Biology

How Proteins Are Made
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<th>Assignment</th>
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<th>Possible Points</th>
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<td>How do mutations occur?</td>
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Chapter 10 DNA: How Proteins are Made
Vocabulary
Use the glossary and don’t shorten the definition. If a page number is listed, use that page to define the term.

Section 1: From Genes to Proteins
1. ribonucleic acid (RNA) –

2. uracil –

3. transcription –

4. translation –

5. gene expression –

6. RNA polymerase –

7. messenger RNA or mRNA –

8. codon –

9. genetic code –

10. transfer RNA –

11. anticodon –
12. ribosomal RNA or rRNA

Section 2: Gene Regulation and Structure

13. operator

14. operon

15. lac operon

16. repressor

17. intron

18. exon

19. point mutation
PowerPoint Notes on Chapter 10 – How Proteins Are Made

Section 1: From Genes to Proteins

Objectives

- Compare the structure of RNA with that of DNA.
- Summarize the process of transcription.
- Relate the role of codons to the sequence of amino acids that results after translation.
- Outline the major steps of translation.
- Discuss the evolutionary significance of the genetic code.

Decoding the Information in DNA

- Traits, such as eye color, are determined by proteins that are built according to instructions coded in _________.
- ---------------------, however, are not built directly from DNA. ________________ is also involved.
- Like DNA, ribonucleic acid (RNA) is a nucleic acid—a molecule made of __________________________ linked together.
- RNA differs from DNA in three ways:

<table>
<thead>
<tr>
<th></th>
<th>RNA</th>
<th>DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td># of strands of nucleotides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>five-carbon sugar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nitrogen bases present</td>
<td></td>
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</tr>
</tbody>
</table>

- The instructions for making a protein are transferred from a gene to an RNA molecule in a process called __________________________.
- Cells then use ________ different types of RNA to read the instructions on the RNA molecule and put together the amino acids that make up the protein in a process called __________________________.
- The entire process by which ____________________ are made based on the information encoded in DNA is called __________________________, or protein synthesis.
Transfer of Information from DNA to RNA

- The three steps of transcription are:
  - **Step 1** RNA polymerase binds to the gene’s _________________.
  - **Step 2** The two DNA strands ________________ and separate.
  - **Step 3** ______________________________________ nucleotides are added.

Types of RNA

The Genetic Code: Three-Nucleotide “Words”

- Different types of ___________ are made during transcription, depending on the gene being expressed.
- When a cell needs a particular protein, it is _________________ RNA that is made.
- **Messenger RNA (mRNA)** is a form of RNA that carries the _________________ for making a protein from a gene and delivers it to the site of _________________.
- The information is translated from the language of RNA—______________________—to the language of proteins—_______________________________.
- The RNA instructions are written as a series of ________________________________ sequences on the mRNA called _____________________.
- The _________________ of mRNA is the amino acids and “start” and “stop” signals that are coded for by each of the possible _____________ mRNA codons.

**Codes in mRNA**
RNA’s Roles in Translation

- Translation takes place in the _________________. Here transfer RNA molecules and ribosomes help in the ________________ of proteins.

- **Transfer RNA (tRNA)** molecules are single strands of RNA that temporarily carry a specific ________________ on one end.

- An ________________ is a three-nucleotide sequence on a tRNA that is complementary to an mRNA codon.

**tRNA and Anticodon**

- The seven steps of translation are:
  
  **Step 1** The ribosomal subunits, the ___RNA, and the ___RNA carrying ________________ bind together.
  
  **Step 2** The ___RNA carrying the ________________ specified by the codon in the A site arrives.
  
  **Step 3** A ________________ bond forms between adjacent amino acids.
  
  **Step 4** The ___RNA in the P site detaches and _____________ its amino acid behind.
  
  **Step 5** The ___RNA in the A site moves to the P site. The tRNA carrying the amino acid specified by the _____________ in the A site arrives.
  
  **Step 6** A ________________ bond is formed. The tRNA in the P site detaches and leaves its amino acid behind.
  
  **Step 7** The process is repeated until a _____________ codon is reached. The ____________ complex falls apart. The newly made protein is released.

**Snapshot of Translation**
Section 2 Gene Regulation and Structure

Objectives
- **Describe** how the lac operon is turned on or off.
- **Summarize** the role of transcription factors in regulating eukaryotic gene expression.
- **Describe** how eukaryotic genes are organized.
- **Evaluate** three ways that point mutations can alter genetic material.

Protein Synthesis in Prokaryotes
- Both prokaryotic and eukaryotic cells are able to regulate which genes are expressed and which are not, depending on the cell’s ___________________.
- The piece of DNA that overlaps the promoter site and serves as the on-off switch is called an _____________________.
- In bacteria, a group of genes that code for enzymes involved in the same function, their promoter site, and the operator that controls them all function together as an _____________________.

**Operon (Video Clip)**
- The operon that controls the metabolism of lactose s called the _____________________________.
- When there is no lactose in the bacterial cell, a ______________________________ turns the operon off.
- A repressor is a protein that binds to an operator and physically _________________ RNA polymerase from binding to a promoter site.

Repression of Transcription in the lac Operon
- The regulator gene codes for a repressor protein that binds to the operator preventing RNA polymerase from binding to the promoter thus stopping transcription.

Activation of Transcription in the lac Operon
- Repressor proteins inhibit genes from being transcribed.
- An inducer binds to a repressor protein and causes it to detach from the operator.
- RNA polymerase can now bind to the promoter and transcription proceeds.

Protein Synthesis in Eukaryotes (from textbook)
- Eukaryotic cells contain much more DNA than prokaryotic cells do.
- Eukaryotic cells must continually turn certain genes on and off in response to signals from their environment; however, eukaryotes lack operons.

Controlling the Onset of Transcription
- Most gene regulation in eukaryotes controls the onset of _____________________________ — when RNA polymerase binds to a _____________________.

---

**Section 2 Gene Regulation and Structure**

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- **Describe** how the lac operon is turned on or off.
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**Controlling the Onset of Transcription**

- Most gene regulation in eukaryotes controls the onset of _____________________________ — when RNA polymerase binds to a _____________________.
• Transcription factors help arrange RNA polymerases in the correct position on the _________________.
• An enhancer is a sequence of DNA that can be bound by a transcription factor.

Enhancers for Control of Gene Expression
• An enhancer is a __________________ region of DNA that may be far away from the gene it affects.
• Transcription factors bind to DNA and regulate _____________________.
• Activators are a type of transcription factor that binds to _____________________.
• Other transcription factors bind to the promoter in eukaryotic genes and help arrange _________ polymerase in the correct position.
• A loop in the DNA allows the activator bound to the enhancer to interact with the transcription factor and RNA polymerase at the promoter, increasing the transcription of the gene.

Intervening DNA in Eukaryotic Genes
• In eukaryotes, many genes are interrupted by __________—long segments of nucleotides that have no coding information.
• __________ are the portions of a gene that are translated (expressed) into proteins.
• After a eukaryotic gene is transcribed, the introns in the resulting mRNA are cut out by complex assemblies of RNA and protein called _________________________.

Removal of Introns After Transcription
DNA Mutations

How Does it happen?
- Environmental influences such as: ______________________ or ____________________.
- Inherited: mutations can be passed down from ______________ to ______________.
- During copying of ______________, ______________ can occur.

Types of Mutations
- **Point mutations**: A mutation in which a ______________________ is changed.
  - This mutation does not affect the ____________________________.
    - Example: ATG TCG CAT TGA CGA Original DNA
    - ATG TCG CTT TGA CGA Mutated DNA
    - Results in either ______________, ______________ or ______________ mutations.
- **Point Mutation Results**: 
  - **Silent Mutation**: The base pair change has ______________ on the ______________ produced.
    - Acts as a ______________________ mutation – meaning it’s a different codon that still codes for the same amino.
    - Regardless of ‘A’ changing to ‘G’, the ______________ glutamic acid is still produced.
  - **Missense Mutation**: A ______________________ amino acid is produced.
    - Example: GAA codes for __________; when the ‘A’ is changed to a ‘C,’ the amino acid produced is ________.
  - **Nonsense Mutation**: The base pair change results in a ______________________ being produced. This may form a ___________________________ protein.
    - TAA, TAG or TGA (DNA triplets) are STOP codons.
    - AUU, AUC or ACU (mRNA codons) are STOP codons.
- **Transition**: A purine is changed to a purine (A or G) or a pyrimidine to a pyrimidine (T or C)
- **Transversion**: A purine is changed to a pyrimidine or a pyrimidine to a purine.
- **Examples**: Sickle cell anemia
  - Glu- changes to Val-
    - What type of mutation is this? Silent, missense or nonsense? ______________
    - What type of mutation is this? Transition or transversion? ______________
- **Frameshift Mutations**
  - Frame shift mutations: The reading frame is ______________________.
- Example:
  Original: THE FAT CAT ATE THE WEE RAT
  Mutated: THE FAT CAA TET HEW EER AT
- Types: ______________________, ______________________, ______________________ of base pairs.
- **Deletion:** a ________________ base pair or ________________ of base pairs may be ____________________ from a sequence of nucleotides.
- **Insertion:** a ________________ base pair or ________________ of base pairs may be ____________________ to a sequence of nucleotides.
  - Example:
    - A ________________ sequence is inserted into the DNA strand, resulting in ________________________________.
    - Original: ACC ATT GGC
    - Mutated: ACC CAG CAG CAG ATT GGC
    - The abnormal ________________ produced interferes with synaptic transmission in parts of the brain leading to ________________________________ and loss of ________________________.
- **Duplication:** a sequence of base pairs may be ______________________ and ______________________ into the strand of nucleotides.
- **What is more severe? Frameshift or point mutations?**
  - **Frameshift mutations** –
    - Alters the reading frame, thus affecting ________________________ created after the point of mutation
    - Mostly ______________________
  - **Point mutations** –
    - Does ________________________ the reading frame, with the chance of not affecting the ________________________ being made
    - Can still be fatal to the ________________________
- **Good mutations?**
  - Mutation of gene CCR5 – deletion of 32 pairs of nucleotides. Leads to resistance of_________. Stemmed from the ________________________
  - Mutation of ________________________cells leads to sickle cell anemia (has 2 alleles for the trait)
  - Leads to ________________________ resistance (has only one allele = sickle cell trait)
- A mutation on protein Apo-AIM helps remove __________________ from arteries, thus leading to less __________________ disease risk.
- Defective __________________ genes leads to immense __________________ strength
- NTRK1 gene mutation results in loss of all ___________ and ______________.

**Chromosomal Mutations**

- Occurs during __________________ - _______ of __________________ in meiosis.
- Types of chromosomal mutations:
  1. __________________________
  2. __________________________
  3. __________________________
  4. __________________________
- Translocations – __________________________ chromosomes __________________________
  - Causes: __________________________, __________________________, and radiation
  - Result: __________________________ or __________________________
- Inversions – a part of a chromosome __________________________, __________________________, then reattaches to previous spot on chromosome
  - Tends to lead to increase risk of __________________________ and __________________________
- Deletions – Genes are __________________________ from the chromosome
  - This can occur __________________________ on the chromosome
  - Can cause disorders such as __________________________, or “cry of the cat” syndrome.
- Duplications - with duplication mutations, sections of DNA are __________________________ on the chromosome.

**Nondisjunction**

- Disjunction: When sperm and egg cells form, each chromosome and its homologue __________________________.
- Nondisjunction: When one or more chromosomes ____________ to separate properly. One gamete ends up receiving ____________ chromosomes and the other gamete receives ____________.
  - Types of Nondisjunction
    - Monosomy: A daughter cell only has ________ chromosome instead of 2
Example of Monosomy: ____________________
Syndrome / X0 – The entire X chromosome on the
___________________ pair is missing

Trisomy: A daughter cell has _____________ chromosomes
instead of 2

Examples of Trisomy

• _________________ Syndrome / Trisomy ____
• _________________ Syndrome / Trisomy ____

Major Types of Mutations

Gene Alterations
Point mutation

Insertion

Deletion

Types of Gene Mutations

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<thead>
<tr>
<th>Normal</th>
<th>Substitution</th>
<th>Frame shift mutation</th>
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</thead>
<tbody>
<tr>
<td>A C G</td>
<td>A C G</td>
<td>A C G</td>
</tr>
<tr>
<td>T C G</td>
<td>T C G</td>
<td>T C G</td>
</tr>
</tbody>
</table>
Chapter 10 Section 1 Questions

1. DNA holds the instruction for determining what macromolecule?

2. What are two functions of proteins?
   a. _________________________________________________________________
   b. _________________________________________________________________

3. What does RNA stand for? _________________________________________

4. What is the monomer (building blocks) of RNA? ______________________

5. What are three ways that RNA is different from DNA?
   a. _________________________________________________________________
   b. _________________________________________________________________
   c. _________________________________________________________________

6. In DNA, the complimentary base rules were A=T and G=C. What are the complimentary base pairing rules for RNA? __________________________________________

7. The process of transferring the coded information in a gene on a DNA strand to an RNA molecule is called? ________________________________

8. The process of using two different RNA molecules to put together amino acids to make proteins is called? ________________________________

9. The entire process by which proteins are made is known as? _______________________

10. During transcription, what is the function of RNA polymerase?

11. During transcription, where does the RNA polymerase begin reading the DNA sequences?

12. Where does the RNA polymerase stop?

13. Where does transcription occur in prokaryotic cells? _______________________

14. Where does transcription occur in eukaryotic cells? _______________________

15. List the three types of RNA and their function:

<table>
<thead>
<tr>
<th>Type of RNA</th>
<th>Function</th>
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</table>

16. What is the language of the RNA? _________________________________
17. What is the language of proteins? ________________________________

18. How many nucleotides make up a codon? __________________________

19. What is the genetic code?

20. Where does translation occur in the cell? ____________________________

21. What part of the tRNA is complimentary with the mRNA’s codon? __________

22. What are ribosomes made of? ____________________________________________

23. How many copies of proteins can be made from the same mRNA molecule? __________

24. Why is the genetic code often described as universal?

Chapter 10 Section 2

1. How many genes does:
   a. A bacterial prokaryotic cell have? _________________________________
   b. A human eukaryotic cell have? _________________________________

2. The DNA that overlaps the promoter site and serves as an “on-off” switch is called?
   _________________________________

3. What three parts of a bacterial gene makes up the operon?
   a. ________________________________
   b. ________________________________
   c. ________________________________

4. What is the effect of lactose on the lac operon repressor protein?

5. How are mutations in gametes different from mutations in body cells?
Section: From Genes to Proteins

Read the passage below. Then answer the questions that follow.

Like DNA, ribonucleic acid (RNA) is a nucleic acid—a molecule made of nucleotides linked together. RNA differs from DNA in three ways. First, RNA consists of a single strand of nucleotides instead of the two strands found in DNA. Second, RNA nucleotides contain the five-carbon sugar ribose rather than the sugar deoxyribose found in DNA nucleotides. And third, RNA has a nitrogen base called uracil—abbreviated as U—instead of the base thymine (T) found in DNA. No thymine (T) bases are found in RNA. Like thymine, uracil is complementary to adenine whenever RNA base-pairs with another nucleic acid.

SKILL: RECOGNIZING SIMILARITIES AND DIFFERENCES

Read each question, and write your answer in the space provided.

1. In the spaces provided, write D if the statement is true of DNA. Write R if the statement is true of RNA. Write B if the statement is true of both DNA and RNA.

   _____ a. consists of a single strand of nucleotides
   _____ b. made of nucleotides linked together
   _____ c. contains deoxyribose
   _____ d. has the nitrogen base uracil
   _____ e. contains ribose
   _____ f. is a nucleic acid
   _____ g. consists of a double strand of nucleotides
   _____ h. contains a base that pairs with adenine

An analogy is a comparison. In the space provided, write the letter of the term or phrase that best completes the analogy.

   _____ 2. RNA is to U as DNA is to
   a. C
   b. G
   c. T
   d. A
Section: From Genes to Proteins

In the space provided, write the letter of the term or phrase that best completes each statement or best answers each question.

1. During transcription, the genetic information for making a protein is rewritten as a molecule of
   a. messenger RNA.
   b. ribosomal RNA.
   c. transfer RNA.
   d. translation RNA.

2. All organisms have a genetic code made of
   a. two-nucleotide sequences.
   b. three-nucleotide sequences.
   c. four-nucleotide sequences.
   d. five-nucleotide sequences.

3. In a cell, the equipment for translation is located in the
   a. cytoplasm.
   b. nucleus.
   c. plasma membrane.
   d. centrioles.

4. Like DNA, RNA contains which of the following?
   a. phosphate
   b. uracil
   c. thymine
   d. deoxyribose

5. In eukaryotes, translation begins when
   a. the A site becomes vacant.
   b. tRNA detaches from the P site.
   c. a stop codon is reached.
   d. mRNA leaves the nucleus.

In the space provided, write the letter of the description that best matches the term or phrase.

6. RNA
   a. enzyme that adds and links complementary RNA nucleotides during transcription

7. mRNA
   b. helps in the synthesis of proteins by carrying amino acids

8. RNA polymerase
   c. single strand of nucleotides containing ribose and uracil

9. tRNA
   d. double strand of nucleotides containing deoxyribose and thymine

10. DNA
    e. delivers the information needed to make a protein to the site of translation
Section: Gene Regulation and Structure

Complete each statement by writing the correct term or phrase in the space provided.

1. To break down lactose, *Escherichia coli* need three different   
   _________________, each of which is coded for by a different gene.

2. The three genes are located next to each other, and all are controlled by the   
   same _________________ site.

3. The piece of DNA that overlaps the promoter site and serves as the on-off   
   switch is called a(n) _________________.

4. The group of genes that codes for enzymes involved in the same function,   
   their promoter site, and the operator all function together as a(n)   
   _________________.

5. The operon that controls the metabolism of lactose is called the   
   _________________ ________________.

6. A(n) _________________ is a protein that binds to an operator and   
   physically blocks RNA polymerase from binding to a promoter site.

Read each question, and write your answer in the space provided.

7. What are enhancers?
   ______________________________________________________________________

8. Why is there more opportunity for gene regulation in eukaryotic cells than in   
   prokaryotic cells?
   ______________________________________________________________________

9. Why have no operons been found in eukaryotic cells?
   ______________________________________________________________________
10. When can gene regulation occur in eukaryotic cells?

11. What are introns and exons?

12. What happens to mRNA that includes introns?

13. What might be the evolutionary advantage of genes being interrupted by introns?

Complete each statement by underlining the correct term or phrase in the brackets.

14. Mutations can only be passed on to offspring if they occur in [gametes / body cells].

15. Mutations that change one or just a few nucleotides in a gene on a chromosome are called [random / point] mutations.

16. If a mutation causes a gene containing the nucleotide sequence ACA to become ACT, the mutation is called a [substitution / deletion] mutation.

17. If a mutation causes a sequence of nucleotides to change from ACGAGA to ACGGA, the mutation is called a(n) [insertion / deletion] mutation.

18. If a mutation causes a sequence of nucleotides to change from ACGAGA to ACGAGGA, the mutation is called a(n) [insertion / deletion] mutation.
Section: Gene Regulation and Structure

In the space provided, write the letter of the term or phrase that best completes each statement or best answers each question.

____ 1. Gene regulation is necessary in living organisms
   a. so that the repressor will never bind to the operator.
   b. to allow RNA polymerase continuous access to genes.
   c. to avoid wasting their energy and resources on producing proteins that are not needed or are already available.
   d. to ensure that the operon is always in the “on” mode.

____ 2. The lac operon enables a bacterium to build the proteins needed for lactose metabolism only when
   a. glucose is present.
   b. tryptophan is present.
   c. galactose is present.
   d. lactose is present.

____ 3. Which of the following is NOT true about gene regulation in eukaryotic cells?
   a. Gene regulation in eukaryotes is more complex than in prokaryotes.
   b. Operons play a major role in eukaryote gene regulation.
   c. Gene regulation can occur before, during, or after transcription.
   d. Gene regulation can occur after translation.

____ 4. Point mutations occur when
   a. one nucleotide is replaced with a different nucleotide.
   b. a gene’s location changes.
   c. long segments of a gene are lost.
   d. gametes are forming during meiosis.

____ 5. The lac operon turns “off” when
   a. glucose is absent.
   b. lactose is absent.
   c. RNA polymerase is absent.
   d. lactose is present.

In the space provided, write the letter of the description that best matches the term or phrase.

____ 6. intron
   a. long segments of eukaryotic DNA that have no coding information

____ 7. gene alteration
   b. includes the substitution, insertion, and deletion of one or more nucleotides

____ 8. exon
   c. sequence of DNA that can be bound to a transcription factor

____ 9. repressor
   d. can bind to an operator, which stops transcription

____ 10. enhancer
   e. portions of a eukaryotic gene that are translated
Complete the crossword puzzle using the clues provided.

**ACROSS**

1. Like DNA, ______ acid (RNA) is a molecule made of nucleotides linked together.
2. RNA ______ is an enzyme involved in transcription.
3. The type of RNA that carries the instructions for making a protein from a gene to the site of translation is called ______ RNA.
4. The entire process by which proteins are made is called ______ expression.
5. process for transferring a gene’s instructions for making a protein to an mRNA molecule
6. a three-nucleotide sequence on the mRNA that specifies an amino acid or “start” or “stop” signal
7. piece of DNA that serves as an on-off switch for transcription
8. long segment of nucleotides on a eukaryotic gene that has no coding information

**DOWN**

1. a protein that binds to an operator and inhibits transcription
2. portion of a eukaryotic gene that is translated
3. a process that puts together the amino acids that make up a protein
HOW DO MUTATIONS OCCUR?

Point mutations are those involving only one or a few bases in DNA. Using the nucleotide sequences you are given, you will:

1. discover what the three types of point mutations are, and
2. simulate these mutations.

Simulating the Mutations

Complete the information on the next page, using the bases provided and the DNA codon or RNA codon tables, Table 1 and Table 2.

Table 1: DNA Codon Table

<table>
<thead>
<tr>
<th>First base</th>
<th>Second base</th>
<th>Third base</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>AAA phe</td>
<td>AGA ser</td>
<td>ATA tyr</td>
</tr>
<tr>
<td>AAG phe</td>
<td>AGG ser</td>
<td>ATG tyr</td>
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<td>AGC ser</td>
<td>ATC STOP</td>
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<tr>
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<td>GGA pro</td>
<td>GTA his</td>
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<tr>
<td>CAT val</td>
<td>CGT ala</td>
<td>CTT glu</td>
</tr>
<tr>
<td>CAC val</td>
<td>CGC ala</td>
<td>CTC glu</td>
</tr>
</tbody>
</table>

Amino acid abbreviations:

ala alanine       leu leucine
arg arginine      lys lysine
asn asparagines   met methionine
asp aspartic acid (aspartate) phe phenylalanine
cys cysteine      pro proline
gln glutamine     ser serine
glu glutamic acid (glutamate) thr threonine
gly glycine       trp tryptophan
his histidine     tyr tyrosine
ile isoleucine    val valine
Here is your DNA sequence of bases. You will be assigned #1 or #2. Complete your work for the number you were assigned.


1. Write the amino acid sequence specified by this DNA.

2. Arrange the RNA bases opposite the DNA bases using your RNA codon table as a guide.
   a. Write the RNA sequence.

   b. What type of RNA have you formed (messenger, transfer or ribosomal)?

3. Three “mistakes” (mutations) occur in the sequence of DNA bases which change both the messenger RNA and the protein sequence it specifies. Working with the DNA bases in front of you, try to figure out how these errors occur. Define the 3 mistakes below. Don’t use the word in your definition:
   a. Substitution -
   b. Deletion -
   c. Insertion -

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<table>
<thead>
<tr>
<th>First base</th>
<th>Second base</th>
<th>Third base</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>UU</td>
<td>UG</td>
</tr>
<tr>
<td></td>
<td>UUU phe</td>
<td>UGU cys</td>
</tr>
<tr>
<td></td>
<td>UUC phe</td>
<td>UGC cys</td>
</tr>
<tr>
<td></td>
<td>UUA leu</td>
<td>UGA STOP</td>
</tr>
<tr>
<td></td>
<td>UUG leu</td>
<td>UGG trp</td>
</tr>
<tr>
<td>C</td>
<td>CUC pro</td>
<td>CGU arg</td>
</tr>
<tr>
<td></td>
<td>CUA leu</td>
<td>CGA arg</td>
</tr>
<tr>
<td></td>
<td>CUG leu</td>
<td>CGG arg</td>
</tr>
<tr>
<td>A</td>
<td>AUC thr</td>
<td>AGU ser</td>
</tr>
<tr>
<td></td>
<td>AUG met</td>
<td>AUA thr</td>
</tr>
<tr>
<td></td>
<td>AUA ile</td>
<td>AGC arg</td>
</tr>
<tr>
<td></td>
<td>AUC ile</td>
<td>AGA arg</td>
</tr>
<tr>
<td></td>
<td>AUG ile</td>
<td>AAU asn</td>
</tr>
<tr>
<td></td>
<td>AUU ile</td>
<td>AAC asn</td>
</tr>
<tr>
<td></td>
<td>GUA val</td>
<td>GAA glu</td>
</tr>
<tr>
<td></td>
<td>GUC val</td>
<td>GAC asp</td>
</tr>
<tr>
<td></td>
<td>GUG val</td>
<td>GAG glu</td>
</tr>
<tr>
<td>G</td>
<td>GUU val</td>
<td>GGU gly</td>
</tr>
<tr>
<td></td>
<td>GCC ala</td>
<td>GGU gly</td>
</tr>
<tr>
<td></td>
<td>GCA ala</td>
<td>GGU gly</td>
</tr>
<tr>
<td></td>
<td>GCG ala</td>
<td>GGU gly</td>
</tr>
</tbody>
</table>
4. These three mistakes are shown below. In the spaces below, record the RNA sequences, the amino acid sequences and the types of mutations. For any one or two letter “codons” record it as a question mark (?).

DNA sequence:
RNA sequence:

Amino acid sequence:

Which type of mutation is demonstrated above? _______________________

DNA sequence:
#1 TAC – TCT - ATG – CCG – CCC – CAT - C
#2 TAC – GAG – GCC – GTT – ACC – CAT - T
RNA sequence:

Amino acid sequence:

Which type of mutation is demonstrated above? _______________________

DNA sequence:
RNA sequence:

Amino acid sequence:

Which type of mutation is demonstrated above? _______________________

5. Are the amino acid sequences the same in each of the 3 cases above? _____________

6. What would be the result if a mutation: (choose from: it would never start or it would be an incomplete protein)
   a. produced a STOP codon at the beginning of a DNA base sequence? _______________________
   b. omitted a START codon at the beginning of a DNA base sequence? _______________________
   c. inserted a STOP codon in the middle of a DNA base sequence? _______________________


7. List any 2 examples of a protein: __________________ and __________________.

8. a. Define a frameshift mutation. ______________________________________________________

   b. Which of the mutations in question # 4 are frameshift mutations? ___________________

   c. Which type of mutation would have a more detrimental effect on the sequence of amino
      acids in a protein, a base-pair substitution or a frameshift mutation? ________________

   d. Explain your answer. ________________________________________________________________
      ________________________________________________________________
      ________________________________________________________________