DNA and Protein Synthesis Concept Questions

1. What are nucleotides? Describe their structure. (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. How would you 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. Why is DNA replication important for every cell? (Each daughter needs a complete copy of the full genome.)
5. Would you expect a brain cell and a muscle cell to have the same amount of DNA? Justify your answer. (They are the same because during cell division all the DNA is copied.)
6. a) Why is the making of exact copies of DNA called 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) What is meant by saying that DNA replication is semi-conservative? (Each daughter molecule is composed of one new strand and one parent strand.)
7. Why is construction of DNA on the leading strand different from 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.)
8. If human DNA contains approximately $3x10^9$ base pairs, and DNA polymerase can work at the rate of about 50 nucleotides per second, how can our DNA be replicated so quickly? (There are many origins and replication proceeds on both strands in both directions, using many molecules of DNA polymerase.)
9. A certain chemical is known to fuse thymine with adenine in DNA. Comment on the expected 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.)
10. If 27 percent of the bases in a certain segment of DNA were adenine, what would be the percentages of thymine, cytosine, and guanine. (27%, 23%, and 23%)
11. Proofreading enzymes scan DNA to check for base pairing errors. Explain why these enzymes are important. (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.)

12. Describe the technique of DNA profiling. (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.)
13. 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. How might you use DNA technology 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.)
14. A segment of DNA providing instructions for the synthesis of one protein is a _____. (gene) Many genes are located on a piece of DNA called a _____. (chromosome)
15. 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.)
16. a) Briefly, what is accomplished by 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) Where in the cell does each one occur? (Transcription occurs in the nucleus. Translation occurs in the cytosol.)
17. Compare and contrast DNA replication and transcription. (During replication the entire genome copied, making new DNA. In transcription one gene is copied, making mRNA.)
18. 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.)
19. a) During the process of translation what language change occurs? (nucleic acid to amino acid)
b) How is it possible to put together 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.)
20. For the DNA triplet CGT, write the complementary mRNA codon and the tRNA anticodon. What amino acid does the DNA triplet GCA represent? (GCA, CGU, arg)
21. a) How does a codon differ from 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) How does an anticodon differ 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.)
22. a) Describe the effect if a mutation in DNA 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 if a mutation in DNA changed the stop codon in the resulting mRNA What would be the effect on translation if the stop codon were changed by mutation? (The polypeptide would be too long because the ribosome would continue moving along the mRNA.)
23. What effect does the nucleotide sequence of DNA have on the cell? (The DNA sequence determines which proteins are made and the order of amino acids for each polypeptide.)

24. Suppose that during protein synthesis, a cell is starved of uracil and another chemical of similar shape is supplied in its place. How will the proteins produced be affected by this substitution? (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.)
25. In eukaryotic cells, mRNAs have been found to have a circular shape with proteins holding one end of the mRNA near the other. How might this increase translation efficiency? (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.)
26. A molecular biologist discovers a drug that blocks the site of attachment of the ribosome to mRNA. How will the drug affect the functioning of the cell? (The drug would stop protein synthesis.)
27. a) Name some common mutagens? (Carcinogens fall into one of three major categories: viruses, chemicals, and radiation.)
b) What effects can they have? (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) Where or when might one be exposed to them? (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.)