Madison: Mutations - Notes
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INSTRUCTOR:

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Vocabulary / Key Terms/ Concepts	Mutations
Carcinogen *Chromosomal Mutation* *Deletion* *DNA Repair* *Mechanism* *Frameshift Mutation* *Genetic Disorder* *Genetic Material*	**Student Expectations:** • *Analyze the causes and factors influencing mutations, including exposure to mutagenic agents, errors in DNA replication, and environmental influences.* • *Evaluate the potential consequences of mutations on organisms, including their effects on protein structure and function, inheritance patterns, and the development of genetic disorders.* • *Assess the role of mutations in driving evolutionary processes, such as natural selection, genetic variation, and adaptation.* • *Investigate and synthesize real-life examples of mutations in different organisms, analyzing their impact on individuals and populations in diverse ecological contexts.* • *Construct hypotheses and design experiments to study the mechanisms and effects of mutations, including the use of genetic models and advanced molecular techniques.* • *Evaluate the ethical considerations associated with mutations, such as the implications of genetic engineering, gene editing technologies, and genetic testing, considering both potential benefits and risks.* • *Analyze and interpret complex genetic data sets to identify and characterize mutations, utilizing bioinformatics tools and databases.*

Genetic Variation

Germline Mutation

Inherited Trait

Insertion

Missense Mutation

Mutation

Mutagen

Nonsense Mutation

Point Mutation

Silent Mutation

Somatic Mutation

Genetic models

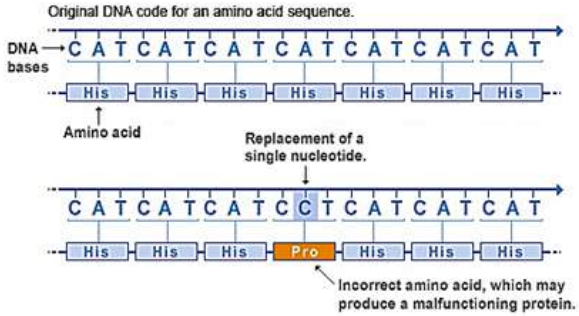
Evolutionary Advantage

Introduction to _____

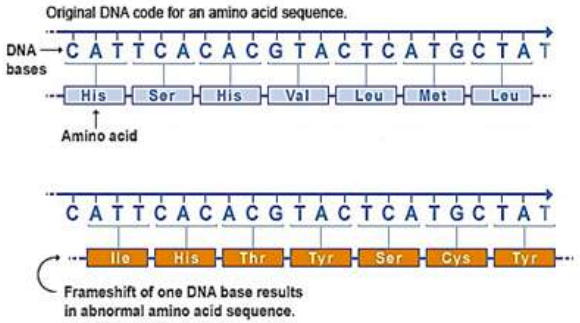
- **Definition of _____**
  - Mutations are _____ in the _____ **sequence** that can _____ the _____ information of an _____ .
- **Importance of studying mutations in biology**
  - - **Mutations** are the source of _____ and play a crucial role in _____ and _____ .

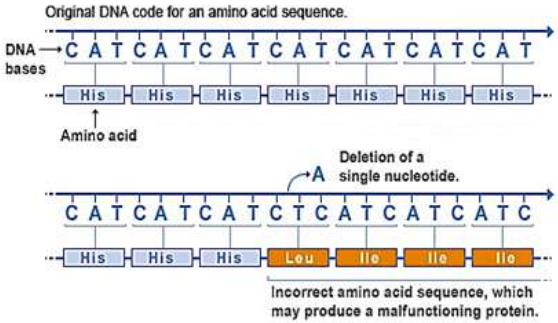
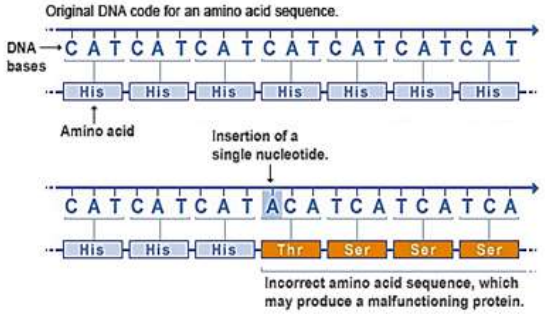
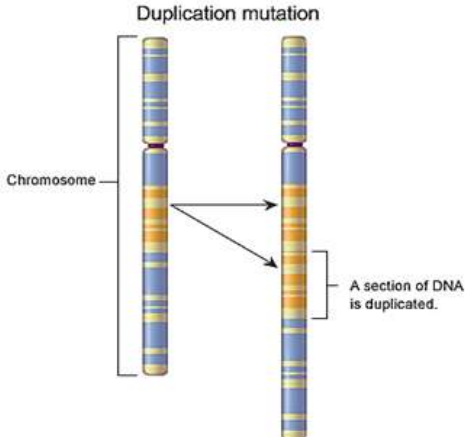
Types and Causes of Mutations

- **_____ mutations**
  - Definition and examples
    - **_____ mutations** involve the **substitution** of a **single** nucleotide **base** in the DNA sequence.
    - **Example**: A **substitution** of adenine (A) with guanine (G) in the DNA sequence.



- **_____ mutations**
  - **Definition and examples**
    - **_____ mutations** occur when **nucleotides** are **inserted** or **deleted**, **shifting** the reading **frame**.



Evolutionary *Constraint*	▪ **Example**: Insertion of an extra nucleotide in the DNA sequence.   • **Chromosomal mutations** ◦ **Definition and examples** ▪ **Chromosomal mutations involve changes in the structure or number of chromosomes.** ▪ **Example:** • **Deletion:** A deletion mutation involves the loss of a segment of a chromosome. This can range from a small deletion involving just a few base pairs to a large deletion involving multiple genes. Deletions can lead to genetic disorders by causing the loss of critical genetic material. **Example:** Cri-du-chat syndrome is caused by a deletion on the short arm of chromosome 5. It results in developmental delays, characteristic facial features, and a cat-like cry in affected individuals. 

	• **Duplication:** Duplication occurs when a segment of a chromosome is duplicated, resulting in additional copies of the same genetic material. Duplications can lead to genetic variation and may provide an evolutionary advantage by providing redundancy or serving as a substrate for further genetic changes. **Example:** Charcot-Marie-Tooth disease, a hereditary neurological disorder, can be caused by duplications in specific genes on chromosome 17, leading to an increased dosage of these genes. • **Inversion:** An inversion mutation involves the reversal of a segment of a chromosome. This occurs when a chromosome breaks in two places, and the segment in between is reinserted in the reverse orientation. Inversions can affect gene expression and disrupt normal chromosomal interactions. **Example:** Inversion 9, also known as the Pericentric Inversion of Chromosome 9, is a common chromosomal abnormality in humans. It involves an inversion in the middle of chromosome 9 and can be associated with reproductive issues and potential health risks. • **Translocation:** Translocation occurs when a segment of one chromosome breaks off and becomes attached to another chromosome. This can result in the relocation of genetic material between chromosomes. Translocations can have various effects, depending on the specific genes involved. **Example:** The Philadelphia chromosome is a translocation between chromosomes 9 and 22. It is associated with chronic myelogenous leukemia (CML) and results in the fusion of the BCR (breakpoint cluster region) and ABL1 (Abelson tyrosine-protein kinase 1) genes, leading to the production of an abnormal protein with oncogenic properties.

- **Insertion:** An insertion mutation involves the addition of extra genetic material into a chromosome. This can result in a disruption of the normal gene sequence and potentially affect gene expression or protein structure and function.
  Example: Duchenne muscular dystrophy (DMD) is caused by an insertion mutation in the dystrophin gene on the X chromosome. This mutation disrupts the reading frame of the gene, leading to the absence or abnormality of the dystrophin protein and resulting in muscle weakness and degeneration.

Factors influencing mutations

- **Exposure to _____ agents**
  - **Mutagenic agents** such as _____ and certain _____ can **increase** the mutation **rate**.
  - **Example**: UV radiation from the _____ causing DNA damage.
- **_____ in DNA _____**
  - _____ during DNA **replication** can **lead** to nucleotide _____ , _____ , or _____ .
  - **Example**: Incorrect pairing of nucleotides during replication.
- **_____ influences**
  - **Environmental factors** like _____ or _____ exposure can affect mutation rates.
  - **Example**: High temperatures increasing the likelihood of DNA damage.

	Consequences of Mutations
	• **Effects on protein structure and function**
	  ○ Impact of mutations on amino acid sequence and protein folding
	  ■ **_____ mutations** result in the **_____** of **one** amino acid for **another**, **altering** the **protein's** structure.
	  ■ **Example**: Substitution of valine for glutamic acid in the hemoglobin protein, leading to **_____** .
	• **Consequences of mutations on protein function**
	  ○ **_____** can **_____** protein **_____** or create new functions.
	  ○ **Example**: Loss-of-function mutations in genes causing genetic disorders.
	• **_____ patterns and genetic disorders**
	  ○ **Definition of genetic disorders**
	  ■ Genetic disorders are conditions caused by mutations in specific genes or chromosomes.
	  ○ **Example** results of specific mutations:
	  ■ **_____** : **Deletion** of **three nucleotides** in the **CFTR gene**, leading to faulty **chloride** ion **transport**.
	  ■ **_____** : **Expansion** of **CAG repeats** in the huntington gene, causing **neurodegeneration**.
	• **_____ on individuals and populations**
	  ○ **Effects of mutations on individual organisms**
	  ■ **Mutations can** confer **_____** , **_____** , or have **_____** effects on an individual's **survival** and **reproduction (***think natural selection***)**.

	■ **Example**: Mutations providing antibiotic resistance to bacteria. • **Role of mutations in genetic diversity and evolution** ○ _____ generate genetic _____ necessary for _____ and _____ . ○ **Example**: Genetic variations in a population leading to adaptation to different environments. Gene duplication can lead to increased genetic variation in several ways: ■ **Functional Divergence:** After duplication, one copy of the gene can maintain its original function, while the duplicated copy is free to accumulate mutations and acquire new functions. Over time, these duplicated genes may undergo functional divergence, resulting in the emergence of new gene functions or the specialization of existing functions. ■ **Example**: *The duplication of the opsin gene in vertebrates led to the development of multiple photoreceptor types, enabling organisms to perceive a wider range of light wavelengths and increasing visual diversity.* ■ **Genetic Redundancy:** Duplicated genes may retain their original function, providing redundancy or backup copies. This redundancy allows mutations to accumulate in one of the duplicated genes without detrimental effects on the organism. These accumulated mutations can eventually result in the evolution of new gene functions or adaptations. ■ **Example**: *In plants, the duplication of floral regulatory genes has contributed to the evolution of diverse flower shapes, colors, and arrangements.* ■ **Subfunctionalization:** Duplicated genes can partition the functions of the original gene, leading to subfunctionalization. Each copy of the gene retains a subset of the original functions, allowing for specialization in different tissues, developmental stages, or environmental conditions.

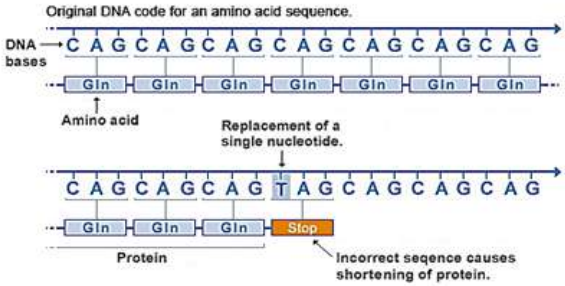
- **Example**: *The duplication of Hox genes in animals has enabled the evolution of more complex body plans and specialized morphological features in different body regions.*
- **Gene Family Expansion:** Gene duplication events can give rise to gene families, where multiple copies of related genes exist within the genome. These gene families can undergo further divergence, leading to the evolution of new gene functions and the expansion of biological processes.
- **Example**: *The expansion of the globin gene family in vertebrates resulted in the development of different types of hemoglobin genes, each specialized for carrying oxygen in different physiological conditions, such as high-altitude environments or fetal development.*

Gene Expression and Mutations

- **Overview of gene _____**
  - **Gene expression** is the process by which **genetic information** is used to **produce** functional _____ .
- **_____ process**
  - **Definition and steps of transcription**
    - **Transcription** is the synthesis of _____ from a _____ template.
    - Steps: _____ , _____ , _____ .
- **Role of RNA polymerase and transcription factors**
  - **RNA _____** binds to the promoter region and catalyzes the synthesis of mRNA.
  - **Transcription factors** regulate gene expression by binding to specific DNA sequences.

- **Example** result of a mutation:
  - _____ **mutation**: Alteration in the promoter region can affect the binding of transcription factors, leading to decreased gene expression.

- **Translation process**
  - **Definition and steps of translation**
    - _____ is the synthesis of a _____ from _____ .
    - **Steps**: Initiation, elongation, termination.
  - **Role of ribosomes, transfer RNA (tRNA), and codons**
    - **Ribosomes** facilitate the **assembly** of **amino acids** into a **polypeptide** chain based on the **mRNA sequence**.
    - **tRNA molecules carry** specific **amino acids** to the **ribosomes** based on the **codons** in the **mRNA**.
    - **Example result of a mutation:**
      - _____ **mutation:** Introduction of a **premature** _____ can result in a truncated protein.



- **Impact of mutations on gene expression**
  - **Alterations in _____ or _____ regions**
    - _____ **mutations** can affect the _____ of **transcription factors** and _____ gene **expression** levels.

- **Mutations** in _____ regions can _____ or _____ gene expression.
- **Example**: Mutations in the promoter region leading to increased or decreased gene expression.
    - One well-known example is the **mutation in the promoter region** of the **lactase gene** (LCT), which regulates the production of **lactase enzyme**. Lactase is responsible for **breaking down lactose**, the sugar **found in milk** and **dairy products**. In individuals with _____ , the activity of the lactase enzyme is reduced after infancy, leading to **difficulty digesting lactose**.
    - A specific mutation in the **promoter region** of the LCT gene, known as the **lactase persistence mutation**, results in increased gene expression and **continued production of lactase** into adulthood. This mutation involves a change in the regulatory elements that control the binding of transcription factors to the promoter region, leading to enhanced transcription and higher levels of lactase enzyme.
    - The **lactase persistence mutation** is prevalent in **populations** with a long **history of dairy farming**, such as certain European and African populations. This mutation allows individuals to digest lactose even in adulthood, providing an evolutionary advantage in regions where dairy consumption became an important part of the diet.
    - In contrast, individuals **without the lactase persistence mutation** experience decreased gene expression of lactase after infancy, resulting in lactose intolerance. This is due to the normal downregulation of lactase gene

	expression as part of the natural developmental process, as lactose consumption decreases after breastfeeding. ○ **Changes in coding sequences** ■ **_____ mutations** have**_____** on the amino acid **sequence** or protein **function**. ■ **_____ mutations** can **_____ to an _____ amino acid sequence** and potentially **_____** protein **function**. ■ **_____ mutations** introduce a **premature_____** , resulting in a truncated and often nonfunctional protein.
Notes Summary:	
