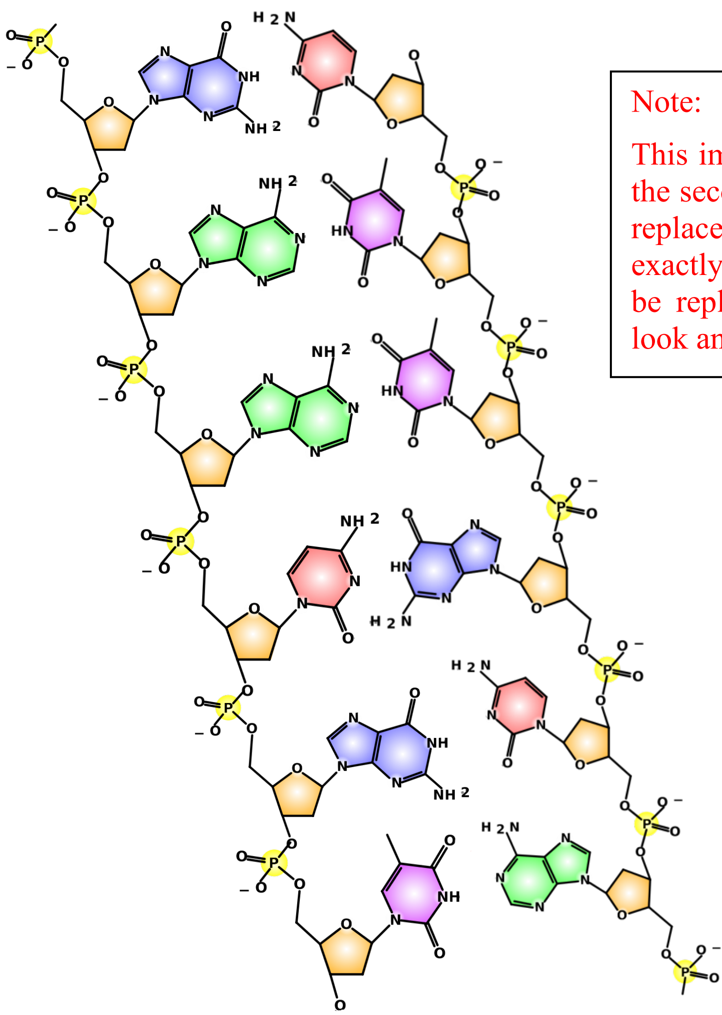
**Module 1: Biological Chemistry**

**Review Activity**

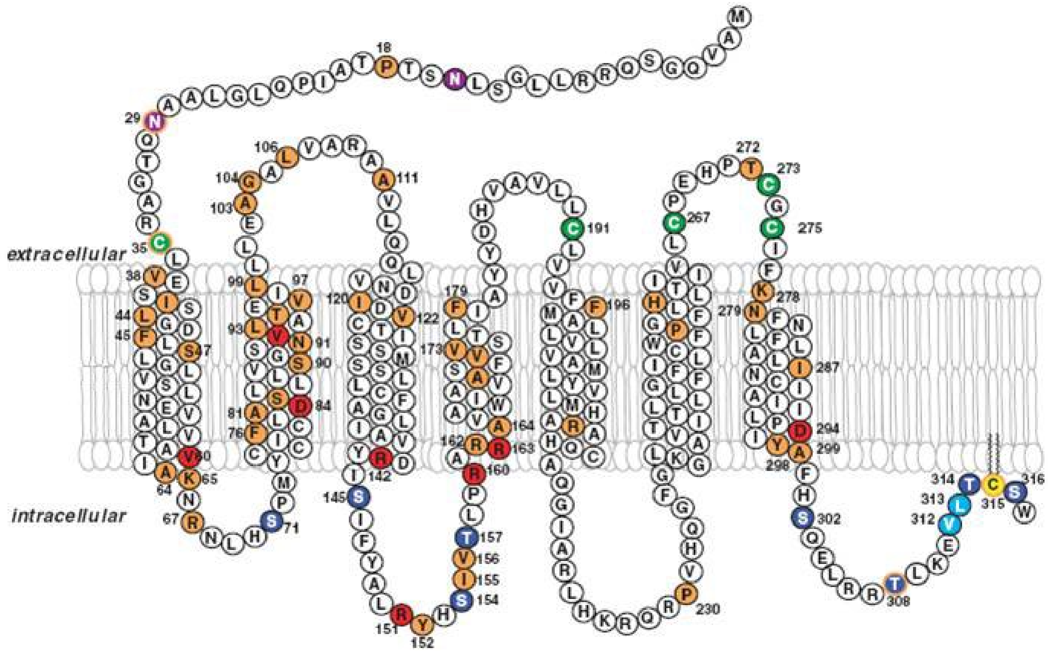
1. Provide a rough sketch of the following nucleic acid strand: **GAACGT**. In your sketch, be sure to draw the phosphate-sugar backbone (circles and rough pentagons are fine), and distinguish between one and two-ringed bases (rings can be roughly drawn). Also indicate 5'-3' directionality for the molecule you've drawn.



Note:

This image displays two strands of DNA. If the second strand was RNA, the T would be replaced by U (which would look almost exactly the same), and the deoxyribose would be replaced by a ribose (which would not look any different in this image).

2. Draw the RNA strand which is complementary to the DNA strand you drew above. Draw the RNA strand such that it is attached through base pairing to the DNA strand. Indicate 5'-3' directionality for the RNA.




During module 4 on evolution, we will spend several classes examining the evolutionary significance of fur colour in a certain group of mice from the Sonoran desert in the South-Western United States. To prepare for this module, in the review activities for the first 3 modules we will be examining the molecular, cellular, and genetic basis for mouse coat colour.

To begin, we will look at a molecule called MC1R, which is pictured above. Based on what you've learned so far about the various biological macromolecules, what kind of macromolecule do you believe MC1R is? Explain your reasoning.

MC1R is a protein. You can tell because of the shape of the molecule, which does not conform to the shapes of nucleic acids, carbohydrates, or lipids we've examined. Also, there are many types of individual monomers linked together; many more than you would find in nucleic acids (only 4), carbohydrates (usually only 1 or 2), or lipids (not really monomers linked together). Finally, the molecule is clearly embedded in a plasma membrane, and only proteins are found here.

How many levels of structural organization can you identify in the image? Explain.

There are 3 levels of structural organization. For one, all proteins have at least 3 levels; there is only one polypeptide strand here, so there is no quarternary structure. However, you can see a sequence of amino acids (primary structure), amino acid helices through the plasma membranes (secondary structure), and clear 3-dimensional loops (tertiary structure).

Where is the MC1R macromolecule found? How can you tell?

MC1R is embedded in the plasma membrane. You can tell because the molecule is surrounded by phospholipids.

Describe the properties of the molecules surrounding MC1R, specifically with regard to the contrast between water, polar, charged, and non-polar molecules.

The molecules surrounding MC1R are phospholipids. These are amphipathic molecules, meaning they have both hydrophilic portions (the charged phosphate) and hydrophobic portions (the non-polar fatty acid tails). The hydrophilic portions form the extracellular and intracellular barriers of the membrane, while the hydrophobic portions form the interior of the membrane.

Based on information from image, speculate on the possible functions of MC1R in the cell.

MC1R is a transmembrane receptor protein involved in a typical cell communication pathway.

Briefly describe the relationship between the MC1R molecule and the genetic information of the cell.

Central Dogma of Molecular Biology: DNA→RNA→Protein

The information for making proteins is stored in the DNA, which makes a working copy in RNA. The RNA instructions are then ‘read’ to actually make the proteins.

Imagine you are examining the labels of two different food products. You happen to notice that one of them contains 3g of sugars and no fat, while the other one contains no sugars and 3g of unsaturated fat. Assuming all other molecules are equal, which of the two food products should have more calories? Explain your reasoning.

The food with the fat will have many more calories. The energy (measured in calories) found in food is stored in the high potential energy C-H bonds. Carbohydrates (which include sugars) do contain C-H bonds, but nowhere near as many per unit mass as lipids, which are almost exclusively C-H bonds. Thus, lipids are the highest energy molecule, and food with high amounts of fat are very high in calories.

While you're reasonably willing to trust the information presented to you in your Biology (and Chemistry) classes, you're still the type of person who needs to empirically figure things out for yourself. You also just happen to have access to a bomb calorimeter, and a box filled with numerous packages of food products A and B. With these resources at your disposal, design an experiment to test out your hypothesis above.

Experimental design: In a controlled environment, burn repeated samples of products A and B in the calorimeter. Might not hurt to do some background research into the constituents of these two food products, to increase confidence that the labels truly represent what's in the food.

Independent variable: Type of food (A or B)

Dependent variable: Calories contained in the food

Control variables (at least 2): Any number of correct answers, although the bomb calorimeter should establish a reasonably controlled environment. Examples could be same amount of food in the calorimeter, using properly distilled water, running tests at similar air pressures, etc…

Let's say your experiment above produces the following results:

| Calories from Product A (kcal) | Calories from Product B (kcal) |
|---|---|
| 135 | 297 |
| 142 | 267 |
| 122 | 308 |
| 164 | 274 |
| 153 | 285 |
| 144 | 312 |
| 134 | 271 |

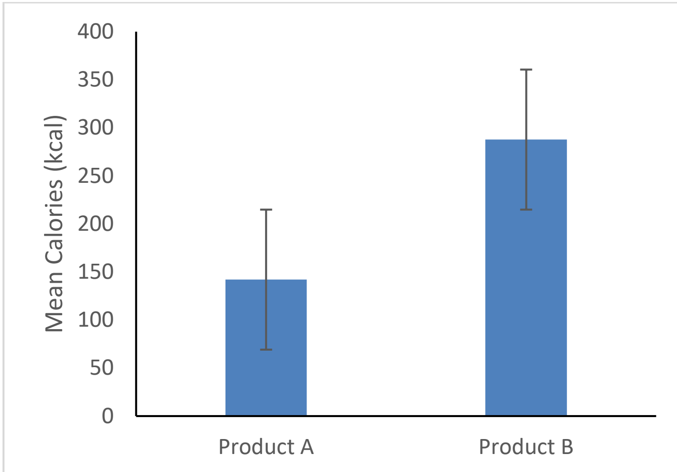
How would you analyze these data? Which statistical test should you use, what kind of output would you expect, and what would you report in a paper?

Nominal independent variable, ratio dependent variable with repeated measures… should use a t-test to test hypothesis, comparing means to identify whether there is a statistically significant difference. Eyeballing it here, the two groups seem quite different, so we would expect a very low p-value, indicating a very low probability of the null hypothesis being correct (null: independent has no effect on dependent, or there should be no difference between the means). In a paper you should report the p-value, the test statistic (t-stat), and the degrees of freedom (df).

Suppose you performed the test you indicated in the previous question and obtained a $p\text{-value} < 0.001$. What conclusions can you draw from this result?

A very low probability of the null hypothesis being correct, suggesting that this can be rejected. This suggests that the independent variable does have an effect on the dependent variable, and that the type of food does have an effect on the number of Calories. Since the only difference between the two types of food is carbs in one and lipids in the other, and the lipid food has more calories, this indicates that lipids are more calorie-rich molecules.

Without doing any explicit calculations (i.e., ballpark it), draw a small figure to represent the important finding from your experiment.




Imagine now that, in addition to 3g of sugars, the first food product also had 15g of fibre, which the second product did not have. Would this have changed your initial hypothesis? Why or why not? Refer to specific macromolecular configurations and functions in your answer.

No, the first answer wouldn't change. Even though fibre is carbohydrate molecules, it is made up predominantly of cellulose molecules, which are large molecules made up of beta-linked glucose monomers. Animals do not possess the enzymes to hydrolyze beta glycosidic links, which means that we are not able to break down cellulose. Because these molecules are not broken down, fibre just passes through our intestines (dragging other stuff with it, which is why fibre is good for us) without being metabolized. Thus, we derive no calories from fibre, and so the food with fat still has more calories (at least for us).

Why is it important for the theory of chemical evolution that essentially no $O_2$ gas was found on early earth?

The theory of chemical evolution provides a hypothesis for how the first precursor molecules of life were formed. These molecules contain high potential energy C-H bonds, where carbon is in a reduced state. The theory of evolution provides a framework for how carbon could have proceeded from being in an oxidized state (as it is in $CO_2$ for example) to being in a reduced state (in C-H bonds). However, oxygen is an extremely potent oxidizer, meaning it will readily pull electrons towards it and away from other molecules. Thus, if $O_2$ gas were present in the atmosphere of early earth, it's likely that any initial reduced carbon C-H bonds produced through the process of chemical evolution would quickly have been oxidized by any $O_2$ molecules present. In other words, if $O_2$ were present, life as we know if probably wouldn't have started.