Mendelian Genetics

Introduction to Mendel's Work

Gregor Johann Mendel, known as the Father of Genetics, conducted experiments on pea plants to understand how traits are inherited. He studied seven pairs of contrasting characters such as flower color and seed shape.

Monohybrid Cross

A monohybrid cross involves one pair of contrasting traits. Mendel crossed tall and dwarf pea plants and observed the inheritance pattern. The F2 generation showed a phenotypic ratio of 3 tall plants to 1 dwarf plant.

Dihybrid Cross

A dihybrid cross involves two pairs of contrasting traits. For example, crossing plants with round yellow seeds and wrinkled green seeds. The F2 generation showed a phenotypic ratio of 9:3:3:1 for the different trait combinations.

Mendel's Laws

Mendel proposed three laws: the Law of Dominance, the Law of Segregation, and the Law of Independent Assortment, explaining how traits are inherited and expressed.

Solved Examples

Example 1: In a monohybrid cross between two heterozygous tall pea plants (Tt), find the genotypic and phenotypic ratios of the offspring.

Solution:

Step 1: Parental genotypes: Tt x Tt

Step 2: Gametes produced: T and t from each parent

Step 3: Punnett square combinations: TT, Tt, Tt, tt

Step 4: Genotypic ratio: 1 TT : 2 Tt : 1 tt

Step 5: Phenotypic ratio: 3 tall (TT and Tt) : 1 dwarf (tt)

Example 2: In a dihybrid cross between two heterozygous plants (YyRr), what is the phenotypic ratio of the offspring?

Solution:

Step 1: Parental genotypes: YyRr x YyRr

Step 2: Gametes produced: YR, Yr, yR, yr from each parent

Step 3: Punnett square combinations result in 16 genotypes

Step 4: Phenotypic ratio: 9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green

Practice Set

Conceptual Questions

- **Level 1:** Define dominant and recessive alleles with examples.
- **Level 2:** Explain the Law of Segregation with a suitable example.

Application-based Question

- **Level 3:** A tall plant (Tt) is crossed with a dwarf plant (tt). What are the expected genotypes and phenotypes of the offspring? Show the Punnett square.

Answer Key

Conceptual Questions

- **Level 1:** Dominant alleles express their trait even if only one copy is present (e.g., T for tall). Recessive alleles express their trait only if both copies are present (e.g., t for dwarf).
- **Level 2:** Law of Segregation states that allele pairs separate during gamete formation, so each gamete carries only one allele. For example, Tt plants produce gametes with T or t alleles.

Application-based Question

- **Level 3:** Cross: Tt x tt
- Punnett square:
  - Parent 1 gametes: T, t
  - Parent 2 gametes: t, t
- Offspring genotypes: Tt, tt, Tt, tt
- Genotypic ratio: 1 Tt : 1 tt
- Phenotypic ratio: 1 tall : 1 dwarf

Chromosomes and Genes

Genes and Alleles

Genes are units of heredity located on chromosomes that determine specific traits. Alleles are different forms of a gene that can be dominant or recessive.

Chromosome Structure

Chromosomes are thread-like structures in the nucleus carrying genes. Humans have 23 pairs of chromosomes, including one pair of sex chromosomes.

Role in Traits

Each gene controls a trait by coding for proteins. Offspring inherit one allele from each parent, forming a pair that determines the trait's expression.

Solved Examples

Example 1: Explain how alleles determine the eye color trait if brown (B) is dominant over blue (b).

Solution:

Step 1: Possible genotypes: BB, Bb, bb

Step 2: BB and Bb result in brown eyes (dominant trait)

Step 3: bb results in blue eyes (recessive trait)

Example 2: How many chromosomes are present in a human diploid cell and how are they inherited?

Solution:

Step 1: Human diploid cells have 46 chromosomes (23 pairs)

Step 2: One chromosome of each pair is inherited from the mother, the other from the father

Practice Set

Conceptual Questions

- **Level 1:** What is the difference between a gene and an allele?
- **Level 2:** Describe the structure and function of chromosomes.

Application-based Question

- **Level 3:** If a child inherits one allele for brown eyes and one for blue eyes, what will be the eye color? Explain.

Answer Key

Conceptual Questions

- **Level 1:** A gene is a segment of DNA that codes for a trait; an allele is a variant form of a gene.
- **Level 2:** Chromosomes are structures made of DNA and proteins, carrying genes. They ensure genetic information is passed during cell division.

Application-based Question

- **Level 3:** The child will have brown eyes because the brown allele is dominant over the blue allele.

Dominance and Recessiveness

Dominant Alleles

Dominant alleles express their trait even if only one copy is present in the genotype.

Recessive Alleles

Recessive alleles express their trait only when both alleles are recessive.

Phenotype and Genotype

Phenotype is the observable trait, while genotype is the genetic makeup determining the trait.

Solved Examples

Example 1: In a cross between two heterozygous individuals (Aa), what are the expected genotypes and phenotypes?

Solution:

Step 1: Parental genotypes: Aa x Aa

Step 2: Gametes: A and a from each parent

Step 3: Punnett square: AA, Aa, Aa, aa

Step 4: Genotypic ratio: 1 AA : 2 Aa : 1 aa

Step 5: Phenotypic ratio: 3 dominant trait : 1 recessive trait

Practice Set

Conceptual Questions

- **Level 1:** Define phenotype and genotype with examples.
- **Level 2:** Explain why recessive traits may skip generations.

Application-based Question

- **Level 3:** A homozygous dominant individual is crossed with a homozygous recessive individual. What will be the genotype and phenotype of the offspring?

Answer Key

Conceptual Questions

- **Level 1:** Phenotype is the physical appearance (e.g., tall), genotype is the genetic makeup (e.g., TT or Tt).
- **Level 2:** Recessive traits may skip generations if masked by dominant alleles in heterozygous individuals.

Application-based Question

- **Level 3:** Cross: TT x tt
- All offspring will be heterozygous (Tt) and show the dominant phenotype (tall).

Sex Determination

Sex Chromosomes

Humans have 23 pairs of chromosomes; 22 pairs are autosomes and 1 pair are sex chromosomes (XX for females, XY for males).

Mechanism of Sex Determination

The sex of a child is determined by the sperm carrying either an X or Y chromosome fertilizing the egg, which always carries an X chromosome.

Environmental and Genetic Factors

In some species, environmental factors influence sex determination, but in humans, it is genetically determined by sex chromosomes.

Solved Examples

Example 1: Explain how the sex of a child is determined using a Punnett square.

Solution:

Step 1: Father's genotype: XY; produces sperm with X or Y

Step 2: Mother's genotype: XX; produces eggs with X

Step 3: Punnett square combinations: XX (female), XY (male)

Step 4: Probability: 50% female, 50% male

Practice Set

Conceptual Questions

- **Level 1:** What are sex chromosomes and how do they differ from autosomes?
- **Level 2:** Describe the role of X and Y chromosomes in human sex determination.

Application-based Question

- **Level 3:** If a father produces 1000 sperm cells, how many would carry the X chromosome and how many the Y chromosome? Explain the significance.

Answer Key

Conceptual Questions

- **Level 1:** Sex chromosomes determine the sex of an individual and differ in shape and size; autosomes do not determine sex and are identical pairs.
- **Level 2:** Females have two X chromosomes (XX), males have one X and one Y (XY). The sperm's chromosome determines the child's sex.

Application-based Question

- **Level 3:** Approximately 500 sperm carry X and 500 carry Y chromosomes, giving equal chances for male or female offspring.

Quick Reference Table

Common Mistakes and Misconceptions

Glossary