BIOLOGY 100
SOLUTIONS TO PROBLEMS

BIOLOGICAL MOLECULES

1. If 500 glucose molecules are used to make starch, how many molecules of water would be produced in the condensation reactions?

Think of starch as a linear chain of glucose molecules. Consider some short sequences of glucose molecules and the number of water molecules produced during condensation:

Glu-Glu	1 H_2O
Glu-Glu-Glu	2 H_2O
Glu-Glu-Glu-Glu	3 H_2O
Glu-Glu-Glu-Glu-Glu	4 H_2O .... and so on.

Following the above pattern, if 500 glucose molecules were linked, 499 molecules of H_2O would be produced (i.e., 499 bonds formed).

2. If a cellulose molecule consisted of 2000 glucose units, how many carbon, oxygen, and hydrogen atoms would it contain?

To solve this problem, first determine how many C, H, and O's are in 2,000 glucose units and then subtract the water that would b released by the condensation reactions.

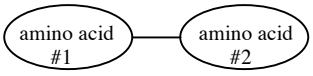
a. 2000 x $C_6H_{12}O_6$ → 6 x 2,000 = 12,000 carbons
12 x 2,000 = 24,000 hydrogens
6 x 2,000 = 12,000 oxygens

b. 1,999 H_2O molecules are released from the condensation reactions (see rationale in question #1).
2 x 1,999 = 3,998 hydrogens lost
1 x 1,999 = 1,999 oxygens lost

c. The cellulose chain containing 2,000 glucose units, therefore, has the following components:

carbons		<u>12,000</u>
hydrogens	24,000 – 3,998 =	<u>20,002</u>
oxygens	12,000 – 1,999 =	<u>10,001</u>

3. How many different dipeptides could be made with 20 types of amino acids?

A dipeptide consists of two, linked amino acids: 

Twenty different amino acids are possible for position #1, and 20 different amino acids can be used in position #2. Thus, the total number of possibilities is 20 x 20 = <u>400</u>.

In a more general sense, this problem deals with permutations (combinations of elements in which the order is important). This problem asks how many permutations can we produce using 20 amino acids, taken two at a time.

Permutations = number of things$^{(\text{number of times})}$ = 20^2 = <u>400</u>

4. If a typical protein is made of approximately 300 amino acids, how many different proteins could be made using the 20 types of amino acids? (This is a challenging question!)

See concept about permutations in question #3.

Permutations = $20^{300} = 2.037 \times 10^{390}$ or

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000,000,000,000,000

If you tried to solve this problem on your calculator, you probably encountered an "overflow error" (i.e., the number was too big). An alternative calculation could be done by breaking down the exponent:

$$
\begin{aligned}
20^{300} = 20^{100} \times 20^{100} \times 20^{100} &= (2^{100} \times 10^{100}) \times (2^{100} \times 10^{100}) \times (2^{100} \times 10^{100}) \\
&= (2^{100})^3 \times (10^{100})^3 \\
&= (1.2677 \times 10^{30})^3 \times 10^{300} \\
&= (1.2677)^3 \times 10^{90} \times 10^{300} \\
&= 2.037 \times 10^{390}
\end{aligned}
$$

It is instructive to consider the magnitude of this number; it is immense! For comparison, the age of the universe is estimated to be about 20 billion years old or 6.3×10^{17} seconds (20×10^9 years x 365.25 days/year x 24 hours/day x 60 minutes/hour x 60 seconds/minute).

Apparently, only a small fraction of the theoretically possible number of proteins exists. If we consider that there are 10 million species on the Earth and assume that each species has 100,000 unique proteins, then there are about a trillion (10^{12}) proteins made by living things (10,000,000 x 100,000 = 10^{12} proteins). When compared to the theoretically possible (2.037×10^{390}), a trillion proteins is an insignificant fraction of one percent!

5. If the distance between an oxygen atom and a hydrogen atom in a molecule of water is 0.1 nm (0.1×10^{-9} m), and a typical animal cell is approximately 20 µm (20×10^{-6} m) in diameter; how large would the typical animal cell be using the scale of the water molecule you constructed? NOTE: the width of the model of a water molecule is approximately 8 cm.

First, determine the magnification factor used with the model kits:

Width of water molecule model = 8 cm = 8×10^{-2} m

Actual width of water molecule = 0.1×10^{-9} m = 1×10^{-10} m

$$\text{Magnification factor} = \frac{8 \times 10^{-2}\ \text{m}}{1 \times 10^{-10}\ \text{m}} = 8 \times 10^{8}$$

Diameter of animal cell = 20×10^{-6} m x (8×10^{8}) = 160×10^{2} m = 16,000 m (or about 10 miles!)

6. A glucose molecule is 0.7 nm (0.7×10^{-9} m) in length. If a plasma membrane of a cell is approximately 7 nm in thickness, how thick would the plasma membrane be using the scale of the model molecule you constructed? NOTE: the diameter of the model of a glucose molecule is approximately 15 cm.

First, determine the magnification factor:

Width of glucose molecule model = 15 cm = 15×10^{-2} m

Actual width of glucose molecule = 0.7 nm = 0.7×10^{-9} m = 7×10^{-10} m

$$\text{Magnification factor} = \frac{15 \times 10^{-2} \text{ m}}{7 \times 10^{-10} \text{ m}} = 2.14 \times 10^{8}$$

Thickness of plasma membrane (using same scale):

7 nm = 7×10^{-9} m

7×10^{-9} m x $(2.14 \times 10^{8}) = 15 \times 10^{-1}$ m = 1.5 m