From Gene to Protein
Chapter 17

1. Protein synthesis occurs in two stages: transcription and translation. State the location and the purpose of each. (Transcription occurs in the nucleus; translation occurs in the cytosol. The purpose of transcription is to make an RNA copy (called mRNA) of the information in DNA. The purpose of translation is to produce a polypeptide from the information in the mRNA.)

2. Describe the relationship between a DNA triplet and a codon. (A codon is complementary to a DNA triplet.)

3. A segment in the middle of an mRNA has the sequence 5'-AGAGAACCGCGA-3'. Translate this sequence, assuming it is downstream of the start codon.

4. Explain how the universal nature of the genetic code provides evidence of evolution. (A language that is shared by all living things must have been in use very early in the evolution of life – likely in the common ancestor of all living things.)

5. The template strand of a gene contains the sequence 3'-TTCAGTCGT-5'. Imagine that the nontemplate sequence was transcribed instead of the template sequence. Draw the mRNA sequence and translate it (Be sure to pay attention to the 5' and 3' ends.) Predict how well the protein synthesized from the nontemplate strand would function. (Nontemplate sequence: 3'-ACGACTGAA-5' (this strand incorrectly serves as the "template" in this scenario). mRNA: 5'-UGCUGACUU-3'. Polypeptide: Cys-stop. This polypeptide would have no function.)

6. Compare the use of a template strand during transcription and replication. (The processes are similar in that polymerases form polynucleotides complementary to an antiparallel DNA template strand. In replication, however, both strands act as templates, whereas in transcription, only one DNA strand acts as a template.)

7. a) Describe a promoter. State whether you would expect to find a promoter at the upstream or downstream end of a transcription unit. (A promoter is the region of DNA to which RNA polymerase binds to begin transcription. It is at the upstream end of the gene (transcription unit).)

   b) Describe how RNA polymerase is able to start transcribing a gene at the right place on the DNA in a prokaryotic cell and in a eukaryotic cell. (In a bacterial cell, part of the RNA polymerase recognizes the gene's promoter and binds to it. In a eukaryotic cell, transcription factors must bind to the promoter first, then the RNA polymerase binds to them. In both cases, sequences in the promoter determine the precise binding of RNA polymerase so the enzyme is in the right location and orientation.)

   c) Imagine radiation is used to cause a substitution mutation in the TATA box of a gene's promoter. Describe the expected result on the transcription of the gene. (The transcription factor that recognizes the TATA sequence would be unable to bind, so RNA polymerase could not bind and transcription of that gene probably would not occur.)

8. Imagine that groups of cells are treated with two different chemicals. One removes the 5' cap from mRNAs while the other prevents the addition of a poly A tail. Describe the effect on each group of cells. (The cap and tail protect the mRNA from being degraded by hydrolytic enzymes. The absence of them would severely limit protein synthesis and the cells would likely die.)

9. Humans have about 20,000 genes coding for proteins, yet human cells are able to make between 75,000-100,000 different proteins. Explain how RNA splicing makes this possible. (Alternative splicing of exons allows genes to produce several different mRNAs and thus direct the synthesis of several proteins.)

10. Imagine you've recorded your favorite show on your PVR and are sitting down to watch it. Describe how RNA splicing is similar. Identify what are analogous to introns. (You only watch segments of the show (the exons) and skip the commercials (the introns). Of course, the introns remain part of the recording whereas they are actually removed during RNA splicing.)

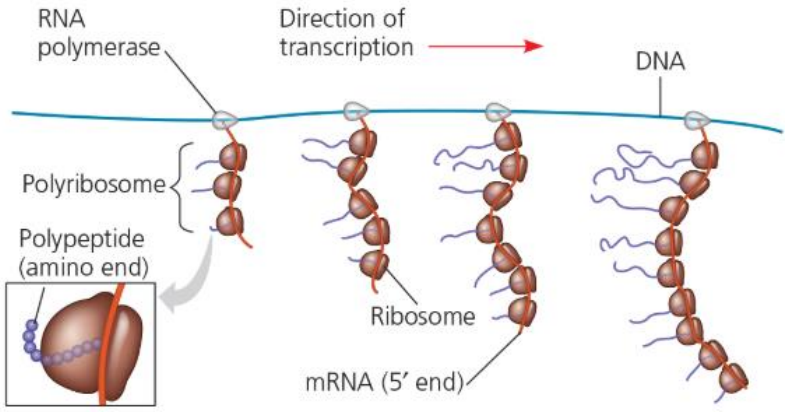
11. As introns are not translated into protein, they seem wasteful and you might predict that natural selection would eliminate them. Explain why this has not happened. (The presence of introns allow exons to be spliced together in a variety of orders, which facilitates the evolution of novel proteins. Introns also allow increased crossing over between the exons of alleles of a gene without interrupting coding sequences. Exons of completely unrelated proteins can also be put together, leading to novel proteins.)

12. Describe the features of a tRNA that allow the molecule to ensure that the correct amino acid is added to a growing polypeptide. (First, each tRNA attaches to a specific amino acid at the amino acid attachment site. Second, each tRNA binds only to a specific mRNA codon, corresponding (as identified in the genetic code) to the amino acid it is carrying.)

13. Consider the tRNA with the anticodon 3'-AAG-5'. identify the codon it would bind to, as well as the amino acid that it would carry. (It would bind to the codon UUC and carry the amino acid Phe.)

14. a) Describe how a polypeptide to be secreted reaches the endomembrane system. (A signal peptide on the end of the polypeptide is recognized by a signal recognition particle that brings the ribosome to the ER membrane. The ribosome attaches to the ER and the polypeptide enters the ER lumen.)

    b) If a protein is to be secreted from a cell, describe what would happen to it after its synthesis were complete. (It would be packaged in a vesicle, transported to the Golgi apparatus for further processing, and then transported via a vesicle to the plasma membrane. The vesicle would fuse with the membrane, releasing the protein outside the cell.)



15. In prokaryotes, which lack a nucleus, transcription and translation are not temporally (or spatially) separated. In the diagram above, identify which of the mRNA molecules started being transcribed

first. On that mRNA, identify which ribosome started translating the mRNA first. (The mRNA farthest to the right (the longest one) started transcription first. The ribosome at the top, closest to the DNA, started translating first and thus has the longest polypeptide.)

16. Draw a tRNA with the anticodon 3'-CGU-5'. Identify the two different codons it could bind to. Identify the amino acid that would be added to the polypeptide in each case. (Because of wobble, the tRNA could bind to either 5'-GCA-3' or 5'-GCG-3', both of which code for alanine.)

17. In eukaryotic cells, mRNAs have been found to have a circular shape with proteins holding one end of the mRNA near the other. Explain how this might 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.)

18. Describe how a point mutation can result in the wrong amino acid being added to a polypeptide. (When one nucleotide is substituted for another, it results in a different codon which might code for a different amino acid.)

19. a) Identify the cause of a frameshift mutation. (The insertion or deletion of one or two nucleotide pairs.)

    b) Explain why frameshift mutations are especially harmful. (The reading frame downstream would be shifted, leading to a long series of incorrect amino acids.)

20. Individuals heterozygous for the sickle-cell allele are generally healthy but can show some symptoms when blood oxygen is low. Explain this in terms of gene expression. (Heterozygous individuals, said to have sickle-cell trait, have a copy each of the wild-type allele and the sickle-cell allele. Both alleles will be expressed, so these individuals will have both normal and sickle-cell hemoglobin molecules. Apparently, having a mix of the two forms of β-globin has no effect under most conditions, but during prolonged periods of low blood oxygen (such as at higher altitudes), these individuals can show some signs of sickle-cell disease.)

21. The template strand of a gene includes the sequence 3'-TACTTGTCCGATATC-5'. It is mutated to 3'-TACTTGTCCAATATC-5'. For both the wild-type and mutant sequences, write the resulting mRNA and the amino acid sequence encoded. Describe the effect of the mutation on the amino acid sequence. (There is no effect. The amino acid sequence is Met-Asn-Arg-Leu-stop before and after the change. This is a silent mutation because the mRNA codons CUA and UUA both encode Leu. Notice the fifth codon is a stop codon.)

22. Knowing the genetic code is universal, a molecular biologist inserts the human β-globin gene into bacterial cells with the intention of having the cells express it and produce functional β-globin protein. Instead, the protein is non-functional and contains many more amino acids than the protein produced by human cells. Propose an explanation for this observation. (Prokaryotic cells do not use RNA processing and so have no means to remove introns from the transcribed human gene. The introns were translated.)