1. EVIDENCE OF EVOLUTION SUGGESTS THAT MECHANISMS OF INHERITANCE, ACCOMPANIED BY SELECTION, ALLOW CHANGE OVER MANY GENERATIONS

Evolution

Evolutionary theory states that all organisms have developed from previous organisms and that all living things have a common ancestor in some initial form of primitive life. It also states that all organisms are fundamentally similar because their basic chemistry was inherited from this very first organism.

Evolution: A gradual change in a species over time.

Natural Selection: Means that organisms with traits best suited to their environment are the most likely to survive, reproduce and pass on their traits. 'SURVIVAL OF THE FITTEST'

Physical conditions

These include natural conditions, such as temperature, climate, exposure to fire and the availability of water.

The Australian climate has become more seasonal, drier and hotter as it drifted north. Some species such as the Antarctic beech and Wollemi pine have become restricted to small pockets, the Myrtaceous plant family, which includes eucalypts, bottlebrushes, tea-trees and lilly-pillies has diversified. Primitive forms still exist in moist rainforest pockets but the specialised forms have evolved in the very dry, highly seasonal and fire prone regions.

Changes in the environment force species to either die out, or survive and diversify.

Eg. The kangaroo:

The Australia landmass has become drier over time and this has led to changes in the species of kangaroos present today. Approximately 25 million years ago, Australia was wet with large areas of rainforest. During this time, kangaroos were small and omnivorous, with unspecialised teeth, eating a variety of foods from the forest floor. Food was nutritious and abundant; and there was no need for specialised grinding teeth.

As Australia became more arid and grass became the dominant vegetation in some areas, environmental selective pressure resulted in larger kangaroos favouring teeth suitable for grass. These teeth, high-crested molars, efficiently grind low-nutrition grass into a more easily digestible paste. Slicing pre-molars have been reduced.

Eg. The Peppered Moth:

Prior to the Industrial Revolution of the late 18th Century, most Peppered moths were light coloured, but there was also a dark form. They survived better as they could camouflage against the white lichen on the trees.

During the revolution, the pollution caused the trees to blacken with soot. The trees could no longer hide the white moths. The darker variant of the moth was better able to hide, and so the population of the Peppered moth shifted from mainly white to mainly dark.

Chemical conditions

Chemical changes in the environment impact on the evolution of organisms by acting as a selection pressure that decides which organisms are the 'fittest'.

Acidophiles have evolved to be able to survive and thrive in acidic environments such as sulphuric pools.

Many parts of Australia have soils that have a high salinity. There are a range of salt tolerant plants that have evolved to inhabit those areas. The animals that feed from these plants have also evolved to inhabit those areas.

Increases in the levels of oxygen in the atmosphere allowed aerobic respiration and animal life to become possible. An increase in oxygen led to the development of the ozone layer, changing the physical conditions by reducing the intensity of UV rays reaching earth. This allowed the evolution of terrestrial life in all its current forms.

Eg. The sheep blowfly:

Is a major problem to the Australian sheep industry. Chemicals have been used extensively to control the blowfly. However, genetic resistance has occurred within the fly population that has made these chemicals ineffective. Continued use of the insecticide has resulted in the mutation of a gene that increases and maintains the resistance.

Eg. Mosquitoes and DDT:

When DDT was first used as an insecticide to kill malarial mosquitoes, low concentrations were effective.

In subsequent doses, higher concentrations were needed and the sprayings became less effective.

The few DDT-resistant mosquitoes that had survived passed on their genes to their offspring, and now the mosquito population is mainly resistant.

Thus the gene pool had changed.

Competition for resources

If there was competition between two species for the same resources it usually results in a 'winner' and a 'loser'-becoming extinct. However, if among the natural variations within either species that are less fussy about their food or nesting site or resource, they will have the advantage to survive. Survivors breed and pass on their characteristics, and over generations the species evolves to be using a slightly different resource so both species can survive. This is called **RESOURCE PARTITIONING.**

Resources can include food, shelter, space or breeding partners.

- Plants in competition for light are believed to have evolved wider canopies as a means of establishing dominance.

- Allelopathy (the production of inhibitory chemicals released into the environment) has evolved in some plants in response to competition.

Eg. Fruit Flies:

Some species of fruit fly have evolved into different species with each confined to a different type of fruit tree. This is possible if there are different flowering and fruiting times on each tree type suited for different breeding cycles in the fruit flies. Eventually, two distinct species can result.

Eg. Mammals and Dinosaurs:

When the dinosaurs were the dominant life form on Earth, mammals were very scarce.

The dinosaurs had access to most of the resources and so mammals were unable to proliferate into different niches.

When the mass extinction of the dinosaurs occurred, the mammals that so scarcely populated the planet quickly diversified to take advantage of all the available resources, such as plants, or other organisms.

Eg. Dingo and thylacine:

When the dingo was introduced to the Australian mainland competition for food was increased with the thylacine. Dingos were more efficient predators because of their pack behaviour so eventually the tiger became extinct on the mainland.

THEORY OF EVOLUTION

Palaeontology

Palaeontology is the study of fossils, the remains or traces of life forms that have been trapped in sediment, ice or amber and preserved. The fossil record provides a time line of evolution of life engraved in the order in which the fossils appear in rock layers.

Ancient life: Simple types, less variety, less like present-day life
Modern life: More complex types, greater variety, more and more resembling modern life

Initially, scientists could only place fossils in relative time order by correlating the sequences of rock and fossil, but now ***radiometric dating*** can also be used, the determination of the actual age of things by measuring the residual radioactivity of certain, naturally-occurring radio-isotopes in the rocks.

Of particular interest are **transitional fossils**, those have features that make them an intermediate form between major groups of organisms:

1. **Seed ferns** – have features of both ferns and gymnosperms. Resembles fern in structure but produces seeds, not spores.

2. **Archaeopteryx** – a bird-like reptile. Had wings, feathers, reptilian teeth and a long jointed tail.

Biogeography

Biogeography is the study of the distribution of living things.

6 Major biogeographical zones in the world:

- *Oriental*
- *Australian*
- *Ethiopian*
- *Palaearctic*
- *Neotropical*
- *Neartic*

These zones are separated by physical barriers such as seas, mountains and rivers.

The basic principle is that each plant and animal species originated only once. Distribution patterns provide evidence that species have originated from common ancestors and, when isolated, have become new species. The explanation for the unique flora and fauna in Australia is based on biogeography.

By looking at the pattern of distribution today plus its fossil distribution in the past, we are able to reconstruct its evolutionary history

Charles Darwin and Alfred Russell Wallace both observed the distribution of species into different biogeographic regions and saw this as major evidence to support the theory of evolution. They argued that animals in different regions had come from ancestors in that region and had adapted over time to the conditions there.

Eg. Waratahs

There is three genera of waratahs; distribution spans southern Pacific Ocean. The present-day distributions of these closely related species in the eastern parts of Australia, and New Guinea and the Western part of South America suggest that the 3 regions may have been connected in the past.

Eg. Galapagos Island Finches

Darwin noted that islands were populated by many different species of finch. Although they were obviously all related, each separate island had its own particular species.

The islands were first colonised by one type of finch which spread to all of the islands in the group. On each separate island conditions were different (different foods available) so each population evolved in a different way, into a different species, seen in particular by beak size and shape, which is related to diet.

Comparative Embryology

The embryos of different vertebrates (fish, amphibians, reptiles, birds and mammals) are very similar.

The embryos of many different vertebrates all have gill pouches, primitive kidneys, spinal cords and the same type of skin at some stage of development.

This suggests that these vertebrates evolved from a common aquatic ancestor, such as the crossopterygian fish.

Comparative Anatomy

Comparative anatomy is the study of the differences and similarities in structure between different organisms. The structures they have in common are evidence of similar inherited characteristics from a common ancestor.

An example of a homologous structure (have same origin but don't necessarily perform the same function) is the **pentadactyl limb** found in amphibians, reptiles, birds and mammals. The basic plan consists of one bone in the upper limb, two in the lower limb leading to five fingers or toes. In bats, the limb is modified to form a wing with the fingers extended and skin stretched between each finger. Whales have within their single paddle-like fin a fully formed pentadactyl limb. They are modified adaptations to different environments.

Some homologous structures have become vestigial organs- they no longer appear to have any function and are greatly reduced. Eg. Whales have part of the pelvis and leg bones that are remnants of their four legged ancestors. Eg. The human appendix is no longer used in digestion.

The **Xylem** is found in almost all plants. This suggests a common ancestor.

Biochemistry

Recent advances in technology have allowed comparison of organisms on a molecular basis rather than simply comparing structures. This was previously impossible between such distantly related organisms as an orchid and a mouse.

Eg. DNA, organisms sharing common proteins, amino acid sequences and haemoglobins. Even organisms as different as humans and bacteria share common proteins. Eg. Cytochrome c is a protein found in all organisms that respire aerobically.

Darwin's theory of evolution by natural selection

Natural Selection:

- There are variations within every population of species.
- Organisms that don't reproduce have their genes removed from the population.
- More offspring are produced that can survive because of limiting factors in the environment.
- Organisms that survive and reproduce are well suited to their environments.
- Favourable variations are passed onto offspring and become common.

The Role of Isolation:

- For a new species to evolve, groups of organisms need to become isolated from each other.
- Usually the organisms become separated by a physical barrier.
- Within each separate population, different mutations occur, and therefore, different variations are produced.
- Natural selection acts differently on each isolated population, as there are different environmental conditions and selection pressures.

- Over time the populations differ so much that they no longer interbreed, and as such, a new species was produced.

- Isolation can be created by a difference in food preference, to the splitting of the continents.

Divergent evolution:

- Also known as adaptive radiation.

- If groups of a population become isolated, the chances are high that they will encounter differing selective pressure as each environment evolves independently. Eventually, the two populations may have changed sufficiently that they become different species.

- **Eg.** Elephants are large plains-dwelling animals that are closely related to a small guinea pig-like animal called a hyrax.

- **Eg.** The biodiversity of flora and fauna that are unique to Australia are the result of divergent evolution. When Australia separated from Gondwana, the organisms then evolved due to selective pressure from the changing environment. This supports the Darwin/Wallace theory of evolution.

- **Eg.** Darwin's finches

Convergent evolution:

- Occurs when two relatively unrelated species develop similar structures, physiology or behaviours in response to similar selective pressures from similar environments.

- **Eg.** Dolphins (mammals) and sharks (cartilaginous fish) have evolved a streamlined body shape and fins that enable them to move efficiently through their aquatic environment, yet they are only remotely related as vertebrates.

PRAC 1 – Natural Selection Model

1. Each group has a clothes peg, a plastic spoon, tweezers and a needle. A tray of beans as well.

2. Within different and shortening time intervals, each 'bird' with a different 'beak' needs to collect 20 beans to survive.

3. The one with the best suited beak for survival gets the most food and reproduces to pass on its characteristics- the spoon

   The spoonbills had a selective advantage and consistently obtained enough food, so went on to reproduce and pass on their favourable characteristic (gene) and eventually dominated the population. (the food type was the selective agent in the environment)

   This became a problem as there wasn't enough food to supply the growing spoon-bill population → die, move on or find new food source.

Environmental change → change in species

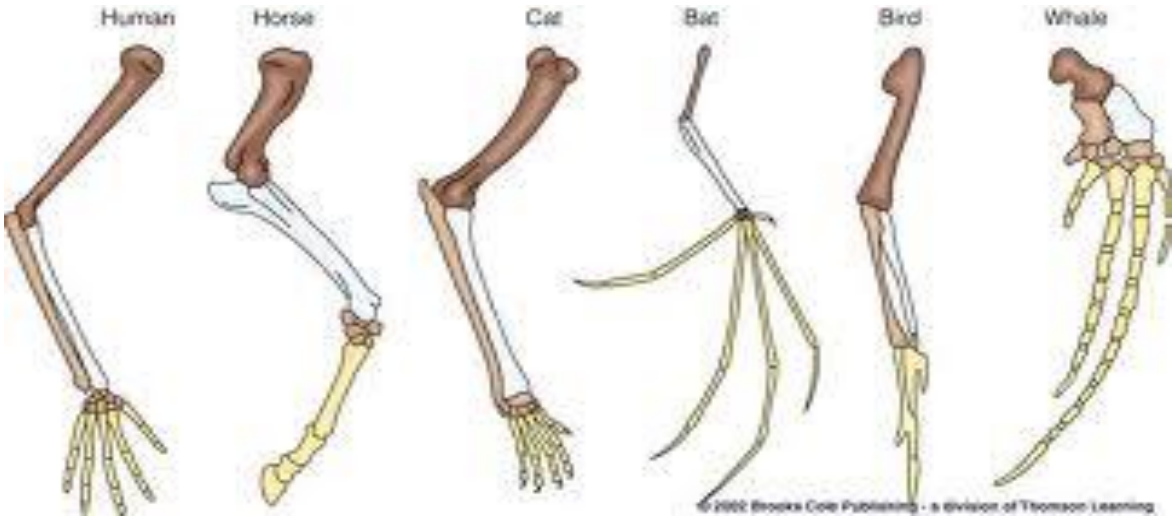
The Peppered Moth:

- The population consisted of 2 variations: the light and dark moth.
- Originally population was mainly composed of lighter moths
- They camouflaged on lichen covered trees to hide from birds
- During Industrial Revolution, trees covered in soot and lichen die off
- Light moths can no longer camouflage, become easier prey. Darker moths can hide better now, on soot covered trees.
- Population shifts from mainly light to mainly dark.

Australian: KOALA

- At the time an earlier variation of the koala lived, the Australian continent was wetter and much more forested than it is today.
- As the continent dried out and the flora became dominated by plants with hard, tough leaves, animals such as koalas had to adapt to this new food source, so the koalas with a more specialised chewing apparatus survived, and now has a more powerful bite force and has the ability to shred the tough leaves of the eucalyptus that are its diet.

Structures of vertebrate forelimbs



All have similar structure: all have humerus, radius and ulna bones.

The proportionate length of these bones varies, along with the wide ranging purposes: for swimming, flying and walking.

This pattern of similarity suggests common ancestry.

Impact of technological advances on scientific thinking about evolutionary relationships

New technologies, especially in the field of biochemistry, have increased knowledge about the relationships between species.

Techniques such as **DNA hybridisation** and **biochemical analysis** between different species have shown the degree of similarity and evolutionary pathways of organisms.

DNA Hybridisation:

DNA hybridisation is a process by which the DNA of different species can be compared.

- The process uses heat to separate the 2 strands of the double helix, from 2 different species.
- The single strands of the different species are then mixed, and cooled.
- On cooling, the hydrogen bonds re-form in varying degrees.
- The greater the number of bonds between the strands, the greater the degree of genetic similarity between the two species.

Eg. DNA hybridisation technology has shown that humans are more closely related to primates than previously thought – shows we share 97% of DNA with chimpanzees.

Eg. It was believed that whales descended from land mammals that had returned to the sea. Anatomical and paleontological evidence suggested the whales' closest living land relatives were cattle or sheep. DNA sequences have suggested that the closest land-bound living relative of whales may be the hippopotamus. Molecular biology in this case has amplified the fossil record.

Biochemical Analysis:

Involves studying the molecular composition of the chemicals that make up organisms.

- Human serum (blood minus clotting agents and blood cells) is injected into another mammal, eg a rabbit.
- The rabbits immune system produces antibodies to these human proteins
- The amount of precipitation that occurs when the serum of two mammals is mixed together is a measure of the difference in some of their proteins.

History of the theory of evolution

1400's – Leonardo da Vinci
Found folssil shells high up on mountains and decided they were once living organisms that had been buried before the mountains were raised.

Early 1700's – *George-Louis Buffon*
Suggested life was older than the 6000 years it was thought to be and that organisms had changed over time

1735 – *Carolus Linnaeus.*
Published classification system and classified humans and apes together, which was strongly resisted.

Late 1700s – *Erasmus Darwin (Charles Darwin's grandfather)*
First suggested all life came from a single source

1809 – *Jean-Baptiste Lamarck*
First explanation of evolution: variation in species has developed due to the 'use' or 'disuse' of body parts. Proved incorrect but challenged belief in creationism and helped make Darwin's ideas more acceptable.

Early 1800's – *Cuvier*
Documented fossils in rock strata and noted each layer was characterised by different types of fossils. Fossils in the deeper layers were the most different from modern species.

Mid 1800's – *Alfred Russel Wallace*
Independently came up with the theory of natural selection and wrote to Darwin to discuss it, prompting Darwin to publish his theory.

1859 – *Charles Darwin*
Published book 'On the Origins of Species by means of natural selection'.

Charles Darwin:

- Born in England in 1809.
- Trained as a physician.
- Keen interest in natural history.
- At the age of 23 set sail on the HMS Beagle as the ships naturalist, although untrained in the field.
- 5 year trip around South America and across the Pacific.
- Made many observations of plants and animals, collecting specimens and keeping notes.
- Intrigued at the variety and diversity of characteristics within a single species and began to question the accepted view that all life on earth was 'fixed'.
- Observations of similarities between different kinds of plants and animals led him to believe they may somehow have evolved from a common ancestral species- 'evolution by natural selection'. Led to a book called *The origin of Species* making two major points: That species were not created in modern form, and that natural selection is the mechanism for change.
- Many objections raised in response to ideas- especially from the church, saying that his work went against the accepted idea of creationism.
- Died in 1882 without recognition for his work.

Lamarck:

- Jean-Baptiste Lamarck (1744-1829).
- First large advance towards modern evolutionary theory.
- Gradual change of species might take place.
- Life started simple and became more complex.

- In 1809 he published an article in which he described a two-part mechanism by which change was gradually introduced into the species and passed down through generations.
- Eg. A muscular man that did weights all his life would have muscular children.
- The classic example is the elongated neck of the giraffe. A giraffe could, over a lifetime of straining to reach high branches, develop an elongated neck.
- A major downfall of this theory was that he could not explain how his may happen.
- Demonstrates how use could change a trait.
- He believed that traits changed or acquired over an individual's lifetime could be passed down to its offspring. Giraffes that had acquired long necks would have offspring with long necks rather than the short necks their parents were born with.
- He studied ancient seashells and noticed the older they were the simpler they appeared.

Darwin and Wallace develop similar theories

Darwin began formulating his theory of natural selection in the late 1830's but he went on working quietly on it for 20 years. He wanted to collect a wealth of evidence before publicly presenting his idea. During those years he corresponded briefly with Wallace who was exploring the wildlife of South America and Asia. Wallace supplied Darwin with birds for his studies and decided to seek Darwin's help in publishing his own ideas on evolution. He sent Darwin his theory in 1858, which, to Darwin's shock replicated his own.

THE DARWIN-WALLACE THEORY OF EVOLUTION

1. **All organisms produce more offspring that can survive**
2. **In every species there is variation among the individuals**
3. **Nature selects which individuals survive**
4. **Those best suited to their environment survive, reproduce and pass on their characteristics**
5. **Over generations, the species changes...it evolves**

SOCIETY AND POLITICS

Predominant view in western cultures, up until Darwin's theory, was creationism- the diversity of living things was created for their environments at the same time by God in six days; the organisms have not changed and are not related.

Darwin's theory of evolution was and still is rejected by many religious people. The theory, particularly the idea that humans and apes have common ancestry, caused social and political outrage. People believed humans had a special place in the world. The idea of evolution reduces humans to the same level as every other organism and threatened the base of their power.

In the 1920's Protestant traditionalists campaigned against the antibiblical ideas of evolution. Several US states banned the teaching of evolution in public schools. A teacher from Tennessee in 1925 was arrested and put on trial for teaching the theory of evolution to his class. There is still today pressure on schools to teach the biblical story of creation instead of or as well as evolution.

2. GREGOR MENDEL'S EXPERIMENTS HELPED ADVANCE OUR KNOWLEDGE OF THE INHERITANCE OF CHARACTERISTICS

Gregor Mendel's Experiments

- Genetics is the study of heredity.
- Heredity is the transfer of characteristics from one generation to the next.
- The founder of the modern study of genetics was an Austrian monk, Gregor Mendel, who lived in the 19th century.
- He studied the genetics of the garden pea plant.
- Mendel chose garden peas because they were easy to grow, produced new generations quickly and had easily distinguishable characteristics.
- He was also able to strictly control the breeding patterns of his peas.
- **Mendel examined the following seven characteristics found in peas:**

    1. Flower colour- purple or white
    2. Flower position- axial or terminal
    3. Seed colour- yellow or green
    4. Seed shape- round or wrinkled
    5. Pod shape- inflated or constricted
    6. Pod colour- green or yellow
    7. Stem height- tall or short

- Mendel needed to control fertilisation. Self-fertilisation was ensured by placing a bag over the flowers to make sure pollen from the stamens lands on the carpel of the same flower. Cross-fertilisation was ensured by cutting off stamens from a flower before pollen was produced, then dusting the carpel of the flower with pollen from another plant. To ensure reliability, Mendel used thousands of plants in each experiment.

    1. Mendel first cross-fertilised two true-breeding plants for one characteristic, for example tall plants were crossed with short plants (Mendel called these plants a P_1 parent generation).
    2. The offspring produced are called F_1 generation.
    3. The F_1 generation were then self-fertilised or cross-fertilised to produce a second generation, F_2.

    Each of the seven traits that Mendel studied had a dominant and a recessive factor. When two true-breeding plants were crossed, only the dominant factor appeared in the first generation. The recessive factor appeared in the second generation in a 3:1 (dominant: recessive) relationship.

Mendel concluded from his experiments that:

- Characteristics were not blended but were discrete units.
- Each characteristic was controlled by a pair of factors.
- The factors separated from one another when sex cells were formed (MENDELS LAW OF SEGREGATION).
- At fertilisation the offspring received one factor from each parent randomly (MENDELS LAW OF INDEPENDENT ASSORTMENT).
- One factor was dominant while the other was recessive.

Today we call Mendel's factors **genes** and the alternate forms are known as **alleles**.

What led to the success of Mendel's experiments?

Mendel was successful because he:

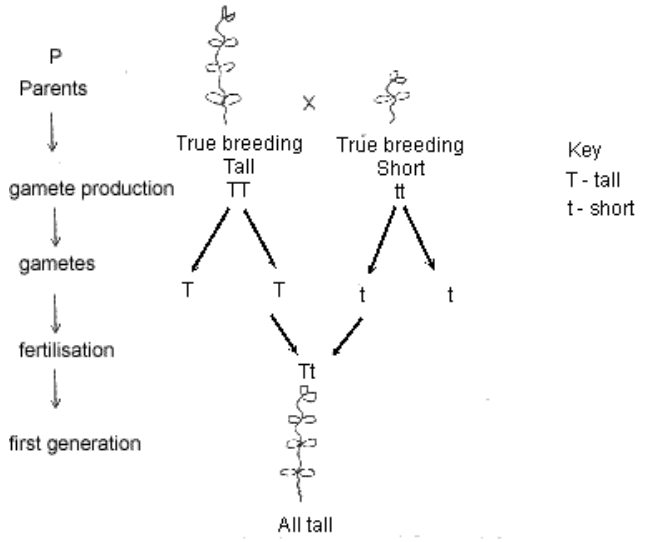
- Used peas, which were easily grown and produced successive generations rapidly
- Selected easily observable characteristics
- Strictly controlled the fertilisation process
- Kept accurate records
- used mathematics rigorously to analyse his results
- used large numbers of plants and repeated many times
- Studied traits that had two easily identified factors

Mendel was also fortunate that the seven factors he studies were all on different chromosomes and weren't genetically linked.

Monohybrid Crosses

Monohybrid crosses involve one factor only.

For example, a cross might involve a true breeding (homozygous) tall plant crossed with a true breeding (homozygous) short plant. This produces a first generation where all of the plants are tall. Mendel explained the first generation trait as the dominant factor.



Thus, Mendel was able to explain his observed ratios, i.e.

F1 - all tall
F2 - 3 tall: 1 short

Homozygous and heterozygous genotypes

Genotype is the type and arrangement of genes.

- Alleles (factors) that are the same are termed ***homozygous***, e.g. TT and tt.
- Alleles (factors) that are different are termed ***heterozygous***, e.g. Tt.
- In the heterozygous condition the factor that is fully expressed is termed dominant and the factor that has no noticeable effect is called the recessive.

Alleles and genes

Chromosome: A long strand of DNA located in the nucleus.
Chromosomes always come in pairs, one from the mother (maternal) and one from the father (paternal).
The pair of chromosomes are called HOMOLOGOUS chromosomes.

Allele: An alternative for a particular inheritable characteristic, e.g. tall (T) and short (t) are two alleles for the characteristic of height in some plants.
With the development of modern genetics, we now identify these factors as genes.

Gene: A section of DNA a chromosome; it codes for a particular characteristic
Alleles are alternative forms of a gene.

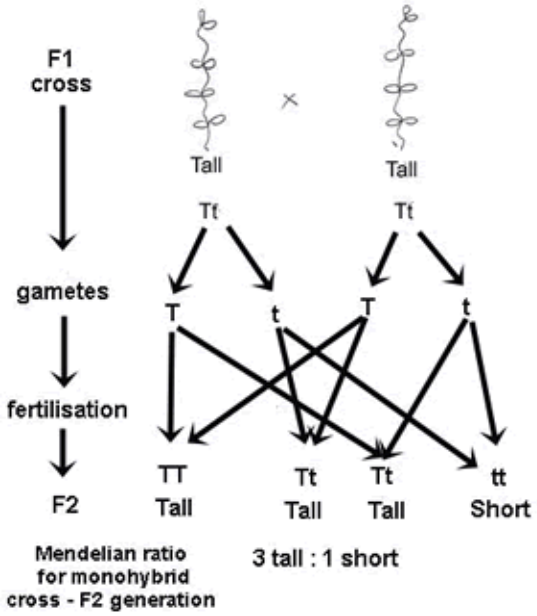
Eg. The gene for eye colour, and the brown allele or the blue allele.

Dominant and recessive alleles and phenotype

Dominant alleles are expressed in the phenotype whether they are heterozygous or homozygous.
Recessive alleles are only expressed in the phenotype if no dominant allele is present.

Phenotype: The outward appearance of an organism.
Genotype: The actual alleles that are present on the chromosomes of the organism.

A **homozygous** tall plant would have two identical alleles for height (TT) and would appear tall.
A **heterozygous** tall plant would have the phenotype of a tall plant but would have non-identical alleles (Tt). In this case, tall is dominant and short is recessive and is not expressed.



Recognition of Mendel's work

Mendel began his work in 1858 and published the results of his experiments in 1866, but his work lay undiscovered until 1900 when others performed similar experiments. It was only then that the importance of his work was realized.

It is unclear why such original work went unnoticed, perhaps:

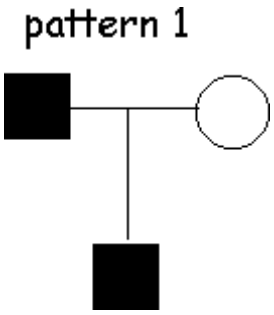
- Mendel was not a recognized, high profile member of the scientific community
- He presented his paper to only a few people at an insignificant, local, scientific meeting
- Other scientists did not understand the work or its significance.
- He used mathematics, which most biologists and scientists weren't familiar with
- Published in German not English, the most widely recognised language in the science world.

Family Trees

Used in human genetic studies to trace occurrence of genetic diseases over several generations. Examining the family pedigree can be helpful when advising prospective parents on the probability of having an affected child.

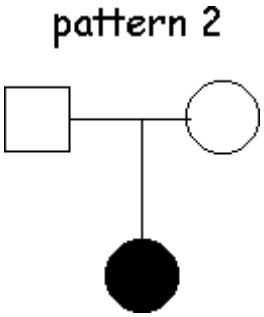
Pedigrees are also used in zoo management and for breeding animals such as dogs and racehorses. Record keeping ensures that the animals do not become inbred.

Squares represent males, circles females
Marriage is shown horizontally, offspring vertically left to right



In pattern 1, the son and father are both affected. This is a reasonable indication that the characteristic is dominant. An affected offspring must have at least one affected parent if the phenotype is dominant. Other features of pedigrees of a dominant trait are:

- Heterozygous individuals will be affected
- Two affected parents can produce an unaffected child (both parents would be heterozygous)



In pattern 2, the daughter is affected but neither parent is. This can only happen if the characteristic is recessive and the offspring are homozygous, e.g. bb. Both parent must be heterozygous, Bb.

Other features of pedigrees of a recessive trait are:

- Heterozygous parents will be unaffected
- Two affected parents will always have an affected child.

Monohybrid Crosses

- One short stemmed pea plant (rr)
- One tall stemmed pea plant (RR)

	R	R
r	Rr	Rr
r	Rr	Rr

Generation F1 = all TALL (Rr)

	R	r
R	RR	Rr
r	Rr	rr

Generation F2= 3 tall : 1 short

Hybridisation

Hybridisation is the act of mating organisms from different species to create a hybrid.
Eg. Liger, mule, wholphin, nectarine, zebroid

Eg: the Zebroid was bred because of practical riding reasons:

- Useful body shape for riding
- Temperamental
- Difficult to handle

Eg: Hybrid Corn produces greater crop yields:

- Grows more vigorously
- Resists disease and pests better
- Tolerates stress more effectively
- Stands upright better

4. CHROMOSOMAL STRUCTURE PROVIDES THE KEY TO INHERITANCE

- Each species has a constant number of chromosomes.
- Chromosomes come in pairs (homologous pairs).
- One of each pair of chromosomes comes from the female parent and the other from the male parent.
- The sex chromosomes are not identical in humans- XX is female and XY is male.
- The sex cells have half the number of chromosomes (haploid) of body cells (diploid).

Sutton and Boveri

Sutton and Boveri were the two scientists credited with the discovery of the role of chromosomes in 1902.

Boveri- A German biologist that worked on sea urchins – showed that a complete set of chromosomes is necessary for normal development of an organism.

Sutton- an American geneticist that worked on grasshoppers – his observations provided evidence that chromosomes could carry Mendel's 'factors', or 'genes'. His data showed that:

- Each chromosome was unique.
- During meiosis the number of chromosomes is halved.
- Fertilisation restored the full chromosome number.
- Not all factors followed Mendel's laws because they were located on the same chromosome and were not independently assorted during meiosis.
- Chromosomes keep their individuality throughout cell division.
- Suggested the lining up of chromatids at the equator was purely chance- increases variation.

Together their work became known as the Sutton-Boveri chromosome hypothesis.

Chemical nature of chromosomes and genes

- Chromosomes are thread like structures found in the nucleus of cells
- Each chromosome is made up of about 60% protein and 40% DNA
- A gene is a section of DNA on a chromosome
- The DNA is made of sugar, phosphate, and nitrogenous bases.
- It is made up of a particular sequence of bases
- Different genes are different lengths

DNA

DEOXYRIBOSE NUCLEIC ACID
DNA is a nucleic acid that has double-stranded molecules in the shape of a helix.

DNA is a double-stranded molecule twisted into a helix.

DNA Strands:
Each strand of DNA is made up of building blocks called ***nucleotides:***

- A nitrogen base
- A sugar
- A phosphate

The four different bases are adenine, thymine, guanine, and cytosine.

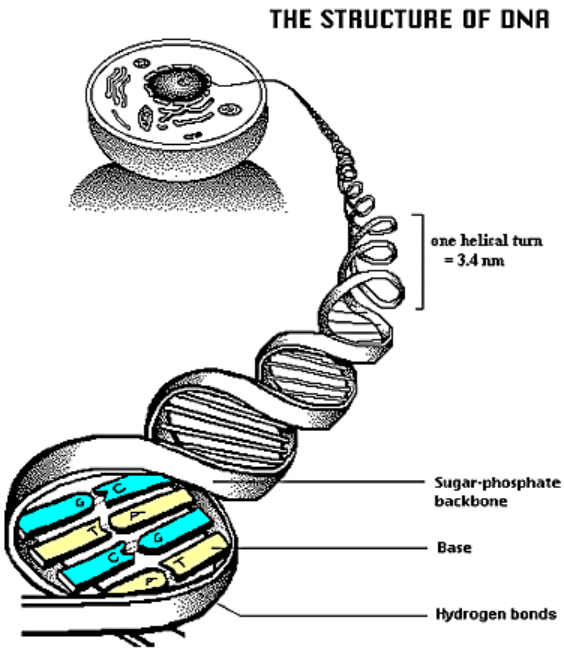
Adenine pairs with thymine (A-T) and guanine with cytosine (G-C).

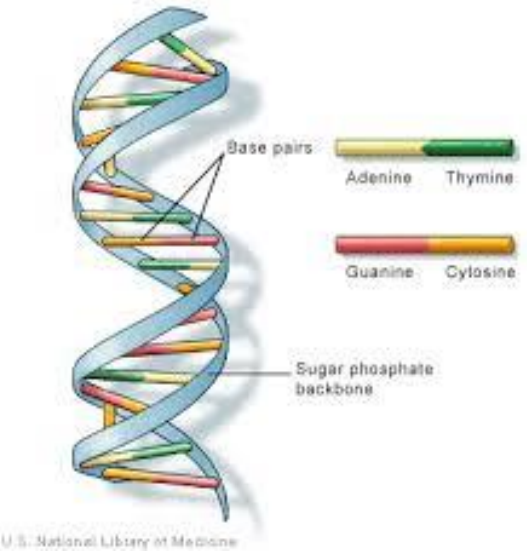
A & T
C & G

- A single DNA strand is made up of a chain of nucleotides (a polynucleotide) where the phosphate and sugar alternate as the backbone of the strand.
- The bases attach to the sugar.
- The other strand of DNA attaches to the strand by complementary pairing of the nitrogenous bases.

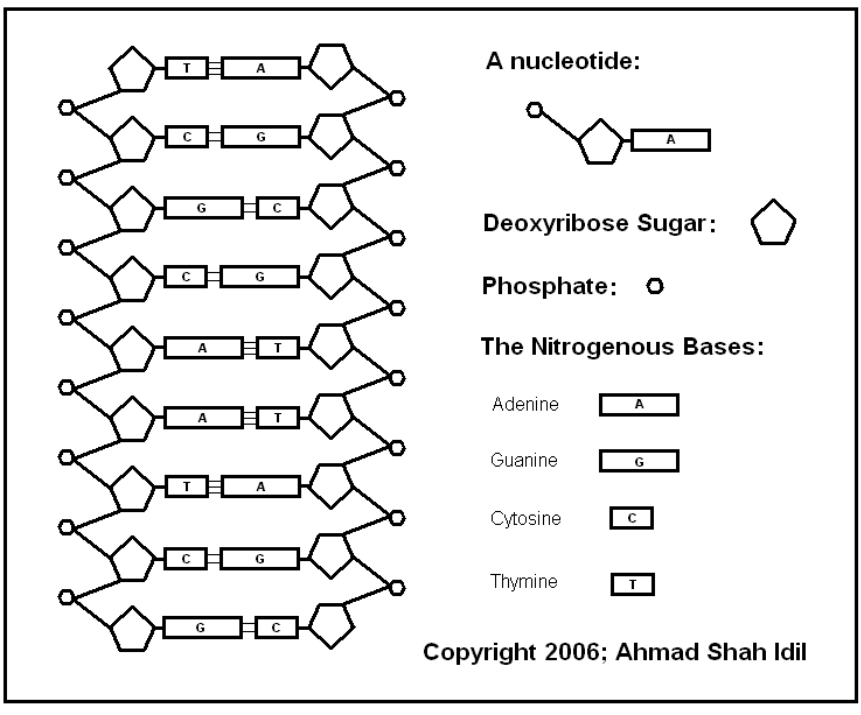
DNA is a 3-base code sequence

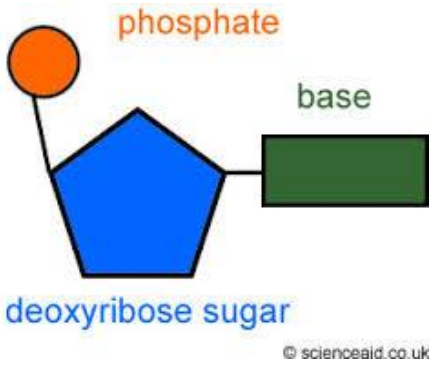
A **gene** is made up of a sequence of genetic units
A gene controls the putting together of amino acids to make proteins.





Mei osis





Meiosis is cell division that produces sex cells and halves the number of chromosomes.

Before a cell undergoes meiosis the chromosomes in the nucleus are replicated. The copies, called chromatids, are linked by a centromere.

During the first stage in meiosis the homologous chromosomes line up. Crossing over may occur, when two chromosomes swap chromatid parts. The new chromosomes are called recombinants.

There are many genes on each chromosome. If genes are located on the same chromosome they are said to be linked. Usually they are inherited together but if crossing over occurs the linkage may be broken meaning some genes change position during meiosis leading to an increase in variability.

During the second stage the chromatids separate and four cells are formed with a haploid number of chromosomes. These are the gametes or sex cells.

Gamete formation and sexual reproduction

- Gamete formation results in the halving of the chromosome number (diploid to haploid) and sexual reproduction results in combining gametes (haploid to diploid) to produce a new diploid organism.
  The processes involved in forming this new organism result in variability of the offspring.

- Gametes are formed during the process of meiosis. In meiosis there are two stages that lead to variability. These are:

  1. Random segregation of individual chromosomes with their associated genes.
  2. The process of crossing over where the maternal and paternal chromosomes of each pair may exchange segments of genes making new combinations of genes on the chromosomes.

- In sexual reproduction each female or male cell produces 4 sex cells (gametes) from the process of meiosis. Each of these sex cells is haploid and has a random assortment of genes from the parent. The genes (Mendel's alleles) are separated and the sex cells have a random assortment of dominant and recessive genes. More variability is introduced depending on which sex cells are successful in fertilisation. The resulting embryo has a completely different set of genes from either of the parents.

RANDOM SEGREGATION: During meiosis, genes on different chromosomes sort independently. They can line up in the middle of the cell in many different ways. This produces many gene combinations, which are different from the parents

CROSSING OVER: Crossing over of genetic material during meiosis results in the exchange of genes between chromosome pairs. The combinations of alleles of the gametes will vary across cells and differ from the parent

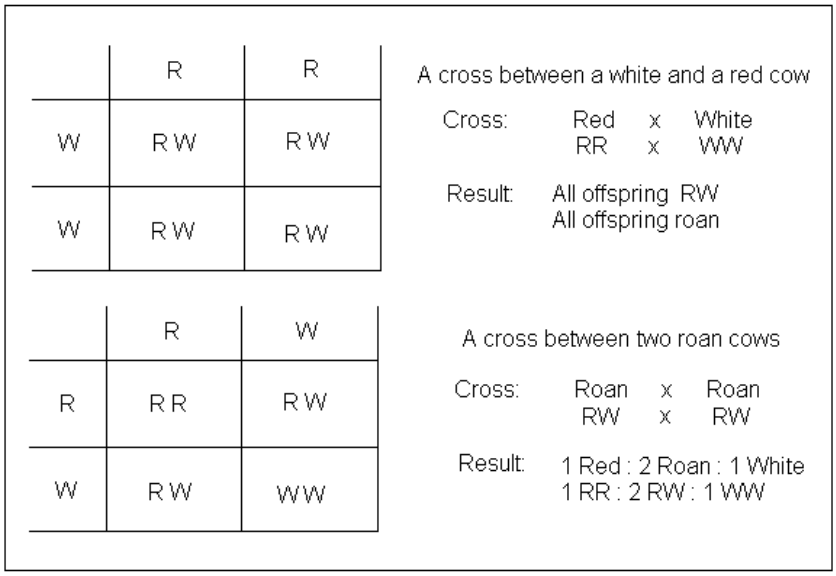
RANDOM FERTILISATION: When the male and the female mate, the two different gametes randomly fuse. Many different combinations are possible, and this causes variation.

Sex Linkage, Co-dominance and Incomplete Dominance

In some instances the heterozygous form has a different phenotype to both heterozygous forms- called **INCOMPLETE DOMINANCE**.

Eg. White snapdragon x red snapdragon = pink snapdragon

In other instances, both alleles are expressed in the F1, called **CODOMINANCE**.
Eg. White cow x red cow = roan cow.



	R	R
W	R W	R W
W	R W	R W

A cross between a white and a red cow

Cross: Red x White
RR x WW

Result: All offspring RW
All offspring roan

	R	W
R	R R	R W
W	R W	WW

A cross between two roan cows

Cross: Roan x Roan
RW x RW

Result: 1 Red : 2 Roan : 1 White
1 RR : 2 RW : 1 WW

SEX LINKED INHERITANCE causes variation on Mendel's predicted outcomes. Results from gene carried on the x(female xx) or y(male xy) chromosome. Eg Haemophilia and red-green colour blindness in humans.

The gene for colour blindness is carried on the X chromosome and there is no corresponding gene on the Y chromosome.

Therefore males need only one allele for colour blindness on the X chromosome while females require two.

This results in many more males being colour blind than females because the father would have to be colour blind and the mother either colour blind or be a carrier for colour blindness.

Morgan's work and sex linkage

- Morgan studied the breeding of the fruit fly- an ideal species for breeding experiments as it has easily observable characteristics that are carried on only 4 pairs of chromosomes. They produce hundreds of offspring in a single mating and can easily be bred in laboratory.
- As he was breeding the flies, he noticed one white-eyed male fly among the offspring of red-eyed parents, this was strange as the normal eye colour was red.
- He further bred this white male with red eyed females and all of F1 had red eyes, showing red is dominant over white.
- He interbred the F1 generation and had a phenotypic ratio of 3 red : 1 white eyed offspring, the white-eyed trait was however only present in males, with half of them having red and half white eyes. The gene for red eyes is located on the X chromosome.

Homozygous and heterozygous genotypes and resulting phenotypes co-dominance

Eg. Roan Cattle

Eg. Andalusian fowls. Homozygous black (BB), homozygous white (WW) HETEROZYGOUS blue (BW)

Eg. Human blood types A and B. Heterozygous AB

Effect of environment on gene expression

- Genes are not the only factor that influence phenotype.
- GENES + ENVIRONMENT = PHENOTYPE.
- Factors in the environment such as availability of water, nutrients, sunlight, soil type, competition and presence of poisonous substances determine how well genes are expressed.

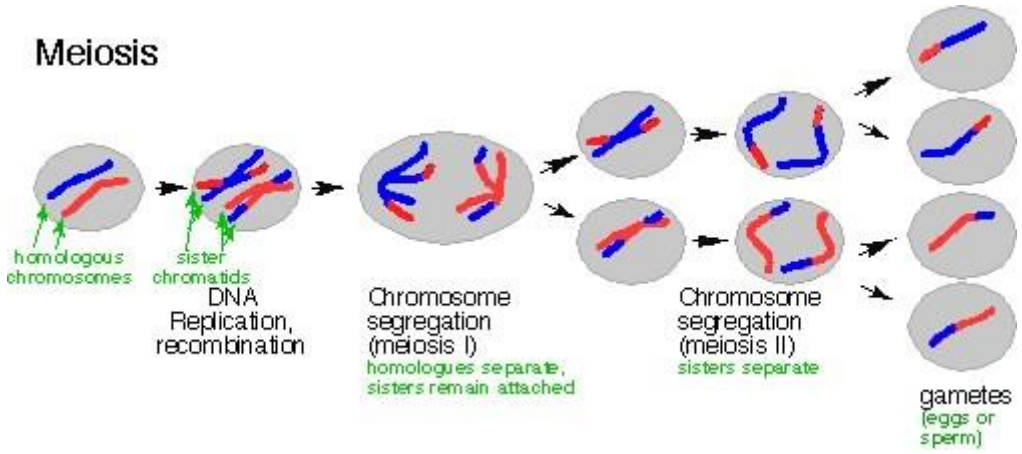
Eg. Hydrangeas are plants that have different flower colour (pink or blue) depending on the pH of the soil they are grown in.

In acid soils (less than pH 5) Hydrangeas are blue.

In soils that have a pH greater than 7 Hydrangeas are pink.

The pH has an effect on the availability of other ions in the soil and it is these ions that are responsible for the colour change.

Meiosis Model



Meiosis I

1. INTERPHASE I

- Chromosomes are fine threads
- Replicating occurs

2. PROPHASE I

- Chromosomes condense and become visible

3. METAPHASE I

- Chromatids visible
- Nuclear membrane breaks down
- Spinal forms
- Chromosomes line up

4. ANAPHASE I

- Centromeres split
- Single strand chromosomes drawn to opposite sides

5. TELEPHASE I

- Nuclear membranes form around new nuclei

Meiosis II

1. PROPHASE II

2. METAPHASE II

3. ANAPHASE II

4. TELEPHASE II

5. CYTOKINESIS

Problem solving with co-dominance and sex linkage

Red haired cow x white haired cow = roan

Genotype	Resulting phenotype
Homozygous RR	Red coat
Homozygous WW	White coat
Heterozygous RW	roan

Carrier mother x non-colourblind father

	XN	**X**n
XN	XNXN	XNXn
Y	XNY	XnY

All female children would have normal vision but would be carriers, and male children would have a 50% chance of being colour blind

PRAC 2 – Influence of environment on phenotype

We tested what role environmental factors play in the phenotype (appearance) of sunflowers

Hypothesis: Environment plays major role on phenotype of sunflowers. High nutrient soil will be taller

Aim: To determine the effect of environment on the phenotype of sunflowers.

Method:

1. Placed 1 sunflower seed in high nutrient soil and 1 in low nutrient soil.
2. We gave them the same environmental factors such as sunlight and water.

Results: The high nutrient soil produced taller sunflowers than the low nutrient.

Conclusion: With the same genotype the phenotype was influenced by environment

Safety:

- Plants should be sensibly located so there is no chance of injury from pots falling.
- Leather shoes should be worn to protect feet.
- Gloves should be worn to protect against infection from organisms in the soil.

4. THE STRUCTURE OF DNA CAN BE CHANGED AND SUCH CHANGES MAY BE REFLECTED IN THE PHENOTYPE OF THE AFFECTED ORGANISM

DNA Replication

The process by which an exact copy of DNA is made.

1. The DNA double helix is unwound by an enzyme (DNA helicase) breaking bonds between nitrogen bases.

2. The DNA unzips forming two single strands. Free nucleotides floating in the nucleus attach to the exposed bases; A with T and C with G, ensuring replication is exact.

3. The joining of the nucleotides together is catalysed by an enzyme (DNA ligase).

4. When fully replicated the two new double strands wind back up into the double helix form.

The two double stranded molecules are the chromatids.

The significance of this process is the genetic information is passed on from generation to generation. During sexual reproduction, the genetic code is copied and then half of the genetic information passes into each of the sex cells. When fertilisation occurs the new organism has half the genetic material from each parent.

The DNA in a cell contains the genetic information to make an entire organism. When a cell divides it takes with it an exact copy of the genetic code of that organism.

Polypeptide/Protein Synthesis

DNA controls the production of long chains of amino acids (polypeptides) which make up proteins. The particular sequence of amino acids results in the protein forming a particular structure/shape for its role- eg. Enzyme, haemoglobin, hormone or structural protein for muscle or skeletal tissue.

STAGE ONE – Transcription:

Chemical code (sequence of bases in DNA) is transcribed into another molecule, RNA.

RNA: Similar to DNA but single stranded and has uracil to attach to andenine instead of thyamine. There are two types of RNA: messenger RNA (mRNA) and transfer RNA (tRNA).

In the nucleus, the double stranded DNA molecules unzip and the DNA code is transcribed into the single stranded mRNA molecule. The mRNA moves out of the nucleus into the cytoplasm and attaches to a ribosome.

Messenger RNA attaches to DNA strand according to base code

STAGE TWO – Translation:

Messenger RNA leaves nucleus and takes its copied code to ribosomes where amino acids are synthesised into polypeptides

- In the cytoplasm, the mRNA is translated into amino acids.
- At the ribosome, the messenger RNA lines up forming a template. A group of three bases, called a *codon*, codes for a specific amino acid.
- Messenger RNA determines the order in which the amino acids are lined up and bonded into polypeptide chains to form the protein

Transfer RNA (and DNA) brings amino acids according to the bases on Messenger RNA

END RESULT – Chain of amino acids = protein

Relationship between proteins and polypeptides

Proteins are the building materials of an organism. A protein is made up of amino acids bonded together by peptide bonds- polypeptides. These polypeptide chains are frequently folded and twisted to give them a particular structure.

Mutations in DNA a source of new alleles

A mutation is a change in the DNA information on a chromosome, changing the base sequence. This means that, possibly, new amino acids will be introduced in polypeptide chains; this will lead to new proteins being produced, and new forms of traits → generation of new alleles. To produce changes in alleles, the mutation must occur in the sex cells of the organism which are then passed on to the next generation.

Three things can happen as a result of a mutation:

1. Most mutations are <u>lethal</u> and kill the cell the mutation takes place in.
2. In some cases, the mutation is not advantageous or lethal to the organism. It is a <u>neutral</u> mutation.
3. VERY RARELY, a mutation will give an organism a phenotypic advantage. These individuals with the new allele will be at a selective advantage, and be better suited to their environment.

Mutations may be caused by:

- Deletion (DNA is lost)
- Duplication (a section of DNA is copied twice)
- Substitution (a different base is included)
- Inversion (DNA breaks and rejoins the wrong way)

Mutagenic nature of radiation

Factors that cause mutations are known as mutagens. They interact with DNA and cause changes to the DNA sequence.

Carcinogen: Mutagen that causes cancer

Teratogen: Mutagen causing birth defects

There is much evidence for the mutagenic nature of radiation. Environmental factors that may increase the rate of mutation include X-rays, radiation from atomic bombs and ultraviolet light.

A mutagen is a natural or human-made agent (physical or chemical) which can alter the structure or sequence of DNA. Mutagens can be carcinogens (cancer causing) or teratogens (birth defects causing)

Evidence:

- UV radiation has been recorded to increase the incidence of skin cancers in humans. Some regard it as the sole cause of skin cancer
- X-rays were the first noticed radiation mutagen- eg. Marie Curie died or leukaemia due to prolonged exposure.
- People who live in areas which have been affected by high-level radiation, such as Hiroshima, or Chernobyl, still show high incidences of cancers and other mutations in their offspring.

Mutagens may cause death in the individual but unless they affect the sex cells the effect is not passed on to the next generation.

Understanding of causes in variation in organisms provided support for Darwin's theory of evolution by natural selection

- We know Darwin's theory requires variation to be present within a population.

- Our knowledge of genetics tells us where this variation comes from:

    - The random segregation of chromosome pairs during meiosis
    - Crossing over of genetic material during meiosis
    - Random fertilisation of sex cells
    - Random mutation of the genetic material

- The phenotypes that are variable are "chosen" by the environment
- Over time, some genotypes become more prevalent than others

Punctual Equilibrium- differs from Darwin's view

Darwin's Gradualism:

He proposed that populations change slowly and gradually over time.
However, the fossil record only shows rare occasions where this happens.

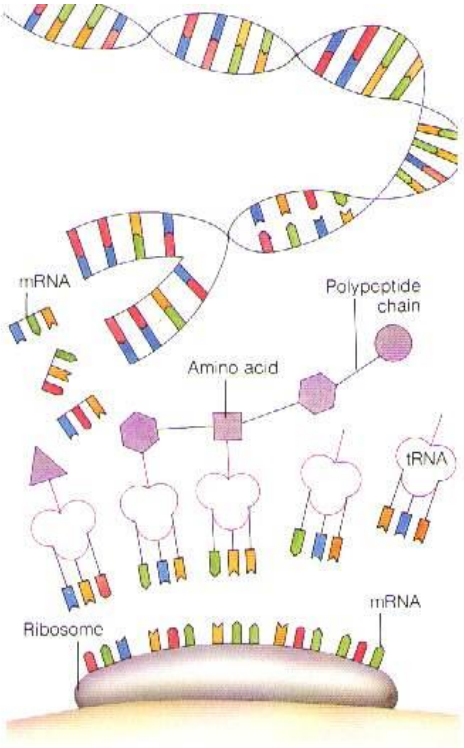
- If an environment remains stable for many years, we would expect there to be no change in the organisms living there.
- It is only when the environment changes that natural selection occurs.
- The fossil record in fact shows periods of stability followed by mass extinctions and rapid change.

Punctuated Equilibrium:

The fossil record suggests that organisms evolve suddenly, and remain stable for millions of years. The earth isn't old enough to support Darwin's theory of only gradual change.

Punctuated equilibrium proposes that, instead of gradual change, there have been periods of rapid evolution followed by long periods of stability, or equilibrium. It helps explain the incompleteness of the fossil record.

Protein Synthesis Model



DNA → mRNA → tRNA → amino acids → polypeptide → protein

Beadle and Tatum's 'one gene- one protein' hypothesis → 'one gene- one polypeptide' hypothesis

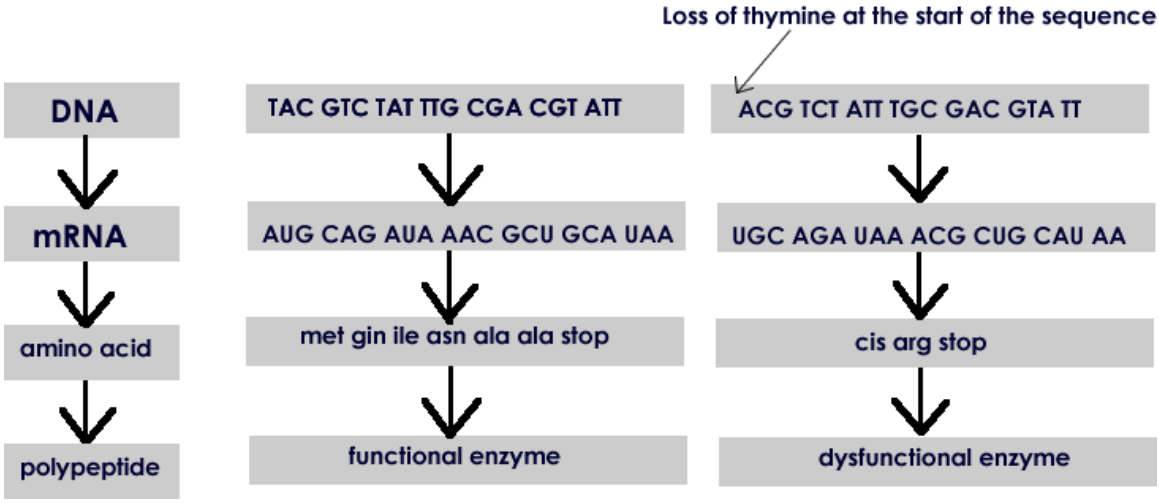
Beadle and Tatum used bread mould to investigate nutritional mutations.

Using X-rays, they produced mould that was unable to produce a specific amino acid. The mould was unable to grow unless the amino acid was added. They showed that genes controlled biochemical processes.

Their hypothesis was that for each gene there was one enzyme or protein. The enzymes that they studied consisted of one polypeptide but many enzymes consist of chains of polypeptides. Therefore, the hypothesis has been changed to the "one gene– one polypeptide" hypothesis.

Changes in DNA sequences → change in cell activity

- If there is a simple substitution for a single base pair on a strand of DNA such as a G-C replaced by A-T, then this will result in a different amino acid codon forming a different polypeptide. If one base pair is lost from the sequence there will be a shift along the DNA molecule producing different polypeptides.



- Cell activity is controlled by enzymes. Enzymes are formed from chains of polypeptides. If the chain of amino acids forming the polypeptide is not in the right sequence, then the enzyme formed will not be functional. In this case, there is a premature stop.

Modern example of natural selection

Some organisms, such as bacteria, produce large numbers of offspring.

Amongst large numbers of bacteria offspring, some individuals may carry genes that give them resistance to antibiotics. These individuals are then able to survive and reproduce with reduced competition from other members of the same species. Each generation will produce a higher percentage of individuals containing the resistant genes. This has been the story for antibiotics since they were first used. The initial use of an antibiotic results in good protection from bacteria. Over time the chemicals become less and less effective.

A similar situation occurs in the resistance of insects to insecticides.

Selecting those individuals that are able to survive and reproduce increases the frequencies of those genes in the population. This is "survival of the fittest" where the fittest are those that have a natural resistance to a selecting factor, which in the case of bacteria described above, is antibiotics.

Work of James Watson, Francis Crick, Rosalind Franklin and Maurice Wilkins in determining the structure of DNA

Scientific discoveries are rarely the work of one person but tend to result from teams of people bringing together different skills. These teams may be working together or may be scattered all over the world working independently in different laboratories.

James Watson and Francis Crick:

- From Cambridge University.
- Suggested double helix structure of DNA.
- Suggested pairing of the bases.
- Suggested this pairing made a possible way for self-replication.
- Rosalind's information was enough to encourage Watson and Crick to develop their model of the double helix for the structure of DNA.

Rosalind Franklin:

- From King's College London.
- A woman working in a field that was male dominated. She didn't get equal recognition for her contributions.
- Provided the crucial scientific evidence upon which Watson and Crick based their double helix model.
- Her work on X-ray diffraction showed that DNA had the characteristics of a helix.
- She wished to gather more evidence of this result but Maurice Wilkins showed her results to Watson and Crick without her permission or knowledge.

Maurice Wilkins:

- From King's college London
- Supplied Watson and Crick with Rosalind's x-ray diffraction

Scientist	Role
Rosalind Franklin	Used X-ray crystallography to discover than the shape of the DNA molecule was a helix
Maurice Wilkins	Studied the structure of large molecules. Informed Watson and Crick of Franklin's discoveries
James Watson	Worked with Crick to model the structure of the DNA molecule. Suggested that pairing of bases made it possible to copy and pass on genetic information
Francis Crick	Worked with Watson to model the structure of the DNA molecule. Studied the genetic code.

Rosalind Franklin died of cancer in 1958 at the age of 37. Watson, Crick and Wilkins received the Nobel Prize for their work in 1962.

5. CURRENT REPRODUCTIVE TECHNOLOGIES AND GENETIC ENGINEERING HAVE THE POTENTIAL TO ALTER THE PATH OF EVOLUTION

Reproductive techniques may alter genetic composition of population

Selective breeding is the deliberate crossing or mating of individuals of the same species with the characteristics wanted; over time, these characteristics become dominant.

Artificial Insemination

- It is the injection of male semen into a female
- The sperm is collected from a male with desirable characteristics

ADVANTAGES: Can be used to inseminate many females from one male. Transport of semen is much easier than transporting a whole animal. Semen can be stored for a period of time.

DISADVANTAGES: Reduced the genetic variations found in populations, making them susceptible to changes in the environment (e.g. new disease), if careful records are not kept individuals closely related may be unintentionally crossed, undesirable genes may also spread through a population

Artificial Pollination

- Plant breeders carry out artificial pollination to breed plants with specific characteristics
- Pollen from the male anther is collected. It is then dusted onto the female stigma of another plant.
- The pollinated flower is covered to prevent pollination from other flowers

ADVANTAGES: Particularly useful and easy way of breeding new varieties of plants. No expensive equipment required

DISADVANTAGES: Genetic variation reduced.

Cloning

- Cloning is a method of producing genetically identical organisms

PLANT CLONING:

- The most commonly used method, and the oldest, is cutting and grafting. A stem of short section of another plant is cut off, dipped in root-growth hormones, and planted into soil. The plant that grows is a clone of the original plant.

- Tissue culture technology has allowed mass cloning of plants. Firstly, a section of a plant, eg, a root tip, is pulverised using a blender to release the individual plant cells. The cells are grown on a nutrient medium, and incubated under controlled conditions. Genetically identical plants are produced.

ANIMAL CLONING:

- Much more difficult than plant cloning
- First animal to be cloned was Dolly

1. Adult sheep tissue cell removed from sheep and cultured in lab
2. Nucleus removed from one of these cells and placed in an enucleated egg cell (egg cell with genetic info removed)
3. Gentle electric pulse causes nucleus to fuse with egg cell
4. A second electric pulse starts cell division and embryo formation
5. This new cell is implanted into a female sheep where it grows into a new organism

ADVANTAGES: In agriculture, cloned plants have identical requirements and grow in similar ways to produce similar yields at the same time. In plants and animals identical copies of desirable varieties can be produced

DISADVANTAGES: In crops – all plants susceptible to the same diseases. Cloning is expensive with limited advantages over reproductive techniques. Cloning of animals has raised ethical questions about the cloning of humans. The health/life expectancy of cloned animals is questionable, with the death of Dolly the sheep being earlier than expected.

Altering genetic composition of a population: *In the case of all the technologies mentioned, the donor gametes or body cells have been carefully selected for predetermined characteristics – or artificially selected. In most cases, one exemplary donor contributes all the genetic material and this results in uniform offspring. Over generations, genetic variability within the species has been reduced.*

Transgenic species

- Transgenic species are organisms which have had genetic material from a different species transferred into their chromosomes, genes from one species have been taken and transferred into another.
- The introduced gene instructs the transgenic organism to produce the desired trait, which may be passed onto future generations
- Special enzymes break the chromosomes into gene fragments that represent a specific DNA sequence. The gene is then coded. After that, the gene is introduced into the reproducing cells of plants or animals to create the transgenic organism.

Reasons for their use:

Enable scientists to artificially combine the qualities of different organisms.

- Increase resistance of plants and animals to diseases, pests and extreme environmental conditions
- To study human diseases for medicines and vaccines
- To improve productivity of crops, pastures and animals
- To improve quality of food

Processes Used to Produce Transgenic Species:

1. A useful gene, and the chromosome it is on, is identified.
2. The gene is 'isolated' or cut-out of its DNA strand.
3. Separate DNA sequences for regulation may have to be added to ensure the gene will work.
4. The gene is inserted into the cell of another organism. Sometimes a vector is used to do this.
5. A vector is a carrier of a substance from one species to another.

Techniques Used to Produce Transgenic Species:

Isolating Genes: Once a useful gene is identified, it has to be isolated by 'cutting' it out of its DNA strand. Special enzymes, called restriction enzymes are used. More than 800 types are known. They cut DNA by breaking the hydrogen bonds in a triplet – the ends are called "sticky ends"

***Making Recombinant DNA*:** The DNA strands from 2 organisms are cut using the same enzyme, the sticky ends will match. When they are mixed, the new gene will match with the DNA strands, and link up. This is called ANNEALING. DNA ligases are added to strengthen the bonds.

Making Trangenes: An isolated gene cannot function if it is transferred alone. It has to be transferred with a promoter sequence attached to ensure it works

Inserting Genes into Bacteria:

Most bacteria contain small, circular pieces of DNA called plasmids.
Plasmids can be used as vectors or carriers to transfer transgenes into bacteria.

Reasons For Using These Processes:

These processes enable scientists to combine the qualities of different organisms
Transgenic species are being developed to:

- Increase the resistance of plants or animals to diseases, pests or extreme environmental conditions
- For medicines and vaccines and to study human diseases
- To improve productivity of crops, pastures and animals
- To improve the quality of food and efficiency of food processing

Examples of the Use of Transgenic Species:

COLD STRAWBERRIES: A gene from a type of salmon that allows it to survive cold temperatures has been isolated, and inserted into a strain of strawberry. This strawberry can survive and grow in cold temperatures.

BACTERIAL INSULIN: Diabetics previously obtained their insulin from animals, esp. pigs. The gene for insulin production, taken from the human pancreas, was placed in to the DNA of a bacterium. This now provides mass production of insulin.

Impact of the use of reproductive technologies on the diversity of species

The main fear behind the use of genetic and reproductive breeding techniques on organisms is that the natural diversity and variation within populations is decreased. In the short term however, genetic engineering can increase genetic diversity because it allows genes to be moved from one species to another to produce new combinations.

E.g. cotton plants. The main crop being grown all over the world is BT cotton. As more and more farmers shift from natural cotton to BT cotton, there are many disadvantages:

- Many natural varieties of cotton will be lost.
- The species itself becomes vulnerable to extinction. If all cotton grown all over the world is BT, and a disease appears, that kills specifically BT cotton, than there is a risk of cotton becoming extinct.

E.g. Genetically modified fish are being used in aquaculture. The fish are designed for rapid growth and because of their increased size, attracts female fish. If these fish escape into wild populations, there is a high chance that their genetically engineered genes will be transferred into wild populations, potentially wiping out other fish populations.

Cloning Method

Recently, plants have been cloned using tissue culture propagation. Tissue from the roots is taken and the root cells separated. These cells are then grown (cultured) in a nutrient-rich medium where they become unspecialised. The unspecialised cells are called calluses. After treatment with the appropriate plant hormones, the calluses are able to develop into seedlings that go on to grow into fully mature plants. These plants are genetically identical to the original 'parent' plant.

Rare orchids have been cultured and grown in this manner.

A more recent example, has been the cloning of tissue from the Wollemi Pine. This rare pine, thought to be extinct but now has been discovered in the Blue Mountains region of NSW and successfully cloned. These cloned offspring are being cultivated in the Royal Botanic Gardens in Sydney and sold to the public for planting in gardens. Thus, the species, which has few numbers in the wild, can be preserved.

In animals, progress in cloning species has not been as rapid. Current techniques require an unfertilised egg to act as a 'host' for genetic material from a specialised cell. The donor egg has had its nucleus physically removed, and the nucleus from a cell of the species to be cloned is inserted. An electrical stimulus is used to fuse the nucleus with the egg cell and to stimulate cell division. At a certain stage in cell division, the embryo is introduced into a surrogate mother where it continues its development. When born the clone is genetically identical to the animal that donated the original nucleus.

Cloning of animals was first performed with tadpoles by John Gurdon in the 1970's. The tadpoles did not survive to grow into adult frogs.

Dolly the sheep was the first successfully cloned mammal in 1997. Since then, other species have been cloned.

Animals can also be cloned from an embryo:

1. A cow is artificially inseminated with sperm from a prize bull.
2. The embryo develops to a mass of 32 identical cells.
3. The embryo is removed and the mass separated into 32 identical cells.
4. Microsurgery separates the nucleus from each of the 32 cells.
5. The genes from the embryonic cells are inserted into the space once occupied by the genetic material in unfertilised eggs of 32 carrier cows.
6. Each embryo is transplanted into the uterus of the carrier cow, where it develops fully.
7. Each carrier cow gives birth to a calf that is genetically identical to the other 31 calves – all clones.

Ethical issues arising from development and use of transgenic species

Genetically engineered salmon:

- The gene coding for a growth hormone protein is incorporated into the genes of salmon.
- Larger, faster growing fish
- Much concern that they will upset or destroy natural ecosystems if escape into the wild.

Potato plants:

- A pea gene for lectin has been incorporated into potato plants.
- Provides protection against insect attack – lectin is a protein which interferes with digestion in insects.
- As potatoes are a staple food source for many populations throughout the world, it is important to maintain and increase production.
- Protection against insect attack improves the success of growing potatoes.
- Concerns exist about controlling the 'escape' of these transgenic potatoes into the wild as the technology is only recent and long-term impacts on the environment have yet to be observed or evaluated.

Cholera and typhoid immunisation:

- Cloning a piece of DNA from cholera causing e-coli

Transgenic tomatoes:

- Increased shelf life in supermarkets

Transgenic soya beans:

- Resistant to herbicide so crop isn't harmed when sprayed to kill weeds

Foraging plants for sheep:

- Produce more of rare amino acid cystine
- When sheep eat altered plants they will be able to produce more wool

Superpig:

- Has 10 extra growth hormone genes
- Genes switched on in presence of zinc

Transgenic sheep:

- Produce a protein in milk important in the treatment of human lung disease

Arguments for	Arguments against
• Increases production of food for growing human population • Reduces need for pesticides and herbicides • Plants can produce vaccines to improve human health • Addition of one gene is a tiny change • Less spoilage of produce during transportation	• Safety of GM foods unknown, especially for people with allergies • Loss of biodiversity • New technology not yet fully researched • Potential for escape of the transgenes into other populations • One gene is enough to cause immense changes or disease • Large multi-national companies own patents for GM crops and also sell the chemicals needed to grow them • Speed up genetic change in species • New pathogens could be created and released • Super weeds could be created by the fertilisation of wild and transgenic species • Transgenic species have basic rights

Ethical Issues of Transgenesis:

- Should we be tampering with nature in this way?
- Should something be done because it's possible?
- Long term effects on humans and animals unknown
- Animal rights questioned- living conditions horrible and testing of disease on animals
- Concerns over return of eugenic movement – eg. Sterilisation of mentally retarded people and race purification
- Is it right to change living organisms for commercial gain?
- Transgenesis disrupts evolutionary relationships between organisms
- If a transgenic species was released into the natural environment, it could out-compete the natural organisms
- Health-risks and side effects with eating GM foods.
- Pollution of natural gene pool
- Accidents could result in the release of cancer cells, bacteria or viruses into the human population