Topic 6 – Inheritance, variation and evolution

Table of Content

6.1 Reproduction

6.1.1 Sexual and asexual reproduction

6.1.3 Advantages and disadvantages of sexual and asexual reproduction (biology only)

Sexual reproduction (meiosis)

- Joining of male & female gametes that produce genetically different offspring
  - Gametes formed by meiosis
    - Mixing of genetic info leads to variety in offspring
    - Requires energy as some animals & plants produce gametes in high no. & process of courtship requires energy

Animals	Flowering plants
• Sperm (contains 46 chromosomes) • Egg cells	• Pollen • Egg cells

Advantages	Disadvantages
• Produce variation in offspring • If environment changes, variation gives a survival advantage by natural selection • Natural selection can be sped up by human in selective breeding to ↑food production	• Advantages of asexual selection

Asexual reproduction (mitosis)

- Involves only one parent & no fusion of gametes
- No mixing of genetic info – produce genetically identical offspring (clones) by mitosis
- E.g. Bacterial reproduce asexually when divide by binary fission

Advantages	Disadvantages
• Only one parent needed • More time & energy efficient as don't need to find mate • Faster than sexual reproduction • Many identical offspring can be produced when conditions are favourable	• Advantages of sexual selection

Some reproduce both sexually & asexually depending on the circumstances

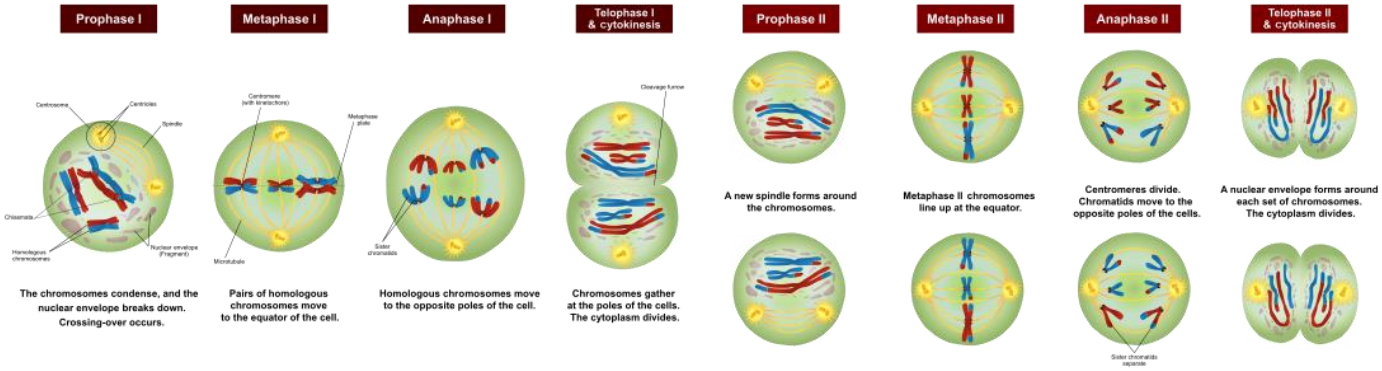
Malarial parasite	• Sexually – in human host • Asexually – in mosquito
Fungi	• Sexually – by sporesto give variation • Asexually – by spores
Plants	• Sexually – produce seeds • Asexually – produce tiny plantlets on runners e.g. strawberry plants – bulb division e.g. daffodils

6.1.2 Meiosis

- Only takes place in reproductive organs
- Male - testes
- Females – ovary

Describe how meiosis halves no of chromosomes in gametes.

1. All chromosomes made copies of their DNA
2. Chromosome pairs line up and exchange pieces of DNA (DNA crossover)
3. Cell divides into 2
4. Chromosomes line up
5. Both cells divide one more time to form 4 gametes, each with a single set of chromosomes
6. DNA is exchanged so all gametes are genetically different from each other



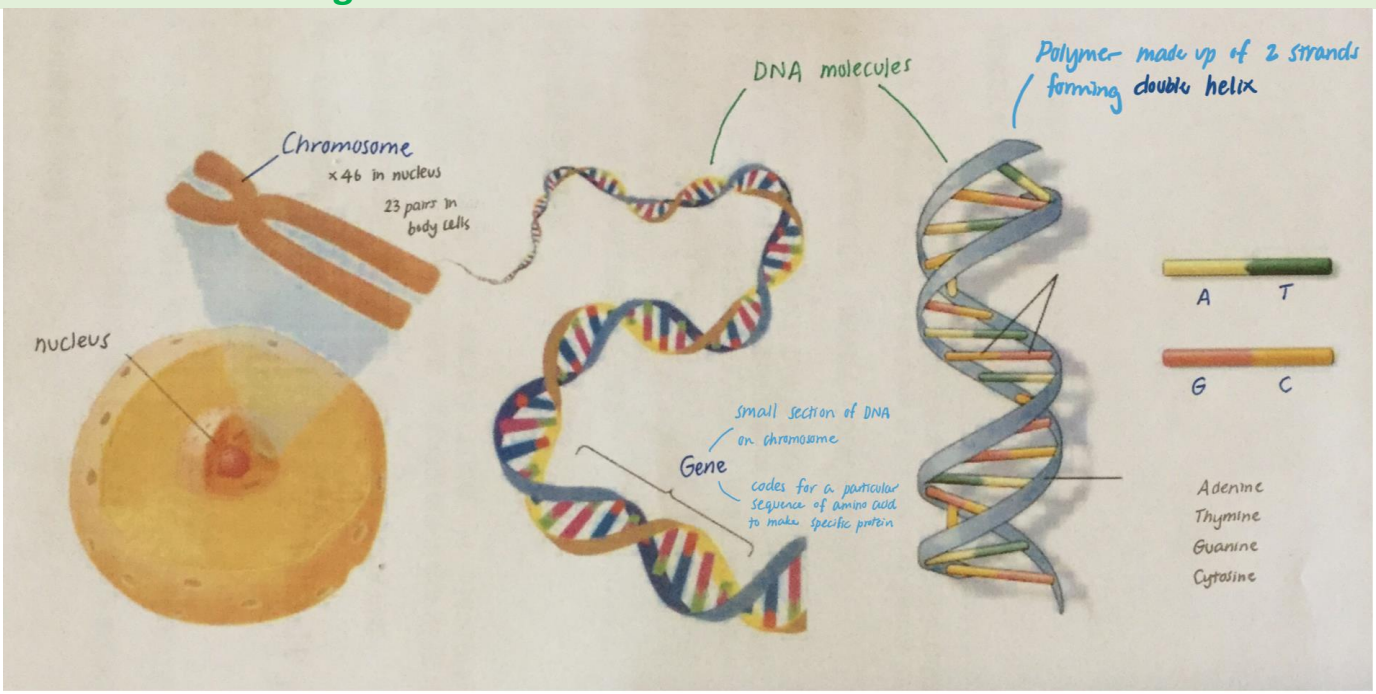
Describe how fertilisation restores full no of chromosomes.

- In sexual reproduction (fertilisation), gametes join together
- Cell now has normal no of chromosomes

Explain why sexual reproduction could produce new variety of onion. (3)

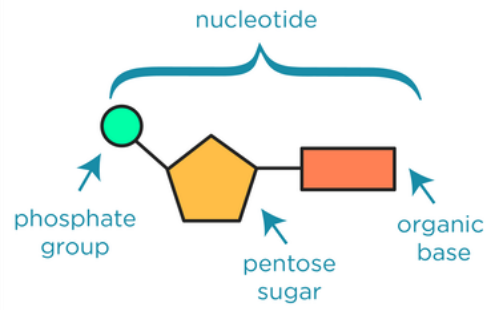
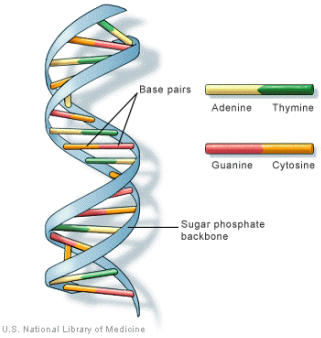
- Meiosis produces 4 gametes from an original cell
- Fusion of gametes in fertilisation
- These gametes are genetically different from each other & have different alleles, produced by meiosis which causes variation

6.1.4 DNA and the genome



(See 6.1.5 DNA structure (biology only) for more notes)

6.1.5 DNA structure (biology only)

Structure of nucleotide	DNA polymer
	

Describe where DNA is found in a human cell. (2)

- In chromosome in nucleus

What is a section of DNA which codes for one specific protein called? (1)

- A gene

In which part of an animal cell is DNA found? (1)

- Nucleus

Describe the function of DNA. (3)

- DNA carries coded info which controls order of amino acids to form specific proteins

Describe difference between alleles & genes (2)

- Alleles - different forms of gene controlling a characteristic & occupying same site on homologous chromosomes
- Genes - units of DNA on chromosomes carrying info that determines characteristics

Why is sequence of compounds A,C,G & T in gene important? (2)

- They are codes for order of amino acid which make a specific protein

Protein synthesis

- Protein - polymers of amino acids
- Sequence of bases in gene determines order of amino acids (aka codes for sequence)
- Specific order of amino acids determines shape of protein
- Shape of protein determines function eg enzyme (amylase), structural protein (collagen), hormones (insulin)

Describe stages of protein synthesis

- Proteins are synthesised on ribosomes, according to a template
- Carrier molecules bring specific amino acids to add to growing protein chain in correct order
- When protein chains are complete, it folds up to form a unique shape. This unique shape enables proteins to work as enzymes, hormones or forming structures in body e.g.collagen

In the cell, where are proteins synthesised? (1)

- Ribosomes

Describe how protein is synthesisd. (3)

- A sequence of 3 bases is coded for 1 amino acid
- Amino acids make up a protein

Explain how DNA is responsible for structure of proteins. (3)

- **DNA carries coded info which controls order of amino acids to form specific proteins**
- A sequence of 3 bases is coded for 1 amino acid
- …

Explain how mutation could causes enzyme not to work. (5)

- **A sequence of 3 bases is coded for 1 amino acid**
- Mutation changes DNA code from CAG to TAG
- Changes order of bases, change order of amino acids, change shape of protein that change active site
- So enzyme no longer fits substrate

6.1.6 Genetic inheritance

Gamete	An organism's reproductive cell (egg in female & sperm in male), which has half no of chromosomes
Chromosome	A structure found in nucleus which is made up of long strand of DNA
Gene	Small section of DNA on chromosome that codes for a particular sequence of amino acids to make specific protein that determine characteristics
Allele	Different forms of a gene controlling a characteristic & occupying same site on homologous chromosome
Dominant eg B	Only expressed if recessive allele is not present Will show a characteristic if inherited from one or both parents

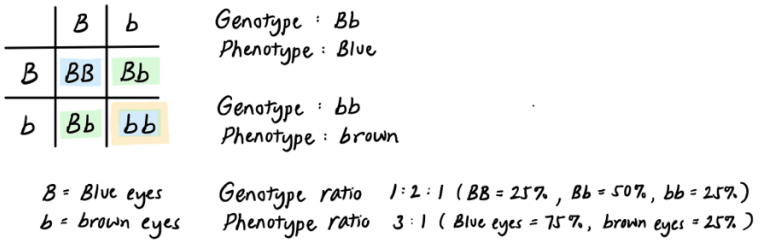
Recessive eg b	Only expressed if dominant allele is not present. Will show a characteristic only if inherited from both parents
Homozygous eg BB or bb	A genotype with two same alleles
Homozygous dominant eg BB	A genotype with two dominant alleles
Homozygous recessive eg bb	A genotype with two recessive alleles
Heterozygous eg Bb	A genotype with one dominant & one recessive allele
Genotype	Genetic make-up of an organism represented by letters
Phenotype	Physical characteristics of an organism as described by words

Explain why it looks similar to its parents. (1)

- DNA passed from parents

Explain why not identical to its parents. (2)

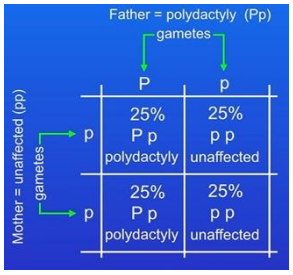
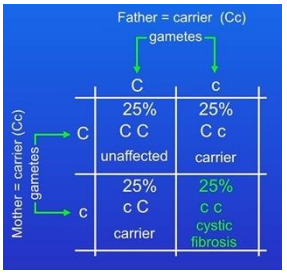
- DNA from 2 parents
- Different alleles
- Environmental effect e.g. mutations



Why might your prediction not proved right? (1)

- It's down to chance / only a prediction

6.1.7 Inherited disorders

Polydactyly	• Have extra fingers / toes • Caused by dominant allele	
Cystic fibrosis	• A disorder of cell membranes • Caused by recessive allele	

Solution – Embryo screening

- Embryos are tested to see if alleles for inherited disorders are present

Describe how embryos can be screened for the alleles that cause genetic disorders. (4)

- DNA isolated from embryo
- Fluorescent probe mixed with embryo DNA
- Probe then binds with embryo DNA
- UV light to show alleles / gene for disorder

Advantages	Disadvantages
• ↑chance of having a baby without disorder • Disorder won't be passed on to future generation • ↓ppl suffer • There're many regulations to stop it going too far • Use more than 1 embryo so more chance of success • Spare embryo have potential use – could be used in stem cell treatment	• Operation hazard eg infection • Ethical - potential damage to embryo • Expensive • Large no of embryo created but only small no are implanted – remaining embryos destroyed • Promote prejudice as it suggests ppl with genetic disorders are unwanted • Encourage ppl to pick characteristics • Embryos might not develop

6.1.8 Sex determination

Human body cell – 23 chromosomes

- 22 pairs – control characteristics
- 1 pair – carriers genes that determines sex
- Sex chromosomes – Male (XY), Female (XX)

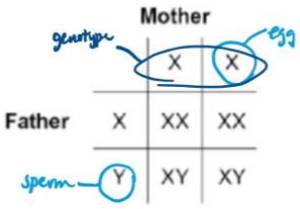
What is the chance of having a female child? Give the reason for your answer. (2)

- 50% coz 2 out of 4 boxes are XX

Humans have two different sex chromosomes, **X** and **Y**.

Figure 2 shows the inheritance of sex in humans.

Figure 2



6.2 Variation and evolution

6.2.1 Variation

Variation - differences in the characteristics of individuals in a population

Cause of variation

- genes they have inherited (genetic causes)
- conditions in which they have developed (environmental causes)
- combination of genes and the environment

See topics below for more notes

6.2.2 Evolution

Evolution

- Change in the inherited characteristics of a population over time via natural selection
- Form new species

Natural selection (Charles Darwin)

- Published in On the Origin of Species (1859)

Explain process of natural selection (6)

1. Individual organisms within a particular species show wide range of variation of characteristics controlled by different alleles caused by mutations
2. Individuals with characteristics most suited to the environment are more likely to survive & breed successfully (aka survival of the fittest)
3. The beneficial characteristics / alleles which enable individuals to survive are passed on to their offspring (to next generation)
4. Over many generations, frequency of alleles for this beneficial characteristic increase within the population

(c) There are many types of rat snake in the world.

The table below shows two types of rat snake.

	 © Kazzpix/iStock/Thinkstock	 © Talkir/iStock/Thinkstock
Type of snake	Japanese rat snake	Texas rat snake
Colour of snake	Green	Pale brown
Type of environment	Grass	Dry and dusty

The different types of rat snake have evolved from similar ancestors.

The rat snakes have evolved to to suit their environments.

Explain how the Japanese rat snake evolved to be different from the Texas rat snake.

- There are lots of different colours of snakes, which is controlled by different alleles caused by mutations.
- Japanese rat snake being green means they're best suited to green environments or are camouflaged, allowing it to catch more food, avoid being eaten, survive & breed successfully
- The beneficial characteristics / alleles which enable it to survive are passed to their offspring
(- Over many generations, frequency of alleles for this beneficial characteristic increase within the population)

(4)

Why many ppl didn't accept his theory? (3)

- They believed God made all living things
- Insufficient evidence & proof
- Mechanism of inheritance & variation not discovered

Why the theory of evolution by natural selection was only gradually accepted? (3)

- Challenged the idea that God made all the animals and plants that live on Earth
- Insufficient evidence at the time the theory was published to convince many scientists
- Mechanism of inheritance and variation was not known until 50 years after the theory was published

An organism during its lifetime can be inherited (Jean-Baptiste Lamarck)

- Changes that occur in an organism during its lifetime can be inherited
- If an individual continually repeated an action, characteristic that allow it to do this would develop further
- But we now know that in vast majority of cases, this type of inheritance cannot occur as changes in environment does not pass on to offspring

Use Lamarck's theory to explain how elephant's trunk evolved (2)

- Ancestor continually stretched its nose to reach food
- This characteristic of stretching its nose develop further during its lifetime
- This characteristic then passed on to offspring

Explain how 2 different species could have developed from a common ancestor (6)

- 2 populations separated by geographical barrier
- Different environmental conditions cause alleles to mutate differently in each population
- Individuals with characteristics more suitable for environment are more likely to survive and breed successfully
- Beneficial characteristics / alleles which enable species to survive are passed on to their offspring
- Over many generations, frequency of alleles for this beneficial characteristics increases within each population
- Eventually 2 types cannot interbreed successfully

Suggest how scientist prove they come from same species

- Interbreeding successfully between island types
- DNA analysis

Suggest why 2 species have not become more different over time (2)

- Similar environment so similar adaptations
- Original ancestor already well adapted

6.2.3 Selective breeding

Selective breeding (artificial selection)

- Process by which humans breed plants and animals for particular genetic characteristics
- By choosing parents with desired characteristics from a mixed population & breed them together

Why – to choose characteristics for usefulness or appearance

- Food crops – disease resistance
- Animals – produce more meat or milk
- Domestic dogs - gentle nature.
- Flowers - large / unusual

(c) Many people have breathing problems because they are allergic to cats.

The allergy is caused by a chemical called Fel D1.

Different cats produce different amounts of Fel D1.

A cat has been bred so that it does not produce Fel D1.

The cat does **not** cause an allergic reaction.

Explain how the cat has been produced using selective breeding.

1. Parents with the desired characteristic are selected.
In this case, those who produced the least Fel D1 are selected.
2. The parents are bred together to produce offspring.
In their offspring there'll be individuals with differing amount of Fel D1 produced.
3. Offspring with the desired characteristics are selected & bred together.
4. This is repeated over many generations until all offspring show the desired characteristic.
In this case, cats will produce less Fel D1.

Advantages	Disadvantages
• Produces organisms that are useful to us eg ↑food production	• Selective breeding can lead to inbreeding (some breeds are particularly prone to disease or inherited defects eg pedigree dogs have hip problems) • ↓no of alleles in a population - ↓variation of species - if environment changes, organisms can't cope & die

6.2.4 Genetic engineering

Genetic engineering

- Process which involves modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic
- Plant crops – resistance to diseases, produce bigger better fruits (See GM crops)
- Bacterial cells – produce useful substances eg insulin to treat diabetes

Describe process of genetic engineering (6)

1. Use enzyme to isolate required gene
2. Insert isolated gene into a vector (bacterial plasmid / virus) which is cut opened using enzyme
3. Use vector to insert gene into required cells
4. Transfer gene to animals / plants cells or microorganisms at an early stage in their development so they develop with desired characteristics

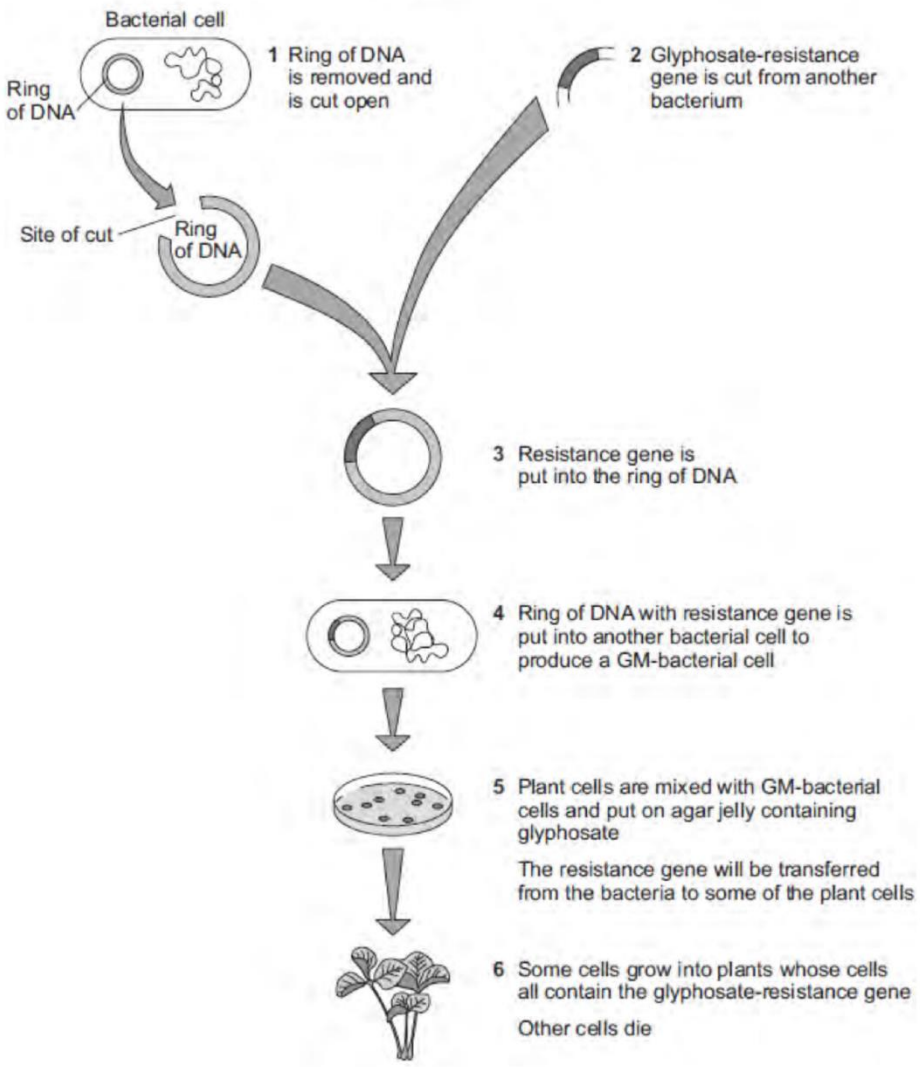
Genetically modified crops (GM crops)

Advantages	Disadvantages
• Resistant to disease • Resistant to insect attack / herbivores • ↑yields /produce bugger & better fruits - ↓starvation in less developed countries • Improve nutritional value eg Golden rice contains carotene - ↓ chance of vitamin A deficiency	• Affect population of wild flowers & insects - ↓ biodiversity • Haven't fully explored effects on GM crops on human health • Shouldn't interfere with God's creation

GM mosquitoes

Advantages	Disadvantages
• ↓mosquitos spreading malaria • ↓ppl get malaria • ↓healthcare needed • Better economically for developing countries	• ↓crops reproduce • ↓crop yield • High cost of GM production • Disrupt food chain

Figure 1 shows how scientists produce GM crop plants. The scientists use a GM-bacterium can invade plant cells.



Explain why scientists add glyphosate to agar? (2)

- The resistance gene will be transferred from bacteria to some plant cells

6.2.5 Cloning (biology only)

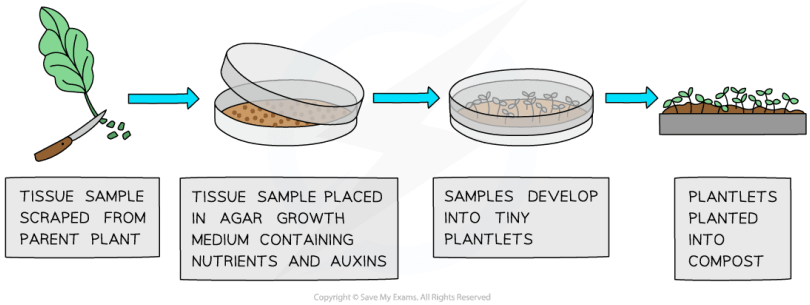
Plants – tissue culture & cutting

Tissue culture

- Using small groups of cells from part of a plant to grow identical new plants
- Importance - preserving rare plant species or commercially in nurseries

Process

1. Remove leaf from plant
2. Scrape off small group of cells (tissue) sample from part of plant onto agar jelly.
3. Grow tissue in agar with nutrients & plant hormones to stimulate plant cells to divide to form big mass of identical plant cells called callus.
4. Use different mixture of hormones & conditions to form tiny identical plantlets.



5. Plantlet clones grown on.

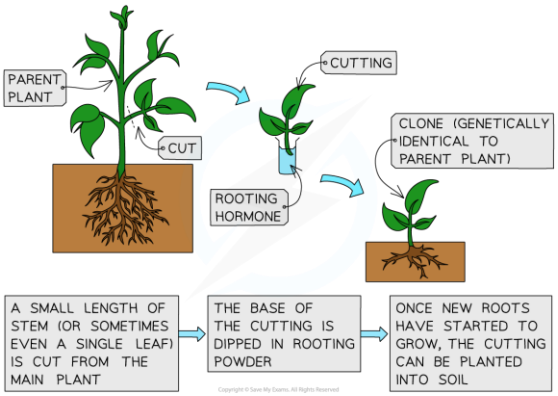
Advantages / Why use tissue culture	Disadvantages
• ↑ yields • Quick • Little space • Grow all year	• Expensive

Cuttings

- An older, but simple, method used by gardeners
- To produce many identical new plants from a parent plant
- Quick & cheap

Process

1. Cut off a branch from parent plant
2. Plant stem in damp compost
3. Keep cuttings in moist & warm conditions
4. After a few weeks, new roots develop & new plant produced

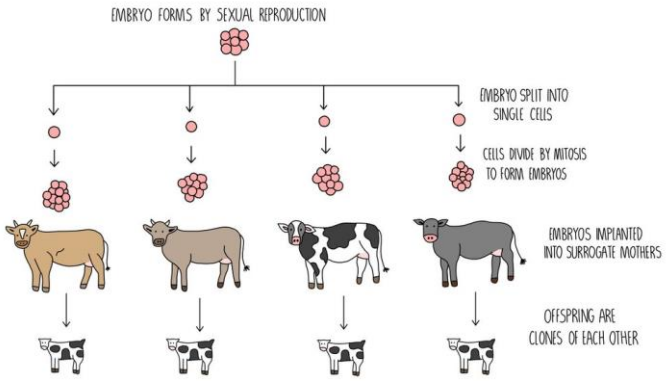


Animals – Embryo transplant & Adult cell cloning

Embryo transplant

Process

1. Split cells apart from developing animal embryo before they become specialised
2. Each cells grows into identical embryo in lab
3. Transplant identical embryos into host mothers
4. Identical cloned calves born



Advantages	Disadvantages
• Produce more animals • Ppl can transfer high-quality embryos around the world • Produce medically useful compounds	• Expensive • Need skilled labour

Adult cell cloning

Process

1. Remove nucleus from unfertilised egg cell
2. At the same time, take nucleus from adult body cell eg skin cell of another individual of same species
3. Insert nucleus from adult cell into egg cell
4. Give egg cell an electric shock to stimulate it to divide to form an embryo
5. When embryo has developed into ball of cells, insert it into womb of adult female to continue its development

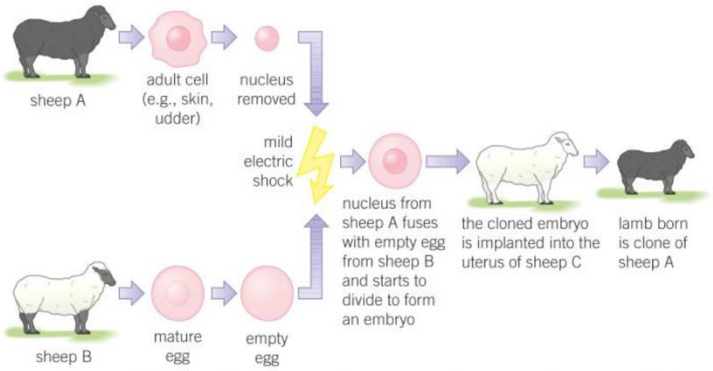


Figure 2 *Adult cell cloning remains a very difficult technique, but scientists hope it may bring benefits in the future*

Advantages	Disadvantages
• Produce animals with desirable characteristics eg cows produce large quantity of milk • Produce large no of cloned medically useful animals • Save animals from extinction • Clone pets/prized animals so DNA continue after original died	• Reduce variation in a population - less able to survive if environment changes • Expensive • Can help infertile couples but can also be abused • Unethical • Possible operation complications

6.3 The development of understanding of genetics and evolution

6.3.1 Theory of evolution (biology only)

See 6.2.2 Evolution

6.3.2 Speciation (biology only)

Speciation

- Populations become extremely varied & no interbreed anymore
- Formation of new species (a group of organisms able to interbreed & produce fertile offspring)

Charles Darwin – see 6.2.2 Evolution

Alfred Russel Wallace

- Published joint writings with Darwin in 1858
- Best known for his work on warning colouration in animals & his theory of speciation

Describe the steps which give rise to new species

1. **Genetic variation** – each population has wide range of alleles that control characteristics
2. **Natural selection**
3. **Speciation**
4. **Isolation**

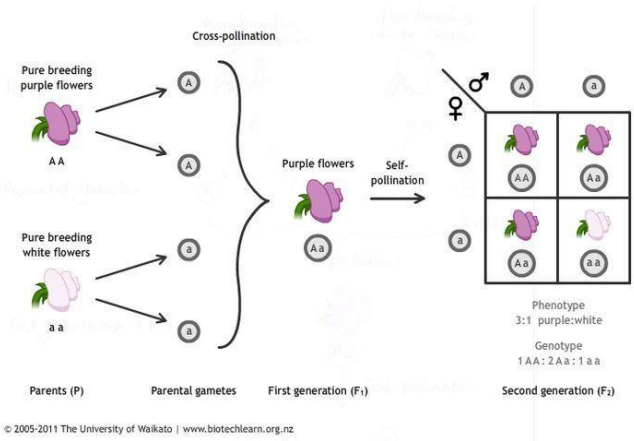
- 2 population of a species become geographically separated
- Different mutations take place in isolated groups

- Overtime species evolve to be different to each other – cannot interbreed

6.3.3 The understanding of genetics (biology only)

Gregor Mendel

- Carried out breeding experiments on pea plants
- Inheritnace of each characteristic is determined by 'units' (genes) that are passed onto descendants unchanged



Describe the development of our understanding of genetics including the work of Mendel

1. Mid-19th century – Gregor Mendal carried out breeding experiments on plants
2. Late 19 – behaviour of chromosomes during cell division was observed
3. Early 20th century – chromosomes and Mendel's 'units' behaved in similar ways - led to the idea that the 'units', now called genes, were located on chromosomes.
4. Mid-20th century - structure of DNA was determined & the mechanism of gene function worked out

Why using large no of offspring plants can improve the investigation (2)

- Large no so more reliable
- Anomalies can be identified

Why importance of Mendel's discovery wasn't recognised at that time? (2)

- DNA not discovered
- Mendel wasn't considered as a scientist / wasn't part of academic establishment

6.3.4 Evidence for evolution

See **6.3.5 Fossils, 6.3.6 Extinction & 6.3.7 Resistant bacteria**

6.3.5 Fossils

Fossils - the 'remains' of organisms from millions of years ago, which are found in rocks

Where are fossils formed? (3)

- Parts of organisms that have not decayed because one or more of the conditions needed for decay are absent
- When parts of the organism are replaced by minerals as they decay
- As preserved traces of organisms, such as footprints, burrows and rootlet traces

How fossils are formed?

- Animal / plant dies & body covered in sediment
- Soft parts decay
- Hard parts (bones) don't decay and are replaced by minerals
- Lack of O_2 and moisture prevent microorganisms to decay
- Preserved traces of organisms eg footprints, burrows & rootlet traces
- Soft parts decay, bones / shells don't decay

Suggest how insects came to be preserved in the amber (2)

- Trapped and engulfed by amber
- Prevented decay (due to lack of O_2 and moisture)

How can fossils give evidence for evolution? (1)

- Show how organisms changed as life developed on Earth

Why scientists are uncertain about how life began on Earth? (1)

- Insufficient evidence

Suggest 2 reasons why there are gaps in the fossil record (2)

- Fossils not found yet
- Fossils are destroyed by geographical activities eg volcanoes
- Conditions not right for fossilisation

6.3.6 Extinction

Extinction – occur when there are no remaining individuals of a species still alive

Why a species may become extinct? (3)

- Environmental changes – species can't adapt fast enough
- Natural disaster eg flooding, drought
- New predator / disease eg no resistant alleles
- Human activities eg hunting, deforestation
- Competition for food / mates
- Catastrophic event wipe out species eg asteroid killed dinosaurs

6.3.7 Resistant bacteria

Bacteria can evolve rapidly because they reproduce at a fast rate

How pathogens produce new strains via mutation (6)

1. Mutations of bacterial pathogens produce new strain
2. Some strains might be resistance to antibiotics and so are not killed
3. Some survive and reproduce by binary fission
4. Gene for resistance passed on to offspring so pathogen being immune
5. Population of resistant strain rises
6. Resistant strain then spread coz ppl not immune to it & has no effective treatment

Methicillin-resistant Staphylococcus aureus (MRSA)

- Bacterium that has evolved to be resistant to lots of antibiotics (superbugs bacteria)

How to reduce rate of development of antibiotic resistant strains? (3)

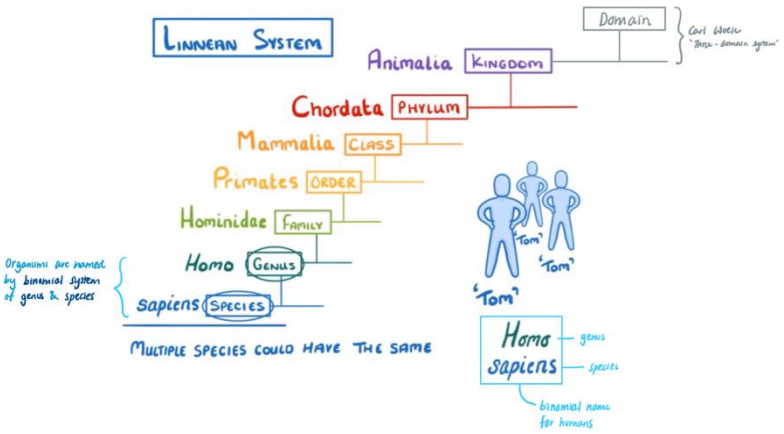
- Doctors reduce use of antibiotics for non-serious / viral infections
- Patients complete course of antibiotics to kill all bacteria so none survive to mutate & form resistant strains
- Restrict agricultural use of antibiotics

Development of new antibiotics

- Costly
- Slow
- Unlikely to keep up with the emergence of new resistant strains

6.4 Classification of living organisms

Classification – process by which living things are placed into groups depending on their structure & characteristics in a system



Linnean system (Carl Linnaeus)

- Linnean system – Dear Kate Please Come Over For Great Spagetti)

Describe the impact of developments in biology on classification systems

- Improvements in microscope
- Better understanding of biochemical process
- Evidence of internal structures become more developed
- New models of classification proposed

'Three-domain system' (Carl Woese)

- **Archaea** - primitive bacteria usually living in extreme environments
- **Bacteria** - true bacteria
- **Eukaryota** - includes protists, fungi, plants and animals

Evolutionary trees

- A method used by scientists to show how they believe organisms are related
- Use current classification data for living organisms & fossil data for extinct organism