

IB Biology Lab "Tool-Kit"

There are two main types of investigations that you will perform in IB biology:

1. **Experiments** are studies that allow scientists to manipulate a variable and observe its effects. For example: Does changing light affect the growth of radishes? Experiments are powerful studies because they can establish whether a variable influences or determines an outcome.
2. Sometimes experiments are neither possible nor desirable. Human subjects, for example, are often unsuitable for experimentation for ethical reasons. Jane Goodall, wishing to discover the behavior and social structure of chimpanzees in their natural habitat, did not perform experiments with her subjects but instead observed them with minimal human interference. When subjects are studied "as is" rather than manipulated in controlled settings, they are part of **descriptive studies**.

The purpose of writing a lab report is to determine how well you performed your investigation, how much you understood what happened during the process, and how well you can convey that information in an organized fashion. Remember that lab reports are individual assignments. You may have had a lab partner, but the work that you do and report on should be your own.

LOGISTICS:

- Raw data must be collected in a bound lab book
- Lab must be typed or neatly hand written
- Title of lab is clear and relevant
- 1.5 line spacing
- Logical order, with clear headings
- The spelling, grammar, and flow of the writing must be understandable. When you write a lab report, you will have already performed the investigation. Please use the past tense throughout the paper.

DESIGN ASPECT 1: Defining the Problem and Selecting Variables

- Include a Background Information section. Introduce and explain the biological principles and/or concepts that are being investigated. Exhibit an independent understanding of what you did in lab and why you did it. Provide the scientific name of the organism being investigated (*Genus species*).
- State the PROBLEM QUESTION (PQ). Be sure your problem question is focused enough so that it specifically states what was under investigation in the experiment. If a controlled experiment was done, the manipulated and responding variables must be clearly identified. Often, but not always, written as, "What is the effect of MV on RV ?"
- In the case of a true experiment, you need to explain what you changed between groups, the Manipulated Variable. Indicate the manipulated variable and list the levels of the MV that you included in your experimental protocol. Provide the unit for your MV. Typically you should have a minimum of 5 levels of the MV. Explain how the range of levels of your MV was selected. If you performed a descriptive study, explain why no variable was or could be manipulated.
- You need to explain what was measured, the Responding Variable. List what was measured (both qualitative and quantitative data) and explain how it was measured. Provide the unit for your RV. If no qualitative data was collected, say so, and explain why qualitative data was not gathered.
- For true experiments in which you are determining the effect of a MV on and RV, you need to include a hypothesis. A hypothesis is like a prediction. It will often take the form of a proposed relationship between two or more variables that can be tested by experiment. Hypothesis statements are often written as: If describe MV manipulation , then explain expected result on the RV . You must also provide an explanation for your hypothesis. This should be a brief discussion (paragraph form) about the science behind your hypothesis and prediction. You should site credible references that support your explanation (see section on citations)

DESIGN ASPECT 2: *Controlling Variables*

- At least three **CONTROLLED VARIABLES** are required, but more may be necessary. The controlled variables you list must be relevant to your investigation. You need to control for all variables that may reasonably affect the outcome of the investigation. **Materials used and measurement techniques are NOT controlled variables** (they are validity measures). While materials and techniques must be consistent, a true variable is something that could directly influence the responding variable, not just how it is measured.
- You must explain why and how variables were controlled. When explaining why a variable needs to be controlled, describe how the variable could impact the results if it was not controlled. Often times, students create a table to organize this information:

CONTROLLED VARIABLES	WHY it must be controlled	HOW it was controlled
1.		
2.		
3.		

DESIGN ASPECT 3: *Developing a Method for Collection of Data*

- Make a list of the **MATERIALS** needed in the investigation. Be as specific as possible (example: '50 mL beaker' instead of 'beaker'); include the volumes of tubes and cylinders, the concentrations of solutions, the model and manufacturer of any complex apparatus. If you have to decide how much of a substance or a solution to use, state your reasoning or show the calculations.
- Include a **DIAGRAM OR PHOTOGRAPH** of how you set up the experiment. Be sure your diagram includes a title and any necessary labels. It is recommended that this be annotated to illustrate how the variables were involved.
- State or discuss the **PROCEDURE** that you used in the experiment. Be sure your procedure explains how you changed the manipulated variable. This can be in paragraph form or a list of step-by-step directions. Provide enough detail so that another person could repeat your work by reading your report.
 - If you use a known, published protocol than you must provide a full citation as a reference.
 - Your procedure must include at least three clear **VALIDITY MEASURES** (i.e. cleaning test tubes prior to use, cleaning the microscope lenses, using the same ruler, etc). Validity measures are things kept constant to make sure experimental measurements are valid and consistent.
 - Your procedure must **CLEARLY STATE HOW YOU COLLECTED DATA**. What measuring device did you use, what data did you record, when did you collect data? What qualitative observations did you look for?
 - Explain how you set up so you had **MULTIPLE TRIALS** of data collection. The procedure must allow collection of "sufficient relevant data". The definition of "sufficient relevant data" depends on the context. The planned investigation should anticipate the collection of enough data so that the problem question can be suitably addressed and an evaluation of the reliability of the data can be made. As a rule, the lower limit is a sample size of five. Very small samples run from 5 to 20, small samples run from 20 to 30, and big samples run from 30 upwards. Obviously, this will vary within the limits of the time available for an investigation.

- If you will be **COMBINING DATA** with data collected by other students in the class, you should indicate that, "pooling data was done to ensure collection of significant, relevant data" (IB Biology subject guide, 2009, page 26). Be sure to cite this reference if you pool data.
- If you are **SAMPLING** only a portion of a population, you must explain how and why you ensured that the sample was randomly selected.
- Your procedure must be safe and ethical. Organisms, including humans, can not be subject to harm in your investigation. List any **SAFETY PRECAUTIONS** that were taken during the lab. If necessary, address the IBO *animal experimentation policy*.

IB Rubric

Design			
Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Defining the problem and selecting variables	Controlling variables	Developing a method for collection of data
Complete/2	Formulates a focused problem/research question and identifies the relevant variables.	Designs a method for the effective control of the variables.	Develops a method that allows for the collection of sufficient relevant data.
Partial/1	Formulates a problem/research question that is incomplete or identifies only some relevant variables.	Designs a method that makes some attempt to control the variables.	Develops a method that allows for the collection of insufficient relevant data.
Not at all/0	Does not identify a problem/research question and does not identify any relevant variables.	Designs a method that does not control the variables.	Develops a method that does not allow for any relevant data to be collected.

DATA COLLECTION AND PROCESSING ASPECT 1: *Recording Raw Data*

- Create a formal **DATA TABLE** in which to present the raw, unmodified data you collected. Be sure your table:
 - Is easy to understand
 - Has a specific title
 - Tables are titled in sequential order as "Table 1: *title*." "Table 2: *title*"
 - Has column headings
 - Includes the unit of measurement of the MV and RV (always in metric units)
 - Includes the measurement uncertainty of the measurement tools used (or, if the data was a count, indicates that "counts have no measurable uncertainty"). Uncertainty is usually stated in a column heading or as a footnote at the bottom of the table.
 - Has a consistent and correct number of digits for each measurement
 - Has decimal points aligning down a column (if applicable) and numbers centered in the column
 - Indicates which data was collected by which student IF the data was collected and pooled across multiple students.
- Your report must include **QUALITATIVE DATA**. This might be a paragraph in which you describe the qualitative observations and results in general or be specific qualitative data for each trial that is presented in table form.

- **LAB DRAWINGS** are considered data by the IB Organization. Not all labs will include a lab drawing. However, when included, please be sure your lab drawings:
 - Are done with a sharp pencil line on white, unlined paper.
 - Have the drawing occupy at least half a page, centered on the page.
 - Include labels written off straight, horizontal lines to the right of the side of the drawing. The labels should form a vertical list.
 - Are accurate. Draw what you see; as you see it, not what you imagine should be there.
 - Include a title that states what has been drawn and what lens power it was drawn under. The title must be informative, centered, and larger than other text.
 - Has a scale that indicates how many times larger the drawing is compared to life size and a scale line that indicates relative size.

DATA COLLECTION AND PROCESSING ASPECT 2: *Processing Raw Data*

- **STATISTICS** are useful mathematical tools which are used to analyze data. Common statistics used in biology are:
 - Mean
 - Range
 - Median
 - Percent change
 - Standard deviation (to determine amount of variation around a mean)
 - T-test (to compare two means to determine if they are statistically different from each other). When a t-test is calculated, you must indicate the significance level at which your critical T value is determined (we typically use the 95% confidence interval, 0.05).
 - Chi-square (to determine if "observed" results are significantly different from "expected" results)
 - Correlation coefficient (to determine the extent two variables are related to each other).

Use only the statistical tests appropriate to investigate and address your problem question.

- For each statistic you calculate, you must **EXPLAIN WHY YOU ELECTED TO DO THAT CALCULATION**. What does the calculation tell you about the data?

DATA COLLECTION AND PROCESSING ASPECT 3: *Presenting Processed Data*

- Show an **EXAMPLE CALCULATION** for each statistic you calculate. Use plenty of room; make sure they are labeled, are clear and are legible. Show the units of measurements in all calculations. Pay attention to the number of digits! Don't lose accuracy by carelessly rounding off. Round only at the end of a calculation. Do not truncate.
- Present your data processing results in a **TABLE**. The initial raw data and the processed (calculated) data may be shown in one table provided they are clearly distinguishable. Be sure your processed data table:
 - Is easy to understand
 - Has a specific title
 - Has column headings
 - Includes the unit of measurement
 - Has a consistent and correct number of digits for each measurement (to the same precision as your raw data)
 - Has decimal points aligning down a column (if applicable) and numbers centered in the column
- You must also present your results in a **GRAPH**.
 - Use the correct type of graph for the type of data you are presenting.
 - Graphs must be clear and easy to understand. Please avoid "creative" or "funny" coloring of graphs.
 - Graphs need to have appropriate scales, labeled axes with units, and accurately plotted data points.

- Graphs are titled in sequential order as "Figure 1: *title*." "Figure 2: *title*"
- If necessary, add smooth lines or curves to show the overall trend of the data.
- If a mean is calculated, only graph the mean, not all data points. When a mean is graphed, its associated standard deviation error bar must also be included (and labeled as such).
- Legends (keys) are not always necessary. Delete "series 1" and "series 2" boxes from graphs created in Excel.

IB Rubric

Data collection and processing

Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Recording raw data	Processing raw data	Presenting processed Data
Complete/2	Records appropriate quantitative and associated qualitative raw data, including units and uncertainties where relevant.	Processes the quantitative raw data correctly.	Presents processed data appropriately and, where relevant, includes errors and uncertainties.
Partial/1	Records appropriate quantitative and associated qualitative raw data, but with some mistakes or omissions.	Processes quantitative raw data, but with some mistakes and/or omissions.	Presents processed data appropriately, but with some mistakes and/or omissions.
Not at all/0	Does not record any appropriate quantitative raw data or raw data is incomprehensible.	No processing of quantitative raw data is carried out or major mistakes are made in processing.	Presents processed data inappropriately or incomprehensibly.

CONCLUSION AND EVALUATION ASPECT 1: *Concluding*

- Write one (or more) paragraphs in which you **DRAW CONCLUSIONS FROM YOUR RESULTS**. Your conclusion should be clearly related to the research question and the purpose of the experiment.
 - Answer the problem question (if you used a T-test, be sure your conclusion matches what the T-test tells you; don't say there is a difference if the T-test says the difference is insignificant).
 - Was your hypothesis supported or refuted? Use the appropriate language, i.e. "Supports my hypothesis" (not 'proves' or 'is correct').
 - Provide a brief explanation as to how you came to this conclusion from your results. In other words, sum up the evidence and explain observations, trends or patterns revealed by the data. Summarize the processed data: mean, range and standard deviation. Refer directly to tables and graphs by referencing tables and figures (i.e. "as seen in Figure 1...")
 - Summarize the results of the T-test: was the effect of the MV significant or not?
- If possible, **CITE LITERATURE** related to your conclusion: Does your result coincide with published results? Does it refute published results?

CONCLUSION AND EVALUATION ASPECT 2: *EVALUATING PROCEDURE*

- In general, how much **CONFIDENCE** do you have in the results? Avoid giving your confidence as a percentage; use words such as "very" or "somewhat." Are your results fairly conclusive, or are other interpretations/results possible?

- Why are you (or aren't you) confident? What did you do to make sure your results are valid? Was the range of the MV levels appropriate? Was the data collected relevant to the problem question?
- Explain any anomalous data points
- **Identify and discuss significant ERRORS that actually affected your data collection.** You must identify the source of error and tie it to how it likely affected your results. Avoid hypothetical errors ("could have" or "I might have") without evidence to back it up. Common errors include:
 - *Human error*: Human error can occur when tools or instruments are used or read incorrectly. Human errors can be systematic because the experimenter does not know how to use the apparatus properly or they can be random because the power of concentration of the experimenter is fading. Automated measuring using a data-logger system can help reduce the likelihood of this error; alternatively you can take a break from measuring from time to time. Do not list time constraints or time management as errors - they should be eliminated with good practical skills. The focus here should be on *the investigation*.
 - *Calibration error*: Some instruments need calibrating before you use them. If this is done incorrectly it can increase the risk of systematic error.
 - *Random errors*: In biological investigations, the changes in the material used or the conditions in which they are carried out can cause a lot of errors. Biological material is notably variable.
 - *The act of measuring*: Could the measurement uncertainty have affected the results? Why or why not?
 - *Uncontrolled variables*: What variables were not controlled? What effect might each of these uncontrolled variables have had on your data? On the conclusion?
 - *Systematic errors*: could the measurement uncertainty have affected the results? Why or why not? Did systematic errors affect the data? The conclusion?

Errors and their effect on the results can be clearly presented in a table.

- What are the **LIMITATIONS** of your conclusion? Can the results be generalized to other situations/conditions? How might your results explain a process in the "real world"?

CONCLUSION AND EVALUATION ASPECT 3: IMPROVING THE INVESTIGATION

- What could you do to make **IMPROVEMENTS** to the investigation? Suggestions for improvements should be based on the weaknesses and limitations identified in aspect 2.
- As appropriate, address modifications to the experimental technique and the data range.
- Propose only realistic and specific modifications. "More time" and "be more careful" are inadequate.

IB Rubric

Conclusion and evaluation			
Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Concluding	Evaluating procedure(s)	Improving the investigation
Complete/2	States a conclusion, with justification, based on a reasonable interpretation of the data.	Evaluates weaknesses and limitations.	Suggests realistic improvements in respect of identified weaknesses and limitations.
Partial/1	States a conclusion based on a reasonable interpretation of the data.	Identifies some weaknesses and limitations, but the evaluation is weak or missing.	Suggests only superficial improvements.
Not at all/0	States no conclusion or the conclusion is based on an unreasonable interpretation of the data.	Identifies irrelevant weaknesses and limitations.	Suggests unrealistic improvements.

REFERENCES AND CITATIONS

- It is permissible in the design and conclusion sections to use brief quotations. Sometimes a book or reference has a phrase or sentence that expresses exactly the thought you are trying to convey; you may use that phrase or sentence *IF* you use quotation marks and cite a reference at the end of the sentence. It is *NOT* appropriate to borrow extensive passages (more than two sentences) from a text or web site. You should also acknowledge where ideas or knowledge not originally your own come from, even if you state your understanding of the idea in your own words. This is usually done by putting the first author's last name and the date of the paper, or the page of a textbook, in parentheses at the end of the sentence containing the idea.

- Any source you mention in the text of your paper should be included in a list of references in a separate section at the end of the paper. These references are usually listed in alphabetical order by the first author's last name. Make sure all the authors of a paper or book are listed, and include the title of the book or article, the journal or publisher (and place), and the date. If you used just part of a book, indicate the chapter or pages used. For web sites, give the exact electronic address and any other information you have about it (the author, the name of the organization that sponsors the site). Examples:
 - Book:
 - Author(s). Year. *Title*. Location: Publisher. Number of pages, or pages cited.
 - Hille, Bertil. 1992. *Ionic Channels of Excitable Membranes*. Second Edition. Sunderland, MA: Sinauer Associates, Inc. 607p.
 - Article:
 - Author(s). Year. Title of Article. *Journal*, volume number, pages.
 - Huxley, A.F. and R. Stämpfli. 1949. Evidence for salutatory conduction in peripheral myelinated nerve fibres. *J Physiol. (Lond.)* 108: 315-339.
 - Web page:
 - Name of web page. Creator or publisher. Subject. Web address.
 - The Animated Brain. Brainviews, Ltd. Saltatory conduction.
<http://www.brainviews.com/abFiles/AniSalt.htm>
 - Lecture or information from a teacher.
 - Name of teacher (alphabetically, by last name). The exact date and topic of the lecture (including the course in which it was given).
 - Or for individual answers to questions you asked a teacher, you can call it "personal communication" and give the date.

- Do not use Wikipedia as a resource site; however you may read it to gain understanding.

MANIPULATIVE SKILLS

Laboratory skills are assessed summatively over the course of the entire IB Biology course. Your teacher will be watching to see if you:

- Follow directions carefully
- Do not fabricate data
- Seek assistance when appropriate (independence is encouraged)
- Consistently carry out proper safety measures
- Effectively use a variety of biological techniques
- Properly use experimental equipment
- Safely dispose and reduce waste
- Work in the lab in a way that does not put yourself or others in harms way
- Follow the IBO *animal experimentation policy*