Name MATTHEW FENG Rec. Section R27 TA SAPPINGTON

7.012 Fall 2018: Problem Set 3

Due: Fri 10/12/2018

The solutions to these problems must be submitted electronically to your TA through the 7.012 Stellar site. All submissions must be received before 9:50 AM on October 12, 2018. Check your file to ensure it was successfully submitted. Only the material that is received prior to the deadline will be graded, no additional material will be accepted after the deadline.

Question 1 (1.5 point)

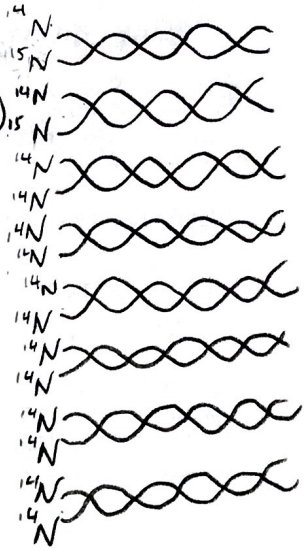
In 1958, Matthew Meselson and Franklin Stahl performed their famous experiment that gave evidence to support the theory that DNA replication was semiconservative in nature. You want to repeat the Meselson-Stahl experiment to impress your TA. You label E. coli with ^{15}N and then grow E. coli on the ^{14}N containing medium. After 3 generations/rounds of replication what would be the percentage of ^{15}N DNA strands remaining in the sample compared to the total number of DNA strands? Briefly explain how you came to this conclusion. Draw the DNA strands after three rounds of replication. Indicate ^{14}N and ^{15}N labeled strands.

Generation ϕ: 100%

Generation 1: 100% (each DNA has 1 ^{15}N strand)

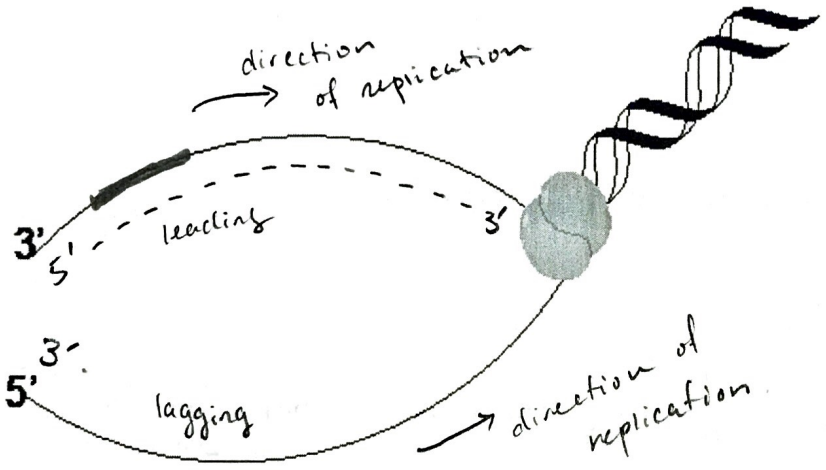
Generation 2: 50% (# DNA doubles, ^{15}N are same)

Generation 3: 25% (# DNA doubles, ^{15}N same).



Question 2 (2.5 point)

Shown below is a schematic of replicating DNA.



A.) On the diagram indicate the overall direction of replication with an arrow(s).

B.) Label the leading and lagging strand templates. How can you tell which is which?

The leading strand has the 3' end towards the replication fork. 3' end facing direction of replication.

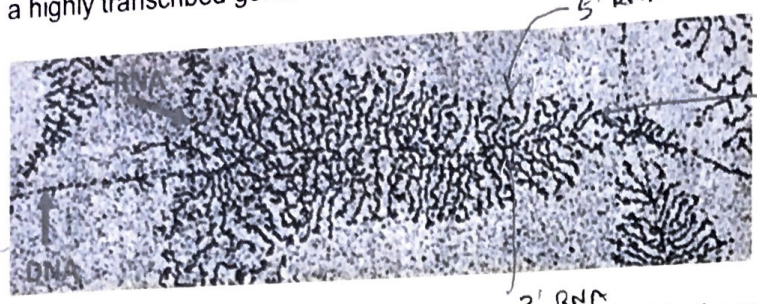
C.) Draw where primer(s) bind to the leading strand template as a thick line.

D.) Draw the leading strand as a dashed line. Label 5' and 3' ends.

E.) What is the purpose of the primer(s)?

We need primer b/c DNA polymerase can only append to a sequence of existing DNA nucleotides (existing DNA sequence). This is particularly important for the lagging strand.

Question 3 (2 points)
Shown below is the electron microscopy image of the nucleus of a frog oocyte during transcription of a highly transcribed gene. DNA and RNA are labeled on one section.



A.) Circle from the list below all proteins that are involved in the process shown above. For all proteins that you did NOT circle, explain briefly why you think they are not involved.

i) DNA polymerase

Since RNA is being transcribed, DNA polymerase is not needed (RNA polymerase is).

ii) RNA polymerase

iii) primase

RNA polymerase does not require a primer, so primase is not needed.

iv) ribosomal proteins

B.) If possible, label on the figure the following on the DNA and RNA strands indicated. (If you cannot tell, indicate so and explain why.)

i) the direction of transcription

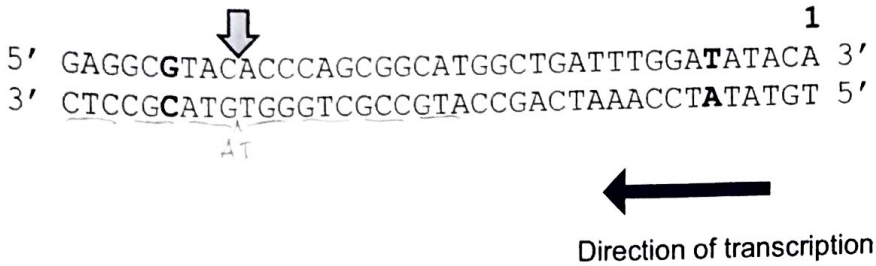
ii) the 5' and 3' ends of the template DNA strand.

iii) the 5' and 3' ends of one growing RNA strand.

iv) the N and C termini of one growing amino acid chain.

There isn't a growing amino acid chain in the picture; RNA is being polymerized.

Question 4 (5 points)
A section of the beginning sequence for the pre-pro-insulin gene is shown below. The genetic code can be found on the last page for your convenience. For questions d through f, please consider each mutation independently from each other in your answers. The genetic code can be found on the last page.



A.) Transcription starts in position indicated as "1" and proceeds in the direction shown by the horizontal black arrow. The 5' and 3' ends of each strand are labeled. Which strand is the coding strand, top or bottom? Bottom, synthesis is using 3'-5' as template.

B.) Give the sequence of the mRNA transcript for gene above. Circle the start codon.

UGUAUAUCCAAAUCAGCCAUGCCGCUGGGGUGUACGCCUC

C.) Translate the portion of the gene starting with the start codon. Use three- letter code to indicate amino acids.

Met - Pro - Leu - Gly - Val - Arg - Leu

D.) If the G-C pair **in bold type** is replaced with a T-A base pair, what effect, if any, would this have on the amino acid sequence of the polypeptide? What type of mutation is this?

Arg → Ser, Missense mutation.

E.) If the A-T pair **in bold type** is deleted, what effect, if any, would this have on the amino acid sequence of the polypeptide? What type of mutation is this?

None, deletion (mutation).

F.) If the two nucleotides (TA-AT, upper-lower) are added between nucleotides shown with the gray arrow, what effect, if any, would this have on the amino acid sequence of the polypeptide? What type of mutation is this?

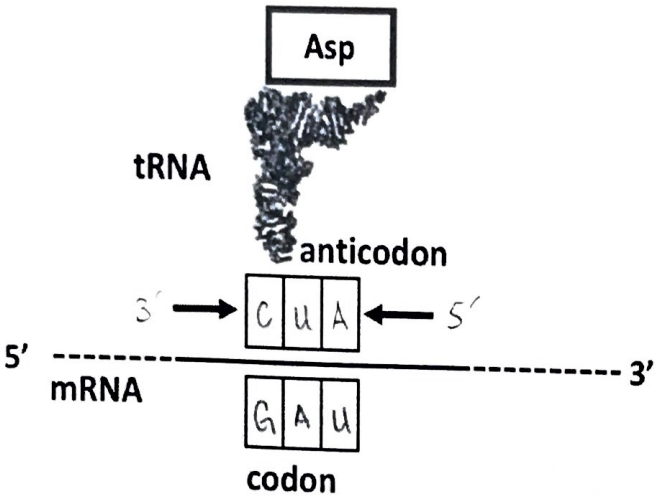
Premature stop; Frameshift mutation

G.) If the three nucleotides (GGG-CCC, upper-lower) are added between nucleotides shown with the gray arrow, what effect, if any, would this have on the amino acid sequence of the polypeptide? What type of mutation is this?

Add a proline after Glycine, insertion.

Question 5 (2 points)

For the following translation figure, answer the following. The genetic code can be found on the last page.



A.) Label the 5' and 3' ends of the tRNA anticodon (shown with arrows)

B.) What are the nucleotides of the codon in the mRNA?

GAU (or GAC)

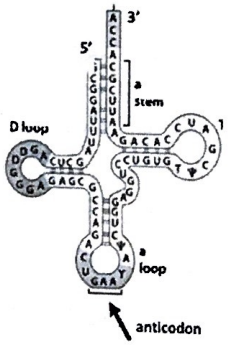
C.) What are the nucleotides in the anti-codon on the tRNA?

CUA (or CUG)

D.) Where will the next tRNA bind at the A site, to the right or left of the tRNA shown in the figure?

To the right; mRNA translated 5' → 3'.

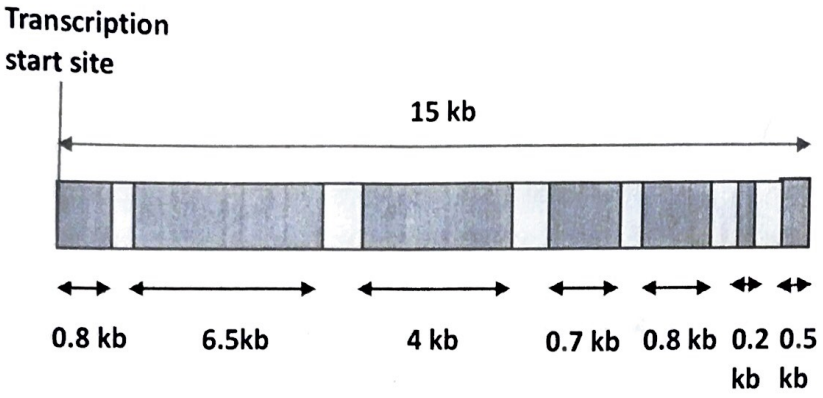
E.) The anticodon is shown underlined and with an arrow for the tRNA structure below. Which amino acid will this tRNA carry?



CUU → Leucine.

Question 6 (4 points)

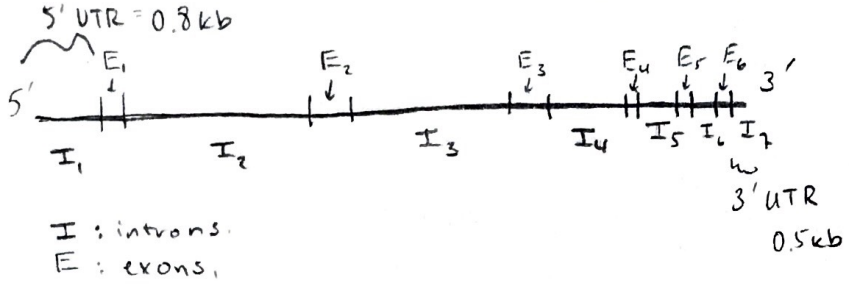
A schematic of genome sequence of a gene is shown below. A thousand nucleotides are indicated as 1 kb (kilobase). Your roommate went to get the new iPhone and forgot to label introns, exons, 5'UTR and 3'UTR.



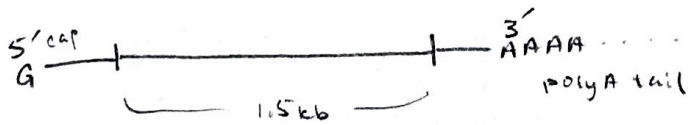
A.) Predict if this gene from a eukaryote or prokaryote? Explain.

Eukaryote; Linear and has introns.

B.) Your roommate indicated that the gene product is 500 amino acids. Draw a pre-mRNA and label/number the introns, exons, 5' and 3' UTR and indicate their length. Show your work.



C.) Draw what the mature mRNA for this gene would look like.



E.) Your roommate was surprised to find that a protein with 317 amino acids made from the same gene. Explain why that might be the case.

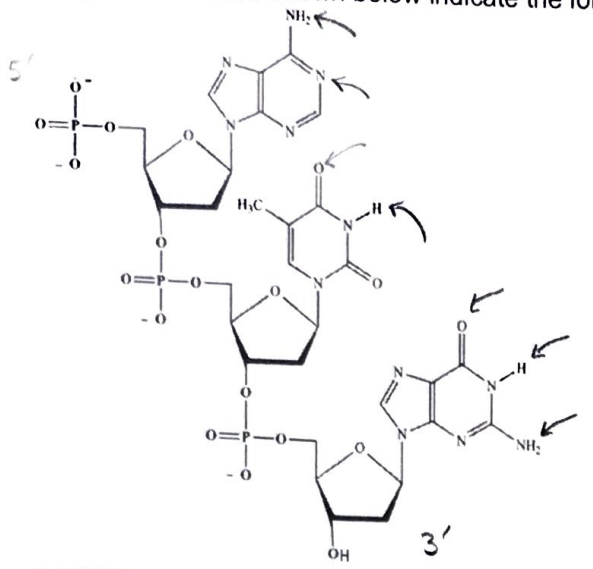
Alternative splicing of the gene can encode different proteins.

F.) Assume that for a specific section of the DNA above, the bottom parent strand (the single strand) contains 25% adenine and 30% guanine while the corresponding daughter strand (single strand) contains 30% adenine and 15% guanine. Calculate the percent of A:T base pairs and C:G base pairs in this section of the final double stranded DNA after it is completely replicated.

55% AT bp

45% CG bp.

Question 7 (3 points)
On the partial structure shown below indicate the following:



A.) Which macromolecule is this?

DNA (2' carbon doesn't have hydroxyl group).

B.) Label the 5' and 3' ends of this molecule.

C.) If a nucleotide is added, to which end will it be added?

3' end.

D.) Write out the sequence of this molecule.

5' – Adenine – Thymine – Guanine – 3'

E.) Indicate the other macromolecule this macromolecule most resembles and list two main chemical differences between the two.

RNA; RNA uses uracil instead of thymine, and has a hydroxyl group on the 2' carbon.

F.) Draw arrows to the sites of hydrogen bonding that are used for Watson:Crick base pairing.