Rieder - Genetics
Worksheet 2
Due: 9/19/17 at the beginning of class

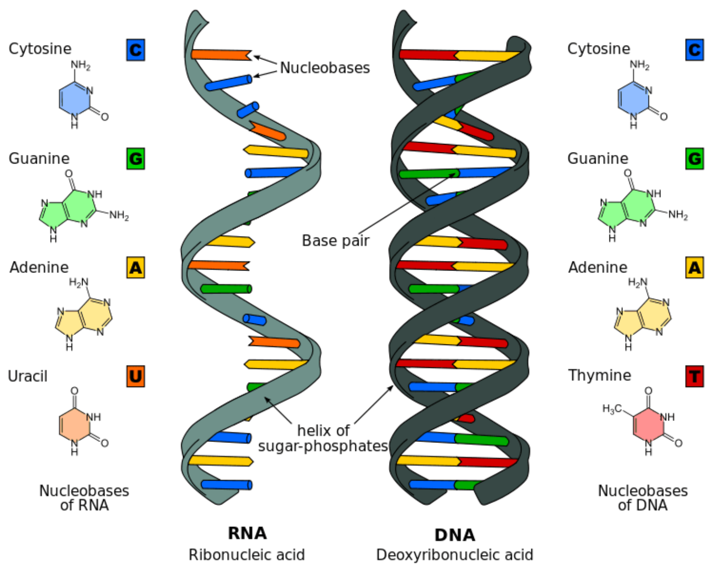
Name: ____

About how long did this homework take you? ___________________________________

I consulted/worked with: ____

POINTS: / 50

1. Two molecular differences between RNA and DNA are: 1) RNA incorporates the base **uracil** (U) instead of **thymine** (T); 2) the "R" in "RNA" stands for "**ribose**" instead of "**deoxyribose**," which is the "D" in "DNA." The sugar ribose takes the place of deoxyribose in the RNA molecule:



Something else you may notice from the picture above: RNA is **single stranded**, while DNA is always double stranded. However, just like those in DNA, the nucleotide bases in RNA (A, U, G, C) "prefer" to be paired through hydrogen bonds if at all possible, and pairing will take place *within the same RNA molecule*. How might the following mRNA molecule pair (5 pts)? Look closely at the sequence. Please draw it out.

5'- AUGAUGAUGUUUCAUCAUCAUUAA -3'

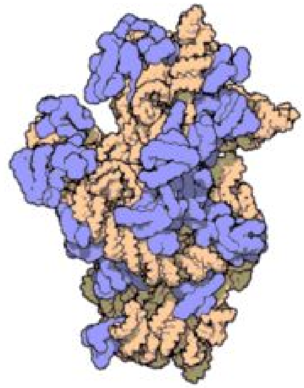
2. We have talked at length about the importance of DNA/RNA directionality (5' and 3'). The **ribosome translates** RNA into protein from 5' to 3', which is yet another reason we write DNA/RNA sequences in this order. For this question you will need to refer to a **codon table**.

2A. (3 pts) Translate the mRNA sequence from question 1 in the correct 5' to 3' orientation. You may write the the amino acids as three letters or one letter. For example, proline can be "pro" or P (your codon table should have these letters):

2B. (3 pts) Now please translate the same RNA sequence in the incorrect order, from 3' to 5':

2C. In A and B you (hopefully!) translated two very different proteins.... Based on the proteins' **primary sequences** do you think these proteins will have similar structures (2 pts)? Will they have similar functions (2 pts)? Why/ why not?

3. The "**RNA World**" hypothesis suggests that RNA evolved first, before DNA or proteins. This is because RNA has certain properties of both DNA and protein: 1) like DNA, RNA stores genetic information (some viruses even have RNA genomes!); 2) like proteins, RNA can **catalyze enzymatic** reactions--that is, it can cause chemical reactions to occur. DNA cannot catalyze chemical reactions, while proteins can not store genetic information. One elegant example of RNA catalysis is the **ribosome**, which is composed of both RNA and protein components:



In this image, the protein components of the ribosome subunit are colored purple, while the RNA components (ribosomal RNAs; **rRNA**) are tan. The ribosome is an example of an RNA enzyme, called a **ribozyme**. As we learned in class, the ribosome matches the messenger RNA (**mRNA**) **codon** sequence with the **anticodon** on the transfer RNA (**tRNA**), which is attached to the corresponding **amino acid**.

3A. (3 pts) What would happen in the protein being synthesized if there was a **mutation** (meaning a change in the sequence) in the anticodon region of a tRNA? Say, for example, the anticodon UAC was mutated to UCC?

3B. (3 pts) What do you think would happen if the mutation in the tRNA occurred outside of the anticodon region, but it changed the shape/structure of the tRNA molecule?

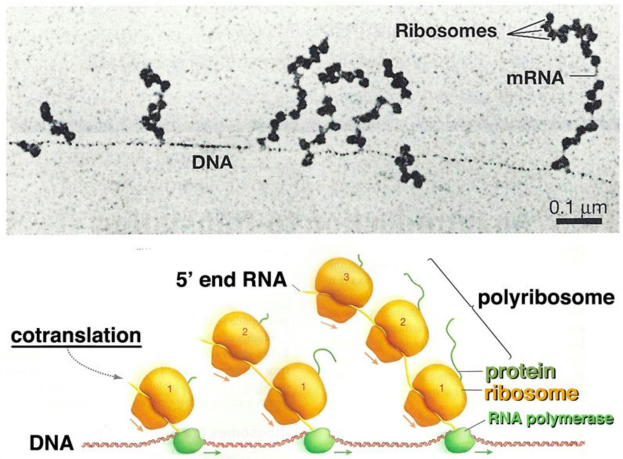
4. (3 pts) **Gene expression** is what happens when a gene is “turned on” and produces its product. Are all gene products proteins? What else might a gene produce when it is expressed?

5A. (2 pts) Why is the DNA sequence of a gene almost always longer than the mature mRNA it encodes?

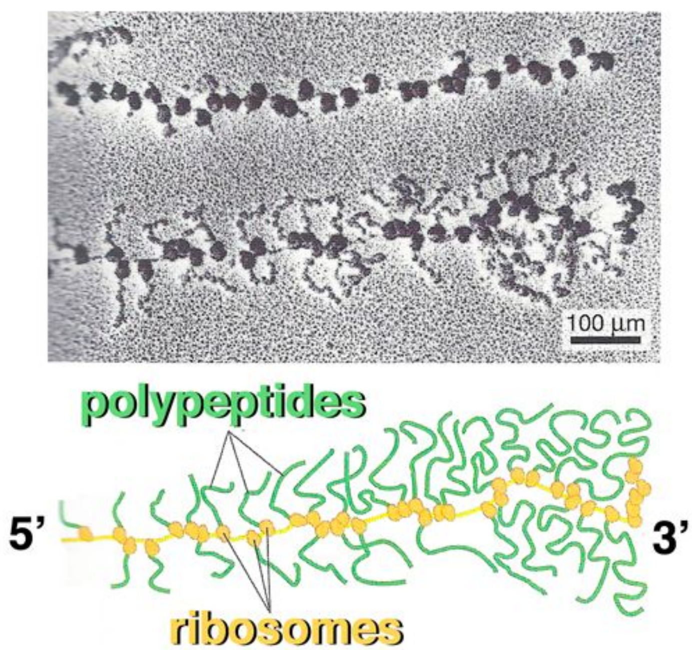
5B. (2 pts) Why is a cell’s **proteome** (the collection of different protein types) almost always larger in number than the genes in a cell’s **genome**?

6. (3 pts) As we’ll discuss next week, most cells are **diploid**; they have two copies of the genome. This means that there are two copies of most genes in each cell. However, there are usually many, MANY **MANY** copies of the genes that encode ribosomal RNA (**rRNA**) molecules in each genome. Why do you think the cell needs so many?

7. In **eukaryotic** cells, like those in humans, transcription and translation occur in separate compartments: transcription in the nucleus and translation in the cytoplasm. Bacteria, **prokaryotic** cells, do not have organelles such as the nucleus. This allows spatial and temporal coupling of transcription and translation:



You can't really see the proteins (also called "**polypeptides**" below) in the above image. Multiple ribosomes on an mRNA molecule are called **polyribosomes**, and this can also occur in eukaryotic cells:



7A. (2 pts) Label the mRNA in the above <u>eukaryotic</u> image.

7B. Why is there no DNA in the eukaryotic image (4 pts)?

8. In the early half of the 1900s, many scientists were convinced that DNA, with its measly four nucleotides, could not possibly be the genetic material; proteins, with 20 amino acids, had a much higher capability for information content (imagine all the English words you can write with 4 letters compared to how many words you can write with 20 letters). The solution appeared when scientists realized that nucleotides (in mRNA) are read in threes (“**codons**”), which means that there are 64 possible codons (4 x 4 x 4).

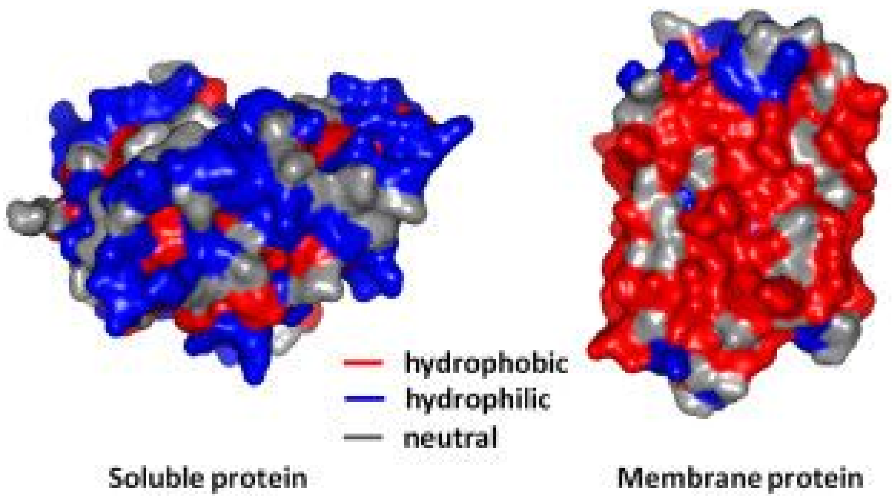
8A. (2 pts) How many possible 3-nucleotide codons would there be if there were 6 “flavors” of nucleotide instead of 4 (let’s say: A, T, G, C, P, and Q)?

8B. How many possible codons would there be if codons were only 2 nucleotides long rather than 3 (1 pt)? Would this be sufficient to encode the 20 amino acids (1 pt)?

9A. Which molecule is physically larger, the mRNA that encodes a protein or the protein itself, and how do you know (2 pts)? Warning: this is tricky.

9B. Which molecule is longer, the DNA (gene) that encodes an mRNA or the the mature mRNA, and how do you know (3 pts)?

10. A protein's **primary amino acid sequence** dictates its **secondary structure** (we discussed alpha helices and beta pleated sheets in class), and when secondary structures fold upon themselves, they form the protein's **tertiary structure**. So you can imagine that primary sequence also affects tertiary structure! <u>Proteins also fold in certain ways depending on their environment.</u> For example, proteins in the cytoplasm are surrounded by water, and they fold so that their **polar**, **hydrophilic** ("water-loving") amino acids are on the surface. They bury their **nonpolar**, **hydrophobic** ("water-hating") amino acids inside:



As you can see above, <u>membrane</u> proteins are surrounded by the lipids (like oil, nonpolar, hydrophobic) in a lipid bilayer cell membrane, so they fold so that their nonpolar, hydrophobic amino acids are on the outside. "Soluble" proteins are surrounded by water in the cytoplasm, so they fold in such a way so that they wear their hydrophilic amino acids on the outside.

10A. (2 pts) What do you think would happen to the protein's shape if you--somehow--surrounded the membrane protein with cytoplasm (water)?

10B. (2 pts) Would the membrane protein still perform the same function if it was in cytoplasm instead of lipid membrane?

Extra credit!

Every time you cook something you are **denaturing** (unfolding) its proteins. The application of heat breaks apart the hydrogen bonds that keep the protein folded-- just like the pineapple demonstration I did in class.

Consider the white of an egg that changes from jiggly and transparent to solid and white. Scientists went through a lot of effort to figure out how to “unboil” an egg (there is a hyperlink here-- find it on Blackboard)... Why do you think it is relatively easy for us to denature proteins, but difficult to **renature** (refold) them (2 pts)?

Why should we care about figuring out how to “unboil” an egg (2 pts)?