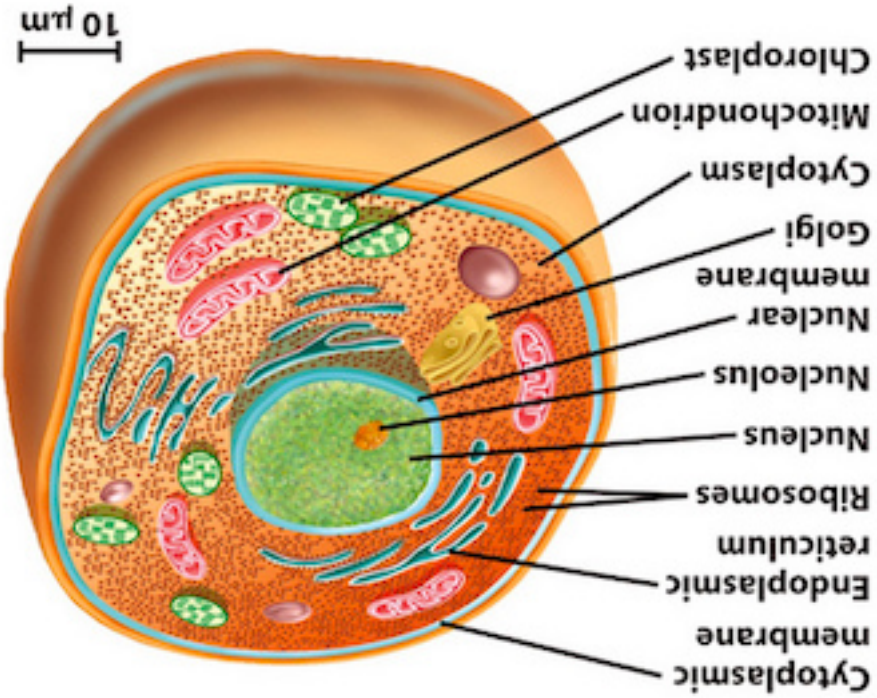


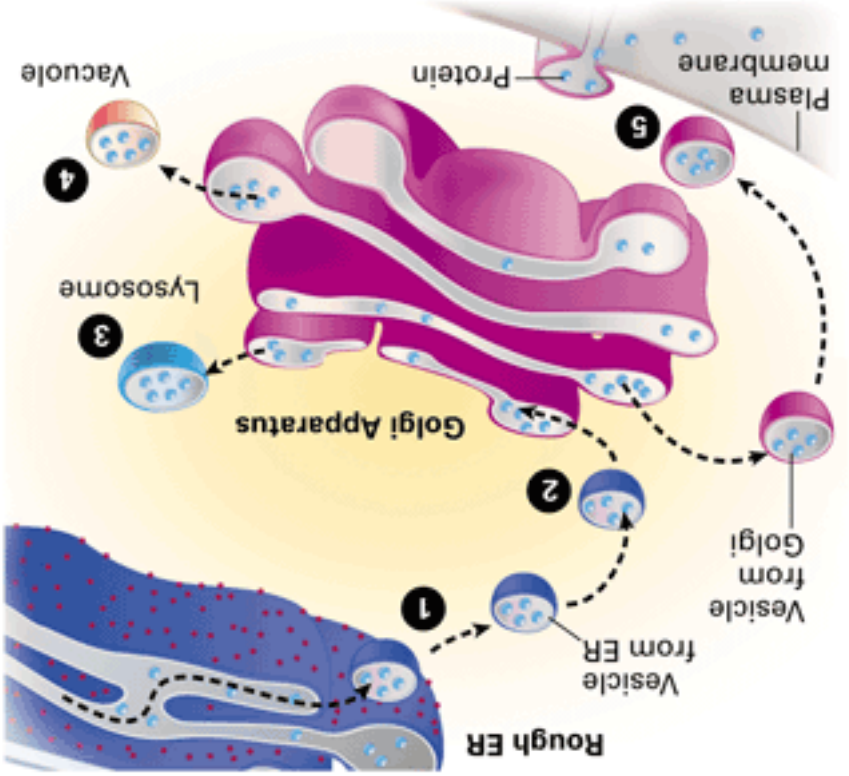
Eukaryotic Cell Structure

Eukaryotic Organelles

- **Nucleus:** Controls cellular activity. Contains the cells DNA (contains the instructions to create proteins). Contains pores to allow mRNA to leave the Nucleus
- **Nucleolus:** Makes ribosomes. Located within the Nucleus
- **Ribosomes:** The site of protein synthesis (translation). Either free floating of attached to RER
- **Rough Endoplasmic Reticulum (RER):** A system of membranes enclosing fluid and covered with ribosomes. Involved in protein synthesis and protein modification
- **Smooth Endoplasmic Reticulum (SER):** A system of membrane enclosing fluid with NO ribosomes. Involved in Sythesis of lipids and lipid modification
- **Golgi Apparatus:** A group of membrane-bound, flattened sacs. Processes and packages proteins and lipids. Makes lysosomes
- **Lysosomes:** A round vesicle containing digestive enzymes involved in breaking down invading cells or in apoptosis
- **Mitocondrion:** The site of aerobic respiration where ATP is produced. Require a lot of energy in the form of glucose
- **Centriole:** Small, hollow cylinders made of microtubules involved in Mitosis
- **Cell Membrane:** A fluid mosaic structure which controls the movement of substances in and out of the cell

Prokaryotic Organelles

- **Cell Wall:** Contains peptidoglycan. Allows cell to retain shape
- **Pili:** Hair-like structures. Allows adherance to surfaces
- **Slime Capsule:** Protects the cell from attack and dehydration
- **Mesosomes:** Inward folds in the cell membrane. Used for respiration/cellular processes
- **Plasmids:** Small loops of DNA. Contain genes for antibiotic resistance. Can be transferred between two bacteria
- **Flagellum:** A long hair-like structure allowing the cell to move
- **Circular DNA:** Not membrane bound (i.e. in a Nucleus) or attached to histone proteins
- **Ribosomes:** Smaller than Eukaryotic Cell Ribosomes. Protein Synthesis
- **Cell Membrane:** Made up of lipids. Controls what substances enter/leave the cell



Cell Dynamics Diagram

Cell Dynamics

- mRNA produced in transcription leaves the nucleus via a nuclear pore
- The mRNA is translated into a polypeptide chain at a ribosome
- The polypeptide chain is folded inside the Rough ER.
- The folded polypeptide chan is packed into a vesicle
- The vesicle is transported to the golgi body
- The polypeptide chain is modified in the golgi body
- The modified protein is packaged in a secretory vesicle
- The secretory vesicle exocytoses the modified protein

CORE PRACTICAL - Eye Piece Graticule & Stage Micro

- An eyepiece graticule is fitted onto the eyepiece of a microscope
- The stage micrometer is plsaced onto the stage of the microscope
- The stage micrometer hasan accurate scale and is used to work out the value of the divisions on the eyepiece graticule at a particular magnification
- This allows samples to measured underneath a microscope

Procedure

- Line up the eyepiece graticule and the stage micrometer
- The number of divisions on the eyepiece graticule within one division on the stage micrometer is calculated e.g. 4.5
- The distance between one gap on the stage is divided by the number of divisions in 1 division on the stage micrometermicrometer e.g. 0.1/4.5 = 0.022mm
- The number calculated can then be multiplied by the number of eyepiece divisions an object measures e.g. 20 x 0.022 = 0.44mm
- Magnification = Size of image/size of real object

Cell Organisation

- A group of cells working together forms a tissue
- A group of tissues working together produce an organ
- A group of organs working together produces an organ system
- Multiple Organ Systems create an organism

- Squamous Epithelium: Single layer of cells lining a surface; found in the alveoli
- Ciliated Epithelium: A layer of cells covered in cilia; involved in moving mucus e.g. trachea
- Cartilage: Connective tissue found in joints and shapes and supports the ears and nose
- Xylem: A Plant tissue involved in transporting water around the plant and provides structural support to the plant; contains xylem vessel cells and parenchyma cells

Organs: Leaf and Lungs

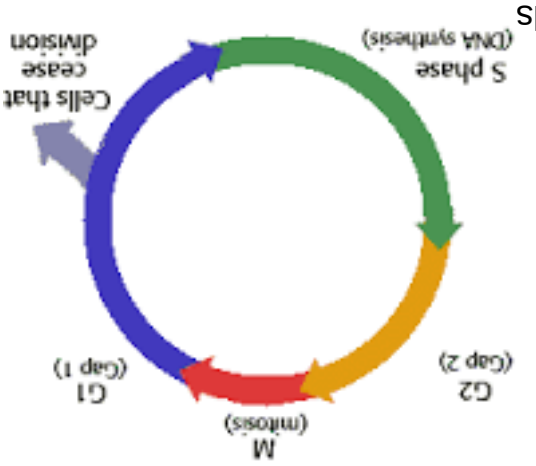
Leaf

- Lower Epidermis - Contains stomata (holes) to let air in and out for gas exchange
- Spongy Mesophyll - Full of space to let gases circulate
- Palisade Mesophyll - The location of Photosynthesis
- Xylem - Transports water to the leaf
- Phloem - Carries sugars away from the leaf
- Upper Epidermis - Covered in a waterproof waxy cuticle to reduce water loss

Lungs

- Squamous Epithelium - Surrounds the alveoli (where gas exchange occurs)
- Fibrous Connective Tissue - Helps force air back out of the lungs when exhaling
- Endothelium Tissue - Makes up the wall of the capillaries surrounding the alveoli and lines the larger blood vessels e.g. the Pulmonary Artery

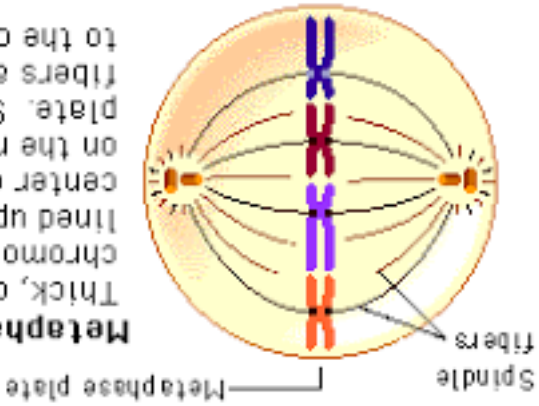
Mitosis: The Cell Cycle

- Mitosis produces two genetically identical daughter cells
- Mitosis is needed for growth, repair and for asexual reproduction
- Interphase is the period between Mitosis (Cell Growth) and is split into 3 stages (G1, S, G2)
- **Gap Phase 1:** Cell grows and new organelles and proteins are synthesised
- **Synthesis:** Cell replicates its DNA, ready to divide by Mitosis
- **Gap Phase 2:** Cell keeps growing and proteins needed for cell division are synthesised
- 

Mitosis: The cell divides into two identical daughter cells

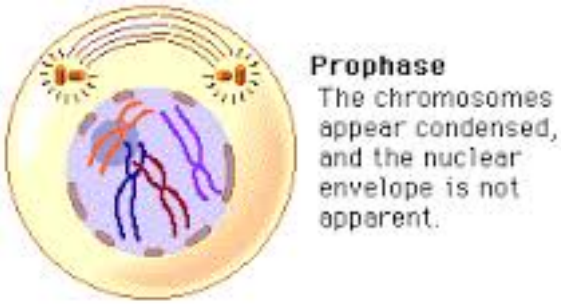
Mitosis: Metaphase

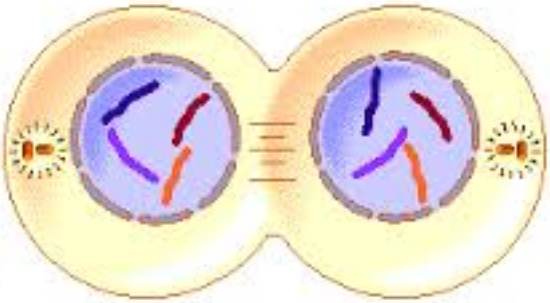
- Chromosome align along the equator of the cell
- Spindle fibres attach to the centromere on each chromosome

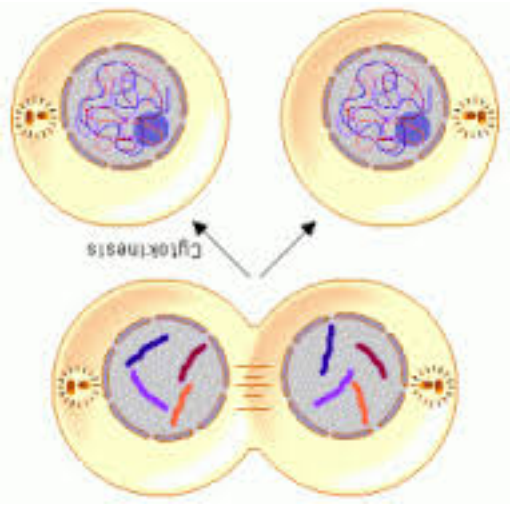


Mitosis: Prophase

- Chromosomes condense (get shorter and fatter) and become visible
- Centrioles start to move to opposite poles of the cell
- Spindle fibres start to form
- The nuclear envelope breaks down





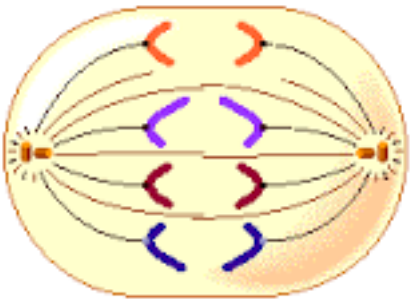


Mitosis: Telophase

- The chromatids reach opposite poles on the spindle
- The chromatids decondense (uncoil and become long and thin)
- A nuclear envelope forms around each group of chromosomes
- The cell starts to divide by the use of actin and myosin
- Cytokinesis occurs and the cell splits into two identical daughter cells

Mitosis: Anaphase

- The centromeres divide, seperating each pair of sister chromatids
- The spindle fibres contract pulling chromatids to opposite poles of the cell



Anaphase
The chromosomes have separated and are moving toward the poles.

CORE PRACTICAL - Observing Mitosis

Procedure:

- Cut 1cm of the meristem (growing tip) of an onion
- Prepare a boiling tube containing 1 M Hydrochloric Acid and put in a waterbath at 60C
- Transfer root tip into the boiling tube and incubate for 5 minutes
- Rinse the root tip with cold water and dry on a paper towel
- Macerate the root tip with a mounted needle to break open the tip and spreas the cells out
- Add a small drop of stain (Toluidine Blue) and leave for a few minutes
- Place a cover slip over the cells and press down to thin out the cells. Don't smear the cover slip sideways or the chromosomes will be destroyed
- Place the slide on the microscope and observe

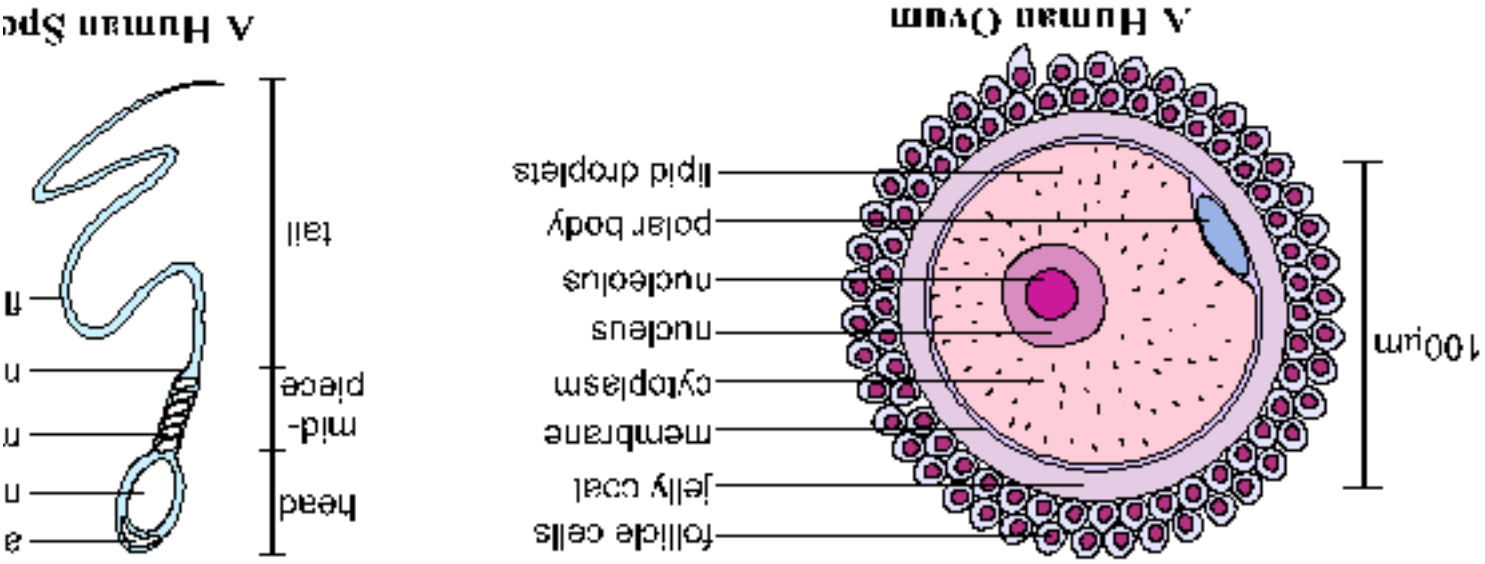
SAFETY: Wear goggles and gloves whilst working with stains and acid

Mitotic Index = No. Cells with visible chromosomes / No. Cells Observed

Gametes

- Gametes are the male and female sex cells (sperm and ovum)
- They join together at fertilisation to form a zygote which divides to form a fetus
- Normal body cells contain a diploid (full number of chromosomes) - 23 pairs in humans
- Half the number of chromosomes come from the mother and the other half from the father
- Gametes contain a haploid number of chromosomes (half the number of chromosomes)
- When fertilisation occurs a zygote ends up with a diploid number of chromosomes
- Fertilisation is the moment when two gametes nuclei fuses together
- Combining genetic material results in genetically unique offspring

Gametes: Ovum and Sperm Structure



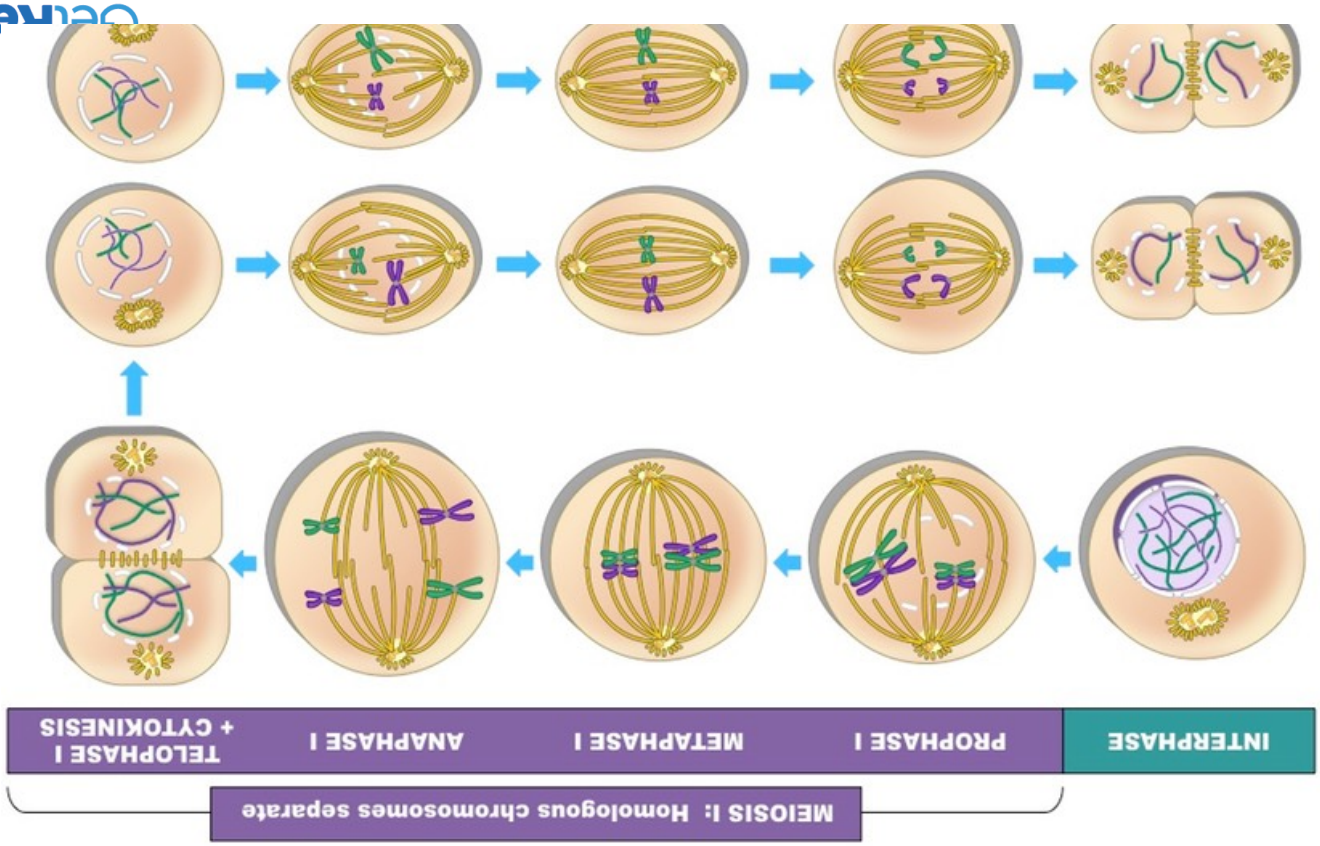
Fertilisation

- Sperm swim towards the ovum in the oviduct
- When one sperm makes contact with the Zona Pellucida the acrosome reaction occurs
- The acrosome swells and releases its enzymes so the sperm can move through the cell membrane of the ovum
- The sperm head fuses with the cell membrane of the ovum
- The cortical reaction occurs when the ovum releases the contents of the vesicles called the cortical granules into the space between the cell membrane and zona pellucida.
- The chemicals from the cortical granules cause the zona pellucida to thicken making it impenetrable for other sperm to ensure one sperm fertilises the ovum
- The two nuclei fuses together to produce a diploid number of chromosomes

Meiosis

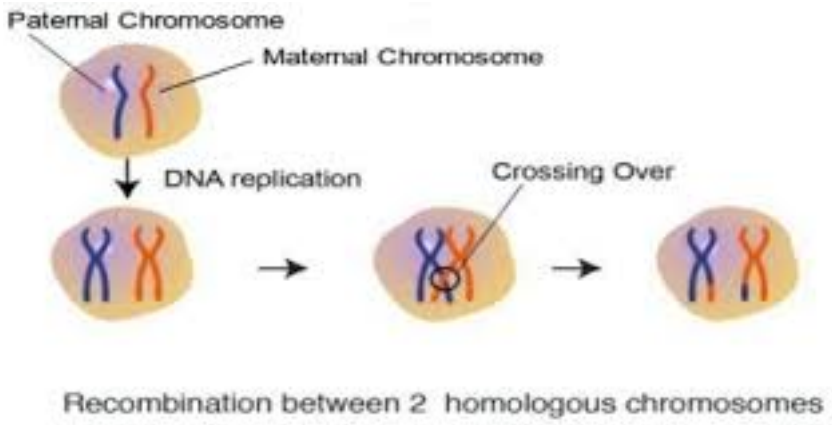
- Meiosis is a type cell division which produces gametes containing a haploid number of chromosomes
- DNA replicates so there are two identical copies of each chromosome (chromatids)
- The DNA condenses to form double-armed chromosomes, made from two sister chromatids
- Chromosomes arrange themselves into homologous pairs - pairs of matching chromosomes
- First division - the homologous pairs are seperated, halving the number of chromosomes
- Second division - the pairs of sister chromatids are seperated
- Four new daughter cells that are genetically different from each other are produced

Meiosis Diagram



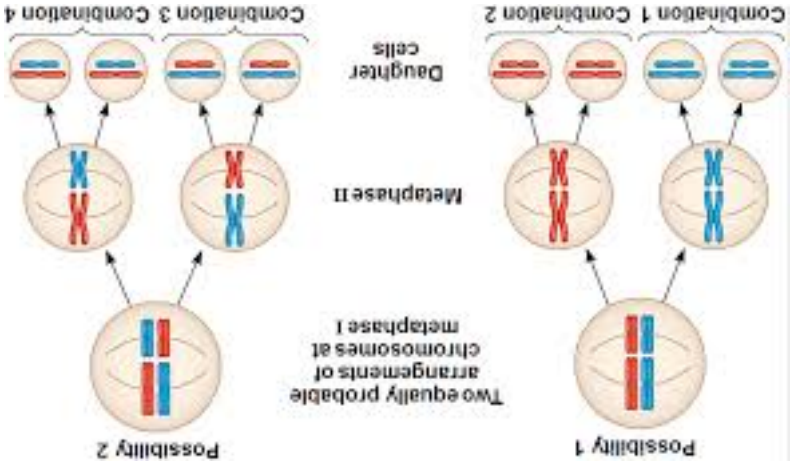
Recombination

- Recombination is the crossing over of chromatids on homologous chromosomes
- Chromatids of each homologous pair twist around each other
- The twisted bits break off their original chromatid and rejoin onto the other chromatid, recombing their genetic material
- The chromatids contain the same genes but have a different combination of alleles
- This means four new cellls are produced from meiosis, containing different genetic material
- This increases the amount of variation between gametes



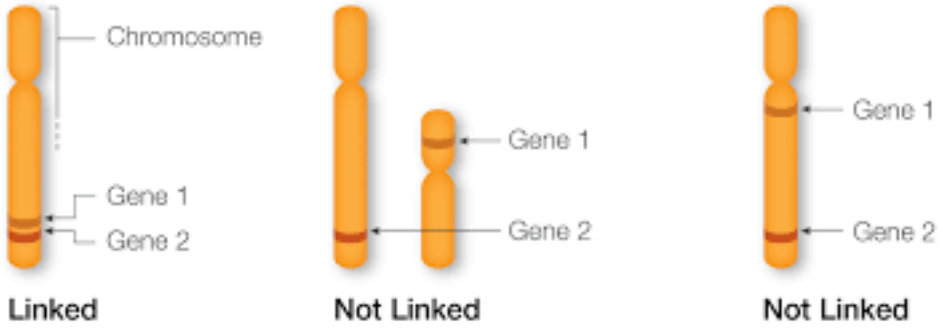
Independent Assortment

- The four daughter cells produced in meiosis have completely different combinations of chromosomes
- Every cell has a combination of chromosomes from each parent; half from your mother (maternal) and half from your father (paternal)
- When the gametes are produced, different combinations of those maternal and paternal chromosomes go into each cell
- This is called independent assortment which results in variation



Linkage

- The position of a gene on a chromosome is called a locus
- Independent assortment means that genes with loci on different chromosomes end up randomly distributed in gametes
- Genes with loci on the same chromosome are said to be linked because the genes are more likely to stay on the same chromosome during recombination and will therefore be passed on together
- The closer the loci of two genes are together on a chromosome, the less likely they are to be recombined and the more likely they are to be linked



Sex Linkage

- A characteristic is said to be sex-linked if the locus for an allele is on a sex chromosome
- In mammals, females have two X chromosomes (XX) and males have one X and one Y (XY)
- The Y chromosome is smaller than the X Chromosome and therefore has fewer genes
- Therefore most genes are only carried by the X Chromosome (X-linked genes)
- As males only have one X chromosome, they often express phenotypes of sex-linked alleles even if it is a recessive disease
- This makes males to express sex-linked diseases
- Examples of sex-linked diseases include colour blindness, haemophilia and fragile X syndrome

	X	X^c
X	X X	X X^c
Y	X Y	X^c Y

Stem Cells

- Multicellular oganisms are made up of many different types of specialised cells
- Every specialised cell originally comes from stem cells
- Stem cells are unspecialised cells that have the potential to develop into other types of cell
- Stem cells divide by mitosis to become new cells, which become specialised
- The process by which a stem cell becomes specialised is called differentiation
- In humans, some stem cells are found in the embryo where they become specialised
- The ability of a stem cell to differentiate into specialised cells is called potency:
- **Totipotent**: Can produce all cell types, including all specialised cells and extraembryonic cells
- **Pluripotent:** Can produce all specialised cells but not extraembryonic cells
- **Multipotent:** Can produce some types of cell but is limitted in which cells it can produce
- Totipotent stem cells are only present in the first few weeks of development of an embryo - After this point they become pluripotent and can't make the placenta or umbilical cord
- Some adult tissues are the location of some multipotent stem cells
- Plants also contain stem cells in their meristems or growing regions

Use of Stem Cells in Medicine

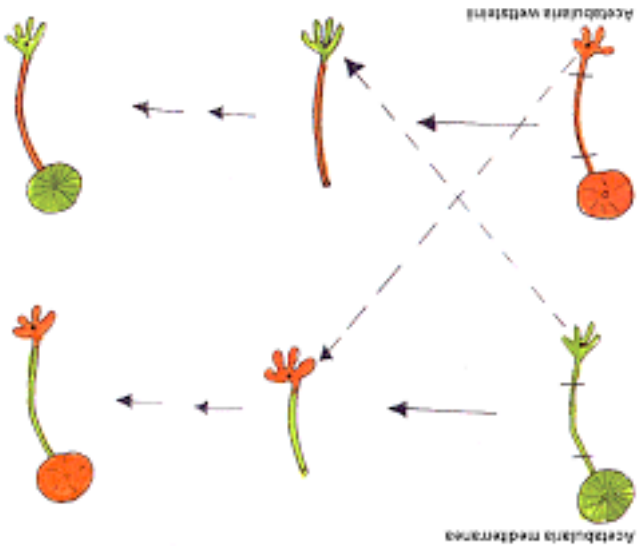
- Stem cells can be used to create replacement tissues to treat diseases e.g. heart attacks
- Stem cells are collected from blastocysts (embryos) which are discarded
- One problem with this approach is that they may be rejected by the immune system of the person they are used in
- In theraputic cloning, the patient needing a transplant would have a diploid cell removed from any suitable tissue
- The cell or nucleus is then fused with an ovum from which the haploid nucleus has been removed
- The result forms a zygote and is known as somatic cell nuclear transfer
- This procedure results in cell lines and perhaps eventually organs for transplantations which are genetically identical to the original diploid cell
- This reduces the risk of rejection by the immune system

Ethics of Using Stem Cells

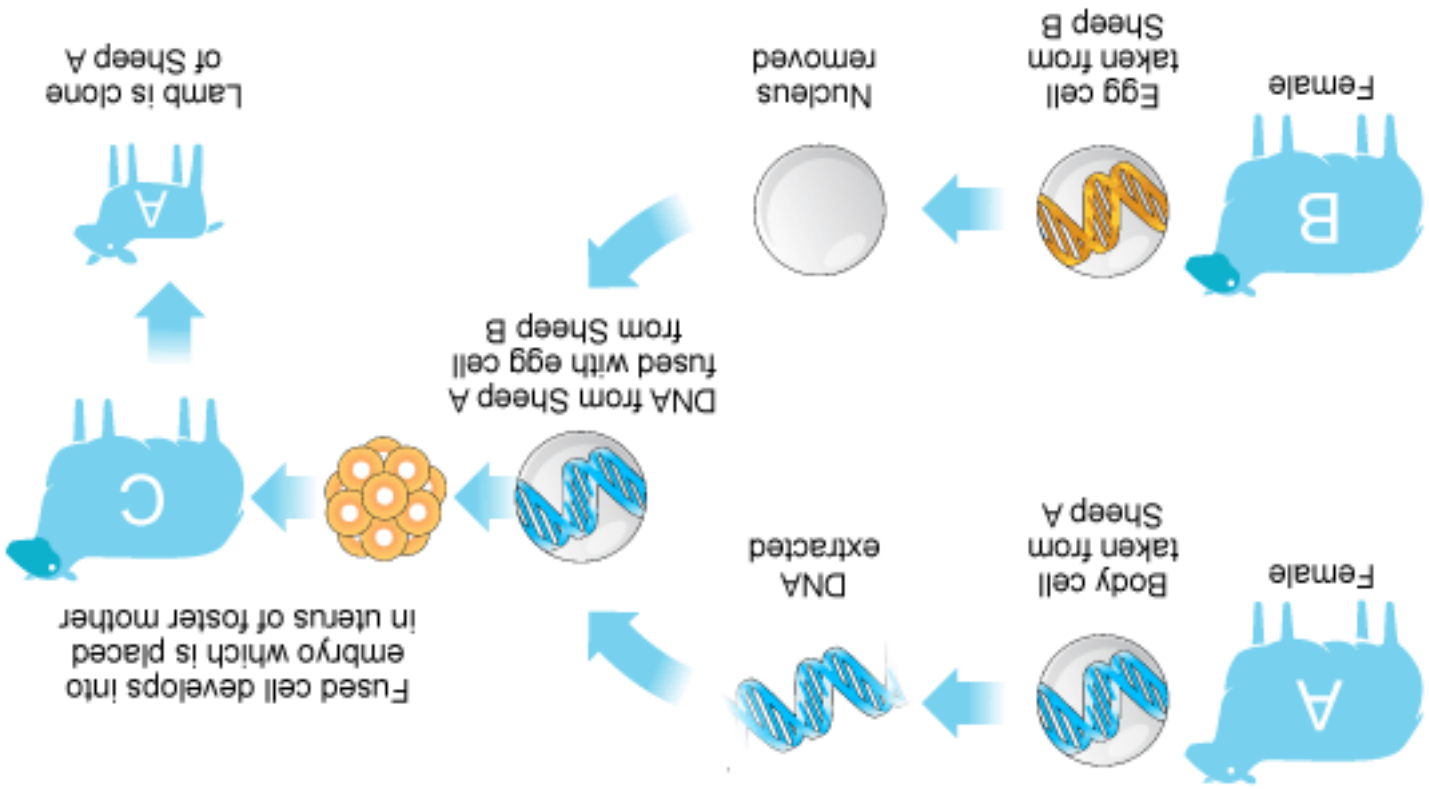
- There are very few ethical issues with the use of multipotent stem cells in medicine
- Multipotent stem cells are less versitile than totipotent or multipotent stem cells
- Extracting stem cells from embryos is considerred unethical as you are taking away a potential life
- Utilitarianists say that it is in the best interest to use stem cells to treat medical conditions and prolong someone elses life
- Most stem cells are extracted from rejected embryos so they would have been destroyed
- The Human Fertilisation and Ebryology Authority (HFEA) regulates research on human embryos
- They aim to restrict the development of stem cells for the use in unethical uses of stem cells such as human cloning

The Role of the Nucleus in Development

- Joachim Hammerling cut off the heads (hats) of two species of giant algal cells
- He then swapped the stalks of the algal cells and attached them to the rhizoids which contain the nuclei
- The algal cells developed features of both species due to mRNA in the stalks
- He then removed the hats and observed that the new ones developed features from the nucleus they were attached to as new mRNA was sent along the stalk to create the hats



Genetic Cloning (Dolly the Sheep)



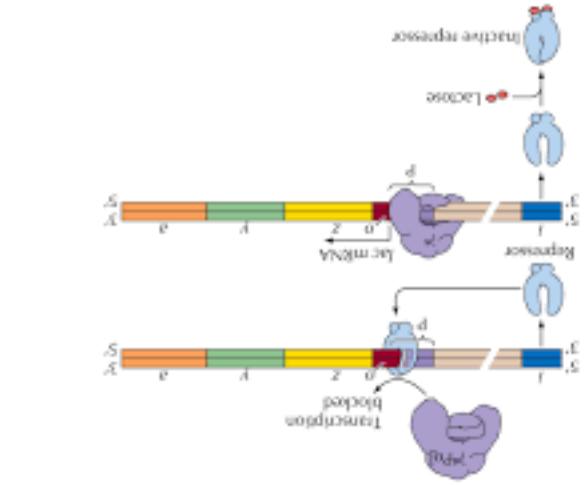
Problems with Genetic Cloning

- Genetic cloning is in experimental stages with many attempts to produce clones being unsuccessful and a high number of the clones produced having health problems
- Dolly took 277 attempts at cloning to produce her
- Dolly wasn't perfect as she suffered from arthritis at a young age and was put down
- The reason for these low success rates are unknown and are most likely multifactorial
- One theory is that the DNA in an adult cell nucleus has been programmed to be a particular cell type
- So when it is transferred to an ovum, the nucleus might not be able to reprogram its DNA quickly enough to switch on developmental genes
- Ethical issues also restrict the use of genetic cloning due to the unknown health risks
- Another issue is that some people feel by cloning, we are playing God

The Epigenome

- The Epigenome influences which genes can be transcribed in a particular cell causing differentiation within a cell by switching on certain genes and switching off others
- DNA is wrapped around histone proteins and both the DNA and histones have chemical markers on their surface; these make up the epigenome
- The attachment f methyl groups to the DNA of a genome prevents the transcription of mRNA by stopping RNA Polymerase from binding to the DNA
- The addition of acetyl groups to the histone proteins contols how tightly the DNA is wrapped around the histone proteins.
- If the DNA is wrapped around the histones tightly, RNA Polymerase can't bind to the DNA to transcribe it
- By restricting the transcription of certain genes, the corresponding proteins won't be synthesised and the function of the cell will be changed

The Lac Operon Model

- *E Coli.* only produced the enzyme #-galactosidase when in the presence of lactose
- When lactose isn't present, a lactose repressor molecule binds to the DNA and prevents the transcription of the #-galactosidase gene by preventing RNA Polymerase from bidiing
- If lactose is present, the repressor molecule is prevented from binding to the DNA and the gene is transcribed producing the enzyme
- 

Gene Expression in Eukaryotes

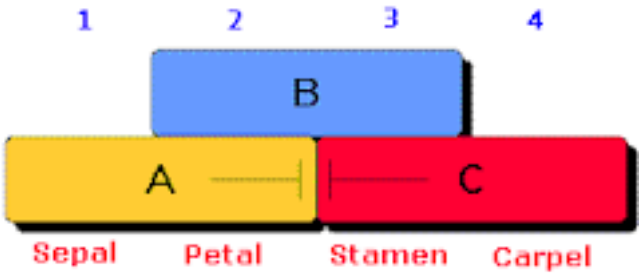
- In order to transcribe a gene, a promoter region must be accessible on the DNA in order for RNA Polymerase to bind to the section of DNA adjacent to the gene and transcribe it
- The gene remains switched off until the enzyme binds to the promoter region and when a regulator protein also is present in order to transcribe the gene and switch on the gene
- Transcription of a gene can be prevented by the addition of a repressor molecule attaching to the promoter region preventing the RNA Polymerase from binding
- If genes are expressed incorrectly with certain genes being switched on, it can result in severe issues e.g. *Fibrodysplasia Ossificans Progressiva* (FOP) occurs when damaged muscle cells are replaced with bone cells and cause joints or muscles to become fixed in place
- If this occurs in the lungs it will result in the person suffocating as their diaphragm and intercostal muscles can't work so breathing stops

Master Genes

- Master genes control the development of segments in certain organisms
- In fruit flies, *Drosophila*, once the main body segments have been determined, the cells in each segment become specialised for the appropriate structures in that segment i.e. legs, antenae
- Master genes were discovered by looking at the mutations that cause the development of the wrong appendage for that segment e.g. legs for antenae
- The master genes produce mRNA that is translated into signal proteins
- These proteins switch on the genes responsible for producing the proteins needed for specialisation of cells in each segment

Expression of Genes in Plants

- When a plant starts to flower, the cells in a meristem become specialised to form the organs that make up the flower
- Most hermaphrodite flowers have four sets of organs: sepals, petals, stamens and carpels
- The expression of genes in cells across the meristem determines which structures will form
- Three genes determine which type of organ will be expressed: A, B and C
- A = Sepal A + B = Petal B + C = Stamen C = Carpel
- These genes produce mRNA that code for signal proteins that switch on appropriate genes



Discontinuous and Continuous Variation

- Discontinous variation are differences that fall in discrete groups with no overlap
- Completely controlled by an organisms genotype and is hardly affected by the environment
- These genes are often found on a single locus
- A persons blood group is determined by the genes that code for the glycoproteins on the surface of the red blood cells

- Continuous Variation are differences that fall within a range of two extremes
- Affected by both the genotype and the environment either directly or by gene expression
- The genes are often found at several locations (polygenic)
- Human height is an example of continuous variation where children can be born in at a certain height between two extremes

Polygenic Inheritance

- Polygenic inheritance is the control of a phenotype by multiple genes e.g. eye colour
- If a dominant gene is present, it will add more pigment to the iris; if a recessive gene is present it won't add any pigment
- If 3 loci are involved in determining the phenotype then a number of possibilities for the colour of the iris could be observed
- BB BB BB would result in a dark brown whilst bb bb bb would result in a pale blue
- A range of possibilities can be experience within these extremes
- The greater the number of loci involved, the more possibilities can be experienced
- Punnett Squares can be used to calculate the probability of an offspring developing each possibility. This results in a bell shaped curve graph

Melanin

- Melanin is the dark pigment in skin and hair
- It is produced in melanocytes and is activated by the melanocyte-stimulating hormone (MSH)
- The receptors for MSH are on the surface on melanocytes
- Melanocytes place melanin into melanosomes and are transferred to surrounding skin and hair cells where they protect DNA from UV light
- The more receptors the darker the colour produced
- UV light increases the amount of MSH increasing melanocyte activity - resulting in darker skin
- UV light causes lighter hair because it destroys melanin in hair cells
- Arctic foxes change their colour depending on the seasons. They do this by producing fewer MSH receptors in summer which reduces the effect of MSH and so no melanin is made in the hair follicles
- To make melanin, animals use the enzyme tyrosinase to change the amino acid tyrosine into melanin
- Himalayan Rabbits and Siamese Cats have mutant alleles for tyrosinase which results in the enzymes being unstable at warmer temperatures. This causes them to have a white body where the temperatures are to high for the enzyme but black ears where the enzyme can operate

Environmental Influences of the Epigenome

- Environmental factors can influence epigenetic changes
- Scientists have tested the effect of High Licking and Grooming (LG) mothers of rats compared to Low LG mothers and have noticed that the offspring of good mothers being brought up by bad mothers results in anxious pups and vice versa
- The pups expressed stimulation of the GR gene which resulted in high stress levels where as methylated GR genes stops the stress response
- The methylation remains throughout the rats lives which results in calmer rats in their adult life
- Studies of mothers who have been starved during stages of their pregnancy show that their children are more likely to have certain genes methylated which could result in abnormal weight gain when they ate a healthy amount.
- Sperm and Ovum Cells are specialised so they would have epigenetic changes to determine their structure
- It is likely that the epigenetic markers are removed during development to allow the cells to return to stem cell configuration
- Some epigenetic changes are observed to pass from parent to child resulting in changes to their phenotypes e.g. height, weight

Causes of Cancer

- Cancers occur when the rate of cell replication is faster than the rate of cell death
- This causes the growth of a tumor, an abnormal number of cells with no purpose
- Tumours use up oxygen and glucose starving other areas of some of the chemicals they need
- DNA controls the genes which coordinate the cell cycle. If these are damaged via mutations or changes to the methylation occur they can be transcribed incorrectly
- During each stage of the cell cycle, proteins are produced that stimulate the next stage in the cycle as well as proteins which stop the cycle and preventing progression to the next stage
- Cancer cells don't respond to these control mechanisms
- Oncogenes and Tumour Suppressor Genes are two genes that play a part in causing cancer
- Oncogenes code for the proteins that stimulate the transition from one stage tin the cell cycle to the next. DNA mutations or epigenetic changes can lead to these genes being continually active resulting in excessive cell division
- Tumour Supressor Genes produce proteins that stop the cycle. DNA mutations and epigenetic changes mean there is no break on the cycle with the cell continually replicating
- Cancers are more common in older people because mutations have accumulated over time

Inherited Cancer

- Cancer can occur frequently in relatives of cancer patients suggesting an inherrited component
- Mutations in the BRCA1 gene predispose a person to have breast cancer
- Functioning BRCA1 genes produce a protein used to repair DNA
- Inheriting one mutated BRCA1 gene may increase the risk of developing breast cancer but won't guarentee it
- Women who inherit 1 faulty BRAC1 gene will have a 60% chance of developing breast cancer
- Women who have 2 normal BRAC1 genes will only have a 2% risk of developing breast cancer
- Only 5% of breast cancer sufferers have a faulty BRAC1 gene

Environmental Cancer

- Smoking results in the biggest risk of developing cancer
- Carcinogens and tar blocking the bronchi and damaging DNA in epithelial cells increases the risk of developing lung cancer
- UV light physically damages DNA in skin cells resulting in moles growing bigger and developing into a tumour which causes skin cancer
- Vitamin C reduces the effect of radicas by providing antioxidants that destroy radicals. Radicals enter our body through bad diet, smoking or are metabolised by the body. They damage DNA resulting in ageing and cancer
- Some viral infections can cause a risk of developing cancer e.g. liver cancer risk can increase after infection from some types of hepatitis
- Radiation from X-rays and other sources may increase the risk of mutations occuring to Oncogenes and Tumour Suppressor Genes increasing risk of developing cancers
- Cancer cells can be spread around the body through the circulatory and lymphatic systems allowing cancers to form in other organs

Monoamine Oxidase A (MAOA)

- Monoamine Oxidase A (MAOA) is an enzyme that breaks down monoamines (a type of chemical) in humans
- Low levels of MAOA have been linked to certain mental health problems including ADHD, autism, depression and schizophrenia
- MAOA also has been linked to issues regarding cancer and cardiovascular disease when high levels are experienced
- MAOA production is controlled by a single gene (monogenic) but taking anti-depressants or smoking tobacco can reduce the amount produced