Solutions to 7.014 Problem Set 1

Question 1

Please read the following two articles, and answer the questions at the end

Article I

Please refer to article:
Fouad, Tamer. "Laptops can affect fertility in males, US researchers warn." (January 1, 2005).
(full text at http://www.thedoctorslounge.net/fertilounge/articles/fertility_laptops)

Please refer to article:
Moore, Charles. "Hot Laptops A Male Reproductive Health Hazard - And Something You Can Do About It." *Road Warrior*, January 4, 2005.
(full text with pictures at http://www.macopinion.com/columns/roadwarrior/05/01/04/)

Question 1

a) Do the articles above present the findings of the laptop study objectively? If yes, justify. If no, give examples of biased reporting and explain why you believe the reporting to be biased. (Feel free to underline or highlight passages in the text, as long as you clearly identify the meaning of your markings)

The first article presents the findings objectively. The article describes procedure used in the study in great detail, and its report on the study's conclusions is limited to those supported by the reported data. Article also relies heavily on direct quotes from the lead author of the study, ensuring a large degree of impartiality. The second article, on the other hand, overstates the reported results of the study to a large degree. For example, compare the quote highlighted in dark blue in the first article with the one highlighted in light blue in the second. While the first article merely reports elevated scrotum temperatures observed in the experiment, the second article makes a connection to reduced sperm production and fertility. This connection is not substantiated by data obtained in this experiment, or by an applicable previously reported experiment. Similarly, compare quotes highlighted in green and yellow. Notice the use of "may want to" in the first article vs "should" in the second, and the truncated quote in the second article with respect to the first.

b) Look again at the second article. Does the Laptop Desk study answer the question of how likely is it that this device would help alleviate the problem of the elevated scrotum temperature associated with laptop use? Why or why not?

Reporting of the Laptop Desk study talks only about measuring the temperatures on the device itself. It gives no indication that the study involved measuring how effective the product would be in alleviating the problem of the elevated scrotum temperature associated with laptop use. To determine that, one would need to conduct a study where the scrotum temperatures were measured when using the Laptop Desk in various configurations with and without a working laptop computer.

c) Based on the information in the two articles, do you think the Laptop Desk is likely to be a significant relief for the problem of the elevated scrotum temperature associated with laptop use? Why or why not?

It is unclear from the data. The claim of the article is that the product would help alleviate the problem of elevated scrotum temperatures by giving the user an option to sit with his legs open. It does not, however, measure what the scrotum temperature would be in such a configuration. A reasonable hypothesis might be that scrotum temperature would still be elevated due to the partially enclosed space and heat coming from the computer.

Additionally, in the part of the article that did not make the excerpt presented here, there is data that shows only an 8-10% reduction in temperature on the bottom of the Laptop Desk with respect to the laptop itself. Given this modest decrease, even in their best case scenario, it is unlikely that the device would help alleviate the problem of elevated scrotum temperatures associated with laptop use.

d) Based on the information in the two articles, do you think it was appropriate to include the information about the Laptop Desk in the second article? Why or why not?

It was inappropriate to include the information about the Laptop Desk in the second article. First, as discussed in part a, the author of the article exaggerates the conclusions of the study to make the link to possible fertility problems seem more definite than it is so far. Second, the author deceptively uses only the first half of the quote by Dr. Sheynkin "It's possible that external protective devices could help," but leaves out qualification "somewhat" and the part of the quote that talks about the need to first determine their protective effect in a clinical trial. He uses the quote as the jumping off point to advertise the Laptop Desk, even though it is has never been clinically tested to illustrate its effectiveness as a means of reducing elevating scrotum temperatures with laptop use.

Question 2

Hemoglobin is the protein complex that carries oxygen around our bodies and distributes it to the organs and tissues. Sickle cell anemia is a disease which results from the presence of abnormal hemoglobin (HbS) in the red blood cells. In order to have the disease a person needs to have only HbS hemoglobin.

Wild-type hemoglobin (HbA) is composed of 2 α and 2 β subunits. The α and β polypeptides are approximately the same length, and are very similar in their primary structure.

a) If you run HbA on a denaturing gel, how many bands are you likely to see? Why?
You are most likely to only see one band, since on the denaturing gel the small difference in size between the α and β *subunits (4 amino acids) is unlikely to be detected. However, it is possible to use a set of conditions that would differentiate between bands 4 amino acids apart. If these conditions are used, you will see two bands.*
When mutant HbS and wild-type HbA hemoglobin molecules are analyzed on a denaturing gel, they produce identical patterns.

b) What is the likely defect in the HbS? Why?
If the patterns are identical, then the problem with the mutant protein is not due to the loss or gain of a major portion of a protein. Therefore, the likely defect in HbS is an amino acid substitution.
At low concentrations of O_2 HbS forms rigid rod-like complexes in the cell. These complexes deform the red blood cells from saucer shape to sickle-like shape. These rigid, sickle-like cells can get stuck in the small blood vessels and cause damage.

The β-subunit of HbS has amino acid valine in position 6, where the wild-type molecule has a glutamic acid.

- At normal oxygen concentrations, the overall shape of the β-subunit and the entire hemoglobin molecule remains unaffected by the substitution.
- At low concentrations of O_2, the Val6 on one β-subunit interacts with two amino acids on a β-subunit of another hemoglobin molecule.

c) What level(s) of protein structure of the β-subunit is (are) affected by the substitution at normal oxygen concentrations? Why?
At normal oxygen concentrations, the shape of the mutant subunit and the entire molecule are unaffected by the substitutions. Thus, only the primary structure of the β-subunit is affected. Since valine and glutamic acid have different shapes, it could also be said that there is a small local effect on the tertiary structure.

d) What level(s) of protein structure of the β-subunit is (are) affected by the substitution at low oxygen concentrations? Why?
At low oxygen concentrations, primary structure is affected, as above. However, a mutant subunit is involved in additional inter-molecular interaction, so the quarternary structure is affected as well.

At low concentrations of O_2, the Val6 on the mutant _-subunit interacts with a surface pocket made up of amino acids Phe85 and Leu88. This pocket is found on both wild type and mutant β-subunits.

e) What is the strongest interaction involved in this binding event?
Phenylalanin, leucine, and valine are all hydrophobic residues, so the strongest interaction is hydrophobic interaction.

f) This pocket is found on both wild-type and mutant β-subunits. Explain why (at low concentrations of O_2) hemoglobin containing only mutant β-subunits forms long rods yet hemoglobin containing wild-type β-subunits does not.

If we consider three molecules of HbS, A, B, and C. Val6 of molecule A can bind Phe85 and Leu88 of molecule B, while Val6 of molecule B can bind Phe85 and Leu88 of molecule C. We can see by extension that HbS can form long chains with these interactions. Wild-type β-subunits can provide a Phe85, Leu 88 pocket for binding with mutant subunits, but they do not have Val6 and can not bind the next subunit to form a chain. Therefore, incorporating a wild-type subunit into a growing chain terminates the chain. HbA can not aggregate at all.

g) A person who has both HbA and HbS is a carrier of the disease, but does not exhibit symptoms. Please explain in terms of molecular interactions why a carrier does not exhibit symptoms of the disease.

A carrier has both wild-type and mutant β-subunits, and, therefore, has both HbA and HbS, as well as molecules containing one wild-type and one mutant β-subunit. As discussed above, whenever a hemoglobin molecule gets incorporated into a growing chain via the hydrophobic pocket on a wild-type subunit, the chain terminates. With both types of β-subunit in the red blood cells, the probability of forming a sufficient number of long enough chains to actually deform the cell and cause the person to exhibit symptoms of the disease is low.

Question 3

In order for a substance to boil, the kinetic energy of the molecules must exceed the energy of the forces between the molecules. For each pair of compounds listed below, explain the difference in the boiling in terms of the intermolecular forces.

Compound	Boiling Point (°C)
methane (CH_4)	-161
methanol (H_3COH)	65
water (H_2O)	100
sodium chloride (NaCl)	1416
diamond*	decomposes without boiling (in vacuum)

*C_n: a covalently-bonded lattice

a) methane vs. methanol

Methane is a non-polar molecule, and therefore the only forces preventing methane from boiling are the van der Waals forces between the molecules. Methanol is a more polar molecule which can form hydrogen bonds between molecules. Hydrogen bonds are much stronger than van der Waals bonds, so methanol will have a much higher boiling point than methane.

b) methanol vs. water

Like methanol, water is a polar molecule, and can form hydrogen bonds with other molecules. Because water has two hydrogen atoms available for hydrogen bonding, it can form more hydrogen bonds per molecule and therefore will be more tightly bound to its neighbors. Therefore, it will require more energy to vaporize water then methanol. Water will have a higher boiling point than methanol.

c) water vs. sodium chloride

The hydrogen bonds in water are due to partially ionized groups (strong dipoles) attracting each other. The Na^+ and Cl^- ions in NaCl are held together by interactions between fully charged ions. Since the attractive force in both cases is due to the Coulomb force, which is proportional to the magnitude of the charges involved, the ionic bonds in NaCl will be stronger than the hydrogen bonds in water.

d) sodium chloride vs. diamond

Since a diamond is really one big molecule, its boiling point will be determined by the energy required to break the bonds between the atoms in the diamond lattice. Since these bonds are covalent, the strongest bonds known, diamond will have the highest boiling point. In order for diamond to boil, it must first break down into free carbon atoms – so, strictly speaking, diamond does not boil (it does not become gaseous diamond like methane becomes gaseous methane), but decomposes.

Question 4

In the past thirteen months, NASA has successfully landed spacecraft on the planet Mars and on Titan, one of the moons of Saturn. One of the goals of each mission was to look for evidence of water. Different evidence of the past or present existence of water was found on both Mars and Titan. Neither Mars nor Titan has oxygen-containing atmosphere.

a) Scientists are not concerned with the absence of oxygen in the atmosphere, but instead view water as a sign of the possible existence of microbial life. Given what we know about the history of life on Earth, why is water regarded as a much more important sign of possible life than oxygen?
Water forms hydrogen bonds, and can form those with other molecules. These hydrogen bonds can be used as part of molecule stabilization or reaction mechanism. In addition, if some useful compound is being produced abiotically or is excreted as part of some organism's life cycle, the compound would diffuse throughout the body of water. This diffusion would ensure that primitive organisms would receive all the available nutrients from the environment. On the other hand, we know that oxygen only appeared on Earth as a waste product of photosynthesis II, so it was not essential to development of life on Earth, although it was key in increasing its diversity and complexity.

The evidence found on the surface of Mars is consistent with a number of scenarios. One is that the surface of the planet once contained oceans, rivers, and lakes. However, currently the atmosphere on Mars is too thin to allow these bodies of water to remain on the surface.

b) Assume that these bodies of water once contained living organisms. Provide two alternative hypotheses for how a planet might move from having a thick atmosphere over the surface with bodies of water containing living organisms to having a thin atmosphere over the dry surface with no detectable living organisms.
(1) Some external development caused the atmosphere to become thin. The thin atmosphere then caused the change in the environment that caused the bodies of water to dry up and the organisms to disappear from the surface.
(2) Organisms on the surface developed some form of metabolism that resulted in a waste product that escaped into the atmosphere and caused it to become thin. The thin atmosphere then caused the change in the environment that caused the bodies of water to dry up and the organisms to disappear from the surface.

NASA scientists describe Titan as an extraordinary world where Earth-like geophysical processes operate on exotic materials in very alien conditions. Instead of liquid water, there is liquid methane (temperature on Titan is sub -170°C); instead of silicate rocks, there is frozen water ice; instead of dirt, there are hydrocarbon particles; and instead of lava, Titan's volcanoes spew very cold ice.

c) We have no idea what life on Titan might look like. However, if we are to find a living organism on Titan, it will have the following three properties:
metabolism, controlled/regulated growth, reproduction.

d) Assume that life is found on Titan and that these organisms live in an environment where energy is freely available from abiotic sources. If in the future, the energy from abiotic sources becomes limiting, what feature would be common in the organisms that would survive and thrive through such a transition? Why?
If energy from abiotic sources become limiting, organisms that can produce their own energy would have selective advantage, since they could grow and replicate regardless of the abundance of abiotic energy in the environment. Such organisms, then, would survive and thrive through a transition to the environment with limited sources of energy from abiotic sources.