Reading the Code

1. What question about reading DNA code did Marshall Nirenberg answer using the cell-free system developed by Zamecnik and Hoagland?

   Does mRNA stimulate protein synthesis?

2. What question does Sydney Brenner ask in "Defining the gene?" Explain why this was an important question to understand how DNA codes for protein.

   How does the sequence of bases correspond to the sequence of amino acids? This question was an important one because a gene could then be defined as a length of DNA.

3. George Gamow thought that three bases in DNA corresponded to one amino acid. To confirm this idea, Marshall Nirenberg used a synthetic RNA containing only one kind of base. What question was his experiment attempting to answer?

   Would a synthetic RNA containing one kind of base stimulate the synthesis of a protein containing one kind of amino acid?

4. List five DNA code questions that, according to Marshall Nirenberg, are still unanswered.

   How did the code originate?
   Is there a reason UUU codes for phenylalanine?
   Is there a physical reason for the code?
   Did the code evolve from a series of precursor codes?
   Was the origin of the code one rare event that was then maintained throughout evolution?

5. Briefly describe Seymour Benzer's experiment that answered the question: "Do mutations in the DNA sequence of a gene correlate with protein changes?"

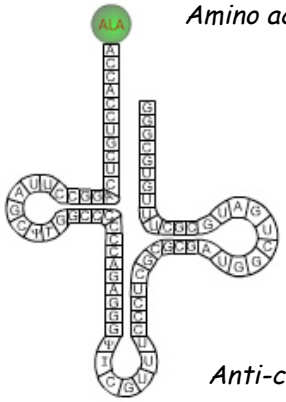
   Benzer realized that a gene was actually a sequence of DNA, not a bead-like structure and thus crossing over could occur within a gene. He used virus mutants from different cultures. Each had a mutant rII gene. Both mutants injected their DNA into a bacterial cell where the DNA replicated and some crossing over occurred. Benzer found some recombinant DNA that did not have a mutant rII gene and that crossing over had occurred within the gene. He found that a change in one nucleotide could cause a change in one amino acid whereas a frame shift mutation caused a greater change in the amino acid sequence. Therefore, changes in the DNA sequence correlated with the amino acid sequence.

6. Marshall Nirenberg and Heinrich Matthaei used mRNA made up of repeating uracil nucleotides in a cell free extract. They obtained amino acid chains consisting of phenylalanine. What did they learn when they asked the question, "What happens when mRNA made up of only cytosine, alanine, and quanine are placed in a cell free extract?"

   They found that different amino acid chains were produced when alanine and cytosine were used. No amino acid chain resulted when guanine was used.

7. Explain how the structure of tRNA helps it to deliver the correct amino acid to the corresponding mRNA codon at the ribosome. Sketch the structure of a tRNA molecule, making sure to label the amino acid and the anti-codon.

   tRNA is single-stranded and cloverleaf shaped. On one of the three "leaves," there is a sequence of three nucleotides, called an anti-codon, which base pairs with a specific mRNA codon. An amino acid binds to the "stem" at the other end of the molecule.



8. List or draw sequentially the steps involved in protein synthesis. Start with the DNA code in the nucleus, and try to end up with a polypeptide in 10 steps. Title your work "10 easy steps to synthesizing your protein."

   1. *In the nucleus, the DNA code is transcribed into a complementary mRNA molecule;*
   2. *mRNA enters the cytoplasm where it associates with a ribosome. The mRNA code is then translated into a polypeptide chain;*
   3. *The codon AUG signals the start of translation;*
   4. *An activated tRNA brings methionine (the first amino acid) to the ribosome;*
   5. *The tRNA anti-codon binds to the AUG codon on the mRNA;*
   6. *The complex shifts and the next codon is read by another tRNA;.*
   7. *Peptide bonds form between the first two amino acids;*
   8. *The second tRNA accepts the growing polypeptide chain;*
   9. *The process continues until it reaches a STOP codon;*
   10. *The ribosome disassembles and the polypeptide chain is released.*

9. Explain why a mutation that occurs in a codon may not result in a change of an amino acid in the protein sequence. Use the genetic code chart to give an example of how this might occur.

   As there is usually more than one codon for an amino acid, a mutation in the third base of a codon will often not cause the wrong amino acid to be inserted into the chain. See the genetic code table for examples.

10. **(advanced)**

a) Explain why using mRNA composed of only uracil nucleotides (UUUUUUUUUU) did not conclusively prove that the DNA code was a triplet code.

Since the code was the same, you couldn't tell if it was based on groups of 2, 3, 4, or more uracils. UU or UUU or UUUU would all provide the same amino acid sequence.

b) Would using a mRNA sequence such as UGUGUGUGU provide more evidence for a triplet code? Use this sequence to predict the result if the code is a triplet.

If the code is a triplet code, the message would be UGU-GUG-UGU, etc. There would be two different amino acids in the chain produced. These would be CYS and VAL.

c) How would the resulting protein differ if it was based on two (a doublet) or four bases at a time rather than three?

If the code were based on either two or four bases, the resulting amino acid chain would be made up of only one kind of amino acid. The message the code would send out is UG – UG – UG, or UGUG – UGUG – UGUG - etc.