Unit Four: Genetics

Genetics: Understanding DNA and RNA

What is Genetics? Genetics is the branch of biology that studies how traits are passed from parents to offspring through genes. These traits are determined by genetic material.

Genetic Materials: DNA and RNA

1. **DNA (Deoxyribonucleic Acid)**
    - **Structure:** DNA is a double-helix structure resembling a twisted ladder. It consists of two long chains of nucleotides. Each nucleotide has a sugar (deoxyribose), a phosphate group, and one of four nitrogenous bases: Adenine (A), Thymine (T), Guanine (G), or Cytosine (C). Adenine pairs with Thymine, and Guanine pairs with Cytosine.
    - **Function:** DNA stores and transmits genetic information. It controls the growth, development, and reproduction of organisms. During cell division, DNA replicates to ensure genetic information is passed to new cells.
2. **RNA (Ribonucleic Acid)**
    - **Structure:** RNA is usually single-stranded and contains ribose sugar, phosphates, and nitrogenous bases: Adenine (A), Uracil (U) (replacing Thymine), Guanine (G), and Cytosine (C).
    - **Function:** RNA plays a crucial role in protein synthesis. It carries genetic information from DNA to the ribosomes, where proteins are made. There are different types of RNA:
        - **mRNA (Messenger RNA):** Carries instructions from DNA to the ribosome.
        - **tRNA (Transfer RNA):** Brings amino acids to the ribosome.
        - **rRNA (Ribosomal RNA):** Makes up the ribosome, which assembles proteins.

Key Concepts

- **Genes and Chromosomes:** Genes are sections of DNA that determine traits. They are located on chromosomes, which are thread-like structures made of DNA and proteins. In humans, there are 46 chromosomes arranged in 23 pairs.
- **DNA Replication:** This process ensures that each new cell has an identical copy of DNA. During replication, the DNA molecule separates into two

strands, and each strand serves as a template for a new strand, resulting in two double-stranded DNA molecules.

Comparing DNA and RNA

Feature	DNA	RNA
Full Name	Deoxyribonucleic Acid	Ribonucleic Acid
Structure	Double helix	Single-stranded
Sugar	Deoxyribose	Ribose
Bases	A, T, G, C	A, U, G, C
Function	Stores genetic information	Translates genetic information into proteins

Understanding DNA and RNA is fundamental to grasping how genetic traits are inherited and how they function in living organisms.

Cell Division

Cell division is a crucial process that allows organisms to grow, repair, and reproduce. Here's a simple breakdown of how it works and its importance:

1. The Cell Cycle

The cell cycle is a sequence of events that a cell goes through to divide and produce new cells. It has two main phases:

- **Interphase**: The cell grows and copies its DNA.
- **Mitotic Phase (M Phase)**: The cell divides into two new cells.

2. Interphase

During interphase, the cell prepares for division in three stages:

- **G1 Phase (First Gap)**: The cell grows and gathers nutrients.
- **S Phase (Synthesis)**: The DNA is replicated to ensure each new cell gets a complete set of chromosomes.
- **G2 Phase (Second Gap)**: The cell continues to grow and prepares for the actual division.

3. Mitosis

Mitosis is the process of dividing the cell's nucleus. It involves several stages:

- **Prophase**: Chromosomes condense and become visible. The nuclear envelope dissolves.
- **Metaphase**: Chromosomes align in the center of the cell.
- **Anaphase**: Chromatids (sister chromosomes) are pulled apart to opposite ends of the cell.
- **Telophase**: Chromosomes start to de-condense, and the nuclear envelope reforms around each set of chromosomes.

Cytokinesis follows, splitting the cell's cytoplasm, resulting in two identical daughter cells.

4. Meiosis

Meiosis is a special type of cell division that produces sex cells (sperm and eggs) with half the number of chromosomes. It involves two rounds of division:

- **Meiosis I**: Homologous chromosomes are separated into two cells.
- **Meiosis II**: The two cells divide again to produce four unique sex cells.

Key Differences Between Mitosis and Meiosis:

- **Mitosis**: Produces two identical diploid cells.
- **Meiosis**: Produces four unique haploid cells with half the chromosome number.

Summary

Cell division is essential for growth, repair, and reproduction. Mitosis results in identical cells, while meiosis produces genetically diverse sex cells. Understanding these processes helps us grasp how organisms develop and reproduce.

Mendelian Inheritance

Introduction to Mendelian Inheritance

Mendelian inheritance explains how traits are passed from parents to offspring. This concept, developed by Gregor Mendel, describes patterns of inheritance

through experiments with garden peas. Mendel discovered foundational principles of heredity that are crucial for understanding genetics today.

Key Concepts

1. **Inheritance:** The process by which traits are passed from parents to offspring through genetic material.
2. **Mendelian Crosses:** Experiments where Mendel crossed pea plants to study the inheritance of traits. He used different types of crosses to analyze how traits are passed down.
3. **Monohybrid Cross:** A cross between two individuals to study the inheritance of a single trait. For example, crossing a tall plant (TT) with a short plant (tt) results in all tall plants (Tt) in the F1 generation. When these F1 plants are crossed, the F2 generation shows a 3:1 ratio of tall to short plants.
4. **Genotype and Phenotype:**
    - **Genotype:** The genetic makeup of an organism (e.g., TT, Tt, tt).
    - **Phenotype:** The observable traits (e.g., tall or short).
5. **Homozygous vs. Heterozygous:**
    - **Homozygous:** Having two identical alleles for a trait (e.g., TT or tt).
    - **Heterozygous:** Having two different alleles for a trait (e.g., Tt).
6. **Punnett Square:** A tool used to predict the genetic outcomes of a cross. It helps visualize the possible combinations of alleles and their resulting phenotypes.
7. **Law of Segregation:** States that each parent contributes one allele for each trait, and these alleles segregate independently during gamete formation.
8. **Law of Independent Assortment:** States that the inheritance of one trait does not affect the inheritance of another trait. This occurs during the formation of gametes in dihybrid crosses.
9. **Test Cross:** A method to determine the genotype of an individual with a dominant phenotype by crossing it with a homozygous recessive individual. If the offspring show a recessive trait, the unknown genotype is heterozygous.

Mendel's Observations

- **Monohybrid Crosses:** Observed that dominant traits appear in the F1 generation and recessive traits appear in the F2 generation in a 3:1 ratio.
- **Dihybrid Crosses:** Studied the inheritance of two traits simultaneously and found a 9:3:3:1 phenotypic ratio in the F2 generation.

Non-Mendelian Inheritance

What is Non-Mendelian Inheritance?

Non-Mendelian inheritance refers to genetic inheritance patterns that do not follow Gregor Mendel's laws of inheritance. Mendel's principles primarily cover simple dominant and recessive traits, but scientists have discovered other patterns of inheritance where these rules don't fully apply.

Key Concepts in Non-Mendelian Inheritance

1. **Co-dominance**
    - In co-dominance, both alleles in a heterozygous individual are fully expressed. This means you can see both traits simultaneously.
    - **Example**: In short-horned cattle, a cross between red and white cattle results in a roan coat color. The offspring have both red and white hairs.
2. **Incomplete Dominance**
    - In incomplete dominance, neither allele is completely dominant over the other. Instead, the heterozygous phenotype is a blend of the two parental traits.
    - **Example**: Crossing red roses with white roses produces pink roses, showing a blend of both parental colors.
3. **Multiple Alleles**
    - Some genes have more than two alleles. These multiple alleles can lead to several different phenotypes.
    - **Example**: The ABO blood group system in humans involves three alleles: A, B, and O. The combination of these alleles determines a person's blood type (A, B, AB, or O).
4. **Rh Factor**
    - The Rh factor is another blood group system that is inherited separately from the ABO blood group. It has two alleles: Rh+ (dominant) and Rh- (recessive).
    - **Example**: A person who inherits at least one Rh+ allele will have Rh+ blood, while those with two Rh- alleles will have Rh- blood.
5. **Sex-Linked Inheritance**
    - Traits linked to the sex chromosomes (X or Y) follow different inheritance patterns. Males have one X and one Y chromosome, while females have two X chromosomes.
    - **Example**: Hemophilia is a sex-linked disorder found on the X chromosome. Males are more likely to express this trait since they have only one X chromosome.
6. **Environmental Influence**

- The environment can affect an organism's phenotype. This effect can mimic or modify genetic traits.
- **Example**: Himalayan rabbits have a white coat in warmer temperatures and a black coat in colder temperatures.

Summary

Non-Mendelian inheritance includes various patterns like co-dominance, incomplete dominance, multiple alleles, and sex-linked traits that extend beyond Mendel's simple dominant-recessive model. Understanding these patterns helps explain the diversity of genetic traits in organisms.

4.9 Genetic Disorders

Genetic disorders are diseases caused by changes, or mutations, in an individual's DNA. These mutations can be inherited from parents and passed on to offspring, resulting in various genetic conditions. Here's a breakdown to help you understand these disorders better:

What Are Genetic Disorders?

- **Genetic disorders** occur when there is a change or mutation in the DNA.
- **Mutation** is a change in the DNA sequence, which can be due to errors during DNA replication or environmental factors.
- Some disorders are carried by dominant alleles, while others are carried by recessive alleles.

Types of Genetic Disorders

Genetic disorders are categorized into three main types:

1. **Single-Gene Disorders**
   - **Definition**: Caused by mutations in a single gene.
   - **Patterns of Inheritance**:
     - **Autosomal Dominant**: Only one copy of the defective gene is needed for the disorder to manifest. Example: Huntington's disease.
     - **Autosomal Recessive**: Both copies of the gene must be defective for the disorder to appear. Example: Cystic fibrosis and albinism.
     - **X-linked Disorders**: The gene causing the disorder is located on the X chromosome. Example: Hemophilia.
2. **Chromosomal Disorders**
   - **Definition**: Result from changes in the number or structure of chromosomes.
   - **Examples**:
     - **Down Syndrome (Trisomy 21)**: Caused by an extra copy of chromosome 21.

        - **Types of Chromosomal Changes**:
            - **Aneuploidy**: Wrong number of chromosomes.
            - **Deletion**: A part of a chromosome is missing.
            - **Inversion**: A chromosome segment flips around.
            - **Translocation**: A chromosome segment moves to another chromosome.
3. **Multifactorial Disorders**
    - **Definition**: Caused by a combination of multiple genes and environmental factors.
    - **Examples**: Diabetes and cancer.

Key Points to Remember

- **Autosomal Dominant Disorders**: Only one copy of the defective gene is required for the disorder to appear (e.g., Huntington's disease).
- **Autosomal Recessive Disorders**: Both copies of the gene must be defective (e.g., cystic fibrosis).
- **X-linked Disorders**: Involve genes on the X chromosome, and can be recessive or dominant (e.g., hemophilia).
- **Chromosomal Disorders**: Result from structural changes or the number of chromosomes (e.g., Down syndrome).
- **Multifactorial Disorders**: Involve a mix of genetic and environmental factors (e.g., diabetes).

4.12.1 Indigenous Knowledge of Ethiopian Farmers

Overview

Ethiopia is known for its diverse agricultural resources, including livestock and crops. According to the Central Statistics Agency (CSA) in 2020, Ethiopia had:

- 65 million cattle
- 40 million sheep
- 51 million goats
- 8 million camels
- 49 million chickens

Ethiopia is also a rich center for crop diversity, producing plants like coffee, tef, wheat, and barley. The agricultural sector is vital to the economy, with five major cereals (teff, wheat, maize, sorghum, and barley) being central to food production.

Indigenous Knowledge in Agriculture

Farmers in Ethiopia have long relied on indigenous knowledge to manage their crops and livestock. This traditional wisdom encompasses:

- **Selection of Livestock**: Farmers choose animals based on desirable traits such as growth rate, body size, and disease resistance.
- **Crop Selection**: Knowledge about which crops thrive in specific environments helps in choosing the right plants for cultivation.
- **Breeding Practices**: Indigenous practices include selecting plants and animals for breeding to improve qualities like yield and resilience.

Inquiry Activity: Investigating Breeding

1. **Artificial vs. Natural Selection**:
    - **Artificial Selection**: Humans selectively breed plants and animals for desired traits (e.g., breeding high-yield crops).
    - **Natural Selection**: Nature selects individuals with traits best suited to the environment to reproduce (e.g., animals with better camouflage surviving in the wild).
2. **Inbreeding and Crossbreeding**:
    - **Inbreeding**: Breeding closely related individuals to maintain or fix certain traits, which can lead to genetic problems due to reduced diversity.
    - **Crossbreeding**: Breeding individuals from different genetic backgrounds to increase diversity and improve traits.

    Advantages and Disadvantages:

    - **Inbreeding**:
        - **Advantage**: Can strengthen specific desirable traits.
        - **Disadvantage**: Increases the risk of genetic disorders and reduces overall health.
    - **Crossbreeding**:
        - **Advantage**: Enhances genetic diversity and can improve health and productivity.
        - **Disadvantage**: May take longer to establish desirable traits and can be more complex to manage.

Indigenous Knowledge in Breeding

Local farmers use their accumulated knowledge to:

- Combat environmental changes.
- Manage diseases and pests.
- Optimize plant and animal reproduction.

This traditional knowledge is often passed down through generations and is highly valuable for maintaining agricultural practices suited to local conditions.

Comparison: Indigenous knowledge provides practical, time-tested methods based on local experience, while modern scientific knowledge can offer more

precise techniques and tools for improving agricultural practices. Both approaches have their strengths and can complement each other in enhancing agricultural productivity.