Mississippi Science

Genetics

Structure and Function of DNA GEN.1

Conceptual Understanding: Chromosomes, the carriers of genetic information, are composed of both DNA and proteins. A significant body of evidence generated through multiple experiments by many scientists led to the conclusion that DNA is the universal genetic material. Once this was established, efforts focused on deciphering the structure of DNA and the mechanism through which DNA is passed on to cells with minimal errors. These discoveries formed the foundation of modern molecular genetics.

A Students will demonstrate that all cells contain genetic material in the form of DNA. GEN.1A

1 Model the biochemical structure, either 3-D or computer-based, of DNA based on the experimental evidence available to Watson and Crick (Chargaff, 1950; Franklin, 1951). GEN.1A.1

2 Explain the importance of the historical experiments that determined that DNA is the heritable material of the cell (Griffith, 1928; Avery, McCarty & MacLeod, 1944; Hershey & Chase, 1952). GEN.1A.2

3 Relate the structure of DNA to its specific functions within the cell. GEN.1A.3

4 Conduct a standard DNA extraction protocol using salt, detergent, and ethanol from various cell types (e.g., plant, animal, fungus). Compare and contrast the consistency and quantity of DNA extracted from various cell types. GEN.1A.4

5 Enrichment: Use an engineering design process to refine the methodology to optimize the DNA-extraction process for various cell types. * GEN.1A.5

6 Investigate the structural differences between the genomes (i.e., circular/linear chromosomes and plasmids) found in prokaryotes and eukaryotes. GEN.1A.6

Conceptual Understanding: Before a cell divides, the DNA sequence of its chromosomes is replicated, and each daughter cell receives a copy. In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow.

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B Students will analyze how the DNA sequence is copied and transmitted to new cells. GEN.1B

1 Compare and contrast various proposed models of DNA replication (i.e., conservative, semi-conservative, and disruptive). Evaluate the evidence used to determine the mechanism of DNA replication. GEN.1B.1

2 Develop and use models to illustrate the mechanics of DNA replication. GEN.1B.2

3 Microscopically observe and analyze the stages of the cell cycle (G1-S-G2-M) to describe the phenomenon and identify methods at different cell cycle checkpoints through which the integrity of the DNA code is maintained. GEN.1B.3

Transcription, Translation, and Mutations GEN.2

Conceptual Understanding: The genetic information stored in the DNA molecule is expressed to produce a protein and result in the formation of an observable trait, or phenotype, in the organism. Gene expression leads to protein production through the processes of transcription in the nucleus and translation in the ribosome.

A Students will analyze and explain the processes of transcription and translation in protein production. GEN.2A

1 Compare and contrast the structures of RNA and DNA and relate this structure to the different functions of each molecule. GEN.2A.1

2 Describe and model how the process of transcription produces RNA from a DNA template in both prokaryotes and eukaryotes. GEN.2A.2

3 Develop a model to show the relationship between the components involved in the mechanics of translation at the ribosome. GEN.2A.3

4 Analyze the multiple roles of RNA in translation. Compare the structure and function of tRNA, rRNA, mRNA, and snRNA. GEN.2A.4

5 Enrichment: Evaluate Beadle and Tatum's "One Gene-One Enzyme Hypothesis" (1941) in the development of the central dogma (DNA → RNA → Protein). Explain how new discoveries, such as alternate splicing of introns, have led to the revision of the central dogma. GEN.2A.5

Conceptual Understanding: Mutations may result in the formation of new gene alleles, alter protein structure, and produce new phenotypes.

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B Students will determine the causes and effects of mutations in DNA. GEN.2B

1 Identify factors that cause mutations (e.g., environmental, errors in replication, and viral infections). GEN.2B.1

2 Explain how these mutations may result in changes in protein structure and function. GEN.2B.2

3 Describe cellular mechanisms that can help to minimize mutations (e.g., cell cycle checkpoints, DNA polymerase proofreading, and DNA repair enzymes). GEN.2B.3

4 Investigate the role of mutations and the loss of cell cycle regulation in the development of cancers. GEN.2B.4

5 Enrichment: Use an engineering design process to research the current status of genetic technology and personalized medicine, then propose and test targeted medical or forensic applications. * GEN.2B.5

Biotechnological Applications GEN.3

Conceptual Understanding: The application of modern molecular genetics led to the development of recombinant DNA technology and the subsequent explosion of biotechnology applications. Biotechnology and the use of genetically modified organisms have altered many aspects of daily life, including forensics, agriculture, and medicine.

A Students will investigate biotechnology applications and bioengineering practices. GEN.3A

1 Explain and demonstrate the use of various tools and techniques of DNA manipulation and their applications in forensics (e.g., paternity and victim/suspect identification), agriculture (e.g., pesticide or herbicide resistance, improved yields, and improved nutritional value), and personalized medicine (e.g., targeted therapies, cancer treatment, production of insulin and human growth hormone, and engineering insect vectors of human parasites). GEN.3A.1

2 Experimentally demonstrate genetic transformation, protein purification, and/or gel electrophoresis. GEN.3A.2

3 Enrichment: Use an engineering design process to refine methodology and optimize the process of genetic transformation, protein purification, and/or gel electrophoresis. * GEN.3A.3

4 Enrichment: Develop logical arguments based on scientific evidence for and against ethical concerns regarding biotechnology/bioengineering. GEN.3A.4

Classic Mendelian Genetics GEN.4

Conceptual Understanding: Gregor Mendel is known as the "Father of Genetics" due to his work with pea plants, which established that traits are passed from parents to offspring in predictable ways. Mendel's findings formed the foundation from which geneticists can determine the mode of inheritance of various traits (e.g., dominant, recessive, and codominant).

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A Students will analyze and interpret data collected from probability calculations to explain the inheritance of traits within a population. GEN.4A

1 Demonstrate Mendel's law of dominance and segregation using mathematics to predict phenotypic and genotypic ratios. GEN.4A.1

2 Illustrate Mendel's law of independent assortment by analyzing multi-trait cross data sets for patterns and trends. GEN.4A.2

3 Investigate traits that follow non-Mendelian inheritance patterns (e.g., incomplete dominance, codominance, multiple alleles, autosomal linkage, sexlinkage, polygenic, and epistasis). GEN.4A.3

4 Construct pedigrees from observed phenotypes. Analyze and interpret data to determine patterns of inheritance and disease risk. GEN.4A.4

5 Enrichment: Construct maps of genes on a chromosome based on data obtained from 2- and/or 3-point crosses or from recombination frequencies. GEN.4A.5

Population Genetics GEN.5

Conceptual Understanding: Most species display considerable amounts of genetic variation. The variation is represented as differences in allele frequencies within the gene pool of populations of a species. Variations in the structure of gene pools form the basis of evolutionary change.

A Students will apply population genetic concepts to explain the variability of organisms within a population. GEN.5A

1 Model the inheritance of chromosomes through meiotic cell division and demonstrate how meiosis and sexual reproduction lead to genetic variation in populations. GEN.5A.1

2 Explain how natural selection acts upon genetic variability within a population and may lead to changes in allelic frequencies over time and evolutionary changes in populations. GEN.5A.2

3 Describe processes that cause changes in allelic frequencies (e.g., nonrandom mating, small population size, immigration and emigration, genetic drift, and mutation). GEN.5A.3

4 Apply the Hardy-Weinberg formula to analyze changes in allelic frequencies due to natural selection in a population. Relate these changes to the environmental fitness of the phenotypes. GEN.5A.4

5 Enrichment: Analyze computer simulations of the effects of natural selection on allelic frequencies in a population. GEN.5A.5

6 Enrichment: Apply the concept of natural selection to analyze differences in human populations (e.g., skin color, lactose persistence, sickle cell anemia, and malaria). GEN.5A.6

7 Enrichment: Use genomic databases for sequence analysis and apply the information to species comparisons, evolutionary relationships, and/or determine the molecular basis of inherited disorders. GEN.5A.7