Chapter 0

These are open-ended and time-dependent questions; hence, answers are not provided. However, some notes or reminders may be useful. They do engage students early in a course, and I have found that many do pursue REU and other opportunities after gaining the exposure provided in these questions. For the accreditation of engineering programs, ABET now likes to see documented outcomes. Assigning these exercises and keeping some samples could be helpful in documenting that your program attempts to address and assess ethics, knowledge of contemporary engineering issues/developments, etc.

Chapter 1

1. (a) If our DNA contained combinations of three bases instead of four, how many amino acids could be encoded when a codon contains one, two, or three bases?

Number of words = n(letters)$^{m(\text{word length})}$
$3^1 = 3$; $3^2 = 9$; $3^3 = \mathbf{27}$. Can cover the coding of 20 amino acids with three bases and by using a triplet to code for a particular amino acid

(b) Why do you suppose living systems use 4 bases instead of 3 bases in the genetic code?

With four bases and more synonyms, the system is more robust. A mutation could wind up coding for the same amino acid, and the same protein would be made. Also stop and start signals can be composed of additional "words."

2. If a cell is maintaining 200 proteins and the average number of amino acids per protein is 75, what is the total number of A, G, C, and T bases used to code for the construction of the proteins?

200 prot * 75 AA/prot * 3 bases/AA = 45,000 bases.

3. Match the statement on the left with the best analogous match on the bottom

A car is either a Toyota or a Ford.	a_____
The Naval Tomcat aircraft was based on the F14 prototype.	d_____
Ford water pumps do not work in Toyotas.	b_____
Each musical measure has the same number of beats.	e_____
A taped message in Mission Impossible incinerates after it is read.	c_____

(a) Taxonomy (b) 16S RNA gene in archaea vs. eucarya (c) mRNA lifetime (d) Phylogeny (e) codon triplet (f) universal genetic code (g) Prions.

4. Which compound(s) below would *not* likely be used by a heterotroph for energy?

   (a) carbon dioxide (b) glucose (c) methane (d) fructose (d) reduced iron (Fe^o)

Cannot oxidize carbon dioxide further and Fe^o is not an organic, C-containing compound.

5. A microbe was found in a fossilized meteor in Antarctica. It appears to have a DNA-like molecule made of 5 different types of base-like molecules. An analysis of other molecules suggests that 25 different amino acid-like molecules make up something that resembles proteins. If there is a genetic code in use, then what is the minimum number of base molecules per codon? Why is the value a minimum?

   $5^2 = 25$, so with two bases per codon, can cover minimally. More bases per codon would provide more redundancy/degeneracy as well as start and stop signals.

6. If the yield for the growth of *E. coli* on glucose is 0.3 g cell (water-free basis)/g glucose, answer the following:

   (a) What will be the mass concentration of *E. coli* on a water-free basis when provided 5 g glucose/liter?

5 g gluc/lit * 0.3 g cell dry wt/g gluc = **1.5 g cell dry wt/lit.**

   (b) What will the total mass of *E. coli* per liter?

1.5 g cell dry wt * 1 g cell total (hydrated)/0.3 g cell dry wt = **5 g cell total/lit.**
Note: In any multicomponent system, concentrations can be on different bases just as income can be on a pre-tax or after-tax basis. A good engineer always asks what basis a concentration or other number is on to make sure everyone is talking about the same thing.

7. Assume that a typical protein has 100 amino acids and a "ballpark" molecular weight for an amino acid is 100 g/mol. How many protein molecules are present per 70 kilograms (i.e., average weight of a human) of hydrated animal cells? If a protein's

typical dimension is 10 Angstroms (1 A = 10^{-8} cm), could the distance between Pittsburgh and Los Angeles be spanned by aligning the protein molecules end-to-end?

100 mol AA/mol prot * 100 g/mol AA * 1 g prot/g AA = 10^4 g prot/mol prot.

70,000 g person * 0.3 g solid/g person * 0.6 g prot/g solid * mol prot/10^4 g prot * 6.0 (10^{23}) molecules/mol = 7.56 (10^{23}) protein molecules.

A protein is about 10 Angstroms in size (10^{-7} cm), which means if all these proteins were laid end to end the total length would be 7.56 (10^{23}) protein molecules * 10^{-7} cm/prot molecule * m/10^2 cm * km/10^3 m = **7.56 (10^{11}) km**, which will get one from California and back quite easily.

8. What type of cell on average has more transcription going on, a growing bacterial cell or a stem cell residing in the bone marrow?

Bacterial cell. Stem cells are typically quiescent and undergo division and differentiation only when required for development or repair.

9. Where would one most likely look to isolate a new *Archaea*--spoiled hamburger or in a boiling hot spring in Yellowstone National Park?

While spoiled hamburger can be pretty nasty, some environments in Yellowstone are more akin to early Earth and present the environmental extremes that Archaea are adapted to.

10. Identify what is not true about the following statement: *Bacteria and animal cells use the same genetic code (i.e., codons) to store protein "recipes" and use the same ribosomal machinery to translate the information into functional proteins*.

The genetic code is fairly conserved, so that part is true. If that were not true, bacteria would not be able to produce human or other proteins, and rDNA technology would be not be as advanced as it is. The parts of the ribosomal machinery do, however, exhibit differences. The similarities and differences are now used as the basis for modern taxonomy.

11. Assume a cell possesses 1000 genes, but at any point in time, ten percent are being used (i.e., "expressed"). If a typical protein has 100 amino acids, what is the total number of A, G, C, and T bases that encode the cell's (a) expressed and (b) total genetic repertoire?

(a) 1000 (0.1) genes expressed * 1 prot/gene * 100 aa/prot * 3 bases/aa = **3 10^4.**

(b) total repertoire = **3 10^5.**

12. A codon in a Martian bacterium contains combinations of four of the five base-like molecules that makes up what passes for Martian DNA. An average bacterium on Earth has 4000 genes. On Mars life is quite different; hence, a larger repertoire of 6000 genes is needed to provide flexibility. By what factor is the DNA larger in a Martian bacterium compared to an Earthling bacterium? Assume a Martian protein contains about as many amino acids as an Earthling protein.

(a) 1.2 (b) 1.33 (c) 1.67 (d) 2.0 (e) 2.66

Application of basic modern biology. Information is stored in DNA. Each gene codes for a protein. A codon specifies each part (amino acid) of the protein. A codon possesses three bases on Earth. So the Martian DNA is larger than Earth's by

(6000/4000)* (4/3) = 24/12 = **2** = (factor of more genes) (factor by how much larger codons are).

13. A new organism may have been found in the University Center dining hall in the cole slaw. What is the best thing to do *first* to characterize the new cell?

(a) Sequence the entire genome.

(b) Measure mRNA stability.

(c) Look for similarity with the 16S RNA encoding stretch of DNA in other known organisms.

Modern biology is based on molecular determinism. A key concept is that cells are classified into three groups (Bacteria, Eucarya, and Archaea). They can be distinguished by not having "interchangeable" 16S RNA. If the cell appears to be "new," then it seems first "best" thing to do is to see which family it belongs to, before getting into more detailed studies. So answer (c) makes the most sense. Another way to view this is that genome sequencing is expensive so eliminate (a). Other data are meaningless if you do not even know what kind of organism it is.

WEB-BASED MATERIAL EXERCISES & RESEARCH

W1. Visit the Protein Data Bank. What is the "Molecule of the Month?" What role does it play in a cell, and in general terms, how does the molecule work?

In November 2008, mechanosensitive channels were featured. These proteins open and close an internal channel in response to the mechanical forces a cell experiences. One can imagine a fist opening and closing and in the process, the "hole the hand makes" opens and narrows. The opening and closing, in turn,

allows for water to enter and leave a cell. Water movement is important because it allows the cell to adjust to changes in the osmotic strength of the environment.

W2. The basic work of Theodor (The) Svedberg on colloid systems has made a significant impact on life science where, for example, people now speak of "16S RNA." Via the Companion Website, obtain and read Svedberg's biography on the web to learn more about him. Report on the following

(a) He constructed a device that allowed him to investigate colloid and macromolecule systems in a new way. What is the device called and what does it do?

The device is an ultracentrifuge. It fractionates molecules and colloids according to size. He found, for example, a given protein has a particular size. Now that we know about genes and codons, that makes sense. At the time, it was quite an interesting finding.

(b) Did he seem to be a boring or interesting person?

He had interesting hobbies (painting, botany). He was married a number of times, had 12 children, so one could conjecture that he was pretty interesting. How he could do all that work with 12 kids is also pretty amazing.

W3. You read in an article a medical term new to you. The term you saw was "craniosynsotis." Is it spelled correctly, and what does it mean?

The correct spelling is craniosynostosis.
From **http://www.genome.gov/glossary.cfm?search=protein+structure**

A birth defect whereby an infant's skull bones are already fused at birth. Because this defect may interfere with the ability of the brain to grow normally, it is often necessary to operate on affected children.