different evolutionary origin**
Arise by **divergent** evolution/ **adaptive radiation** **Different selective pressures**	Arise by **convergent** evolution **Same selective pressures**
Used for **natural** classification	Used for **artificial** classification
Classification based on these **matches evolutionary history** and is **therefore** used in cladograms (rather than using analogous structures)	

F. ADAPTIVE RADIATION, DIVERGENT EVOLUTION & CONVERGENT EVOLUTION



A **basic structure** that **evolved** from a **common ancestor** has **adapted different functions** in different organisms through **evolution**

e.g. pentadactyl limb of **vertebrates**
e.g changes in the beaks of finches on the **Galapagos Islands**

Individuals in a **species** become **separated** and exposed to **different selective pressures**, leading to **speciation**

Different species acquire **similar features** due to being exposed to the **same selective pressures**