AP BIOLOGY QUANTITATIVE SKILLS

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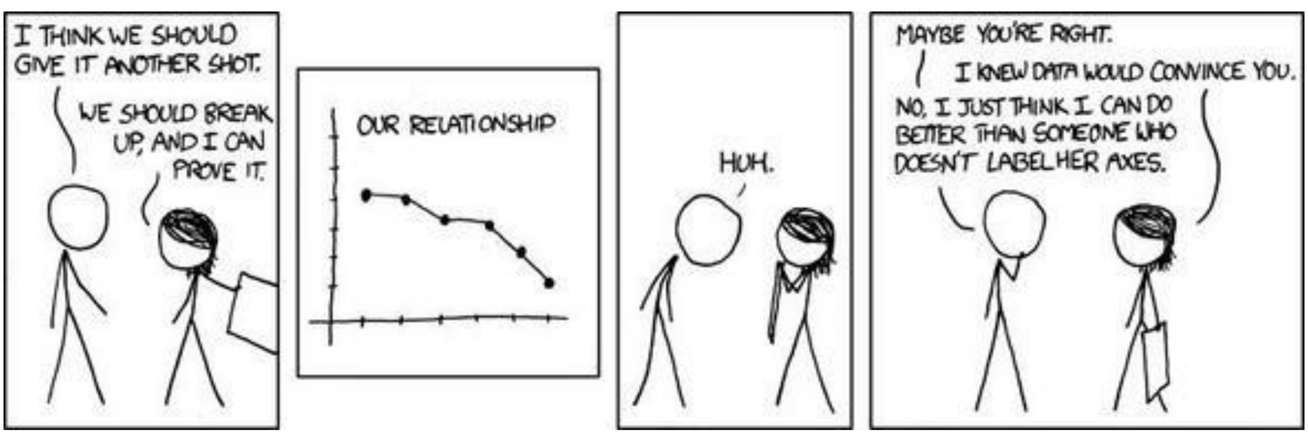


GRAPHING

One of the best ways to communicate the results of a scientific investigation is graphing, or creating an effective visual representation (a graph) of the data that have been counted, measured, and calculated. Investigators often can easily see patterns in a carefully crafted visual display that may not be as readily apparent in a data table of numbers. Visual displays also can clarify how two measured variables affect each other.

The AP Biology laboratory manual is designed to encourage students to ask their own questions by designing and carrying out investigations. This process of inquiry requires data analysis and communication of results. The data collected to answer questions generated by students will generally fall into three categories: (1) normal or parametric data, (2) nonparametric data, and (3) frequency or count data. Normal or parametric data are measurement data that fit a normal curve or distribution. Generally, these data are in decimal form. Examples include plant height, body temperature, and response rate. Nonparametric data do not fit a normal distribution, may include large outliers, or may be count data that can be ordered. A scale such as big, medium, small (qualitative) may be assigned to nonparametric data. Frequency or count data are generated by counting how many of an item fit into a category. For example, the results of a genetic cross fit this type of data as do data that are collected as percentages.

There are five types of graph you need to understand: **bar graphs**, **box-and-whisker plots**, **pie charts**, **scatter graphs** and **mosaic charts**.

A. Bar graphs are graphs used to visually compare two samples of categorical or count data. Bar graphs are also used to visually compare the calculated means with error bars of normal data (Figure 1).
B. Scatter plots are graphs used to explore associations between two variables visually.
C. Box-and-whisker plots allow graphical comparison of two samples of nonparametric data (data that do not fit a normal distribution).
D. Histograms, or frequency diagrams, are used to display the distribution of data, providing a representation of the central tendencies and the spread of the data.
E. Mosaic charts are modified bar graphs that can show multiple axes simultaneously allowing a more complete comparison.

Elements of effective graphing

A. Title: must inform the reader about the experiment and tell the reader exactly what is being measured
B. Type: the reader must be able to easily discern the type of graph
C. Axes: must be clearly labeled with units
    a. The x axis is the independent variable
    b. The y axis is the dependent variable
    c. Intervals must be uniform
    d. It is not necessary to label every interval
    e. Labels, including units, should allow the readier ti easily see the information
D. Multiple conditions: more than one condition can be present in a graph, however, they need to be clearly labeled and a key must be present. This is the preferable method for comparing multiple experiments that differ by only a single variable.
E. Origin: the origin of the graph must be clearly labeled whether it is at (0,0) or not.
F. Standard error: you may include standard error bars to inform the reader of the accuracy of your data collection.

			Parametric Test (Normal Data)	Non Parametric Tests	Frequency Tests (Counts)
Descriptive Statistics			**Mean, Standard Deviation, Error 95% Ci**	**Median, Quartiles, Interquartile Range**	**Percent by Category**
Comparative Statistics	Graph Type		Bar Graph	Box-and-Whisker Plot	Bar Graph or Pie Chart
	Independent Samples	2 Groups	Unpaired T-Test	Mann Whitney U-Test	Chi-Square Test
		≥ 2 Groups	Anova	Kruskal-Wallis Test	
	Matched Samples	2 Groups	Paried T-Test	Wilcoxon Test	
		≥ 2 Groups	Matched Anova	Friedman Test	
Association Statistics	Graph Type		Scatter Plot	Scatter Plot	Mosaic Chart
	Test For Association		Pearson Correlation	Spearman Rank Correlation	Chi-Square Test For Association
	Linear Relationship		Linear Regression	-	-

Source: Redrawn from "Statistics for AS Biology," available as part of a download at: http://www.heckmondwikegrammar.net/index.php?highlight=introduction&p=10310

DATA ANALYSIS

1. Most numeric data falls into one of two categories: measurements or counts
2. Measurements: used to compare a quantitative data point to a universal standard
    a. Continuous data: infinite number of potential measurements over a given range
    b. Discrete data: limited number of possible measurements over a given range
3. Count data: recordings of categorical data
4. Descriptive statistics: enables reader to estimate important parameters of the data set and determine a confidence interval
    a. Examples: standard deviation, mean, median, mode
5. Inferential statistics: uses tools that rely on probability theory and an understanding of distributions to determine precise estimations

HYPOTHESIS TESTING

1. Statistical hypothesis testing focuses on trying to reject a null hypothesis.
    a. A null hypothesis is a statement explaining that the underlying factor or variable is independent of the observed phenomenon.
    b. Alternative to the null hypothesis is a statement that the underlying factor or variable is not independent of the observed phenomenon.

	Possible Outcomes of Hypothesis Testing	
Investigator action	Null hypothesis is true	Null hypothesis is false
Rejects the null hypothesis	Type I error (false positive)	Correct
Fails to reject null hypothesis	Correct	Type II error (false negative)

1. We use a critical (p) value (usually 95% sure of answer).
    a. Using this system, there is only a 5% chance of making a type I error.
2. Chi-square testing $\sum \frac{(o-e)^2}{e}$
    i null hypothesis: there is no difference between (the item being studied) and (random chance)
    b. degrees of freedom = number of samples - 1
    c. use the 0.05 value for your critical value
        (a) if the value is higher than the critical value- reject null hypothesis
        (b) if the value is lower than the critical value-fail to reject null hypothesis

Mathematical Modeling

Process of creating mathematical or computer based representations of the structure and interactions of complex systems

1. Models are formed after experimentation and ask these types of questions
    a. What can we measure
    b. What should we measure
    c. What are the relevant variables
    d. What are the simplest informative models we can build
2. Aspects of models
    a. Introducing power of the model
        (a) Approximating real world conditions
    b. Introducing limitations of the model
        (a) Assumptions
        (b) Simplifications
3. Components of mathematical models
    a. Examine a system to identify which variables seem to be most likely to have an effect
    b. Develop graphical or physical models to capture the essence of the phenomenon.
    c. Translate the model into a "word equation."
    d. Translate word equations into formal equations
    e. Implement the model on a computer
    f. Evaluate, revise, extend the model
        (a) Look at the basic assumptions, can they be eliminated?
        (b) Look at the simplification, can it be minimized?
        (c) Look at the approximation, can it be improved?

Mode = value that occurs most frequently
Median = middle value
Mean = average
Range = value obtained by subtracting the smallest observation from the greatest observation

$\bar{x}$ = sample mean
n = size of sample
s= sample standard deviation
o= observed results
e=expected results

$$\sqrt{\frac{\Sigma(x_i-\bar{x})^2}{n-1}}$$

standard deviation

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

standard mean error

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

mean

Example problem:

One of the lab groups collected the following data for the heights (in 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

Find the mode, median, mean, and range. Show your work where necessary.

Mode:_____ Median:_____ Mean:_____ Range:_____

Find the standard deviation by filling in the following table.

Heights (x)	Mean ($\bar{x}$)	$x-\bar{x}$	$(x-\bar{x})^2$
5.4			
7.2			
4.9			
9.3			
7.2			
8.1			
8.5			
5.4			
7.8			
10.2			

← $\Sigma(x-\bar{x})^2$

Standard deviation:

Interpret the standard deviation in the context of the problem.

Formulas:

Chi Square $\chi^2 = \Sigma \frac{(o-e)^2}{e}$

o = observed individuals with observed genotype

e = expected individuals with observed genotype

Degrees of freedom equals the number of distinct possible outcomes minus one

	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

Example problem:

Wisconsin Fast Plants have two very distinctive visible traits (stems and leaves). Each plant will either have a purple (P) or green (p) stem and also have either have green (G) or yellow (g) leaves. Suppose that we cross a dihybrid heterozygous plant with another plant that is homozygous purple stem and heterozygous for the leaf trait. Make a Punnett square to figure out the expected ratios for the phenotypes of the offspring.

Suppose a class observed that there were 234 plants that were purple stem/green leaves and 42 that were purple stem/yellow leaves. Does this provide good evidence against the predicted phenotype ratio?

Using your understanding of genetics, what might be one reason why the class got these results?

WORKSHEET #3: HARDY-WEINBERG A

Formulas:

$p^2 + 2pq + q^2 = 1$ p = frequency of the dominant allele in a population
$p + q = 1$ q = frequency of the recessive allele in a population

For people, being right handed (R) is the dominant trait over being left handed (r). Suppose there is a sample of 20 people that reveals the following genotypes:

(RR)	(Rr)	(RR)	(Rr)	(rr)	(Rr)	(RR)	(RR)	(Rr)	(RR)
(Rr)	(rr)	(Rr)	(Rr)	(RR)	(RR)	(Rr)	(RR)	(rr)	(Rr)

What percentage of the people are right handed? Left handed?

Find *p* and *q* and interpret each in the context of the problem.

Now suppose that we took another sample of 10 people. This time we only know their phenotypes.

(Right) (Left) (Right) (Right) (Right) (Right) (Right) (Right) (Left) (Right)

What percentage of the people are right handed? Left handed?

Can you find *p* and *q* exactly? Why?

Estimate *p* and *q* and interpret each in the context of the problem.

Estimate how many of the right handed people are homozygous and how many are heterozygous.

WORKSHEET #4: HARDY-WEINBERG B

Formulas:

$p^2 + 2pq + q^2 = 1$ p = frequency of the dominant allele in a population
$p + q = 1$ q = frequency of the recessive allele in a population

Example problem:

In 1990 the Garces Memorial High School student body was made up of 90% right handed students. Being right handed (R) is the dominant trait over being left handed (r).

What is p and q for the population of 1990 NA High School students. Interpret each.

Find the percent of the student body in 1990 that are homozygous right handed, heterozygous right handed, and left handed.

Fast forward to today at Garces. We took a random sample of 100 students today and found that 18 of them were left handed.

c. What are the new p and q values? How do they compare with the values from 1990?

There are many reasons why this apparent change could have occurred. Come up the five you will be expected to know and give an example for each:

WORKSHEET #5: POPULATIONS A

Rate	**Population Growth**	**Exponential Growth**	**Logistic Growth**
dY/dt	dN/dt = B – D	$\frac{dN}{dt} = r_{max} N$	$\frac{dN}{dt} = r_{max} N\left(\frac{K-N}{K}\right)$

dY = amount of change B = birth rate D = death rate N = population size
K = carrying capacity r_{max} = maximum per capita growth rate of population

Notes

$$\frac{dN}{dt} = \frac{\Delta N}{\Delta t} = \frac{change\ in\ population\ size}{change\ in\ time}$$ = population growth rate

Example 1:

There are 300 falcons living in a certain forest at the beginning of 2013. Suppose that every year there are 50 falcons born and 30 falcons that die.

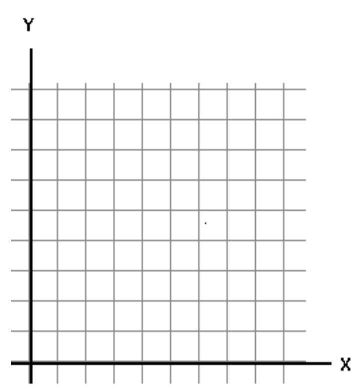
What is the population growth rate (include units)? Interpret the value.

What is the per capita growth rate of the falcons over a year? Interpret the value.

$$\frac{dN}{dt} = r_{max} N$$

c. Fill in the table and construct a graph.

Year	Population
2013	
2014	
2015	
2016	
2017	
2018	



Find the average rate of change for the falcon population from 2013 to 2018 (include units). Interpret the value.

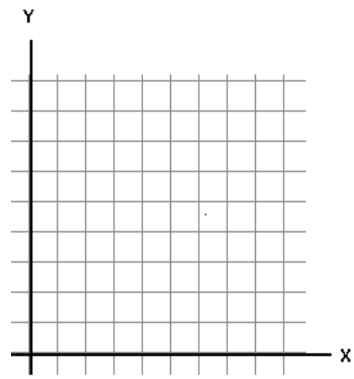
WORKSHEET #6: POPULATIONS B

Wexford had a population of 49,000 in the year 2013. The infrastructure of the city allows for a carrying capacity of 60,000 people. r_{max} = .9 for Wexford.

a. Is the current population above or below the carrying capacity? Will the population increase or decrease in the next year?

b. What will be the population growth rate for 2013 (include units)?

c. What will be the population size at the start of 2014.



d. Fill in the following table:

Year	Population size	Population growth rate
2013		
2014		
2015		
2016		
2017		

e. What happened to the population size over the years? What happened to the population growth rate over the years?

f. Explain your answer from part (e) using what you know about carrying capacity.

g. Explain your answer from part (e) using the formula: $\frac{dN}{dt} = r_{max} N\left(\frac{K-N}{K}\right)$

WORKSHEET #7: TEMPERATURE COEFFICIENT

$$Q_{10} = \left(\frac{k_2}{k_1}\right)^{\frac{10}{T_2 - T_1}}$$

T_2=higher temperature
T_1 = lower temperature
K_2= reaction rate at T_2
K_1=reaction rate at T_1
Q_{10}=factor by which the reaction rate increases when the temperature increases by 10°C

The rate of metabolism of a certain animal at 10°C, is 27 µL O_2 $g^{-1}h^{-1}$.

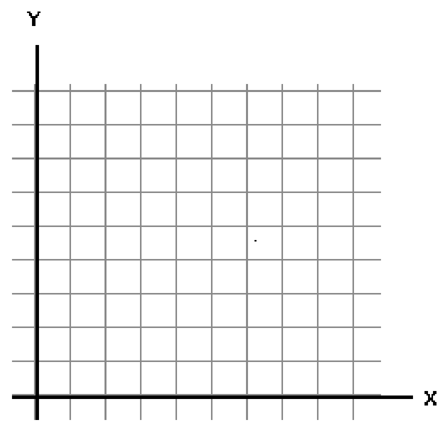
What are its rates of metabolism at 20, 30, and 40 °C if the Q_{10} is 2? If it is 2.5?

$R2 = R1 \text{ x } Q_1$

Temperature °C	**Rate2 if Q_{10} = 2**
20	
30	
40	

Temperature °C	**Rate2 if Q_{10} = 2.5**
20	
30	
40	

Graph showing the effect of Temp on Rx rate



The following table reports the rates of metabolism of a species at a series of ambient temperatures:

Temperature (°C)	**Rate of Metabolism (µLO_2 $g^{-1}h^{-1}$.)**
15	10
20	13.42
30	21.22

Calculate the Q_{10} values for each temperature interval

Within which temperature interval (15-20 or 20-30) is the rate of metabolism most sensitive to temperature change?

For this species, would a Q10 calculated for 15 to 30 °C be as useful as several for smaller temperature ranges? Calculate that Q10 as part of your answer.

The reaction rate for a certain process at **14 °C is 15 units / time.** What would be the reaction rate at 20 °C if the Q10 = 1?

WORKSHEET #8: DILUTIONS

$$C_1V_1 = C_2V_2 \text{ aka. } M_1V_1=M_2V_2$$

C_1 = original concentration of the solution, before it gets watered down or diluted.
C_2 = final concentration of the solution, after dilution.
V_1 = volume about to be diluted
V_2 = final volume after dilution

For all dilution problems $C_1 > C_2$, and $V_1 < V_2$. It makes sense because to dilute, we add water. This ***increases*** the volume but ***lowers*** concentration.

Examples by Type:

1. Easiest: Joe has a 2 g/L solution. He dilutes it and creates 3 L of a 1 g/L solution.

   How much of the original solution did he dilute?

2. A little trickier: Joe has 20 L of a 2 g/L solution. He diluted it, and created 3 L of a 1 g/L solution. How did he make such a solution?

3. Trickier too: Joe has 20 L of a 2 g/L solution. To this solution he adds 30 L. What is the final concentration of the solution?

WORKSHEET #9: SA:V

Surface area to Volume and Water Potential Review

Cells throughout the world have variable shapes and sizes. Because of this, and because structure is designed around function, certain shapes are optimal for certain processes.

Analyze the following cells (units not to scale), and determine the following…

Cell 1 (spherical) where the diameter is 6 mm

Cell 2 (flat and rectangular) where the height is 0.5mm, length is 4mm, width is 2mm

Cell 3 (cube) where side length is 6 mm

A) What is the surface area to volume ratio of each cell?

Cell	Surface area	Volume	Surface area to Volume Ratio
Cell 1			
Cell 2			
Cell 3			

B) Conclusion: Compare the ratios and explain why one cell would be more efficient than another.

C) Which is better, a square cell or a round cell. Explain what this means.

D) Are you made of lots of large cells or lots of small cells? Why? How do you actually grow in height?

E) Provide 5 examples of ways organisms use SA:V ratio to survive.

WORKSHEET #10: WATER POTENTIAL

$\Psi = \Psi_P + \Psi_S$ Ψ_P= pressure potential; Ψ_S = solute potential

$\Psi_S = -iCRT$ *i* = ionization constant; C = molar concentration; R = 0.0831; T=Temp (K)

The water potential will be equal to the solute potential of a solution in an open container

i is 1.0 for sucrose because sucrose does not ionize in water

Water potential in potato cells was determined in the following manner. The initial masses of six groups of potato cores were measured. The potato cores were placed in sucrose solutions of various molarities. The masses of the cores were measured again after 24 hours. Percent changes in mass were calculated. The results are shown below

Molarity of Sucrose in Beaker	Percent Change in Mass
0.0 M	18.0
0.2	5.0
0.4	-8.0
0.6	-16.0
0.8	-23.5
1.0	-24.0

Graph these data. From your graph, label where the cells were hypotonic and the solution was hypertonic, and vice versa. Determine the apparent molar concentration (osmolarity) of the potato core cells.

Looking at the water potential equation,

Pressure potential is always (positive/negative), while solute potential is always (positive/negative).

When Solution potential goes down (gets more negative), water potential DECREASES

When Pressure potential goes down (gets smaller), water potential DECREASES

When would the pressure in a cell rise? (Under what conditions?)

What would happen to the solute potential when Concentration is increased (justify with equation)? WHY?

What would happen to the solute potential when Temperature is increased (justify with equation)? WHY?

What would happen to the solute potential when the dissolved substance is glucose vs. salt (justify with equation)? WHY?

Why is water potential important for plants? What are they lacking?

Predict what would happen to animal cells placed in 0.0M and 1.0M concentration solutions.

WORKSHEET #11: GIBBS FREE ENERGY BASICS

$\Delta G = \Delta H - T \Delta S$

What is Entropy? = a measurement of

When **Δ**S is positive this means there is

When **Δ**S is negative this means there is

What is **Δ**H? = a measurement of

When **Δ**H is positive this means the reaction is

When **Δ**H is negative this means the reaction is

What is Gibbs Free energy? = a measurement of

When **Δ**G is positive this means the reaction will happen

When **Δ**G is negative this means the reaction will happen

ΔG (Joules)	ΔH (Joules)	T (Kelvin)	ΔS (J/K)
	1000	300	5
	1100	300	5
	1200	300	5
	1300	300	5
	1400	300	5
	1500	300	5
	1600	300	5
	1700	300	5
	1800	300	5
	1900	300	5

What happens to ΔG when ΔH goes up ? WHY?

What happens to ΔG when ΔH goes down ? WHY?

ΔG	ΔH	T	ΔS
	1700	300	5
	1700	310	5
	1700	320	5
	1700	330	5
	1700	340	5
	1700	350	5
	1700	360	5
	1700	370	5
	1700	380	5
	1700	390	5

What happens to ΔG when T goes up ? WHY?

What happens to ΔG when T goes down ? WHY?

ΔG	ΔH	T	ΔS
	7500	300	5
	7500	300	10
	7500	300	15
	7500	300	20
	7500	300	25
	7500	300	30
	7500	300	35
	7500	300	40
	7500	300	45
	7500	300	50

What happens to ΔG when ΔS goes up ? WHY?

What happens to ΔG when ΔS goes down ? WHY?

WORKSHEET #12: GIBBS FREE ENERGY APPLICATION

Energies are usually given as standard free energies of hydrolysis. For example

glucose-6-phosphate + water → glucose + P_i

has ΔG° = -4.0 kcal/mole (-16.5 kJ/mole) under standard conditions. Therefore, the opposite reaction, the phosphorylation of glucose, is unfavored. However, the phosphorylation of glucose occurs readily in the cell, catalyzed by the enzyme hexokinase:

glucose + ATP → glucose-6-phosphate + ADP + P_i

The other half of the phosphorylation reaction is the hydrolysis of ATP to yield ADP and inorganic phosphate (P_i):

ATP + H_2O → ADP + P_i

under standard conditions has ΔG° = -7.3 kcal/mole (-31 kJ/mole).
The standard free energy change of the reaction can be determined by adding the two free energies of reaction:

Glucose + P_i → glucose-6-phosphate + H_2O and ΔG° =+-4.0 kcal/mole

Note that the reaction as written is unfavored; its free energy change is positive. Another way of stating this is that the reaction is **endergonic,** that is, the reaction involves a gain of free energy.
For the **exergonic** hydrolysis of ATP (the reaction involves a loss of free energy):

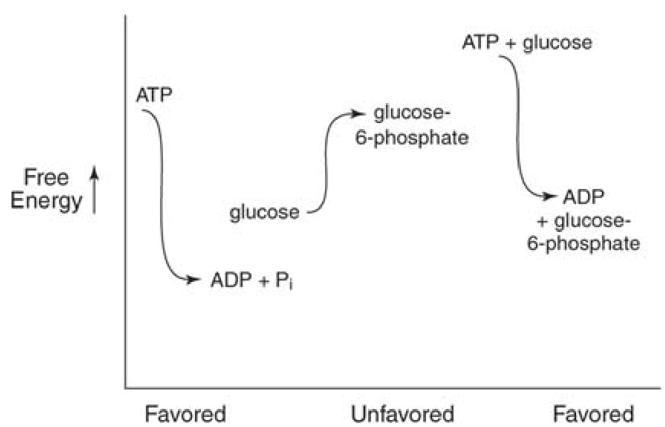
ATP + H_2O → ADP + P_i ΔG° = -7.3 kcal/mole

The two reactions are summed:

Glucose + ATP → glucose-6-phosphate + ADP + P_i ΔG° = -3.3 kcal/mole

This is a simple example of energetic **coupling,** where an unfavorable reaction is driven by a favorable one.

Coupling doesn't occur all by itself. In this example, if this experiment were set up so that the ATP would have to be hydrolyzed in one tube and the glucose phosphorylated in another, no coupling would be possible. Coupling can occur only when the partial reactions are part of a larger system. In this example, coupling occurs because both partial reactions are carried out by the enzyme hexokinase. In other cases, coupling can involve membrane transport, transfer of electrons by a common intermediate, or other processes. Another way of stating this principle is that coupled reactions must have some component in common.



The “orderliness” of your body is not favored by free energy. Explain (in terms of free energy and disorder) why you need to perform digestion?

Why does decomposition of a dead animal happen in terms of energy? What would happen if we increase temperature? Why do we freeze food?

Explain why plant cells need light to build sugar (in terms of energy).

WORKSHEET #13: PRIMARY PRODUCTIVITY

$$\frac{mg\,O_2}{L}\,x\,\frac{0.698mL}{mg}=\frac{mL\,O_2}{L} \qquad \frac{mL\,O_2}{L}\,x\,\frac{0.536\,mg\,C\ fixed}{mL\,O_2}=\frac{mg\,C\ fixed}{L}$$

One can determine Primary Productivity by measuring dissolved oxygen in the water (as it is hard to measure it in the air)

1 ml of O_2 = 0.536 mg of Carbon assimilated
mg O_2/L x 0.698 = ml O_2/L; ml O_2/L x 0.536 = mg carbon fixed/L

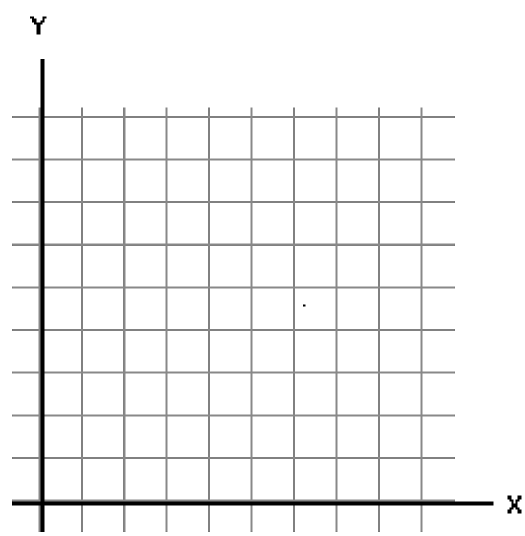
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

<u>Fill in the table and Graph Net and Gross Productivity vs. % of light</u>

% light	DO_2 (mg O_2/L)	Gross PP = DO_2-dark (mg O_2/L)	Net PP = DO_2 -initial (mg O_2/L)	Gross carbon fixed in mg C/L Gross PP x 0.698 x 0.536
Initial	8.4	—	—	—
Dark	6.2	—	—	—
100%	10.2			
65%	9.7			
25%	9.0			
10%	8.5			
2%	7.1			

Using your data table, what seems to be the trend as the % of light decreases? WHY?

Using your data table, what seems to be the trend as the % of light increases? WHY?



Where would you say this organism is using as much energy as they are making? WHY?

Using your table and graph, explain why most of the time there are bigger plants on land than in the sea? Explain this in terms of evolution.