7.013 Spring 2005 Problem Set 1
FRIDAY February 11, 2004

Problem sets will NOT be accepted late.

Question 1

a) Circle the correct answer.
   
   i) Homo sapiens emerged ____________years ago.
      
      5,000  50,000  500,000  5,000,000  50,000,000

   ii) There are __________________billion letters (bases) in the human genome.
      
      one   three   thirty   3 hundred

   iii) An alpha helix is an example of _________________structure.
      
      primary   secondary   tertiary   quarternary

b) What are the four major types of biological molecules discussed in lecture? What monomers make up these molecules? Give one important function of each type of biological molecule in the cell.

<table>
<thead>
<tr>
<th>Name of molecule</th>
<th>Monomer</th>
<th>One function of the Polymer</th>
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MIT Department of Biology
7.013: Introductory Biology - Spring 2005
Instructors: Professor Hazel Sive, Professor Tyler Jacks, Dr. Claudette Gardel
c) Name the molecules depicted below.

\[
\text{adenine} \quad \text{thymine} \quad \text{uracil}
\]

d) Circle one peptide bond if there is any in the figures above.
Question 2

a) Draw the energy profile for this reaction. Refer to Chapter 6 in the textbook.

\[
A + B \rightarrow C + D \quad \Delta G^o' = -3.4 \text{ kcal/mol}
\]

On the diagram be sure to:

1) show relative energy levels of the reactants and the products.
2) label the axes.
3) label reactants and products.
4) indicate the energy of activation.
5) indicate \(\Delta G\).

b) An enzyme _____________ the activation energy of a reaction.

- lowers
- raises
- does not affect

c) An enzyme _______________ the \(\Delta G\) of a reaction.

- lowers
- raises
- does not affect

d) Using a dashed line in the above diagram, draw the energy profile in the presence of an enzyme.
Question 3

Some receptors are transmembrane proteins found on the cell surface.

extracellular

intracellular

Receptor proteins

a) The majority of the molecules that constitute a membrane belong to what class of macromolecules? ________________________________

b) Explain the important qualities/properties of these molecules that allow them to form membranes.
A smaller schematic of the receptor is shown here.

Sequence from this region shown below

\[
\text{NH}_3^+ \cdots \text{Ile-Val-Phe-Leu-Ala-Val-Trp-Met-Phe-Arg-Lys-Thr-His} \cdots \text{COO}^-
\]

c) Which stretch of amino acids in the above sequence is within the interior of the transmembrane region of the receptor? Circle these amino acids and briefly explain your reasoning below.

When a "LIGAND" binds to the extracellular domain of the receptor, a conformational change occurs in the receptor. Ligand binding causes dimerization of two adjacent receptors in the cell membrane. Upon dimerization, the intracellular domains of the receptors become activated. See schematic below.
c) Regions of the two receptors that interact upon dimerization are drawn below. In parts (i - iv) below, name the strongest type of interaction (choose from: hydrogen bond, ionic, covalent, van der Waals) that occurs between the side chains of the amino acids indicated.

<table>
<thead>
<tr>
<th>Interacting Side chains</th>
<th>Type of interaction</th>
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<tbody>
<tr>
<td>i) Phe50 : Val98</td>
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<tr>
<td>ii) Asp68 : Lys65</td>
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<td>iii) Cys75 : Cys82</td>
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<tr>
<td>iv) Ser53 : Gln12</td>
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</tbody>
</table>

d) Gln12 is the 12\textsuperscript{th} amino acid in primary sequence. Val 98 is the 98\textsuperscript{th} amino acid in the primary sequence. Explain how these amino acids are far apart in the primary sequence of the protein yet are close to each other in the region of the protein diagrammed above.
e) Molecular interactions between the two receptors are important for dimerization. Thus, substitution of certain amino acids in the protein can affect receptor dimerization.

Predict whether the receptors will or will not be able to dimerize given the substitutions (i - iv) below. EXPLAIN your reasoning.

i) Asp68 → Arg

ii) Ser53 → Thr

iii) Phe50 → Asn

iv) Val98 → Ile

f) Substitution of one amino acid, Cys75 → Gly, leads to dimerization of the receptors with or without ligand. Provide a brief explanation for this observation.
You have identified a new, rapidly reproducing species of dog that you have named the “mitbull”. The mitbull is diploid and two autosomal chromosomes are shown. One chromosome carries gene $A$ with two alleles designated $A$ and $a$. The other chromosome carries gene $B$ with two alleles designated $B$ and $b$.

a) Diagram mitosis in a heterozygous $(AaBb)$ mitbull cell shown below. Draw your diagrams in the outlines of the ovals adjacent to the stages. Include the alleles and the mitotic spindle in your diagrams.
b) Indicate the genotype of cells that would result after telophase. ____________
c) A cell in Metaphase I is shown below where a crossover event takes place. Diagram the indicated stages in meiosis. Designate the alleles and the spindle.
d) You determine another gene, gene D, maps 20 cM or map units away from gene A.

i) Given the cell with chromosome configuration below, what would be the genotypes of all the gametes if a recombination takes place between A and D?

\[
\begin{array}{c|c}
A & d \\hline
a & D
\end{array}
\]

ii) Circle the genotypes of the recombinant gametes above.

iii) At what frequency do you expect each of the recombinant genotypes to occur?_________

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**STRUCTURES OF AMINO ACIDS at pH 7.0**

- **ALANINE** (ala)
- **ARGININE** (arg)
- **ASPARAGINE** (asn)
- **ASPARTIC ACID** (asp)
- **CYSTEINE** (cys)
- **GLUTAMIC ACID** (glu)
- **GLUTAMINE** (gln)
- **GLYCINE** (gly)
- **HISTIDINE** (his)
- **ISOLEUCINE** (ile)
- **LEUCINE** (leu)
- **LYSINE** (lys)
- **METHIONINE** (met)
- **PHENYLALANINE** (phe)
- **PROLINE** (pro)
- **SERINE** (ser)
- **THREONINE** (thr)
- **TRYPTOPHAN** (trp)
- **TYROSINE** (tyr)
- **VALINE** (val)