Guidelines for Writing Lab Reports in Biology 107

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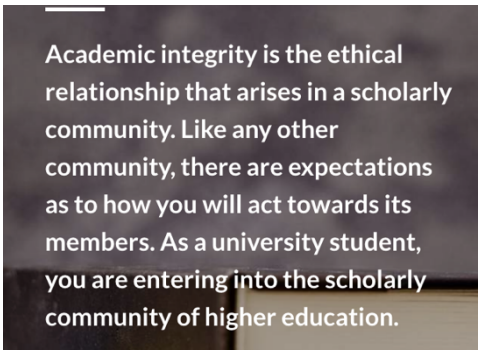
*Unit 2 Assignments submitted without the Academic Integrity Training Certificate will not be graded

Get help when you need it!
Below is a screenshot from the Academic Integrity Tutorial. The tutorial explains the services offered to support students in developing their writing skills. Take advantage of the Writing Centre!

What students had to say about how they feel about sitting down to start writing a paper

Writers are not born, *they are made*

Writing is hard. You are putting your ideas on the page for others to read and for your instructor to assess. At the Writing Centre we understand this process and we are here to help you.



Why do you have to write lab reports in Biology 107?

Lab reports are assigned to provide you with experience in what is the fundamental process of science: the opportunity to acquire and report data. Regardless of your career path, this experience in scientific writing should assist you in organizing ideas in a logical way and supporting your arguments using literature sources. Scientific writing has specific requirements and expectations that will be presented in general here, and specifically on your assignment handout.

A written lab report presents information as to exactly what your purpose was, what you did, what your results were, and your interpretations and conclusions of your results. Reports are to be written in past tense, in a clear, concise style that is understandable by someone unfamiliar with the experiment. Typically, a lab report consists of 5 main sections: Introduction, Methods, Results, Discussion, and Literature Cited/ References, presented in that order. But in Biology 107, you will not be writing a Methods section.

When beginning to write a report, a general recommendation is to start with the Results section. Once you clearly know what information is being presented, you can clearly define your Discussion and Introduction.

We often see an entire Introduction or Discussion section as one paragraph. Remember, ideas need to be **organized into paragraphs; one topic/paragraph.**

Scientific Literature and Academic Integrity*

Scientists communicate their results by publishing their work in science journals. Generally, in biology when you read literature from scientific journals, you will read both review articles and primary articles. These articles are reviewed by experts before they are published. The peer review process is summarized in Figure 1.

A. A review article does not present original research, rather it summarizes the existing knowledge on a topic. The topic can vary in depth, some review articles summarize the existing knowledge about a very specific topic, others are more broad. These articles are written by researchers, are found in scholarly journals, and are peer reviewed.
B. Primary articles report on original research. They are written by researchers, are found in scholarly journals, and are peer reviewed.

Your Introduction and Discussion sections should use scientific articles. Reading papers is hard work, particularly when you do not have a solid background in the research area. For all of the papers, the background information summarized in the Introduction section will be very useful. When you are reading the primary articles, you may not understand them in their entirety, but you will understand many parts of them. It is important that you start reading scientific literature, as this is how scientists disseminate their research, and this is how scientists inform their own research. In practice, if you were to cite information from the introduction of a primary article, you would need to go to the original source, and cite the original (to give appropriate credit to that person's work). However, in Biol 107, we have not taught you the research skills to locate literature, so it is okay to cite as follows: (as cited in Smith et al, 2015). Please note, this is not the standard in biology, but is acceptable for the purpose of Biology 107 lab reports.

Figure 1. The peer review process. https://www.elsevier.com/reviewers/what-is-peer-review

When using sources (textbook, papers, the lab manual) to support your Introduction and Discussion, you must **write the information in your own words and provide an in-text citation**. Copying directly, or poor paraphrasing is a violation of the Academic Integrity Policy. Quotes are not accepted, because although putting information in quotation marks is not plagiarism, it is generally not done in science. We expect you to synthesize the information and communicate it in your own words. MacEwan has an incredible Academic Integrity Tutorial that does an outstanding job explaining academic integrity, how to paraphrase, and how to cite. You must complete the Academic Integrity (AI) Training on Blackboard and submit your certificate with your assignment. Assignments that do not include the certificate will not be graded. We encourage you to take the AI training seriously, as many students end up with Academic Integrity violations because they didn't understand the expectations. The information presented in this tutorial is exceptionally valuable to you for all of your coursework, including Biology 107.

The tutorial is a self-enroll course on BlackBoard: Academic Integrity Tutorial. Please read all of the information contained in the modules and then complete the quizzes to obtain your certificate. There is a video on BlackBoard that shows you how to self-enroll in this course.

Introduction Section

The introduction explains the purpose of conducting the experiment and describes the significance of the work. Why was it studied? What is important about it in relation to biological systems? Essential background information should be provided (and cited!). The information and reasons which formed the basis for selection of your hypotheses should be explained and logically presented. The introduction also should contain clear hypotheses.

A well-written Introduction will provide the reader with sufficient background information relevant to the research being presented, a point of relevance for the research, a clear definition of research objectives and associated experimental design, and finally the expected outcome of the experiments with supporting rationale/evidence. The Introduction must include many in- text citations and needs to be organized into paragraphs.

I. **Relevance ---** A broad and general base that highlights why the research is important/relevant to the real world. This should be a paragraph and clearly relate to the work you are presenting in the lab report.

II. **Background –**It is necessary to provide the reader with background information about the topic that is pertinent to the independent variables tested in the experiment. One needs to think carefully about which information to include, as random information will take the reader off on an undesired tangent. The background information should directly relate to the Results and Discussion in order to create a unified research story.

III. **Presentation of research –** A general explanation of the experimental purpose, what experiments were carried out, a brief mention of the key aspects regarding how the experiments were carried out. This is not the same as a MATERIALS AND METHODS section! --- it is meant to be a summary, which highlights the independent and dependent variables.

IV. **Hypothesis ---** The hypothesis for each experiment should be specific, clearly stated, with logical reasoning.

Tips for good hypotheses:
Define the relationship between the independent and dependent variable.
- link the variable to an effect (ex. changes in kinetic energy can damage the plasma membrane)
-state the expected effect (ex. increase in kinetic energy causes an increase in plasma membrane damage and thus betacyanin leakage)

Explain how or why the variable is causing the effect.
- provide a mechanism/rationale (ex. …. is because increased kinetic energy causes phospholipids….).

Be compatible with and based upon the existing body of evidence
-be supportable by scientific literature. (ex…. as supported by --------- et. al (2017)…. temperatures of …. lead to ….)

The goal of the hypothesis is to provide a plausible answer to the scientific question posed; this will

include both a predication and a brief rationale for that prediction. Hypotheses are formulated and supported by scientific knowledge (NOT based on a guess or gut instinct). This scientific knowledge should come from reliable reference material – textbook, lab manual, and scientific articles.

Results Section

The results section is the most important part of the report. Experimental results are a permanent record that does not change; the discussion is interpretative work which may change as new discoveries are made. This section presents in explanatory text any observations, measurements, or statistical analyses relevant to the experiment. Findings presented as graphs, tables, and figures must be referred to and described in the text of the Results. These finding should be a clear and well-organized presentation of the data. Thought should go into presentation of results so that they are easy to follow. This section should not include discussion, interpretation or conclusions.

A good results section of a lab report identifies the overall trend in the results from an experiment, summarizes the results, and highlights the important findings in an objective way. Listing every data point in an experiment is not appropriate. It is important that the overall trend is identified, and specific values can be used to highlight the key trends in the data. It takes practice to write a good Results section that objectively and concisely states the results. For example, in the Membranes lab, it is easy to be too brief (ex: only mention the -20°C and 70°C results, while ignoring other temperatures) or too detailed (ex: listing the concentration of betacyanin at each temperature without connecting it to the overall trend).

In this section:

- write about the results as illustrated in the figures.
- include statistics when reporting the results (where appropriate).
- compare experimental results to the control.
- refer the reader to the figure(s).
- Use past tense

The written information should stand alone if necessary, i.e. the reader should be able to determine the results without consulting the figures (but the text should still refer the readers to the figures). Example: As shown in Figure 1, …….

No conclusions, interpretations, speculation or opinions should be given in a results section. Although it is tempting to interpret the data, be careful to only objectively report the results (for example, in the membranes experiment, stating that a specific treatment caused membrane damage is actually an interpretation of the data, which is done in the Discussion section. For the Results section it is appropriate to say that a specific treatment resulted in an increase in concentration of betacyanin.) The Results section should not include in-text citations because it is the original work of the author.

Discussion Section

Interpretation of results and justification for conclusions is presented in the discussion section. Do the data support or not support the hypotheses presented in the introduction? Experimental results **do not prove** hypotheses: at best they are consistent or not consistent with the hypothesis. Preparation for writing this section requires studying your data, discussing it, consulting references, etc. Explain why you believe the results do or do not support the hypotheses in the context of general biological knowledge. Were your assumptions correct? How does your work compare to others? Were there any error sources in the experiment? Be sure to support your arguments with reference to your results and to other work in the literature. It may make your discussion easier for the reader to follow if you provide and refer to appropriate results (figures, tables, and diagrams). **A clear, logical explanation of your results integrating your knowledge of the biological system being investigated is crucial**.

A good discussion will:

1. Draw conclusions from the data and highlight the key experimental findings. Did the data support or refute the hypothesis? For example, this data supports the hypothesis that…….
2. Support the data with findings from the scientific literature. (ex: Smith et al (2015) also found that……) There are papers posted on Blackboard that can be used for this purpose.
3. Provide a feasible biological explanation that could explain the results. You will need to use the literature to support this part of the Discussion. The explanation must be thorough and show that you have a thorough understanding of the biology. Notice that in the grading rubric, this component has the most marks assigned. This is because in order to sufficiently provide an explanation for the results, the discussion must be thorough and must convince the reader that the writer has a deep understanding of the biology.
   This part of the Discussion must be heavily cited.
4. Identify limitations to this study. Are there weaknesses in the experimental design that limit the conclusions you can draw? This is not a place to identify mistakes you made (we assume that if you made human-error type mistakes, you would have re-done the experiment). If you know you made a technical mistake, you should identify this when you draw conclusions. Be careful though not to assume that if your data "looks weird" or is unexpected that you must have made a mistake. But if you KNOW you did the experiment wrong, definitely identify this in the Discussion.
5. Propose future work that would help fill in the knowledge gaps that result from your work. Propose the next experiment you should do to address the limitations identified above. Provide a rationale for the future work. Clearly communicate why this future work is important and how it will generate new knowledge that contributes to this field of research.

In text citations and References

It is required that sources used to write scientific reports will be referenced, using 1) an in-text citation as well as 2) all required publication details in a Reference section. Scientists do not have a format that they use for all publications (ex: MLA, APA), rather, they format their references for the journal they are publishing in.

An important component of any lab report is the use of other sources (i.e., textbooks, reference books and scientific journals) in helping you to formulate your question/ hypotheses, provide background information, and assist in analyzing/ interpreting your results/ conclusions. However, when you use any type of information, ideas, opinions, etc. from any other source you must reference the source(s) that you obtained it from. If you take this information and write it in your own words, this is called a reference citation; if you copy it word for word this is called a reference quotation. Although quotations are common in other disciplines, scientific writing rarely uses them. The point of Biology 107 lab reports is for you to synthesize the information and write it in your own words. **Therefore, direct quotations will not be accepted in your lab reports. All of the information you will need to use should be paraphrased, followed by an in-text citation.**

In-text Citations

You are expected to provide an in-text citation every time you use information, ideas or knowledge from a source (textbook, lab manual, paper etc.). For Biology 107 you will be required to provide an in-text citation for **each sentence** that contains information from another source, even when it has been paraphrased into your own words. Even when the information is from the same sentence as the previous sentence you must still provide a reference for the current sentence. Failure to provide the in-text citations is considered plagiarism and will be treated as such according the Academic Integrity Policy. Please review the section on plagiarism if you are unclear on how to cite information in your lab report.

To correctly format your in-text citations please use the following format. The citation immediately follows the information that requires a citation (which may mean that is within a sentence sometimes).

> One author papers/books: (Last Name Year)
>
> Two author paper/book: (Last Name and Last Name Year)
>
> More than two authors: (Last Name of first author et al. Year)

Note, the et al. is Latin for “and others” so you only include the last name of the first author followed by this notation.

Example use of in-text citations in your lab report:

> “There are at least four mechanisms that might explain the organization of human protocadherin genes (Wu and Maniatis 1999). In the first two mechanisms alternative splicing is involved. However, for these to operate there must be a mechanism by which alternative splicing is regulated in a cell-specific manner (Wu and Maniatis 1999). Although alternative splicing is often used for cell- specific expression, the mechanisms involved are poorly understood (Black 1998).”

Note how often an in-text citation is provided. In your lab reports any information from your textbook, your lab manual or other sources must include an in-text citation. Students often are

confused about what information requires an in-text citation. Very common or general statements do not require an in-text citation, but any specific knowledge or information (regardless of whether you looked it up or not) requires a citation. Failure to do so is considered plagiarism. When in doubt, it is always better to cite!! You should also seek clarification from your Instructor if you are unsure of what information needs to be cited.

*****If your Introduction and Discussion do not contain any in-text citations, it means you have either failed to provide sufficient information or you have failed to correctly cite information. *****

Each reference that is used as an in-text citation also requires a full citation in the reference section. This is an **alphabetical list** of all sources used that provides all the information that the reader will need if they wish to look up the original source of the information. It is very important that there is a full citation for every reference that has an in-text citation. Also, there should be no references in your reference section that do not have a corresponding in text citation in the body of your paper.

Unfortunately, there is no universally accepted format for presenting references in the Literature Cited or References section in biology journals or books. However, in all styles the placement of periods and commas are extremely important, please make sure you follow the format we have assigned for your Biology 107 lab report. An overview of the expected style for Biology 107 assignments is presented below:

For journal articles:

First author's last name, Initials and Initials of second author Last name. Year of publication. Title of journal article. Name of journal Volume: page numbers of article.

If a journal has more than two authors, you will need to list all of the names in the full reference.

Black, D.L. 1998. Splicing in the inner ear: a familiar tune, but what are the instruments? Neuron 20: 165-168.

Wu, Q. and T. Maniatis. 1999. A striking organization of a large family of human neural cadherin-like cell adhesion genes. Cell 97: 779-790.

For textbooks:

Russel, P.J., P. E. Hertz, B. McMillan, M. B. Fenton, D. Maxwell, T. Haffie, B. Milsom, T. Nickle, and S. Ellis. 2019 . Biology, Exploring the Diversity of Life, 4thCanadian Edition. Nelson Education Ltd, Toronto, ON Canada

Reece, J.B., L.A. Urry, M.L. Cain, S.A. Wasserman, P.V. Minorsky, and R.B. Jackson. 2011. Cambell Biology, 9th Ed. Pearson Benjamin Cummings, San Francisco, CA USA

Talaro, K. and A. Talaro. 1993. Foundations in Microbiology. Wm. C. Brown, Dubuque, IA.

Using Web sites for references

Web references are **not recommended**, but if you are using the information, **do cite it!** You must be careful when using information from the internet because of the varying type and quality of the information. Unlike scientific journals and most text and reference books, the majority of internet sites

are not reviewed by experts in that field (called “peer review”) before they are posted or published. Before you use any information from the internet you have to carefully evaluate it to make sure that it is appropriate and valid. You can find information on evaluating internet sources (and others) at the library website (http://library.macewan.ca/how_to).

- As a general rule of thumb, user edited sites such as Wikipedia, answers.com, and ehow.com **are not** considered citable sources.
- University, science society, or government agency sites are considered citable sites.

When you cite information from the internet, use the same basic format that you use for journal articles and books; the author(s) name and year posted/ last updated. If the site does not have an author then give the name of the organization, group or company that produced the site; if you cannot locate that information, then give the title of the site.

- Example of how to write Internet Site references in the Literature Cited or Reference section of your lab report:

Brown, J.C. 1996. Genetically-engineered adenovirus that kills cancer cells! <http://falcon.cc.ukans.edu/~jbrown/p53.html>

If you are citing the lab manual, the in-text citation would be (Biological Sciences Department, 2021) and the full reference is:

Biological Sciences Department. 2021. Lab title. *In* Biology 107: Introduction to Cell Biology Laboratory Manual 2021. Faculty of Arts and Science, MacEwan University, Alberta, Canada.

DO NOT	DO
Reference a source if there is no matching in text citation	Provide an in-text citation behind all pieces of sourced information
Put an in in-text citation if there is no matching reference	Ask your instructor if you are not sure if your information is common knowledge or not
Use one in-text citation for a paragraph from one source if there are many citable pieces of information in the paragraph	Provide full publication details (on a Reference page) for each in-text citation in the format outlined in the lab manual.
Use quotation marks (material will not be considered)	Read and reread until you feel ready to write from your thoughts as opposed to the source (this helps make sure your paraphrasing is appropriate)
	Revisit the source to ensure your information is accurate

Figures

A graph is a diagram showing the relationships between independent and dependent variables. The independent variable is set by you when you design an experiment and is plotted on the x-axis (also called the horizontal axis). The value of the dependent variable is a function of the independent variable and is plotted on the y-axis (also called the vertical axis).

1. Use a computer graphing program (ex: EXCEL or Sheets) to plot the values (means if you have replicates, with error bars (using standard deviation or confidence intervals, depending on the data). If you do not have replicates but are graphing the results from a single value, you cannot have error bars).

2. The intervals on each axis should be appropriate for the range of data so that most of the area of the graph can be used. For example, if the highest data point is 147, the highest value labeled might be 150. When labeling axes, try to make sure that your scale is not misleading (for example, a very small range of values that make small differences look very large).

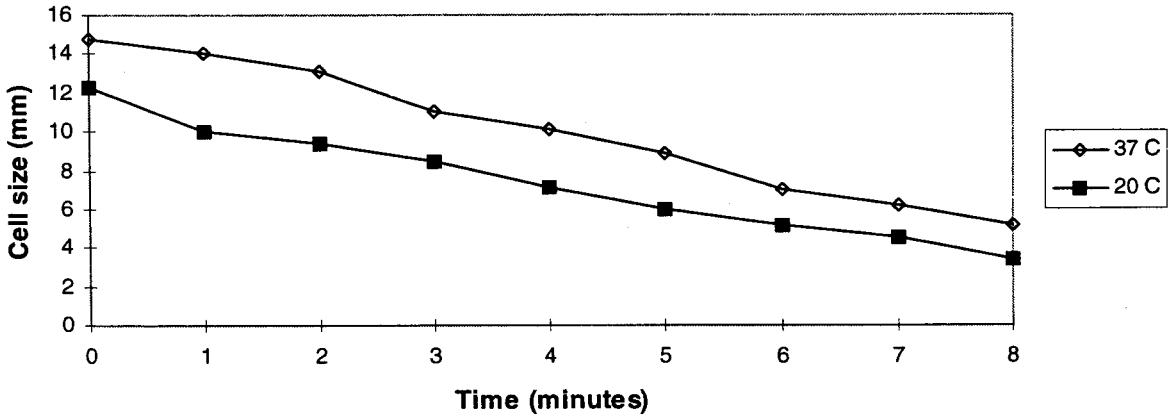
3. For continuous data, the intervals labeled on the graph should be evenly spaced. For example, consider the length of time of exposure given above. You might choose 2-minute intervals and label the x-axis at 0, 2, 4, and 8.

4. Label each axis with the name of the variable and specify the units used to measure it. For example, the x-axis might be labeled "time of exposure in minutes". You may also indicate the units in parentheses following the name of the variable (*i.e.,* length of time of exposure (minutes)").

5. **Choose the type of graph that best presents your data**. Line graphs and bar graphs are described below.

    a. Line graphs show changes in the quantity of the dependent variable and emphasize the rise and fall of the values over the range of the independent variable. Use a line graph to present continuous data. The change in cell size as a function of time is best displayed in a line graph (see Figure G.1). Keep the following points in mind when drawing a line graph:

    - Plot data as separate points.
    - Draw a smooth curve or straight line to fit the values.
    - If more than one set of data is presented on a graph, provide a key to indicate which set is which.



b. Bar graphs show differences between discrete groups or categories. For example, if you examined the cell size after exposure to different drugs, you might display the results in a bar graph (see Figure G.2). Bar graphs are constructed like line graphs, except that the height of the vertical bar represents the value of the dependent variable.

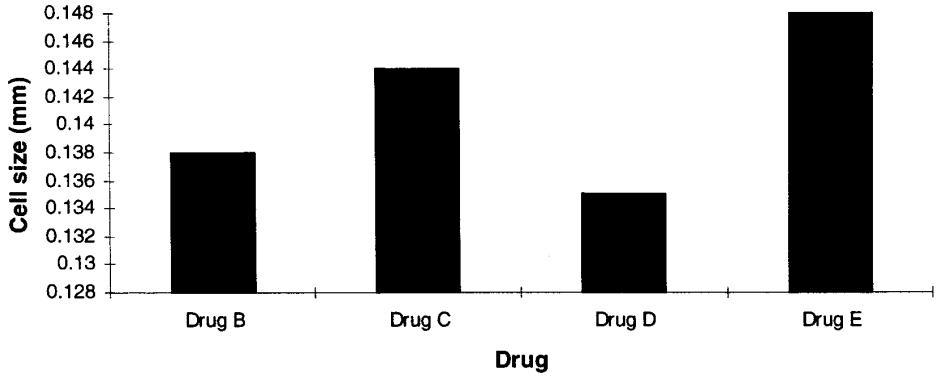


Figure legends

Figure legends are a valuable part of scientific writing and it takes practice to be able to write a good one. Good figure legends allow the reader to understand your Figure. They need to be comprehensive and succinct, which can be hard when you are starting out. When scientists publish their work in scientific journals, they must look up the journal's requirements for the information required in a figure legend. The requirements vary, we are asking you to follow the guidelines below. But in Units 2 and 3, when you are reading papers, take note of the range in expectations for Figure legends in different journals.

Please go to following website for details on how to write an excellent figure legend:
http://www.biosciencewriters.com/Tips-for-Writing-Outstanding-Scientific-Figure-Legends.aspx

Figure legends are written in **past tense and active voice**. They are typically 100-300 words, and include:

1. A descriptive title. It's difficult to write a good title because the title should essentially summarize the figure in one sentence.
2. **Brief** statement of how the data was collected/ design of the experiment. It can be difficult to achieve the balance of providing the reader with the information needed to understand the figure without going into unnecessary detail.
3. Statement that summarizes the results with values and significance (p-values)where appropriate
4. Defines and describes symbols, lines, colours, etc., used in the figure.
5. Includes information about descriptive statistics, inferential stats and sample size, where relevant.

Raw Data Appendix

Include your data tables. Typically this is not included in scientific publications, but your instructor needs to see your data to assess your interpretation of the data. Each assignment will specify what to include in the appendix.

At Home Experiment Appendix

If you miss your on-campus lab, make sure you include an Appendix with the following:

1. A description of what you tested in your at home experiment, and how you did it.
2. Pictures of your experiment/ data.
3. Conclusions from your experiment.
4. Problems you encountered.

Failure to include this appendix will result in a 5% deduction, as it is the same as missing the lab, but since you are at home, there is no reason to miss this lab.

We know that the at-home version will not be as easy to do, and it will be harder to draw conclusions; you will not be penalized for this. However, we do want to see a good attempt at conducting a meaningful experiment at home, so instructors reserve the right to deduct 2.5% if the Appendix does not show that a thoughtful effort was made.

Example of an Excellent Lab Report

Here is an example of an **Excellent Lab Report** (from the Cell Membranes Lab). At the end of each section is feedback. Apply this to your own lab report even though it is a different topic. The example doesn't have Figures or References, but you have seen examples of excellent, average, and less than average figures in the Unit 1 assignment.

Introduction

Due to global warming and the prediction that the global temperature will continue to rise (IPCC Expert Meeting Report, 2007) there is concern about the effect on agriculture. Heat stress to plants can occur with a rise of 10-15°C (Wahid et al., 2007) and causes damages to plant growth and development. Understanding the effects of temperature on the cell membrane will provide a better understanding of the effects of heat stress, and can lead to better storage of food crops leading to a reduction in food waste (Wahid et al., 2007). Our study will look at the effects of temperature on the cell membrane of Beta vulgaris.

Cell membranes provide separation of the cellular contents from the environment (Reece et al., 2014) using a bilayer of phospholipids and proteins (Reece et al., 2016). The bilayer forms when the hydrophobic tails of the phospholipids interact with each other. This orientation allows the hydrophilic heads of the phospholipids to interact with the water outside the cell and the water inside the cell (Reece at al., 2014). The phospholipid bilayer is fluid, where the degree of fluidity can be influenced by temperature (Reece et al,, 2014). Proteins also play an important role in the function of the membrane. Membrane proteins have nonpolar regions which allow them to imbed within the nonpolar region of the membrane (Reece et al., 2014). These proteins serve a variety of purposes, and their presence is important to the integrity of the membrane (Reece et al., 2014).

Changes in temperature can affect the function of the membrane (Biological Sciences Department, 2016). Heat causes an increase in kinetic energy, which increases the fluidity of the membrane (Reece et al., 2014) and denatures the proteins within the membrane (Reece et al., 2014) compromising the

membrane's integrity. In contrast, as the temperature decreases the kinetic energy decreases resulting in less fluidity of the membrane (Reece at al., 2014). When the temperature decreases to the point of freezing, ice crystals are formed within the cells, damaging the membrane (Fuller, 2004).

In this experiment beet cells were exposed to six different temperatures, ranging from -20°C to 70°C, and the amount of betacyanin released from the cells was measured using a spectrophotometer. Betacyanin is contained in a membrane-bound vacuole (Biological Sciences Department, 2017), therefore increased concentrations of betacyanin leakage indicate membrane damage.

When the cells are exposed to extreme temperatures, there will be increased damage to the membrane. At high temperatures, the lipid fluidity will increase and membrane proteins will denature (Reece et al., 2014), resulting in membrane damage. At freezing temperatures, the water inside the cell will freeze and expand, resulting in membrane damage (Ninigawa et al., 2016). This damage will result in the release of increased amounts of betacyanin from the cells.

The relevance would score 9-10/10 because the link to the students own research is clear. Often times it is easy to state something relevant without actually making the link to the research being presented.

The background info would score 10/10 bc the choice of information clearly relates to the research. This student could have written about lots of different things about membranes but chose to focus on the background relevant to the effect of temperatures on membrane integrity.
The presentation of research would score 8-9/10. It clearly states what was done, and how, without going into procedural detail.

This hypothesis scores 10 on the rubric; it is specific, makes a prediction, and is supported by scientific rationale.

** Notice how many in-text citations are present!

Results:

As shown in Figure 1, large increases and decreases in temperature result in high concentrations of

betacyanin. -20°C and 70°C resulted in the highest concentrations of betacyanin, 0.936 µM and 0.629µM respectively. This was significantly different from the control ($p<0.001$). The -20°C treatment had the largest effect, with a 24x increase in the concentration of betacyanin compared to the control, followed by 70°C with a 16.6x increase. Temperatures ranging from 5°C to 25°C resulted in concentrations similar to the control ($p>0.05$). At 55°C there was a small, but statistically significant, increase in the betacyanin concentration (0.178 µM, $p=0.04$). The 40°C treatment showed a small increase in betacyanin (0.105 µM), however it was not statistically significant ($p= 0.67$).

This results section would score a 9-10 according to the rubric. It identifies the trend, highlights important results, compares to the control, refers to the figure, and incorporates the statistical significance. It is written in a way that effectively communicates the results.

Discussion

The membrane can function at a range of temperatures before sustaining significant damage as shown by the minimal changes to betacyanin concentration for temperatures 5°C to 40°C (Fig 1). The more extreme temperatures caused substantial damage to the membrane as shown by the large increases in betacyanin released from the cells. Freezing the cells (-20°C) caused the most damage, shown by largest increase in betacyanin concentration of 24.6x that of cells at room temperature, while 70°C had a 16.6x increase compared to room temperature. At 55°C, there was a small, but statistically significant ($p= 0.04$), amount of membrane damage. This supports the hypothesis that the more extreme temperatures would result in the most membrane damage.

Ninigawa et al (2016) also showed that freezing cells resulted in membrane damage, and caused cell deformation. At -20°C , water inside the cell freezes. As the water freezes, ice crystals rapidly expand across the cell (Ninagawa et al., 2016), the cell expands, which exerts pressure on the cell membrane, resulting in damage. The damage to cell membranes at freezing temperatures is well known in the field of cryobiology (Fuller, 2004).

At 70°C there was also a significant amount of membrane damage. As the kinetic energy within the cell increases, the phospholipids within the cell membrane move at a higher speed (Reece et al., 2014; Biological Sciences Department, 2017), this causes the membrane to become more fluid and the space between the components of the membrane to widen (Reece et al., 2014). At this temperature, the bonds that hold a protein in its three-dimensional shape are broken, causing the proteins in the membrane to denature (Reece et al., 2014). As these proteins denature, (Reece et al., 2014) this results in gaps in the membrane, allowing more of the intracellular contents to leak from the cell. At 70°C there has been a large increase in the amount of betacyanin released from the cell due to the increase in lipid fluidity and denatured membrane proteins.

At 55°C, there is a moderate increase in betacyanin released over the room temperature sample (4.7x increase) indicating that the membrane is still functioning but the membrane is allowing more of the betacyanin to cross. The membrane has become more fluid due to the increase in kinetic energy at this temperature (Reece et al., 2014) and this allows more of the intracellular contents to pass through the membrane (Reece et al., 2014).

This study supports the hypothesis that temperature has an effect on cell membranes, but the temperature ranges are large. Future work could look at smaller temperature ranges to more closely determine how high and how low temperatures can go without causing membrane damage. For example, testing smaller increments of temperatures between 40-70°C. Although this studies shows that freezing causes significant damage, it would also be interesting to see if temperatures between 0- -20°C are harmful. This experiment also used plant cells, so it would be interesting to see if the results could be generalized to animal cells. Although it would not be as simple to measure, as animal cells do not have betacyanin, maybe red blood cells could be used.

This is an excellent Discussion; it is thorough and demonstrates that the writer has an in-depth understanding of the biology. They draw clear conclusions (10/10), use the scientific literature to support their findings (Ninigawa also showed….) (10/10) and then go on to use their knowledge to thoroughly explain why temperature would have this effect (10/10). The information that is not common knowledge is cited. The author recognizes the limits to the study and suggests practical and logical follow up work to help build on the results from the membranes experiment. (10/10)

Example of an Average Lab Report

Introduction

Concern over global temperature changes has been growing in recent years (Inglesias-Acosta et al. 2009). One of the reasons is that temperature change can have a detrimental effect on cellular membranes (Inglesias-Acosta et al. 2009), which raises concerns over the ability of our food crops to be able to adapt to changing temperatures and raises concerns over how best to store and transport food without damage.

Membranes are the key separation between living cells and their external environment (Reese et al. 2014). Phospholipids and proteins are combined to structure the membrane and are arranged into the fluid mosaic model (Biological Sciences Department, 2017). The hydrophobic nature of the phospholipids in an aqueous environment is what precipitates the formation of a phospholipid bilayer – where the water-loving (hydrophilic phosphate heads interact with the internal and external water molecules, and the water-disliking (hydrophobic) lipid tails interact with each other to form a dense hydrophobic core (Reece et al. 2014). Proteins contain sections that are hydrophobic, which allows them to imbed within the cellular membrane (Biological Sciences Department, 2017). Due to the nature of the interactions holding the membrane together (hydrophobic interactions), the individual components of the membrane are free to move within the membrane itself (Biological Sciences Department, 2017) resulting in the membrane being modeled as a fluid mosaic model (Reece et al. 2014).

In our study we will test the effect that changing the temperature will have on the cell membrane of *B. vulgaris* by testing the amount of cellular content (betacyanin) released from cells exposed to different temperatures.

It is hypothesized that the greater the temperature change from the normal cellular environment (room temperature) will result in increased damage to the cell membrane resulting in more released cellular

contents.

Relevance: 6/10. The connection to the real world relevance can be expanded and the link to the student's work is not made. (compare to the excellent report)

Background information: 6/10. Although it is important to discuss the structure of the membrane, missing information about how temperature might affect it.

Presentation of research: 5-6/10. Although this part should not have procedural details, this presentation is too vague. How did they do it?

This hypothesis scores a 4-5. It is not supported by scientific rationale.

Results

Overall as the temperature moved away from room temperature the amount of betacyanin increased, as seen in Figure 1. From 5°C to 25°C there was very little change to the concentration of betacyanin, see figure 1. The extreme temperatures of 70°C and -20°C had the highest concentrations with -20°C having the highest concentration betacyanin (Fig1). The -20°C treatment resulted in an 24x increase in the concentration of betacyanin over the room temperature (25°C) sample.

This written results section would score 6 according to the rubric. It touches on the main points, but is missing some key results, including the statistical significance (see Example 1). Compare this to the excellent example.

Discussion

It was shown that temperatures moving away from room temperature caused damaged to the cell membrane. The more extreme temperatures resulting in substantial damage to the membrane as shown by the large increases in betacyanin released from the cells. Freezing the cells (-20°C) caused the most damage, shown by largest increase in betacyanin concentration of 24.6x that of cells at room temperature, while 70°C had a 16.6x increase over room temperature.

Freezing the cell resulting in the most damage to the membrane. During the freezing of cells ice crystals form inside the cells (Ninagawa, et al. 2016), which puncture the cell membrane causing damage. As the

heat increases the kinetic energy within the cell increases, causing the molecules within the cell membrane to move at a higher speed (Biological Sciences Department, 2017), this causes the membrane to become more fluid and the space between the components of the membrane to widen (Biological Sciences Department, 2017). Once the temperature has increased to 70°C, the amount of betacyanin released from the cell is 16.6x that of the room temperature sample. At high temperatures proteins denature (Biological Sciences Department, 2017). As the proteins within the cell membrane denature due to the increase in temperature (Reese et al. 2014) holes appear in the cellular membrane allowing more of the intracellular contents to leak from within the cell. At 70°C there has been a large increase in the amount of betacyanin released from the cell indicating increased damage to the cell membrane has occurred.

We forgot to wipe the test tubes with a KimWipe, therefore these results might not be accurate. In future, we should wipe the tubes and retest to see if we get the same results. We could also try using carrots instead of beets.

The conclusions are good, but missed pointing out that membranes are stable at a range of temperature (7/10). Although they used Ninigawa to support their findings, they could have more clearly stated that they found similar results (6/10). The biological mechanisms are good, but if you compare them to the excellent example, you can see that this student did not demonstrate as thorough an understanding as the excellent example (6-7/10).

Rather than identify limits to the study, this student identified human error as something to change for future work. This is not what we are looking for. Assuming everything went well in your experiment, suggest follow up work that would improve our understanding of the effect of temperature on membranes. Refer to the excellent discussion to see how that student identifies questions that arise from the first experiment and then suggests the next logical step to build upon the information gained from the first experiment. This student would get 4/10 on their future work.

Example of an Inadequate Lab Report

Introduction

The function of a membrane is to separate the contents of a cell from its external environment and organize reactions and chemicals into organelles (specific compartments) inside the cell. The plasma membrane is a fundamental component of all cells, a boundary defining the internal from the external that plays critical roles in transport and signaling. The phospholipid bilayer of a membrane is impermeable to polar compounds because it has a hydrophobic, non-polar interior (Biological Sciences Department, 2017). The plasma membrane is also reorganized to form and release vacuoles during the processes of endocytosis and exocytosis. The plasma membrane vibrates continuously allowing molecules in and out past the bilayer. Due to the fluidity and continuity of the plasma membrane, it is easily damaged by any factor effecting the alteration in fluidity of the phospholipid bilayer (Reece et al. 2011). The interference could take over if the cell's homeostasis is disrupted (Biological Sciences Department, 2017). In this study the effect of temperature on the cell membrane will be measured by a spectrophotometer. Beets contain a red molecule called betacyanin, that is found in the large central vacuole of the cell. This substance is protected both by the plasma membrane, as well as by a specific membrane for the vacuole, known as the tonoplast. The red colour of this pigment allows for scientists to study membrane stress, as if the membranes are damaged the betacyanin will release from the cell which may be observed by the red colour. This pigment could be used to make a healthier food using red pigment instead of using red food dye. It is hypothesized that the changes in temperature will cause damage to the cell membrane.

** This student should organize ideas into paragraphs, always one topic/ paragraph! Missing in-text citations in a few places.

Relevance: 4/10. Need to expand/ better connect the real world relevance of food dyes.

Background information 3-4/10: Contains information that is irrelevant to the research, reads like random facts about membranes, missing information about the independent variable.

Presentation of research: 4/10 It is not clear what/how the experiment was done.

Hypothesis: This hypothesis would score a 3 on the rubric. It is too vague, doesn't make a specific prediction and has no supporting scientific rationale.

Results

Overall as the temperature moved away from room temperature the amount of betacyanin released from the beet cells (Fig. 1). The extreme temperatures of 70C and -20C had the highest concentrations with -20C having the highest absorbance of betacyanin (Fig1).

This results section would score a 4 on the rubric, because:

- The trend identified is not correct (there is no damage at 5 and 40, only at higher temps and freezing conditions)
- No comparison to the control or mention of statistical results
- It does not mention results for other temps
- Overall, it does not effectively communicate the results from this experiment.

Discussion:

It was shown that temperatures moving away from room temperature caused an increase in the amount of betacyanin released into solution from the cells. The more extreme temperatures resulting in substantial damage to the membrane. Freezing the cells (-20C) caused the most absorbance of betacyanin, shown by an increase in betacyanin of 24.6x that of cells at room temperature, while 70C had a 16.6x increase over room temperature.

As you heat the cell, the membrane becomes more fluid, which allows the betacyanin to escape from the cell and be released into the surrounding environment. The phospholipids in the membrane can then change their shape and composition to account for the changes in temperature which will result in less damage to membrane. At 70C the phospholipids within the membrane melt, resulting in the release of betacyanin from the cell.

This discussion is not adequate. The conclusions are partly inaccurate (4/10) , and are not supported with literature that showed similar findings (0/10). The biological explanations are vague and not

scientifically accurate (3/10). This student also did not identify the limitations of the study, nor did they suggest follow up work. (0/10) Additionally, this Discussion has information that is NOT considered common knowledge, but contains no citations. This would be considered plagiarism, even though the student did not mean to plagiarize.