GENETICS

1. Introduction to Genetics. Mendelian analysis

CHAPTER OUTLINE

- A Brief History of Genetics: Defining Experiments in Genetics
- The theory of spontaneous generation
- The theory of preformationism
- The theory of epigenesis
- Inheritance of acquired traits
- The particle theory of inheritance
- Mendel's experiments
- Monohybrids, dihybrids and multihybrids crosses
- Variations on dominance
- Mendelian genetics in agriculture and humans
- Pedigree analysis
- Mendelian analysis and definition of probability. Product and sum rules
- The χ^2 test

LEARNING OUTCOMES

After completing this chapter, the student will be able to:

- Interpret the outcomes of crosses between monohybrids, dihybrids and multihybrids and define in detail the genotypes and phenotypes of all individuals.
- Calculate χ^2 to decide whether observations of progenies ratios in particular crosses deviate from expectations purely on the basis of chance.
- Estimate the number of genes that control a Mendelian trait based on progenies ratio from appropriate crosses.
- Estimate the frequency of gametes produced from an individual for independent genes.
- Deduce the inheritance of a trait based on pedigree analysis.

2. Extensions of Mendelian analysis

CHAPTER OUTLINE

- Multiple alleles
- ABO blood group in humans
- Incompatibility alleles in plants
- Operational test of allelism
- Lethal alleles
- Gene interaction
- Epistasis
- Complementation test
- Three or more gene interaction
- Pleiotropism - Penetrance – Expressivity
- Modifier genes
- Genetic suppression
- Position effect
- Genetic anticipation

- Epigenetic inheritance
- Paramutation
- Parental imprinting

LEARNING OUTCOMES

After completing this chapter, the student will be able to:

- Predict the outcome of crosses and progenies proportions for incompatibility genes in different plants species
- Predict the outcome of crosses and progenies proportions for genes with lethal alleles
- Explain the results of dihybrids crosses under interaction or epistasis assumption
- Explain the results of dihybrid crosses and define in full detail the genotype and phenotype of all individuals intergenerational and intragenerational
- Test experimental results in dihybrids crosses under different regimes of dominance and epistasis and use the χ^2 test to reject or not a precise null hypothesis
- Describe in detail the specific case of epistasis that exists between two genes, based on outcomes of crosses between individuals for these genes

3. Genotype and Environment

CHAPTER OUTLINE

- The norm of reaction
- Genotype-environment interactions
- Developmental noise
- Twin studies

LEARNING OUTCOMES

After completing this chapter, the student will be able to:

- Understand the influence of the environment on the manifestation of the phenotype. Comprehend the concept that for a specific genotype, the phenotype can be modified by environmental factors such as temperature and nutrients.
- Apply knowledge about the norm of reaction of a genotype, in the prediction of the phenotype.
- Understand the applied use of knowledge on genotype-environment interactions, for the development of varieties that thrive in specific conditions or in a wide range of environmental conditions.
- Understand the usefulness of twin studies in elucidating the hereditary component of human characteristics or diseases.
- Understand the concept of developmental noise.

4. Linkage and chromosome mapping

CHAPTER OUTLINE

- Chromosome recombination from independent assortment
- Intrachromosomal recombination
- Genetic and cytological events correlation of intrachromosomal recombination
- Tetrads analysis and stage of meiosis during which crossing - over occurs
- Linkage of two genes
- Genes in coupling or repulsion phase

- Meiotic crossover and recombination is absent in *Drosophila* males
- Linkage of genes on the X chromosome
- Estimation of recombination frequency from dihybrid crosses
- Genetic distance between two genes
- Maximum recombinant frequency between linked genes
- Linkage map of three or more genes
- Three – point testcross
- Coefficient of coincidence
- Coefficient of interference
- Estimation of progenies proportion from linkage map
- Mapping function
- Sister chromatid exchanges
- Intralocus recombination

LEARNING OUTCOMES

After completing this chapter the student will be able to:

- Provide the expected genotypic and phenotypic ratios in progenies from crosses between heterozygotes for linked genes.
- Calculate the estimated distance between linked genes based on outcomes for crosses involving these genes.
- Explain the outcomes of crosses between dihybrids for linked genes and define in detail the genotypic and phenotypic ratios of progenies in all generations.
- Perform a three – point testcross and draw a linkage map of the linked – genes, showing the order and the distance in map units.
- Calculate the estimated coefficients of coincidence and interference in a specific region of a chromosome.
- Calculate the estimated genotypic and phenotypic ratios in progenies of crosses for linked genes given the distance between genes and the interference coefficient.

5. Cell cycle. Mitosis. Meiosis. Spermatogenesis. Oogenesis

CHAPTER OUTLINE

- Cellular structure and genetic function
- Diploid organisms and homologous chromosomes
- Mitosis
- Meiosis
- Gamete formation, spermatogenesis and oogenesis
- Sexual reproduction in diploid organisms
- Chromosome structure in mitosis and meiosis

LEARNING OUTCOMES

After completing this chapter the student will be able to:

- Understand the phases of the cell cycle
- Understand the genetic continuity of sexually reproducing organisms during mitosis and meiosis.
- Understand the importance of homologous chromosomes in diploid organisms.
- Understand that in cell proliferation, mitosis is the mechanism by which the duplicated chromosomes are distributed to daughter cells.

- Understand that during meiosis, each chromosome of the homologous pair is distributed between the daughter cells, the diploid number of chromosomes reduces in half and the resulting cells have a haploid number of chromosomes.
- Understand that meiosis creates genetic diversity through the distribution, in gametes or spores, of different combinations of maternal and paternal chromosomes from the homologous pairs.
- Understand that during mitosis and meiosis, the genetic material of chromosomes condenses into distinct structures.
- Acquire knowledge on the formation of gametes during oogenesis and spermatogenesis.

6. Sex determination – Sex chromosomes – Sex-linked inheritance

CHAPTER OUTLINE

- Sex chromosomes
- Sex determination (*C elegans, Drosophila*, Mammals)
- Mechanism of gene dose compensation
- Syndrome Turner and Klinefelter
- Y chromosome, SRY gene in the development of testis, Sex reversal, holandric genes
- X chromosome, X inactivation, Epigenetic mechanisms
- Sex-linked inheritance, recessive and dominant X-linked
- Sex-influenced inheritance
- Sex-limited inheritance

LEARNING OUTCOMES

After completing this chapter the student will be able to:

- Understand the mechanisms of sex determination in animals with emphasis in *C elegans*, *Drosophila*, and mammals.
- Understand the structure of sex chromosomes in humans, and syndromes that are related with changes in their number.
- Learn about the structure of Y chromosome and the importance of the SRY gene in the development of testis in mammals, while also interprets what causes sex reversal.
- Learn about the structure of X chromosome and the importance of X-inactivation for the dose compensation through epigenetic mechanisms.
- Understand the sex-linked inheritance and distinguishes it from sex-influenced and sex-limited inheritance.

7. Gene and Chromosomal Mutations

CHAPTER OUTLINE

- Types of gene mutations, effect in protein structure and function, examples of related diseases.
- Mechanisms causing mutations
- Types of chromosomal mutations, deletions, duplications, inversions, translocations.
- Aneuploidy, Trisomy 21, 13, 18.

LEARNING OUTCOMES

After completing this chapter the student will be able to:

- Learn about the types of gene mutations, and interpret their effects in protein structure and function as well as in diseases.
- Understand the mechanisms, endogenous and exogenous, that cause mutations.
- Know the types of chromosome mutations, such as deletions, duplications, inversions, translocations, and understand how they develop and what is their effect in individuals and their gametes.
- Understand the mechanisms that cause changes in chromosome number such as aneuploidy with emphasis in trisomy 21, 13 and 18.

8. Changes in chromosome number

CHAPTER OUTLINE

- Aneuploidy
- Aneuploidy in humans
- Nullisomics , monosomics and trisomics
- The trisomic condition in humans
- Euploidy
- Monoploids and triploids
- Autotetraploids
- Autotetraploids genetics
- Double reduction process in autotetraploids meiotic pairing
- Allopolyploids

LEARNING OUTCOMES

After completing this chapter the student will be able to:

- Use plant monosomic lines for a gene and through appropriate crosses identify the chromosome that carries the gene.
- Calculate the estimated gametes ratio in autotetraploids for a specific gene based on the quadrivalents frequency and the distance between gene and centromere.

9. Extranuclear inheritance

CHAPTER OUTLINE

- Molecular genetics of mitochondria and chloroplasts.
- Mitochondrial DNA and related diseases.
- Chloroplast DNA.
- Origin of mitochondria and chloroplasts.

LEARNING OUTCOMES

After completing this chapter the student will be able to:

• Understand the concept of extra-nuclear inheritance, which refers to the cases in which the phenotype is determined by genes not found in the parent nuclear chromosomes.

• Understand the theory of endosymbiosis, which argues that chloroplasts and mitochondria originated from bacteria that were engulfed by primitive eukaryotic cells about 2 billion years ago.

• Understand the molecular genetics of mitochondria and chloroplasts, and applications thereof. Chloroplastic DNA mutations affect the photosynthetic capacity of plants, while mitochondrial DNA mutations mainly affect cells that have high energy needs. Mitochondrial

DNA mutations are the genetic basis for a wide variety of human diseases, and are linked to aging.

• Understand the meaning of hetero-cytoplasmic segregation, and as a consequence, the phenotypic diversity of diseases associated with mutations in mitochondrial DNA.

• Understand the concept of maternal effect, where the phenotype of the offpring is determined by the mother's nuclear genotype, through molecular events that occur during ovulation and the early stages of embryogenesis.

10. LABORATORY EXERCISES

Laboratory exercises aim to deepen the understanding of the concepts and applications of Mendelian genetics for the study of one or multiple genes, epistasis, genetic linkage and genetic maps, estimation of recombination frequency from genetic crosses, X-linked genes, gender-affected and gender-restricted heredity.

The exercises include approximately 60 genetic problem covering all fields of genetics with a focus on the following applications:

• Predicting the heredity of a trait by studying the results of experimental crosses. Support predictions with the chi-square (x^2) statistical test.

• Predicting the offspring of a cross, for a trait with a given type of heredity. Applications in probability calculations.

• Experimental design to confirm the results and predictions mentioned above.