

# Genetic Mutations

What mistakes can occur when DNA is replicated?

## Why?

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The genes encoded in your DNA result in the production of proteins that perform specific functions within your cells. Various environmental factors and spontaneous events can lead to changes in genes. These changes, called **mutations**, can lead to alterations in the structure and activity of the proteins your cells use in their daily activities. In other words, changes to your genotype can result in changes to your phenotype. We all have mutations in most of our body cells—yet we are, for the most part, normal and functional human beings. How can that be?

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## Model 1 – Gene Mutations

### Sequence 1 (normal)

DNA sequence	... T A C G T A G T C A C C T A A T G G A T C...
mRNA sequence	A U G C A U C A G U G G A U U A C C U A G
Amino acid sequence	Met His Gln Trp Ile Thr stop

### Sequence 2 (substitution)

DNA sequence	... T A C G T A G T C A G C T A A T G G A T C...
mRNA sequence	A U G C A U C A G U C G A U U A C C U A G
Amino acid sequence	Met His Gln Ser Ile Thr stop

### Sequence 3 (insertion)

DNA sequence	... T A C G T A T G T C A C C T A A T G G A T C...
mRNA sequence	A U G C A U A C A G U G G A U U A C C U A G...
Amino acid sequence	Met His Thr Val Asp Tyr Leu...

### Sequence 4 (deletion)

DNA sequence	... T A C G T A G T C C C T A A T G G A T C...
mRNA sequence	A U G C A U C A G G G A U U A C C U A G...
Amino acid sequence	Met His Gln Gly Leu Pro...

1. How many nucleotides are present in the “normal” DNA sequence in Model 1?
2. How many codons are contained in the mRNA that is produced by the “normal” DNA in Model 1?
3. How many amino acids will be in the polypeptide produced by the normal DNA/mRNA sequence?

4. What is the amino acid sequence of the polypeptide produced by the “normal” DNA sequence in Model 1?
5. Consider DNA sequence 2 in Model 1. The mutation in that sequence is a **substitution** mutation.
  - a. Compare sequence 2 with sequence 1 and describe the mutation that has occurred.
  
  - b. What is the effect of this substitution mutation on the amino acid sequence?
6. Consider DNA sequence 3 in Model 1. The mutation in that sequence is an **insertion** mutation.
  - a. Compare sequence 3 with sequence 1 and describe the mutation that has occurred.
  
  - b. What is the effect of the insertion mutation on the amino acid sequence as compared to the “normal” amino acid sequence in Model 1?
7. Consider DNA sequence 4 in Model 1. The mutation in that sequence is a **deletion** mutation.
  - a. Compare sequence 4 with sequence 1 and describe the mutation that has occurred.
  
  - b. What is the effect of the deletion mutation on the amino acid sequence as it is compared to the “normal” amino acid sequence in Model 1?



8. In your group, use grammatically correct sentences to define each of the following mutations.

Substitution mutation—

Insertion mutation—

Deletion mutation—

9. Considering your knowledge of codons and how they code for an amino acid, would all substitution mutations lead to a change in the amino acid sequence? Explain your reasoning.
  
10. Would all insertion or deletion mutations lead to a change in the amino acid sequence? Explain your reasoning.
  
11. What could potentially cause more damage (or a greater benefit) to an organism, a substitution mutation or an insertion mutation? Explain your reasoning.
  
12. What could potentially cause more damage (or a greater benefit) to an organism, a deletion mutation at the beginning of a DNA sequence or at the end of a DNA sequence?
  
13. All of the DNA and mRNA sequences in Model 1 have ellipses (...) on one or both ends of the sequences shown. Propose an explanation for this use of this symbol in that context.
  
14. The amino acids produced from sequence 1 and sequence 2 in Model 1 do not have ellipses on the end of them, however the amino acids produced from sequence 3 and sequence 4 do have ellipses. Propose an explanation for the use or absence of the ellipses on these sequences.

## Model 2 – Comparing Substitution Mutations

Original DNA:           ... T A C C C T A G G A A T A T C A A A...  
mRNA:                    **A U G G G A U C C U U A U A G U U U...**  
Amino acid:             Met      Gly      Ser      Leu      stop

Mutation A:           ... T A C C C T A G G A A A A T C A A A...  
mRNA:                    **A U G G G A U C C U U U U A G U U U...**  
Amino acid:             Met      Gly      Ser      Phe      stop

Mutation B:           ... T A C C C T A G C A A T A T C A A A...  
mRNA:                    **A U G G G A U C G U U A U A G U U U...**  
Amino acid:             Met      Gly      Ser      Leu      stop

Mutation C:           ... T A C A C T A G G A A T A T C A A A...  
mRNA:                    **A U G U G A U C C U U A U A G U U U...**  
Amino acid:             Met      stop

Mutation D:            T A G C C T A G G A A T A T C A A A...  
mRNA:                    **A U C G G A U C C U U A U A G U U U...**  
Amino acid:             No protein will be translated because there is no start codon.

15. For each of the mutations A – D in Model 2, circle the substitution that occurred by comparing the mutated DNA with the original DNA.



16. As a group, describe the range of changes in the amino acid sequence that can result from this type of mutation.



17. Gene mutations can be positive, negative or neutral. Suppose that the normal gene in Model 2 produced a polypeptide that was necessary for cellular respiration.
- Choose a mutation from those in Model 2 that would be neutral for a cell. Explain your reasoning by relating the mutation to the cellular respiration process.
  - Choose a mutation from those in Model 2 that might be positive for a cell. Explain your reasoning by relating the mutation to the cellular respiration process.
  - Choose a mutation from those in Model 2 that might be negative for a cell. Explain your reasoning by relating the mutation to the cellular respiration process.

## Read This!

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Mutations are the source of all new alleles in nature. Variations in alleles lead to variations in organisms within a population. Positive mutations lead to the organism having a better chance of survival, which means the mutation may be passed on to the offspring. Negative mutations may lead to an early death—probably before the organism can produce offspring. Therefore, changes in alleles from one generation to another form the basis of evolution.

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18. Which types of mutations, positive, negative or neutral, are most likely to be seen in offspring several generations after the mutation occurred? Explain your reasoning.



19. Consider the following scenarios. State whether the mutation is likely to be passed on to the offspring of the organism. Explain your reasoning.
- A single bacteria cell contains a positive mutation in its DNA.
  - A skin cell on a cat contains a positive mutation in its DNA.
  - A sperm cell in a whale contains a positive mutation in its DNA.

20. All cells have DNA errors due to the mistakes that occur each time DNA is replicated prior to cell division. There are proofreading enzymes in cells that correct many of these mistakes, but on average, 3 – 5 errors are found in DNA after each replication.

*a.* If each cell has multiple mutations, why do most of us have normally-functioning tissues and organs?

*b.* Why is only a tiny subset of these mutations passed on to our children?



## Extension Questions

21. A gene mutation is a change in the sequence of nucleotides that occurs during cell replication (mitosis and meiosis) within a single coding section of DNA. Mistakes can also occur in the transcription of mRNA or the translation of a polypeptide. However, these changes are not considered to be mutations, because they are not permanent changes to the cell. Explain why “mistakes” in transcription or translation are not as serious as mutations in a gene.
  
22. Insertion and deletion mutations are said to cause shifts in the “reading frame” (the sets of three nucleotides) of the mRNA. Substitution mutations do not cause these so-called **frameshifts**. Explain why insertions and deletions are called frameshift mutations, using the terms *reading frame*, *codons*, and *amino acids* in your answer.