AP Biology **Exam Review**

North Salem University

MISSION: *Engage students to continuously learn, question, define and solve problems through critical and creative thinking.*

Spring 2021

This packet is designed to familiarize yourself with the location and proper use of the AP Biology equations and formulas you may encounter on the Calculations Section of your AP exam. This packet will also review some of the more important biological concepts frequently tested on the exam as well provide you with some sample FRQ questions relating to the most important topics.

If you have any problems – please sign up for extra help after school.

Mr. Collea

Topic	Page

AP Biology Test Format:

The AP Biology Exam is approximately 3 hours in length. There are two sections:

Section I

This section is **90 minutes** and consists of **60 multiple-choice** questions and **6 calculation** questions accounting for **50 percent** of the final score.

Calculation Tips:

1. These questions may require you to use the Formula Sheet.
2. If a diagram is provided, analyze the diagram before you start calculating.
3. They won't ask you for units in your answers on the calculation questions, but they may on the short / long response questions.
4. Don't round your work until you get to the answer!
5. Read the directions carefully for each question you answer. The question will indicate whether you should round to the nearest whole number, tenth, hundredth, etc. If you round to a different place, your answer will be scored as INCORRECT!
6. You must be able to convert back and forth between scientific notation and whole numbers.
   Examples:
   $5.1 \times 10^3 = 5100$ $6.2 \times 10^{-4} = 0.00062$ $442 = 4.42 \times 10^2$ $0.008 = 8.0 \times 10^{-3}$

DO THE CALCULATION QUESTIONS FIRST!!!!

Section II

1. **Section II** is **90 minutes** and consists of **2 long free-response questions and 4 short free-response questions** accounting for **50 percent** of the final score. The 2 long free-response questions should require about 25 minutes each to answer. Questions 3 through 6 are short free-response questions and should require about 10 minutes each to answer.

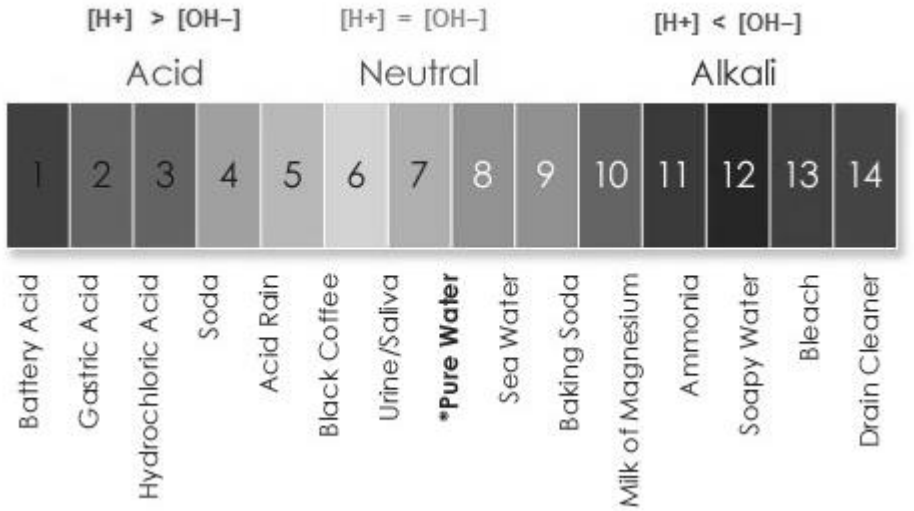
   The long questions ask students to:
   - Interpret and evaluate experimental results.
   - Interpret and evaluate experimental results with graphing.

   The short-answer questions assess students' understanding of the following:
   - Scientific investigation
   - Conceptual analysis
   - Analysis of a model or visual representation
   - Data analysis

You are **NOT** expected to know the answers to **EVERY** question!!!

I. **pH** = -log[H^+] - A measurement of the hydrogen ion concentration in a solution.

The pH Scale



(1) What is the hydrogen ion concentration of a solution of pH 5?

(2) What is the hydrogen ion concentration of a solution of pH 2?

(3) How much more acidic is a solution with a pH value of 2 compared to a solution with a pH value of 5?

II. REACTION RATES

(1) **Catalase** is an enzyme found in peroxisomes that facilitates the breakdown of hydrogen peroxide (H_2O_2), a toxic by-product of cellular respiration, into oxygen and water. An experiment was conducted to measure the reaction rate of catalase under ideal enzymatic conditions. Using the data collected and recorded below, properly create and label a line graph depicting the results of the experiment.

Time (seconds)	Initial H_2O_2 in beaker before catalase	Remaining H_2O_2 in beaker after catalase	Total H_2O_2broken down by catalase
10	5 mL	4.5 mL	mL
30	5 mL	3.5 mL	mL
60	5 mL	2.0 mL	mL
90	5 mL	1.0 mL	mL
120	5 mL	0.5 mL	mL
180	5 mL	0.0 mL	mL

Graph Title: _____

What is the reaction rate for the catalase in this experiment between 30-90 seconds? _____

(2) An experiment was conducted to measure the amount of oxygen used by crickets over time at two different temperatures. Create a double-line graph displaying these results.

Temp (°C)	Time (min)	O_2 used
22° C	0	---
	5	0.2 mL
	10	0.3 mL
	15	0.5 mL
	20	0.7 mL
42° C	0	---
	5	0.8 mL
	10	1.5 mL
	15	2.2 mL
	20	3.0 mL

Graph Title: _____

What was the of oxygen consumption (*with proper units*) by the crickets **at 22° C**? _____

at 42° C? _____

Why the difference?

_____

III. BASIC STATISTICS

(1) Your lab group collected the following data for the heights (***cm***) of their Wisconsin Fast Plants:

5.4 7.2 4.9 9.3 7.2 8.1 8.5 5.4 7.8 10.2

a) Find the mean, median, mode and range for the data above. *Give your answer to the nearest whole number*.

Mean: **Median:** **Mode**: **Range**:

b) Find the standard deviation by filling in the following table. **Standard Deviation:**

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

Heights (x)	**Mean ($\bar{x}$)**	$x - \bar{x}$	$(x - \bar{x})^2$
		$\Sigma(x - \bar{x})^2 \rightarrow$	

Now calculate the **Standard Error:** $SE_{\bar{x}} = \frac{S}{\sqrt{n}}$

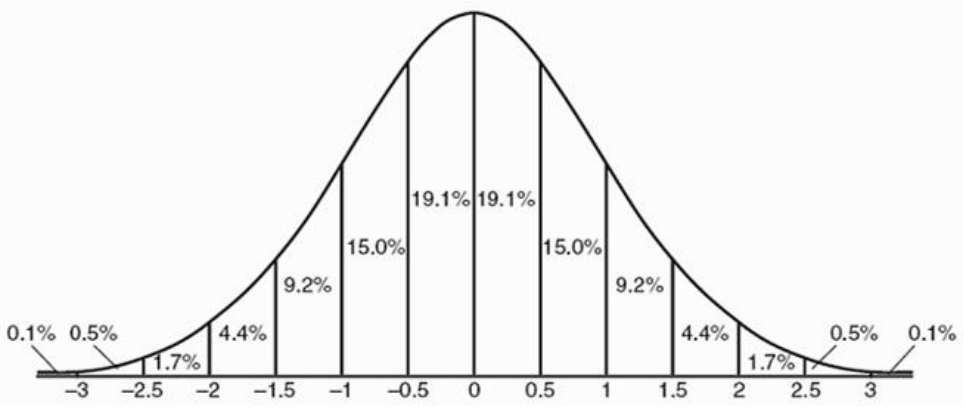
What does this mean?

_____

_____

Standard Normal Distribution or "The Bell Curve"

For normally distributed data, _____ of data points lie between **±1** standard deviation of the mean, _____ of data points lie between **±2** standard deviations of the mean and _____ of data points lie between **±3** standard deviation of the mean.



Standard Deviations

(2) Calculate the standard deviation and standard error for Data Sets A and B.
<u>Show all of your work</u> and round your answer to the nearest thousandth.

Standard Deviation: $s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$

Data Set A: 9, 15

Data Set A (x)	**Mean ($\bar{x}$)**	$x - \bar{x}$	$(x - \bar{x})^2$
		$\Sigma(x - \bar{x})^2$	

Standard Error: $SE_{\bar{x}} = \frac{s}{\sqrt{n}}$

Data Set B: 10.9, 11.9, 12.2, 12.2, 12.9, 12.6, 12.3, 12.3, 12.5, 10.2

Data Set B (x)	**Mean ($\bar{x}$)**	$x - \bar{x}$	$(x - \bar{x})^2$
		$\Sigma(x - \bar{x})^2$	

Standard Deviation: $s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$

Standard Error: $SE_{\bar{x}} = \frac{s}{\sqrt{n}}$

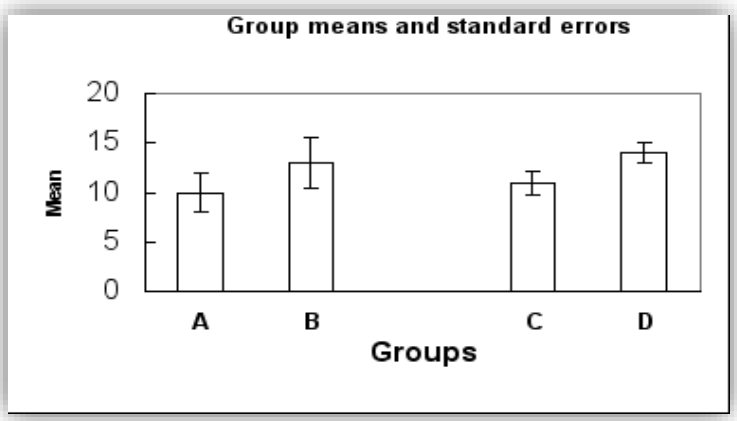
Explain your results:

_____

_____

_____

(3) Common practice is to add ***standard error bars*** to graphs, marking one standard error above & below the sample mean (*see graph to the right*). These give an impression of the *precision* of estimation of the mean, in each sample. Construct a bar graph with standard error bars of the mean for data sets A and B from question 2 on the graph below.



Data Set A **Data Set B**

What does the graph say about the two sets of data collected?

(4) A fertilized egg (zygote) undergoes 8 rounds of cleavage including cell partitioning. After the 8th round, half of the cells divide again while the remaining cells undergo **apoptosis** *(programmed cell death*). After this event those remaining cells undergo 2 more rounds of cleavage.

Round answer to the nearest whole number.

How many cells are present after these events?

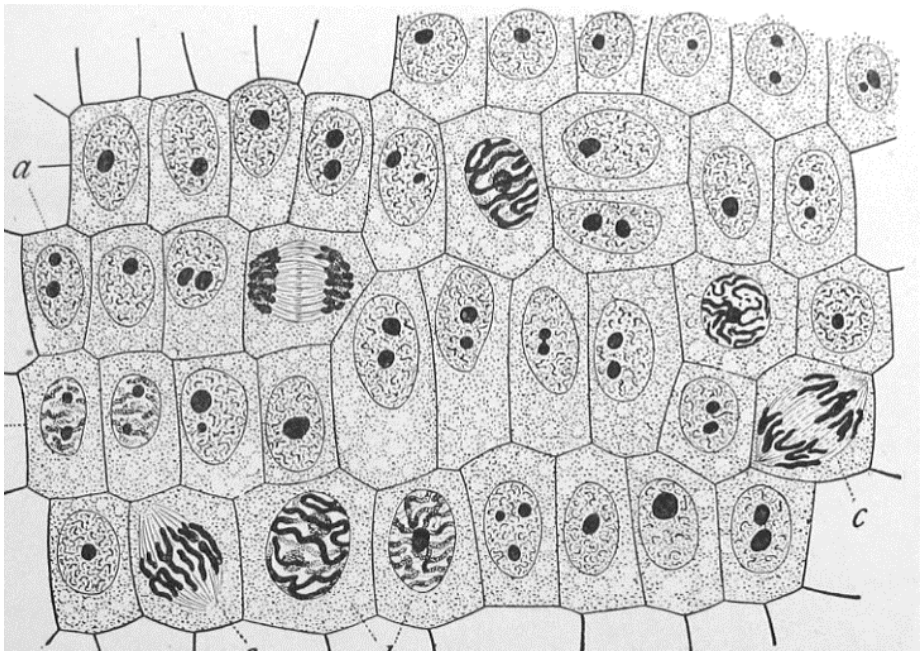
(5) During embryonic paw formation in dogs, there are initially 623 cells between the first 2 digits of the paw. Each of these cells and their subsequent daughter cells must undergo 3 rounds of cell division to provide enough cells for proper paw development. Next, differential gene expression initiates **apoptosis** causing the loss of 85% of the cells. *Round answer to the nearest whole number.*

How many cells remain after these events?

(6) Use the diagram below to calculate the percentage of cells in each stage of the cell cycle.

Round answer to nearest tenth.

Stage	Percentage
Interphase	
Prophase	
Metaphase	
Anaphase	
Telophase	



IV. WATER POTENTIAL

A. Water potential is the free energy of water and will always move from an area of higher water potential to an area of lower water potential (*high free energy to low free energy*).

B. Water/Osmotic Potential is dependent on **pressure potential (Ψ_P)** and **solute concentration (Ψ_S)**.

Water Potential = Pressure Potential + Solute Potential

$$\Psi = \Psi_P + \Psi_S$$

Water basically moves from a higher water potential to a lower water potential.

(high free energy) *(low free energy)*

(1) Water potential is measured in what units? _____

(2) What two factors determine water potential? (See the equation above) _____

_____

(3) State which direction water will move regarding water potential.

_____

(4) Pure/distilled water has a water potential of _____

(5) If water potential is **-2 bars** and solute potential is **-2 bars**, then pressure potential = _____

(6) If solute potential is **-3 bars** and water potential is **0 bars**, then the pressure potential = _____

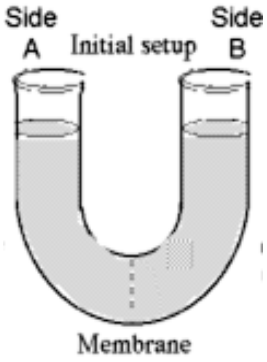
(7) If water potential is **-9 bars** and pressure potential is **+4 bars**, then solute potential = _____

(8) If a cell's pressure potential is **3 bars** and it's solute potential is **-4.5 bars,** what is the resulting **water potential**? *Give your answer to the nearest tenth.*

(9) If the cell from the previous question is placed into a beaker of sugar water with a solute potential of **-4.0 bars.** In which direction will the net flow of water be and WHY?

(10) The initial concentration of Side A and Side B are indicated on either side of the U-tube. The membrane shown is permeable to sucrose and NaCl but NOT starch.

1.5M sucrose
0.8M starch
0.4M NaCl



0.6M sucrose
1.2M starch
1.6M NaCl

a) Initially, which side is hypertonic? hypotonic?

c) Please use the correct letters to fill in the blanks below. In order to reach equilibrium:

sucrose will move from side _____ to side _____

starch will move from side _____ to side _____

NaCl will move from side _____ to side _____.

d) After this system reaches equilibrium: what is the molarity of each side? **A** = _____ **B** = _____

Which side will lose water? _____ How will you know?

(11) Given the following scenarios, draw an arrow representing the movement of water across these semipermeable membranes.

a)

ψ = 1.2 | **ψ = 3.2**

b)

ψ = 0 | **ψ = -2.3**

c)

ψ = -2.3 | **ψ = 0**

Solute Potential of a Solution

$$\Psi_S = -iCRT$$

i = ionization constant (For sucrose this is 1)
C = osmolarity
R = pressure constant (0.0831 L bars/mole ^oK)
T = temperature in Kelvin (273 + ^oC)

(12) A cell is in equilibrium with its surroundings at 30^{o}C. **Work Space:**
The molarity of the surrounding sucrose solution is 0.5M**.**

a) Calculate the solute potential of the surrounding solution.
Give your answer to the nearest tenth.

b) What is the water potential of the surrounding solution?

-

c) What is the water potential of the cytoplasm of the cell?

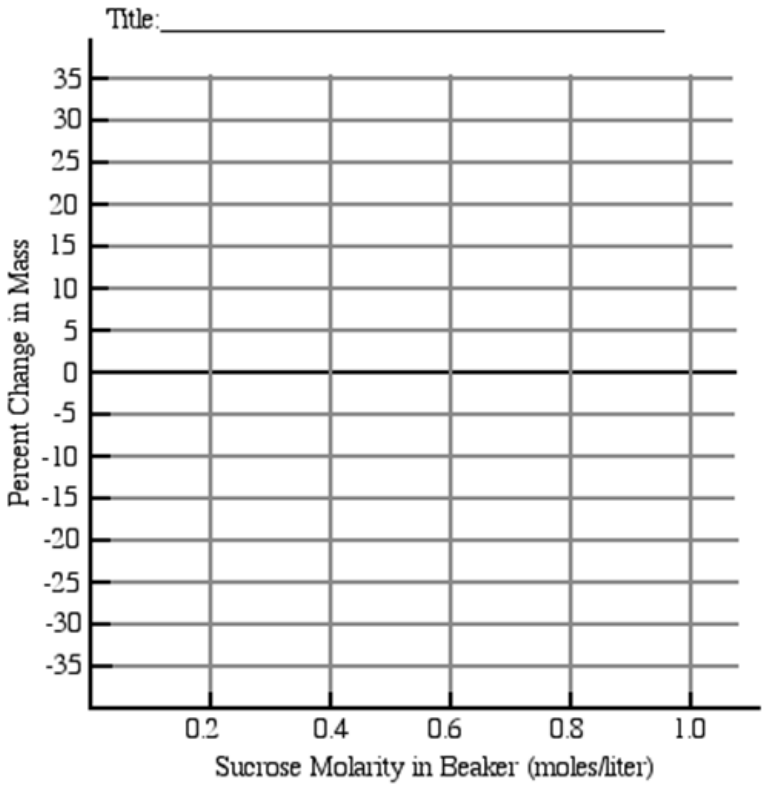
(13) The value for water potential in root tissue was found to be -3.3 bars. If you take the root tissue and place it in a 0.1M solution of sucrose at 20^{o}C in a open beaker, what is the solute potential of the solution and in which direction will the net flow of water be.

(14) NaCl dissociates into 2 particles in water: Na^+ and Cl^-. If the solution in question 13 contained 0.1M NaCl instead of 0.1M sucrose, what is the solute potential of the solution and in which direction will the net flow of water be.

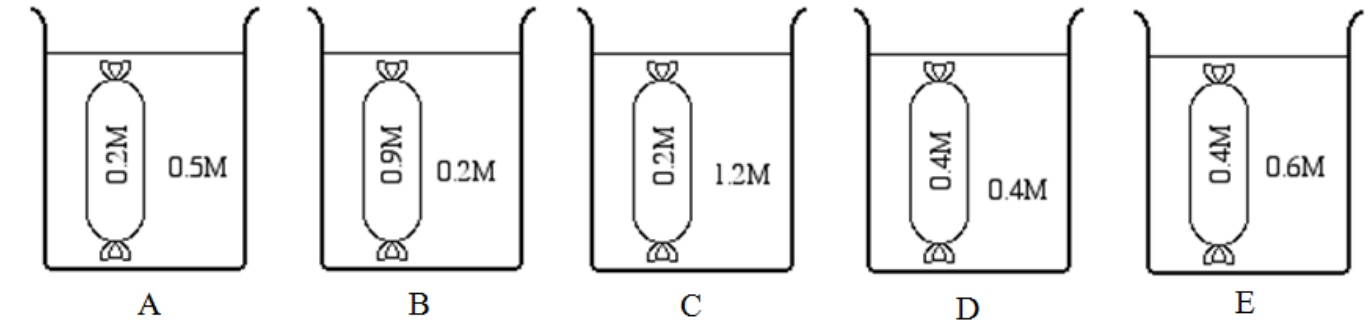
(15) Graph the data in the data table below and use it to calculate the solute potential of carrots at 23°C.

Carrot Water Potential Data	
% Mass Change	Sucrose Molarity
23%	0
12%	0.2M
2%	0.4M
-10%	0.6M
-24%	0.8M
-38%	1.0M

ψ = _____



(16) The dialysis bags pictured in the diagram below are impermeable to solutes, but permeable to water.

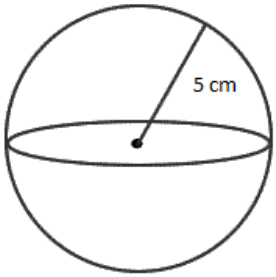


a) Which dialysis bag in the beakers below will lose the most water? _____

b) Which will gain the most water? _____

c) Which will not change in mass? _____

V. SURFACE AREA AND VOULME



(1) What is the SA/V for the cell to the right?
Give your answer to the nearest hundredth.

(2) Is it better for a cell to have a **HIGH** or **LOW** SA/V ratio? Explain.

VI. GENETICS / PROBABILITY

A. Rule of Addition

The rule of addition applies to the following situation. We have two events A and B, and we want to know the probability that **either** event occurs – the events are mutually exclusive.

$$P(A \text{ or } B) = P(A) + P(B)$$

Example: The chance of rolling a 1 or a 2 on a six-sided die is _____

The probability of rolling a 2, 5 or a 6 is _____

B. Rule of Multiplication

The rule of multiplication applies to the situation when we want to know the probability of the intersection of two events; that is, we want to know the probability that two events (A and B) **both** occur.

$$P(A \text{ and } B) = P(A) \times P(B)$$

Example: If two coins are flipped the chance of both being heads is _____.

The probability of rolling a snake eyes (2 twos) is _____.

(1) What is the probability the parents shown below would create the genotypic offspring listed?
Give your answer as a fraction.

HhOoDdAaYy x HhooDdAayy

a) HhOoDdAaYy = _____ **b)** hhooDdAayy = _____

VII. GENETICS / CHI-SQUARE

Collected/Observed (O) data rarely conform exactly to prediction, so it is important to determine if the deviation (difference) between the expected (E) values (*based upon the hypothesis*) and the observed results is **SIGNIFICANT** enough to discredit the original hypothesis.

Chi-Square Formula:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Chi-Square Table

	Degrees of Freedom							
p	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0.05	3.84	5.99	7.82	9.49	11.07	12.59	14.07	15.51
0.01	6.64	9.32	11.34	13.28	15.09	16.81	18.48	20.09

Sample Problems:

(1) In corn (*Zea mays*), purple kernels (P) are dominant to yellow kernels (p). Cobs from the offspring of a cross between a purple plant and yellow plant were used in a lab. A student counts **329** purple and **299** yellow kernels on one cob.
Calculate the chi-squared value for the null hypothesis that the purple parent was heterozygous for purple kernels. *Give your answer to the nearest tenth.*

Expected Results:

(2) In *Drosophila*, "bow-legged" is a mutation that is hypothesized to be X-linked recessive. A homozygous wild-type female was crossed with a bow-legged male. The F_1 generation contained equal numbers of wild-type males and wild-type females. The F_2 generation contained 30 wild-type males, 40 bow-legged males, 75 wild-type females, and 0 bow-legged females.

Calculate the chi-squared value for the null hypothesis that the "bow-legged" mutation is X-linked recessive. *Give your answer to the nearest tenth.*

VIII. HARDY WEINBERG:

Population Genetics $p^2 + 2pq + q^2 = 1$

p = frequency of the **dominant** allele in the population
q = frequency of the **recessive** allele in the population
(p + q = 1)
$\mathbf{p^2}$ **=** percentage of **homozygous dominant** individuals
$\mathbf{q^2}$ **=** percentage of **homozygous recessive** individuals
2pq = percentage of **heterozygous** individuals

Hardy Weinberg Strategies:

1. Figure out what you are given:
allele **p/q** OR genotype: $\mathbf{p^2}$ $\mathbf{q^2}$ **2pq**
2. Figure out what you are solving for.
3. Manipulate formulas to go from given to solving

Hardy and Weinberg also argues that if five conditions are met, the population's allele and genotype frequencies will remain constant from generation to generation. These conditions are as follows:

1. **The breeding population is large.** *The effect of chance on changes in allele frequencies is greatly reduced.*
2. **Mating is random.** *Individuals show no mating preference for a particular phenotype.*
3. **There is no mutation of the alleles.** *No alteration in the DNA sequences of alleles.*
4. **No differential migration occurs.** *No immigration or emigration.*
5. **There is no selection.** *All genotypes have an equal chance of surviving and reproducing.*

Sample Problem:

(1) Utica Free Academy High School Class of 1986 (*of which Mr. Collea was the Vice President*) was made up of 90% right handed students. Right handed (**R**) is the dominant trait over being left handed (**r**).

a) The frequency of the recessive allele **(q)** = _____. *Give your answer to the nearest tenth.*

b) The frequency of the dominant allele **(p)** = _____. *Give your answer to the nearest tenth.*

c) The frequency of homozygous dominant individuals $\mathbf{(p^2)}$ = _____. *Give your answer as a percent.*

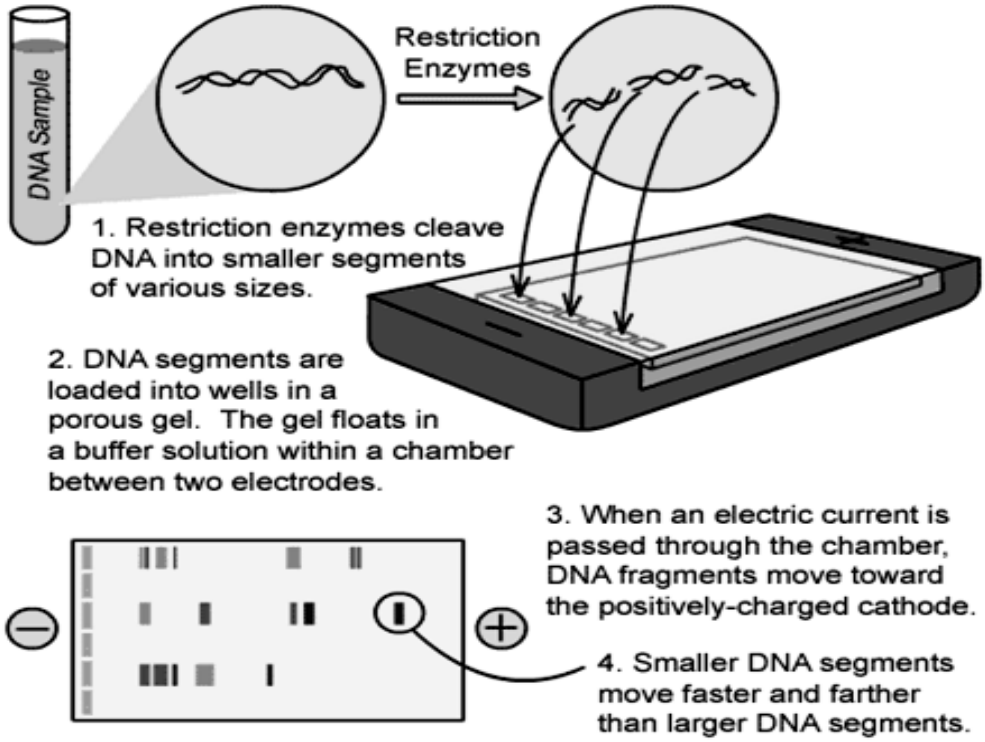
d) The frequency of heterozygous individuals **(2pq)** = _____. *Give your answer as a percent.*

e) The frequency of homozygous recessive individuals $\mathbf{(q^2)}$ = _____. *Give your answer as a percent.*

IX. GEL ELECTROPHORESIS

http://www.sumanasinc.com/webcontent/animations/content/gelelectrophoresis.html

DNA Gel Electrophoresis:



(1) According to the **BANDING PATTERN** to the right created by the process **DNA Gel Electrophoresis**, which separates various size pieces of DNA called **restriction fragment length polymorphisms** (*rflps*) that have been created through the digesting (*cutting*) of DNA with **restriction enzymes** according to **SIZE** and **CHARGE** (*smaller rflps move faster and farther than larger ones*), which suspect's DNA was left at the crime scene? **WHY?**

_____

_____

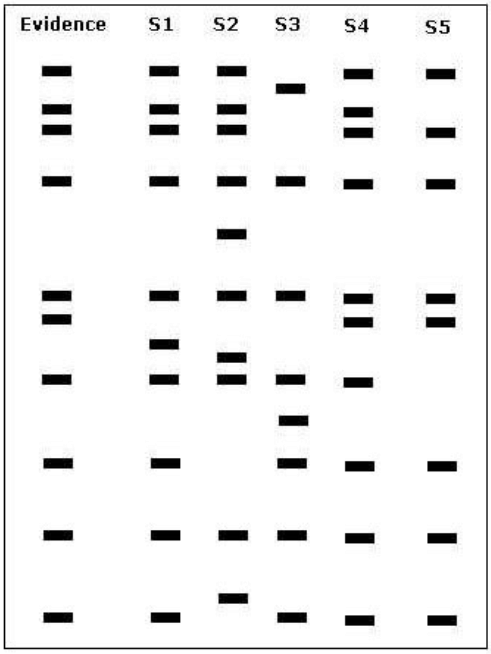
_____

_____

_____

_____

DNA Fingerprint:



X. Simpson Diversity Index

Biodiversity is defined as the total number of species living in an ecosystem. The **Simpson's Diversity Index** is a quantitative measure that reflects how many different types of species there are in a community. At present about 1.5 million species have been named, but this figure is not certain. It is impossible to know how many species actually exist because we have not explored every part of the biosphere yet. Most species are also less than 1mm long so they are easily overlooked. Human actions such as over exploitation, habitat destruction, introduction of alien species as well as pollution have all contributed to a decrease in local and global biodiversity. There are several reasons why we should want to maintain a high biodiversity on Earth. ***High biodiversity is an indication of the health of an ecosystem and if an ecosystem comes under stress from over exploitation or pollution, it will show low diversity.*** Once diversity is lost from an ecosystem it can't recover easily because species need to migrate back in from neighboring ecosystems or if the organism has become extinct, it is lost forever.

Formula:

$$1 - \sum\left(\frac{n}{N}\right)^2$$

n = total number of organisms of a particular species
N = total number of organisms of a ALL species

Simpson's Diversity Index takes into account the number of species present, as well as the abundance of each species. The value of this index starts with 0 as the lowest possible value. When using the Simpsons Index, the number you will calculate **should be a value between zero and one**. Values near zero indicate a highly diverse (*heterogeneous*) ecosystem and values near one indicate a less diverse (*homogeneous*) ecosystem.

The LOWER the value, the GREATER the diversity.

Sample Question:

(1) Use the Simpson's Diversity Index to calculate the diversity value for the habitat to the right *Give your answer to the nearest hundredth.*

Species	Population
A	4
B	3
C	1
D	2
E	2
F	1
G	3
H	1
TOTAL (N)	

$$1 - \sum\left(\frac{n}{N}\right)^2$$

n = total number of organisms of a particular species
N = total number of organisms of a ALL species

(2) Use the Simpson's Diversity Index to calculate the diversity value for the habitat to the right *Give your answer to the nearest hundredth.*

Species	Population
R	3
S	5
T	36
U	52
V	8
W	2
X	7
Y	3
Z	6
TOTAL (N)	

$$1 - \sum\left(\frac{n}{N}\right)^2$$

n = total number of organisms of a particular species
N = total number of organisms of a ALL species

(3) Use the Simpson's Diversity Index to determine which of the following 4 communities of 100 organisms in most diverse. *Give your answer to the nearest hundredth.*

Community	
1	Contains 5 species with 20 individuals in each species.
2	Contains 2 species with 50 individuals in each species.
3	Contains 2 species with 99 individuals in one and 1 individual in the other.
4	Contains 5 species with 96 individuals in one and 1 individual in the other 4 species.

$$1 - \sum\left(\frac{n}{N}\right)^2$$

XI. Free Response Questions

1. The unique properties of water make life on Earth possible. Select three properties of water and for each property:

a) **identify** the property and **explain** it in terms of the chemical/physical nature of water. **[15]**

b) **describe** how water affects the functioning of living organisms by **explaining** each of the following:

(i) the ability of water to moderate temperature within living organisms and in organisms' environments**. [3]**

(ii) the movement of water from the roots up and out the leaves of plants. **[3]**

(iii) the role of water as a medium for the metabolic processes of cells. **[3]**

2. Proteins – large complex molecules – are major building blocks of all living organisms.

Discuss each of the following in relation to proteins:

a) their chemical composition. **[5]**

b) levels of structure of proteins with a specific example of each. **[12]**

c) the roles of DNA, mRNA and tRNA in protein synthesis. **[6]**

3. Most enzymes are globular and therefore tertiary in structure.

(a) **Describe** the tertiary structure of proteins being sure to include the interactions between the side chains that contribute to its overall shape.

(b) Explain how the tertiary structure of an enzyme allows it to perform its function.

(c) **Compare** and **contrast** the effects of competitive and noncompetitive inhibition on enzyme action by explaining how each affects enzyme structure.

4. **(a)** What are enzymes and how EXACTLY do they affect chemical reactions. **Draw** and **label** an "idealized" graph to *help* you **explain** the difference between a catalyzed chemical reaction and a noncatalyzed chemical reaction in terms of the activation energy required.

(b) **Draw** an "idealized" graph for each of the following to *assist* you in **explaining** the effect each on enzyme activity.

(i) temperature

(ii) pH

(iii) [substrate]

5. **Describe** the structure of a eukaryotic cell by:

(a) **stating** the ways in which a prokaryotic cells differ in structure from eukaryotic cells. **[4]**

(b) **comparing** and **contrasting** the structure and function of the mitochondria and the chloroplast. **[10]**

(c) **defining** and **explaining** the Endosymbiotic Theory in terms of the evolution of eukaryotic cell being sure to **state** three observations that support it. **[6]**

6. The unique properties of water make life on Earth possible.

(a) **<u>Describe</u>** the general structure of a plasma membrane. **[7]**

(b) **<u>Explain</u>** the role water, a polar molecule, plays in the overall structure of plasma membranes. **[5]**
(be sure to include a detailed description of the chemical and physical structure of the plasma membrane)

(c) In terms of water potential, **<u>explain</u>** the need for a contractile vacuole by paramecium. **[3]**
(be sure to define and include the terms hypotonic, hypertonic and isotonic in your answer)

7. Viruses and radioactive isotopes were commonly used in scientific experiments leading up to the discovery of the structure and function of DNA.

(a) Describe how and why (*viral structure/function*) bacteriophages (*bacteria-infecting viruses*) and radioactive isotopes were used in the Hershey/Chase experiment. **[10]**

(b) **Compare** and **Contrast** the following activities in prokaryotes and eukaryotes:
i) Replication of DNA **[4]** **ii)** Transcription **[6]**

8. Gene regulation results in differential gene expression leading to the production of various proteins needed by the cell/organism. Various control mechanisms regulate gene expression in bacteria to make sure that these proteins (*enzymes*) are produced only when they are needed. **Discuss** these control mechanisms by **describing** the lac operon and its ability to control protein synthesis at the transcription level in bacterial cells. **[10]**

9. The cell cycle in eukaryotes can be divided into three parts: interphase, mitosis and cytokinesis.

(a) **List** and **describe** the three stages of interphase in order. **[6]**

(b) **List** and **describe** the three checkpoints of the cell cycle. **[6]**

(c) Describe how the cell cycle is regulated and discuss the impact each of the following has on the regulatory process: **i)** p53 **[3]**
ii) BRCA1 **[3]**

(d) Name and describe ONE consequence of abnormal cell cycle regulation being sure to include a specific cause. **[2]**

10. Meiosis is a type of cell division that reduces chromosome number and rearranges genetic information. **Describe** how this reduction **[2]** and rearrangement is accomplished in meiosis. When describing the rearrangement be sure to **explain [8]** the major events of **Prophase I**.

11. Describe the modern theory of biological evolution and discuss how it is supported by evidence from each of the following areas being sure to include specific examples where appropriate:

(a) Fossil record **[5]**

(b) Molecular biology **[5]**

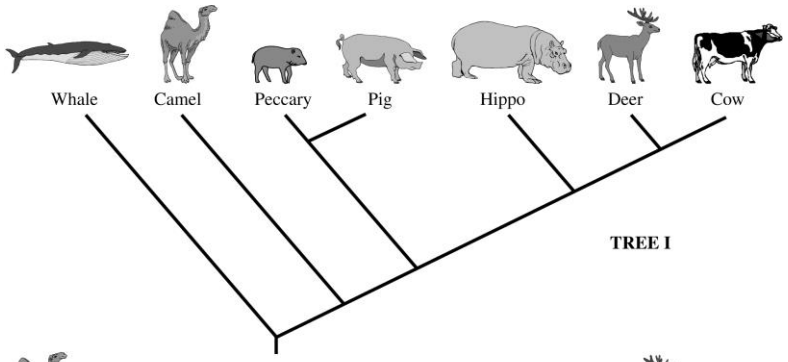
(c) Comparative anatomy **[5]**

(d) Comparative embryology **[5]**

12. Phylogeny reflects the evolutionary history of organisms.

(a) **Name** and **describe** TWO methods used to investigate the phylogeny of organisms. **[6]**

(b) Based on the principle of parsimony (*the simplest explanation is the best*) and the genomic information in Table 1, **identify** which tree is the best representation of the evolutionary relationship of these animals being sure to refer to Table 1 to justify your answer. **[5]**



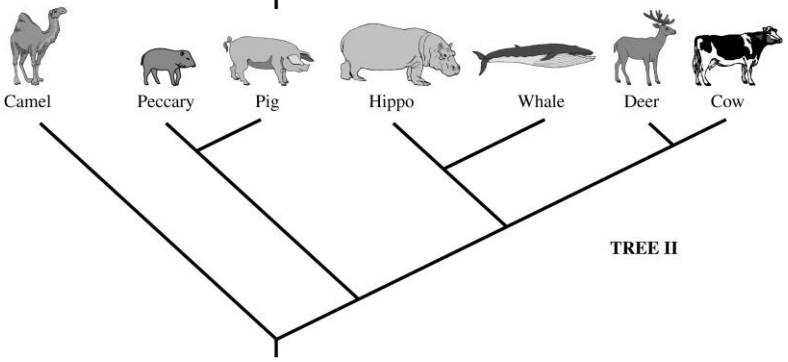


Table 2. - DNA Fingerprint

Locus	Cow	Deer	Whale	Hippo	Pig	Peccary	Camel
1			■				
2			■				
3			■	■			
4			■	■			
5			■	■			
6	■						
7	■	■		■			
8	■		■	■			
9	■	■	■	■			
10	■	■					
11	■	■					
12	■	■	■	■	■		
13					■	■	

13. Consumers in aquatic ecosystems depend on producers for nutrition.

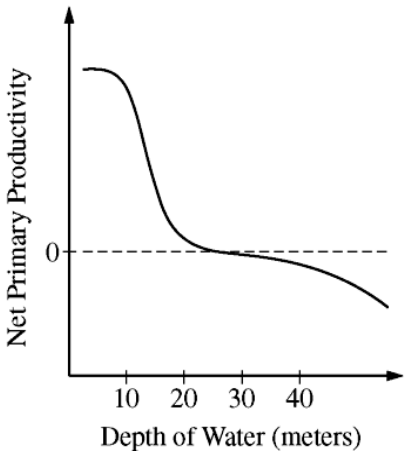
(a) **Explain** the difference between gross and net primary productivity. **[4]**

(b) In an experiment, net primary productivity was measured in the early spring from water samples taken from different depths of a freshwater pond in a temperate deciduous forest.

i) **Explain** the data presented by the graph to the right, including a description of the relative rates of metabolic processes occurring at different depths of the pond. **[4]**

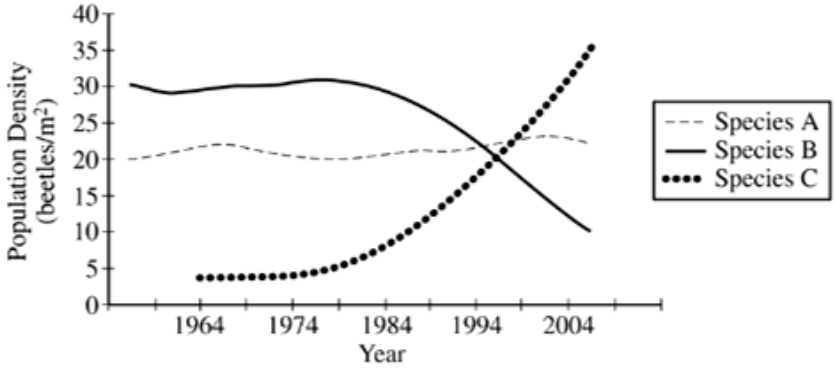
ii) **Describe** how the relationship between net primary productivity and depth would be expected to differ if new data were collected in mid-summer from the same pond. **Explain** your prediction. **[2]**

NET PRIMARY PRODUCTIVITY IN A FRESHWATER POND ECOSYSTEM DURING SPRING



14. According to fossil records and recent published observations, two species of leaf-eating beetles (species A and B) have existed on an isolated island in the Pacific Ocean for over 100,000 years. In 1964 a third species of leaf-eating beetle (species C) was accidentally introduced on the island. The population size of each species has been regularly monitored as shown in the graph below.

VARIATION IN POPULATION DENSITY OF BEETLES



(a) **Propose** an explanation for the pattern of population density observed in species C. **[2]**

(b) **Describe** the effect that the introduction of beetle species C has had on the population density of species A and species B. **Propose** an explanation for the patterns of population density observed in species A and in species B. **[3]**

(c) **Predict** the population density of species C in 2014. Provide a biological explanation for your prediction. **[2]**

(d) **Explain** how an invasive species can be unsuccessful in colonizing a one habitat but successful in colonizing another. **[3]**