HEREDITY

5.1. REPRODUCTION

HOW DOES REPRODUCTION ENSURE THE CONTINUITY OF A SPECIES?

MECHANISMS OF REPRODUCTION

Fertilisation in animals:

- ***External Fertilisation:*** *a male organism's sperm fertilises a female organism's egg outside of the body.*
- ***Internal Fertilisation:*** *union of an egg cell with a sperm during sexual reproduction inside the body.*

ADVANTAGES OF INTERNAL	***ADVANTAGES OF EXTERNAL***
Able to control the environment, meaning increased chance of gamete union and safer	*Results in the production of a large number of zygotes and thus more offsprings can be produced*
Female produces less gametes - saves energy	*A lot of eggs can be fertilised at the same time.*
Higher survival rate	*Parents don't have to be together at the same time.*
Doesn't require an aqueous environment.	*Easier to find mates as the gametes can drift.*

Reproduction of plants:

- ***Asexual reproduction*** *is where offspring arise from a single organism, and inherit the genes of that parent only, meaning theres no genetic variation and it does not involve the fusion of gametes.*
  - *Artificial vegetative propagation: a stem cutting produces new roots and root cutting produces new stems. Some plants can be grown from leaves, which produce stems and roots.*
  - *Fragmentation: runners are stems that grow horizontally and have nodes where buds are formed. These buds grow into a new plant. Sometimes leaves will grow into a new plant if they become detached from the parent. Other plants grow small plants (plantlets) on their leaves.*
- ***Sexual Reproduction*** *requires pollen from the male anthers of the plant pollinating the female stigma.*
  - *Self Pollination: a single plant can have both male and female parts so even though it is one plant, it is still sexual reproduction. The pollen from the anthers of a flower pollinates its own stigma, and the plant will be genetically identical to the parent.*
  - *Cross Pollination: pollen from one plant is transferred to another by insects, wind or birds. This creates more* ***robust*** *plants and increases genetic diversity in a species, allowing for evolution.*

Reproduction of Fungi:

- ***Budding:*** *asexual reproduction where a new organism develops from an outgrowth or bud due to cell division at a specific site. When mature, the bud will detach from the parent and become an individual.*
- ***Spores:*** *mushrooms produce spores sexually and asexually on the underside of their cap. They are unicellular reproductive cells that are produced in great numbers.*
  - ***Spore Cycle:*** *When conditions are favourable they reproduce asexually by developing sporangia (spore-producing units). Each spore has several nuclei and cytoplasm surrounded by a wall. It sexually reproduces with homothallic or heterothallic mycelia. As the sporangia grows /ripens it will rupture when mature, releasing spores that'll germinate and put down own hyphae.*

Reproduction of Bacteria:

- ***Binary Fission:*** *a single DNA molecule replicates and attaches each copy to a different part of the cell membrane. Body is pinched into two parts or halves, the parental body is replaced by two daughter nuclei. When the cell begins to pull apart, the replicated and original chromosomes are separated.*
- *All cells are genetically identical / made of the same genetic material.*

Reproduction of Protists

- ***Protists can reproduce via binary fission much like bacteria.***
- ***Budding:*** *a daughter nucleus is produced and split from the parent with some surrounding cytoplasm.*

PREGNANCY AND BIRTH IN MAMMALS

For all mammals, sexual reproduction typically produces genetically variable offspring, promoting the continuity of their species while permitting diversity. All mammals reproduce using internal fertilisation.

- ***Placental:*** *uterus provides nourishment/protection until birth, umbilical cord provides milk-develops fur.*
- ***Marsupial:*** *give birth to live, developed young, nourished in the parent's pouch.*
- ***Monotreme:*** *lay eggs.*

Fertilisation and Implantation

- *Sexual reproduction starts with the production of gametes. Males continually produce sperm after puberty, though for females, meiosis has begun before birth in all oocytes but pauses at an early stage.*
- *This occurs in the ovaries where the ovum (eggs) are released into the fallopian tubes.*
- *There is a 12-24 hr window where* ***fertilisation*** *(fusion of gametes) can be successful, called ovulation.*
- *Fusion of the haploid egg and sperm nuclei result in a diploid zygote cell.*
- *The zygote divides and moves from the fallopian tubes into the uterus, becoming a blastocyst.*
- *The blastocyst embeds itself into the nutrient-dense lining (endometrium) of the uterus;* ***implantation****.*

Hormonal control of pregnancy:

Hormones transmit signals to specific target cells that contain surface receptors for a specific hormone. They are transported by the circulatory and lymphatic systems, or by the diffusion through extracellular fluid.

HORMONE	FUNCTION
Luteinising Hormone	*Triggers ovulation and development of the corpus luteum.*
Oestrogen	*Main female sex hormone, triggers the release of egg from ovary (ovulation). Maintains and stimulates production of other hormones, like oxytocin.*
Human Chorionic Gonadotropin	*Released during implantation to keep the corpus luteum active. Ensures adequate progesterone and maintains endometrium.*
Progesterone	*Released by corpus luteum during implantation/first trimester to maintain endometrium, then by the placenta to prevent contractions and miscarriage.*
Oxytocin	*Released towards the end of the third trimester to stimulate contractions, then milk production.*

SCIENTIFIC KNOWLEDGE AND THE MANIPULATION OF PLANT AND ANIMAL REPRODUCTION

Selective breeding

- *Scientific research has had a great impact on the manipulation of plant and animal reproduction. An example is selective breeding. Selective breeding, or artificial selection, is a process in which new organisms develop with desirable traits or characteristics. Breeders and farmers select two parents that have beneficial or desirable traits to reproduce new, desirable offspring with a mix of the said traits. This is common amongst both plants and animals, and has been a process used by humans for tens of thousands of years, and defines the change of humans from hunter-gatherers to farmers.*
- *As technology and biotechnology has become more advanced, scientists can take a look into not only the phenotype but the genotype of animals, creating the opportunity to breed offspring that have not only no undesirable dominant traits, but no undesirable recessive traits.*

5.2. CELL REPLICATION

HOW IMPORTANT IS IT FOR GENETIC MATERIAL TO BE REPLICATED EXACTLY?

THE CELL CYCLE

Mitosis: *one mother cell is divided into **two** identical daughter cells having the same number of chromosomes.*

1. ***Interphase:*** *the segment of the cell cycle before mitosis and meiosis. There are 3 sub-phases:*
   - ***G_1:*** *cells synthesise a number of materials like enzymes, regulators and nutrients required.*
   - ***S:*** *DNA packed in chromosomes are replicated.*
   - ***G_2:*** *cells synthesise materials required for the formation of spindle fibre*
2. ***Prophase:*** *P is for 'preparation'*
   - *The chromatin material shortens and thickens by coiling. The nuclear membrane breaks down.*
   - *The DNA separates into chromosomes, where each one chromosome contains two copies of DNA. Each copy is called a chromatid, and is joined at the centre by a centromere.*
   - *A spindle forms from the material of the broken down nucleus and extends across the cells*
3. ***Metaphase:*** *M is for 'middle' (of the cell)*
   - *The chromies line up along the equator, attached to the spindle fibres by its centromere.*
   - *Each chromosome still has two genetically identical sister chromatids.*
4. ***Anaphase:*** *A is for 'away' (to the two poles of the cell)*
   - *The proteins in the centromere are split and this allows for the sister chromatids to separate.*
   - *Each chromatid then becomes its own daughter chromosome.*
   - *Spindle fibres contract and the chromies are pulled by the centromeres to opposite ends of cell.*
5. ***Telophase:*** *T is for 'two' (nuclei)*
   - *The daughter chromies are gathered at opposite poles of the cell, and the spindle breaks down.*
   - *Nuclear membrane and nucleolus reappears in both groups of chromies, creating two identical daughter nuclei, and mitosis is now complete.*
6. ***Cytokinesis:*** *the process of division of a cell's cytoplasm (happening during anaphase and telophase).*
   - *In animals, two proteins, Actin and Myosin help form the cell by creating a cleavage furrow.*
   - *In plant cells, a cell plate is formed and separates the cell into two separate daughter cells.*

Meiosis: *where one mother cell divides into four daughter cells that have half the number of chromosomes.*

- *PMAT happens twice (meiosis I and meiosis II).*
- ***In prophase:*** *crossing over occurs in meiosis I but not meiosis II*
- ***In anaphase:*** *during meiosis I chromosomes are pulled apart when sister chromatids stay connected at centromere but then the chromatids are pulled apart during meiosis II.*

Watson and Crick:

Model: *DNA is a double helical nucleic acid molecule carrying genetic info in nucleotide base sequences. A single nucleotide is a phosphate bonded to a deoxyribose sugar group, bound to a nitrogenous base. These nucleotides bond to a sugar, forming a sugar-phosphate backbone. The bases are bound by hydrogen bonds.*

DNA Replication is as follows:

1. ***Initiation:*** *helicase unwinds and unzips complementary strands by breaking the hydrogen bonds.*
2. ***Elongation:*** *primers (small pieces of RNA) bind to the strands and signal the start point for replication. Polymerase binds to the DNA at primer sites and adds new base pairs complementary to the strand.*
3. ***Termination:*** *polymerase reaches the end and two identical daughter strands have been produced. The strands recoil into the double helix and nuclease enzymes proofread the two new DNA molecules.*

CELL REPLICATION AND THE CONTINUITY OF A SPECIES

- ***DNA replication:*** *DNA directs all processes in a cell. Cell reproduction is dependent upon DNA replication, as if it weren't replicated, there would be half as much and resulting cells would die. DNA ensures that information important for life is being passed down through generations.*
- ***Mitosis:*** *essential for development and growth as it produces all body cells, new and replacement, allowing proper function in the body. Facilitates asexual reproduction, creating the next generation.*
- ***Meiosis:*** *Purposely introduces variation within an organism and a population due to independent assortment and random segregation. Genetic diversity is very important for the continuity of a species.*

5.3. DNA AND POLYPEPTIDE SYNTHESIS

WHY IS POLYPEPTIDE SYNTHESIS IMPORTANT?

EUKARYOTES AND PROKARYOTES

Prokaryotic Cells

- *First cells, unicellular and therefore very simple - no membrane bound organelles and no nucleus*
- *Genome is compact and contain little repetitive DNA and no introns located in the nucleoid.*
- *Replication process relatively simple and speedy - takes about two proteins to initiate*
- *Information content in operons which code for multiple proteins*

Eukaryotic Cells:

- *Unicellular or multicellular so more complex and have membrane-bound organelles and like a nucleus*
- *Paired linear chromosomes and genome contains large amounts of repetitive DNA and introns*
- *Replication process more complex and slower*
- *Each gene codes for single protein*

POLYPEPTIDE AND PROTEIN SYNTHESIS

Transcription: ***Converting DNA to mRNA in the nucleus.***

- *A double-stranded DNA molecule unwinds a section of itself to expose a strand of a gene to be copied.*
- *The RNA polymerase enzyme moves along the strand, attaching loose RNA nucleotides to the DNA until the whole gene is copied. This new strand of RNA is called mRNA.*
- *mRNA exits the nucleus through nuclear pores and enters the cytoplasm.*

Translation: ***Converting tRNA to amino acids in the cytoplasm.***

- *The mRNA binds to a ribosome in the cytoplasm, and the ribosome moves along the mRNA strand.*
- *tRNA molecules floating in the cytoplasm carry amino acids to the ribosomes to form a polypeptide chain. At the bottom of every tRNA molecule is an anticodon that binds to the codon on the mRNA strand. Anticodons have bases complementary to the codons of the mRNA. As the tRNA releases its amino acids to attach to the ribosome, it leaves to find another amino acid.*
- *Ribosome moves along the mRNA strand and more amino acids are attached to the chain by peptide bonds. When a stop codon is reached, the chain is released into the cytoplasm to become a protein.*

The importance of mRNA and tRNA in transcription and translation

- ***mRNA** plays a very important role in carrying the genetic information copied from DNA in the form of a series of three-base codes, which are known as 'codons', each of which specifies an amino acid.*
- ***tRNA** is vital to deciphering the code words in mRNA. Each amino acid has its own type of tRNA, which binds it and carries it to the end of a polypeptide chain, if the next code word on mRNA calls for it. The correct tRNA and its attached amino acid is selected at each step because each specific tRNA molecule contains a three-base sequence that can pair with its complementary code word in mRNA.*

Function and importance of polypeptide synthesis:

- *Polypeptide synthesis forms the basis for the central dogma of biology. It provides the basic framework for how genetic information flows from a gene to a protein inside cells. This process of genetic information flows from DNA to RNA to amino acids, polypeptide chains and proteins is called gene expression. Gene expression is the switching 'on' and 'off' of genes to make the required proteins.*

How genes and environment affect phenotypic expression:

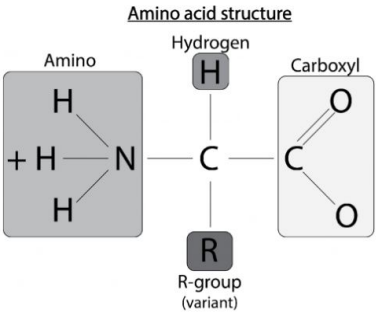
Environment (climate, lifestyle, diet, chemicals) affects gene expression: Genes + environment = phenotype.

- *Genes that are 'expressed' dictate the phenotype of an organism. Each step in polypeptide synthesis is regulated by a protein, so genes must produce proteins to regulate their own expression. It is extremely important that proteins are made according to DNA's instructions, as this gives rise to a fully functional 3D protein, which is essential for the correct functioning of cells and production of a healthy phenotype.*

EXAMPLE	ENVIRONMENTAL FACTOR	EFFECT
Siamese Cats	*Climate*	*Colour is darker in cooler climates and lighter in warmer climates.*
Hydrangeas	*Soil pH*	*If acidic, the colour is bright blue. If basic, the colour is pale pink/off-white.*

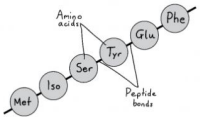
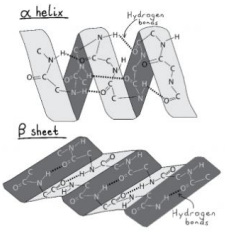
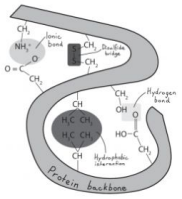
STRUCTURE AND FUNCTION OF PROTEINS

Structure:



Proteins are all composed of amino acids. They have a central carbon, an amine group, a carboxyl, a hydrogen, and a R-group, which varies in each type of amino acid, and gives the molecule different properties. These side group properties define the structure and function of the protein overall. Amino acids become part of polypeptide chains because of polypeptide bonds between the amine and carboxyl groups. Polypeptide chains fold into proteins, influenced by the reactions between the side groups.

- *Amino acids with hydrophobic side chains will be found on the inside of proteins, because they do not like water. Amino acids with hydrophilic side chains will be on the outside, as they are attracted to it.*

STRUCTURE	PROCESS	EXPLANATION	DIAGRAM
Primary	*The sequence of amino acids.*	*The primary structure of proteins refers to the arrangement of amino acids sequences in a polypeptide sequence determined by the mRNA code, and formed during translation.*	
Secondary	*The formation of alpha helices and beta sheets.*	*Hydrophobic interactions and hydrogen bonding between amino acid side groups influences the formation of two core structures: alpha helices and beta sheets.*	
Tertiary	*Formation of the overall 3D shape.*	*The protein backbone will twist and bend to achieve maximum stability. This is facilitated by side group interactions; for example, disulphide bridges between cysteines, salt bridges between positively and negatively charged side chains, or hydrophobic interactions. The total of interactions within the polypeptide chain will result in the formation of a 3D structure.*	
Quaternary	*Interaction of protein subunits.*	*Some proteins are composed of multiple polypeptide subunits. The interaction of these influences quaternary structure. For example, haemoglobin is composed of four individual subunits, bound together to form the final complex.*	

Function:

Proteins are super important to the function of living things. They perform most of the work inside of cells, and are vital to tissue and organ structure, function and regulation. Examples of these functions include:

STRUCTURE AND SUPPORT	*Proteins form the basis of the cellular cytoskeleton, as well as composing important macro-molecular structures like connective tissues, hair and nails.*
TRANSPORT AND STORAGE	*Proteins in the cellular membrane are responsible for trafficking molecules into and out of the cell, and sometimes around the body Storage proteins reserve important biological materials for use in the body, like ferritin stores iron.*
ENZYMES	*Proteins may function as biological catalysts, carrying out thousands of chemical reactions inside of the cell. They are used in energy production, DNA replication, transcription and translation, and basically everything else.*
ANTIBODIES	*Proteins form an important part of the immune response by recognising and binding to foreign particles.*
MESSENGERS	*Hormones are proteins which transmit signals around the body, allowing the complex array of biological processes which occur to be coordinated effectively.*