Name_____ Biol 211 - Group Number_____

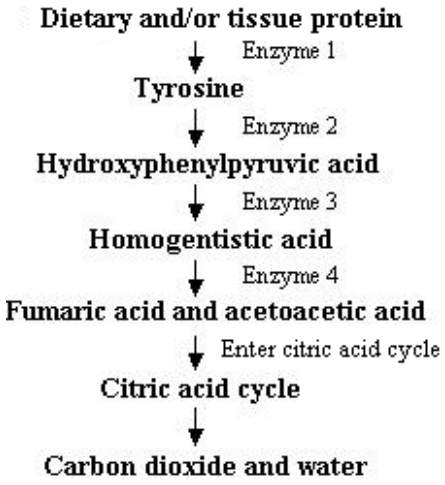
Active Learning Exercise 10. From Gene to Protein

Reference: Chapter 17 (*Biology* by Campbell/Reece, 8th ed.)

RNA and Transcription

1. How does the DNA inherited by an organism determine the specific traits displayed by that organism? That is, how does the specific order of nucleotides in the DNA inherited by a critter determine its phenotypic characteristics such as eye and hair color, the kind of digestive enzymes produced, whether wings or arms will be produced, etc.?

2. The metabolic pathway to the right, discovered by the British physician A.E. Garrod, ensures that the amino acid ***tyrosine***, derived from the digestion of excess protein, is disposed of metabolically. However, in certain individuals large quantities of ***homogentistic acid*** are excreted in the urine, which then turns black on standing. This condition, known as ***alkaptonuria***, runs in families—i.e. it is inherited. *Explain the genetic basis for alkaptonuria.*



3. Which of the following is the best example of *gene expression*?
   a.) A frog adapts to variation in its environmental temperature.
   b.) Mouse fur color results from pigment formed by gene-encoded enzymes.
   c.) DNA is replicated during the S phase of the cell cycle.
   d.) The percent of allele "A" versus the percent of allele "a" in a population is altered by natural selection.
   e.) Mutation alters the sequence of a region of DNA.

4. Distinguish between *Beadle and Tatum's* "***one gene—one enzyme hypothesis***" (for which they won a Noble Prize in 1958) and the "***one gene—one polypeptide hypothesis***" and then explain why *neither* hypothesis is entirely true.

5. Compare and contrast ***DNA*** and ***RNA*** by completing the following table:

	DNA	**RNA**
Number of strands		
Type of sugar		
Nitrogenous bases		
Cellular Function		

6. a.) What is the name of the process that produces RNA? _____

   b.) Where does the process occur in the cell? _____

7. Looking at the synthesis of ***messenger RNA***.....
   a.) What enzyme is needed for its creation? _____

   b.) Where on the DNA does this enzyme begin activity?_____

   c.) What is the enzyme's direction of movement on the DNA molecule? _____

   d.) What prevents this enzyme from working all the way to the end of the DNA molecule?

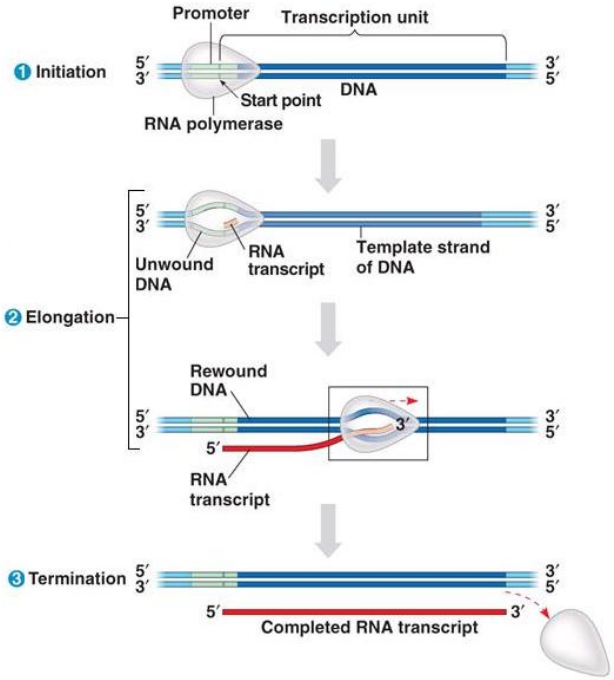
   e.) Discuss the roles played in transcription by each of the following…
      i.) ***TATA box***

      ii.) ***Transcription factors***

      iii.) ***transcription initiation complex***?

f.) After ***processing*** of the ***pre-mRNA*** molecule to produce a functional ***mRNA***, where does this newly created messenger RNA molecule go next? For what purpose?

8. Explain how ***RNA*** is ***transcribed*** from ***DNA*** by discussing what is happening in each of the three stages in the figure to the right.



9. Enzymes in the nucleus of eukaryotic organisms modify ***pre-mRNA molecules*** (also called ***primary transcripts***) before they exit the nucleus for the cytoplasm where they act as a blueprint for protein synthesis. Identify the *functions* for each of the following post-transcriptional modifications of the primary transcript.....

a.) ***5' cap:*** A modified guanine nucleotide is added as a cap on the 5' end of the pre-mRNA.

b.) ***Poly(A) tail:*** 30 to 200 adenine nucleotides are added to the 3' end of the pre-mRNA .

c.) ***RNA splicing or RNA processing: Introns*** are removed from the pre-mRNA by ***spliceosomes*** and the resulting ***exons*** are connected.

10. Eukaryotic cells make ***pre-mRNA transcripts*** that are on average about 6 to 7 times longer than required to make the average polypeptide. Thus pre-mRNA molecules require a cut and paste job (***RNA splicing***) to bring them down to the correct size. Is the presence of ***introns*** between the functional ***exons*** and ***RNA splicing*** energetically wasteful? Of what functional and/or evolutionary importance is ***RNA splicing*** and the production of ***introns***?

11. a.) What is meant by the term **"*Triplet Code"***?

    b.) On what molecule(s) is the triplet code found? _____

12. What is the ***template strand*** (also known as the "***sense strand***")? What role does it play?

Peptides and Translation

13. a.) What is a ***codon***? What role do they play?

    b.) On what molecule are ***codons*** found? _____

14. a.) What is an ***anticodon***? What role do they play?

    b.) On what molecule are ***anticodons*** found? _____

15. What is the **"*Dictionary of the Genetic Code*"**?

16. Why is it unnecessary to produce a dictionary for ***anticodons***?

17. What is a ***"reading frame"***? Of what importance is the reading frame?

18. A segment of a gene has the base sequence: **5' AATTTGCCTGGGCATCATAAAGA 3'**
    a.) What is the base sequence of the ***complementary strand***? *Indicate the 5' and 3' ends*.

    b.) What experimental evidence supports the sequence in part a? (Hint: Edwin Chargaff)

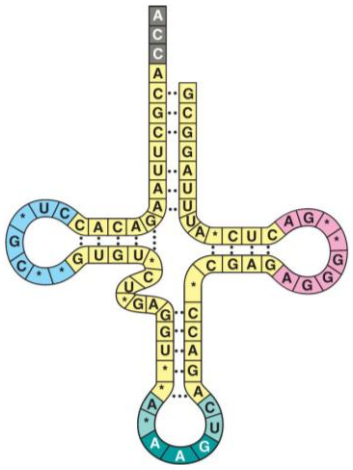
    c.) What is the *maximum number* of ***amino acids*** coded for by this segment on DNA? _____

    d.) ***Transcribe*** the ***complementary strand.*** Use letters to show the base sequence of the product below. Indicate the 5' and 3' ends.

    e.) ***Translate*** the mRNA produced above into a peptide. Remember that ribosomes read mRNA in only one specific direction. Use three letter abbreviations to show the amino acid sequence below.

19. List in order the sequence of events that take place when a DNA sequence (i.e. gene) is used to direct the synthesis of an enzyme or other polypeptide. ***Number your steps.***

20. On this model of a ***tRNA*** molecule, label each of the following:
    - 5′ and 3′ ends
    - hydrogen bonds
    - unpaired regions
    - anticodon loop
    - binding site for amino acid



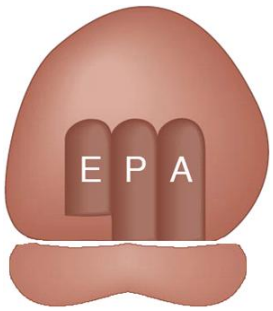
21. What are the *two* most important functions of a ***tRNA*** molecule? **Hints:** anticodon/codon, amino acids.

22. ***Aminoacyl-tRNA synthetase*** is an enzyme whose function is to attach a molecule of a/an _____ to a molecule of _____.

23. What is represented at each of the lettered sites and what occurs at each of these during ***translation***?
    a.) A

    b.) P

    c.) E



24. What does ***"wobble"*** refer to? What is its significance?

25. Which of the following molecules is (are) <u>*produced*</u> by ***transcription***? (Circle the letter of all that apply.)
    a.)Ribosomal RNA c.) Messenger RNA e.) Amino acids
    b.) Proteins d.)Transfer RNA f.) DNA

26. Which of the following molecules is (are) <u>*produced*</u> by ***translation***? (Circle the letter of all that apply.)
    a.) Ribosomal proteins c.) Messenger RNA e.) Amino acids
    b.) RNA polymerase d.)Transfer RNA f.) Pepsin (a digestive enzyme)

27. The final product of an expressed gene can be which of the following? (Circle the letter of all correct choices.)
    a.) mRNA b.) tRNA c.) rRNA d.) polypeptide

28. Describe the ***Initiation Process of Translation*****.** Include in this description the following words:

a.) small ribosomal subunit	e.) mRNA	i.) initiation factors
b.) large ribosomal subunit	f.) P-site	j.) GTP
c.) A-site	g.) initiator tRNA; methionine	k.) codon recognition
d.) AUG codon	h.) UAC anticodon	

29. Describe the ***elongation process of translation***. Include in your description the following words:

a.) P-site	d.) codon recognition	g.) translocation
b.) A-site	e.) peptide bond formation	h.) E-site
c.) aminoacyl tRNA	f.) growing polypeptide chain	i.) GTP

30. Describe the termination of ***translation***, explaining the roles of ***stop codons*** and ***release factor***.

31. a.) How do ***transcription*** and ***translation*** differ in ***prokaryotes*** and ***eukaryotes***?

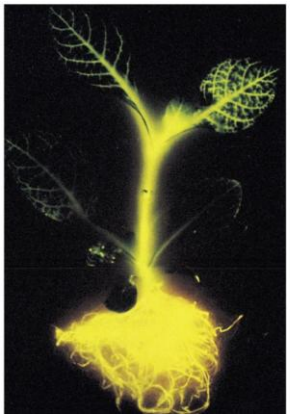
b.) Why is impossible for ***post-transcriptional editing*** of mRNA to occur in prokaryotes?

32. Considering that all cells in an organism's body have the same genes, what is it that allows cells to become different from each other or specialized, i.e. ***differentiated***. (e.g. muscle cells, nerve cells, bone cells, etc.)?

33. Review the functions of the various kinds of ***RNA*** by completing the table below.

Type of RNA	Major functions
Pre-mRNA (Primary transcript)	
mRNA (Messenger RNA)	
tRNA (Transfer RNA)	
rRNA (Ribosomal RNA)	
snRNA (Small Nuclear RNA)	
SRP RNA (signal- recognition particle RNA	

34. These examples demonstrate the ability of genes from one species to be expressed in a different species. This is possible because of which property of the ***genetic code***?



a.) Tobacco plant expressing a firefly gene

b.) Pig expressing a firefly gene (yellow feet and nose!)

35. Record the letter (in alphabetical order please!) of the terms below that are <u>*directly*</u> involved with each process. Each can be used once or more than once.

a.) stop codon	e.) amino-acid tRNA synthetase	i.) tRNA	m.) RNA polymerase
b.) peptide bond	f.) anticodon	j.) spliceosome	n.) mRNA,
c.) P site	g.) promoter	k.) TATA box	o.) rRNA
d.) GTP	h.) terminator sequence	l.) DNA polymerase,	p.) DNA

i.) ***Replication***: _____

ii.) ***Transcription***: _____

iii.) ***RNA processing*** _____

iv.) ***Translation***: _____

Mutations

36. Determine the kind of ***mutation*** present in the hypothetical template strands of DNA found in the table below. The nucleotide bases are listed as triplets for convenience.

Select from the following list of mutations:

- <u>*Base-pair substitution*</u>: ***silent***, ***missense***, or ***nonsense mutation***.
- <u>*Frameshift mutation*</u>: ***insertion*** or ***deletion***

Wild type DNA: 3' TAC - TTC - ACA - GTG- ATT 5'

Wild type mRNA: 5' _____ - _____ - _____ - _____- _____ 3'

Wild type peptide: _____ - _____ - _____ - _____

(order of amino acids using 3 letter abbreviations)

	Mutant DNA #1	**Mutant DNA #2**	**Mutant DNA #3**
	3' TAC–**A**TC–ACA–GTG–ATT 5'	3' TAC–TTC–AC**G**– GTG –ATT 5'	3 TAC–TTC–ACA–G**A**G–ATT 5'
mRNA			
Peptide			
Kind of Mutation			

	Mutant DNA # 4	**Mutant DNA #5**
	3' TAC– TC–ACA–GTG–ATT 5'	3' TAC–**G**TT–CAC–AGT–GAT–T 5'
mRNA		
Peptide		
Kind of Mutation		

37. Which of the following mutations would likely be most dangerous to a cell?
    a.) Deletion of three nucleotides
    b.) Substitution of one nucleotide for another
    c.) Addition of one nucleotide
    d.) Addition of three nucleotides

38. In the disease of ***sickle cell anemia*** (autosomal recessive), a *single base mutation in DNA* (point mutation) results in the symptoms demonstrated by affected individuals. Sickle cell anemia was discussed in chapter 5—see the index of your textbook if you need review.)
    a.) List all possible ***DNA point mutations*** responsible for the disease and the consequences they have on the resulting mRNA and polypeptide. Be specific—list the specific DNA triplet codes, codons, and amino acid(s) in the table below. ***Hint:*** You need to compare the amino acid sequences of the normal and mutant polypeptides (see figure 5.22, page 84, *Biology*, 8th ed.), then work backwards to figure out all possible point mutations in the DNA responsible.

Correct DNA triplet code →	Mutated DNA triplet code →	Codon produced as a result of the mutation →	Amino acid inserted due to the mutation
→	→	→	
→	→	→	

    b.) What affect do these point mutations have on the amino acid sequence of the resulting polypeptide? Answer this question by completing the table to the right.

Correct amino acid →	Incorrect amino acid inserted
→	

    c.) Indicate the effect of these point mutations on the resulting mRNA codons by completing the table to the right.

Correct codon →	Incorrect codon
→	
→	

    d.) Are ***introns*** or ***exons*** affected by these point mutations? *Explain your reasoning*.

    e.) Name the ***polypeptide*** affected: _____

    f.) Why does the ***changing of a single amino acid*** out of 146 have such a profound affect on the ***function*** of this polypeptide?

    d.) Name the ***type of cell*** in the body affected: _____

    e.) What are the major ***symptoms*** associated with…
        i.) an affected individual (homozygous recessive)?

        ii.) a carrier (heterozygous) individual?

        ii.) Why the difference?