DNA and Protein Synthesis Concept Questions

1. Describe the structure and function of nucleotides. (Nucleotides are the monomers which make up nucleic acids. They consist of a five carbon sugar, a phosphate and a nitrogen base.)

2. Describe how the work of Hershey and Chase, Chargaff, and Wilkins and Franklin contributed to the discovery by Watson and Crick of the double helix. (Hershey and Chase used a bacteriophage to show that DNA was the genetic material. By measuring the amounts of the four nucleotides in different DNA samples, Chargaff showed that A=T and C=G, suggesting to Watson and Crick that the bases might be in complementary pairs inside the helix. Wilkins and Franklin used X-ray crystallography to produce data showing the structure of DNA.)

3. While you're trying to enjoy your lunch one day, your friend says she is working on an art project about DNA and needs to understand a little bit about the structure. Describe it for her. (DNA is a double helix, meaning it consists of two strands twisted around one another like a rope ladder. Each strand is made of nucleotides, consisting of a phosphate, a five carbon sugar and a nitrogenous base. The nucleotides are linked together in long chains (or strands) and the strands are arranged such that the phosphates and sugars make up the sides of the ladder while the nitrogenous bases pair together forming the rungs. The base A always bonds with the base T, while C always bonds with G.)

4. Explain why DNA replication is important for every cell. (Each daughter needs a complete copy of the full genome.)

5. Predict the amount of DNA you would expect to find in a brain cell compared to a muscle cell. Provide justification for your answer. (They are the same because during cell division all the DNA is copied.)

6. a) Provide reasoning for referring to the making of exact copies of DNA as replication rather than duplication. (In duplication we think of having the copy and the original. DNA replication is semi-conservative meaning that each daughter molecule is composed of one new strand and one parent strand.)
   b) Explain why DNA replication is referred to as semi-conservative. (Each daughter molecule is composed of one new strand and one parent strand.)

7. Provide an explanation for the difference in the construction of DNA on the leading strand compared to that on the lagging strand. (DNA polymerase works by adding nucleotides to the 3' end of a growing chain (*i.e.*, 5'-3'). Because the strands are antiparallel, this is only possible on the leading strand. The lagging strand must be synthesized in short segments.)

8. In prokaryotes, DNA pol III constructs new DNA and DNA pol I replaces the RNA primer with DNA.
   a)Predict the effect on DNA synthesis of exposure of a cell to a drug that completely inhibits DNA pol III. (The strands would be separated and primers would be constructed but the cell would be unable to synthesize new DNA.)
   b) Predict the effect on DNA synthesis of exposure of a cell to a drug that completely inhibits DNA pol I. (The newly synthesized strands of DNA would contain RNA primers because they would not be replaced with DNA.)

9. Human DNA contains approximately $3x10^9$ base pairs and DNA polymerase can work at the rate

of about 50 nucleotides per second. Given these facts, explain how your DNA can be replicated in only a few hours. (There are many origins and replication proceeds on both strands in both directions, using many molecules of DNA polymerase.)

10. A certain chemical is known to fuse thymine with adenine in DNA. Predict the effects of exposure to this chemical on DNA replication and transcription. (If they were on the same strand they would be impossible for DNA polymerase to read because they would be fused together. If they are on different strands helicase couldn't separate the strands. Also, without separating the strands, protein synthesis would not be possible.)

11. A particular sample of DNA contains 27 percent adenine. Predict the percentages of thymine, cytosine, and guanine. (27%, 23%, and 23%)

12. Explain the importance of the enzymes that identify and repair base-pairing errors in DNA. (DNA polymerase must be able to recognize four different substrates so base-pairing errors occur naturally. If they were not corrected, these mutations would accumulate with each cell division.)

13. Explain how DNA profiling can be used to match a person to a DNA sample. (A DNA sample from an individual is cut up using a restriction enzyme. The strands are separated using gel electrophoresis and stained for visualization. Each individual would produce a unique pattern of bands which can be used to identify him or her. By comparing the profile from a person to an unknown DNA sample we can determine if the sample is from that person.)

14. As a research biologist, you know of a bacterium that produces an antifungal molecule that is quite effective against a certain crop plant fungus. There would be great economic importance in enabling the plant to resist the fungus. Describe how DNA technology could be used to accomplish this. (The gene for the antifungal would be isolated and inserted into a plasmid and bacterial cells could be induced to accept the plasmid. Once cells had the plasmid they could produce the antifungal molecule. Alternatively, the gene could be inserted cells of the plant and complete plants grown from these cells. In this way, the plant would produce the molecule on its own.)

15. Describe the difference between a gene and a chromosome. (A gene provides the instructions to construct a single protein. A chromosome is a piece of DNA that can consist of hundreds or thousands of genes.)

16. Describe how DNA and RNA differ in their composition, structure, function, and location. (The composition of the two differs in that DNA contains deoxyribose and T while RNA contains ribose and U. Their structures are different in that DNA is double stranded while RNA is single stranded. The function of DNA is to act as the genetic information while mRNA is the copy of a gene, rRNA forms part of the ribosome, and tRNA brings amino acids to the ribosome during translation.)

17. a) Describe the purpose of each of the two major steps in protein synthesis. (Transcription makes a mRNA copy of a gene. Translation changes it from nucleic acid to amino acid language.)
    b) Identify the location of each of the steps in the cell. (Transcription occurs in the nucleus. Translation occurs in the cytosol.)

18. Identify the similarities and differences between DNA replication and transcription. (During replication the entire genome copied, making new DNA. In transcription one gene is copied, making mRNA.)

19. Explain the role played by each of the following in protein synthesis.
    a) coding strand of DNA (The coding strand contains the instructions to make a protein. Remember it is the template strand (complimentary to the coding strand) that is actually copied into mRNA.)
    b) RNA codon (Each RNA codon corresponds to an amino acid as designated in the genetic code.)
    c) RNA polymerase (RNA polymerase is the enzyme that makes mRNA.)
    d) ribosome (A ribosome attaches each new amino acid to the growing polypeptide.)
    e) rRNA (Ribosomes consist of RNA and protein. The RNA is called rRNA.)
    f) tRNA (Translates the mRNA having an anticodon and an amino acid attachment site.)

20. a) Identify the language change that occurs during translation. (nucleic acid to amino acid)
    b) Explain how it is possible to construct a polypeptide with the correct sequence of amino acids. (The mRNA is read one codon at a time, so that amino acids can be connected in order.)

21. For the DNA triplet CGT, write the complementary mRNA codon and the tRNA anticodon. Identify the amino acid coded by the DNA triplet GCA. (GCA, CGU, arg)

22. a) Describe the difference between a codon and a DNA triplet. (A codon and the DNA triplet from which it was made are complementary but if the triplet contained A, the codon would contain U instead of T.)
    b) Describe how an anticodon differs from a DNA triplet. (An anticodon and the DNA are the same (but the anticodon would contain U instead of T) because they are both complementary to the codon.)

23. a) Describe the effect of a mutation in DNA that changed the start codon in the resulting mRNA. (Without a start codon translation could not start so the polypeptide would not be made.)
    b) Describe the effect of a mutation in DNA that changed the stop codon in the resulting mRNA. (The polypeptide would be too long because the ribosome would continue moving along the mRNA.)
    c) Predict the effects of these mutations on the cell in which they occurred. (The effect of the mutation in both cases depends on the importance of the protein affected.)

24. Describe the effect of the nucleotide sequence of DNA on the cell. (The DNA sequence determines which proteins are made and the order of amino acids for each polypeptide.)

25. Cells are genetically modified to be unable to synthesize uracil. In an experiment, the cells are grown on a medium lacking uracil and a chemical of similar shape is supplied in its place. Predict the effect on protein synthesis in these cells. (Any codon with U would not be transcribed, although if the chemical were similar enough maybe it would be used instead so there would be no effect. This would likely be catastrophic because any codon with a U would not be transcribed, including the start codon.)

26. In eukaryotic cells, mRNAs have been found that have a circular shape with proteins holding one end of the mRNA near the other. Explain how this structure might increase the efficiency of translation. (When the ribosome finishes translating the mRNA, it would be very close to the

beginning which might facilitate its binding to the mRNA to translate it again.)

27. A molecular biologist discovers a drug that blocks the site of attachment of the ribosome to mRNA. Predict the effect on a cell of exposure to this drug. (The drug would stop protein synthesis.)

28. a) Identify some common mutagens. (Mutagens fall into one of three major categories: viruses, chemicals, and radiation.)
b) Describe the effects they can have on protein synthesis. (These mutagens can cause point mutations which result in an incorrect amino acid being included in a protein (missense mutation), a stop codon being formed (nonsense mutation), or the loss of a start codon so that protein is not made at all. Because of redundancy in the genetic code a point mutation can also result in the same amino acid being included.)
c) Describe some situations in which one might be exposed to such mutagens. (Radiation exposure comes from UV solar radiation and medical and dental X-rays. Environmental exposure to a wide range of chemicals including pesticides is nearly unavoidable. Viruses pose a constant risk.)