Interesting Problems

Problem 1

True or False:

a) It is possible for an RNA polymerase molecule and a ribosome to be attached to a eukaryotic mRNA simultaneously.
b) At no time during protein synthesis does an amino acid make direct contact with the mRNA being translated.
c) Because the two strands of DNA are complementary, the mRNA of a given gene can be synthesized using either strand as a template.

Problem 2

a) In how many cases in the genetic code would you fail to know the amino acid specified by a codon if you knew only the first two nucleotides of the codon?
b) In how many cases would you fail to know the first two nucleotides of the codon if you knew which amino acid is specified by it?

Problem 3

Which of the following mutational changes would be predicted to harm an organism? Explain your answers.

a) Insertion of a single nucleotide near the end of the coding sequence (CDS).
b) Removal of a single nucleotide near the beginning of the CDS.
c) Deletion of three consecutive nucleotides in the middle of the CDS.
d) Deletion of four consecutive nucleotides in the middle of the CDS.
e) Substitution of one nucleotide for another in the middle of the CDS.

Problem 4

The Sonrisa protein is a hypothetical protein that causes people to smile more often. It is inactive in many chronically unhappy people.
The mRNA isolated from a number of different unhappy persons in the same family was found to lack an internal stretch of 173 nucleotides that is present in the Sonrisa mRNA isolated from a control group of generally happy people.
The DNA sequences of the Sonrisa genes from the happy and unhappy families were determined and compared. They differed by just one nucleotide change – and no nucleotides were deleted. Moreover, the change was found in an intron.

What can you say about the molecular basis of unhappiness in this family?

Problem 5

a) Complete the following table. Assume that

- the reading is from left to right
- the columns represent transcriptional and translational alignments

C												**DNA double helix**
						T	G	A				
	C	A				U						**mRNA transcribed**
									G	C	A	**Appropriate tRNA anticodon**
			Trp (W)									**Amino acids incorporated into protein**

b) Label 5' and 3' ends of DNA and RNA, as well as the amino and carboxyl ends of proteins. [*Introduction to Genetic Analysis* by Griffiths et al., 2005]

Problem 6

A single nucleotide addition followed by a single nucleotide deletion approximately 15 bp apart in the DNA causes a change in the protein sequence from sequence a to sequence b:

a) Lys – Ser – Pro – Ser – Leu – Asn – Ala – Ala – Lys
b) Lys – Val – His – His – Leu – Met – Ala – Ala – Lys

1) Which nucleotide has been added and which nucleotide has been deleted?

2) What are the original and the new mRNA sequences?

[*Theory and Problems of Genetics* by W. D. Stanfield, 1969]

Problem 7

Consider the gene that specifies the structure of hemoglobin. Arrange the following events in the most likely sequence in which they would take place.

a) Anemia is observed.
b) The shape of the oxygen-binding site is altered.
c) An incorrect codon is transcribed into hemoglobin mRNA.
d) The ovum (female gamete) receives a high radiation dose.
e) An incorrect codon is generated in the DNA of the hemoglobin gene.
f) A mother (an X-ray technician) accidentally steps in front of an operating X-ray generator.
g) A child dies.
h) The oxygen-transport capacity of the body is severely impaired.
i) The tRNA anticodon that lines up is one of a type that brings an unsuitable amino acid.
j) Nucleotide-pair substitution occurs in the DNA of the gene for hemoglobin.
[*Introduction to Genetic Analysis* by Griffiths et al., 2005]

Problem 8

The following double-stranded DNA sequence is part of a hypothetical yeast genome which happens to contain a very small gene. Transcription starts

at the Transcription Start Site (TSS), proceeds in the direction of the arrow and stops at the end of the Transcription Terminator (the boxed region).

a) Which strand of DNA shown, the top or the bottom, is the template strand?

b) What is the sequence of the mRNA produced from this gene? Label the 5' and 3' ends.

c) What is the sequence of the protein produced from the mRNA in (b)? Label the N and C termini.

d) If a mutation (an insertion) were found where a T/A (top/bottom) base pair were added immediately after the T/A base pair shown in bold, what would be the sequence of the mRNA? What would be the sequence of the protein?

Problem 9

The following double-stranded bacterial (E. coli) DNA sequence codes for a hypothetical protein. Both strands are shown; the top strand reads 5' to 3' left to right, while the bottom strand reads 5' to 3' right to left. The nucleotides are numbered 1 to 100. NOTE: Transcription begins with and includes the underlined C/G (top strand/bottom strand) base pair in position 9, and the RNA polymerase proceeds from left to right along the DNA.

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    1                   20                  40
5'-GTGTCCGTCTAATATTGTGAGATGTTATATCCCGCCGTCAACACCATCAA-3'
   ---------+---------+---------+---------+---------+
3'-CACAGGCAGATTATAACACTCTACAATATAGGGCGGCAGTTGTGGTAGTT-5'

              60                  80                  100
5'-ACAGGATAATCGCCTGCTGGGGCAAAGGCGGTGAAGGTAAAGGTGTTGCC-3'
   ---------+---------+---------+---------+---------+
3'-TGTCCTATTAGCGGACGACCCCGTTTCCGCCACTTCCATTTCCACAACGG-5'
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a) Which strand is used as a template for transcription, the top or the bottom?

b) Where would the promoter be relative to the start of transcription?

c) What are the first 15 nucleotides of the resulting mRNA? Indicate the 5' and 3' ends.

d) What are the first 5 amino acids translated from the resulting mRNA? Indicate the amino and carboxyl termini of the protein.

e) Do the underlined nucleotides TAA encode a stop codon for the protein? Explain your answer.

Consider the situations in parts (f-h) independently.

f) A mutation occurs which results in the insertion of an extra G/C (top strand/bottom strand) base-pair immediately after base pair 11 (A/T shown in bold). What effect will this insertion mutation have on the mRNA transcript and on the resulting protein?

g) A different mutation results in the substitution of the T/A base pair at position 30 (shown in bold and underlined) with a G/C base pair. How would this mutation affect the sequence of the protein that is produced?

h) A different mutation occurs which results in the substitution of the C/G base pair at position 42 (shown in bold italics) to a T/A base pair. How would this mutation affect the sequence of the protein that is produced?

Problem 10

A mutation is found in a tRNA-encoding gene. The wild type allele produces a tRNA that recognizes the codon GAA, and is charged with the amino acid glutamic acid (Glu). The mutant tRNA is still charged with Glu, but the anticodon is mutated such that it recognizes the codon UAA. What effect will this have on translation in these cells? How will the proteins produced be different?

[Problems 8, 9, 10 are adapted from *Fundamentals of Biology* by E. Lander et al., 2012]