The scientific investigation

Internal assessment overview

Along with the external assessments (Paper 1 and Paper 2), you need to submit a scientific investigation (SI) for the internal assessment (IA) component. The internal assessment is mandatory and assessed against the same criteria for both SL and HL students.

The purpose of the scientific investigation is to give you an opportunity to engage with your own interests within IB Biology and display the skills and knowledge that you have gained throughout the course.

You will submit a report that will be assessed by your IB Biology teacher. The assessment is then checked for consistency against other reports and a sample of the reports is sent to an externally appointed examiner for moderation.

The scientific investigation has a maximum of 24 marks and accounts for 20% of your IB Biology Diploma grade. The time allocation for the internal assessment is 10 hours and the report should be no more than 3000 words in length.

Planning and guidance

In the scientific investigation, you must select and justify techniques for data collection and analysis. The IB Biology syllabus gives you a wide range of choices to select from. Possible areas of focus include (but are not limited to) microbiology, cell transport (osmosis, diffusion and active transport), animal physiology, plant growth, enzymes, animal behaviour, embryology, genetics, bioinformatics and ecology.

You can work on your own or with others; collaborative work is allowed, but you must develop your own research question, carry out your own analysis and develop your own conclusions.

The following guiding questions may help you develop a plan for your scientific investigation:

- What exactly are you going to investigate?
- Why is it worthwhile to investigate? Can you justify your choice?
- What is already known in the biological literature?
- What new biological knowledge is currently being investigated in this area?
- Is your research question answerable within the constraints of time and resources in your biology department?
- What apparatus, instruments or techniques will you use? Do you need chemicals (for example, enzymes) or prepared biological materials (for example, algal balls wrapped in alginate)? Do you know how to use the apparatus? Do you need access to specific software?
- Do you have enough time to complete all the experiments in the lessons available and an overall time of 10 hours?
- How will you control and monitor the controlled variables? Can you find secondary data?
- How many samples will you be able to analyse? Which planned statistical test and sampling techniques will you use (if appropriate)?

Types of investigation

There are different types of investigation you could choose. For example:

- practical laboratory work
- ecological fieldwork
- using spreadsheets for analysis and modelling
- using databases to extract data for analysis
- using a simulation.

Guidance

You are allowed a total of 10 hours to complete the scientific investigation. The 10 hours include:

- time for initial explanation of the scientific investigation requirements by your teacher
- time to ask questions
- time for consultation with your teacher to discuss the research question before the investigation is carried out, and throughout the execution of the scientific investigation
- time to develop the method and collect data
- time to review and monitor progress
- time for final report writing.

You are expected to develop your own research question, based on your knowledge and the experience developed during the first year of the biology course. There are no IB requirements in terms of planning or a timeline for the scientific investigation, but your school may require you to complete a preliminary scientific investigation proposal. This could involve you suggesting a research question and methodology, doing a risk assessment and requesting any apparatus, biological materials and biochemicals (for example, enzymes) for preliminary work. Your teacher is allowed to give feedback on your draft scientific investigation report once. You will then amend your report following this advice, before submitting the final report.

It may be helpful to set up a timeline with start dates and deadlines for each part of your investigation if your school has not done that. A sample timeline is shown in Table 1.

Table 1 An example timeline for your scientific investigation

Stage	Start date	Task	Deadline date
Planning 1		Read scientific investigation guidance (this chapter and information provided by your teacher).	
Planning 2		Decide on your research question, methodology (including controls and statistical test, if appropriate) and outline your data collection.	
Planning 3		Prepare a risk assessment for these experiments and show your biology teacher the completed risk assessment form.	
Planning 4		Check that the apparatus, biological materials and chemicals will be available in your school laboratory.	
Practical		Complete the experimental work and collect raw data in the time allocated. Allow time to carry out duplicates, extending the range of data collected and for preliminary work. Document any alterations to your plan as soon as they occur and, if necessary, make alterations to the supporting theory.	
Report 1		Write the first draft of your report and show it to your teacher.	
Report 2		Consult with your biology teacher on your draft and make the suggested improvements.	
Report 3		Finish your report and submit the final version to your teacher.	

Academic honesty and integrity

You need to ensure that the scientific investigation report that you submit for your IA is your own work. You will need to sign a declaration to confirm this. Throughout the IB Biology course (and not just in the IA), your IB Biology teacher is required to ensure that any submitted work is your own. When in doubt, your IB Biology teacher will check the authenticity of any of your work by:

- discussing it with you
- asking you to explain the method and to summarize the results and analysis
- asking you to repeat an investigation
- using software (such as Turnitin) to check for plagiarism.

If you use any experimental method from another source, then you need to ensure that you acknowledge it. This also applies if you use diagrams, tables, graphs or literature values from the internet or reference books. Each lab report should have a bibliography acknowledging the sources used.

Plagiarism

Plagiarism is defined by the IB as: 'The representation, intentionally or unwittingly, of the ideas, words or work of another person without proper, clear and explicit acknowledgment' (IB Africa, Europe & Middle East Regional Conference, 2014).

Examples of plagiarism include:

- copying the work of another IB Biology student (past or present) and passing it off as your own work
- using 'essay-writing' services, such as those available online or from a tuition centre
- copying text or images from a source (book chapter, journal article or website, for example) and using this within your report without acknowledgement
- quoting others' words without indicating who wrote them or said them
- copying scientific ideas and concepts from a source without acknowledgement, even if you paraphrase them.

Referencing

By referencing work, you are acknowledging the contribution that other people have made to your work and therefore avoiding plagiarism (as long as you express their ideas in your own words). This is part of academic honesty – the process of using collective knowledge in the pursuit of new knowledge, giving credit where credit is due. Isaac Newton is famous for his phrase 'standing on the shoulders of giants', meaning that all new knowledge is built on the knowledge of others. This is the essence of what you are doing in your scientific investigation, and by correctly referencing all sources, you are recognizing this process.

Words, paragraphs, quotes, figures, tables, digital images, theories, scientific ideas and facts originating from another source that are used in your scientific investigation report must be referenced (i.e. acknowledged). Referencing is also done so that your teacher can verify quotations and consult the sources you have accessed.

Referencing is an internationally or nationally standardized method of acknowledging the sources of information you have consulted for writing your scientific investigation report. There are many ways to acknowledge sources of information, for example, APA (American Psychological Association), Chicago, ACS (American Chemical Society), MLA (Modern Language Association) and Turabian. No one way of referencing is mandated by the IB, although your school may dictate a referencing style that you must adopt. The APA style tends to be used for references in psychology and the sciences. Make yourself familiar with your school's requirements for referencing and citation. Be consistent and familiarize yourself with the format and terms that your school or IB Biology teacher expects you to use.

Assessing sources

It is important that you check the validity of the sources you are using and evaluate their information. There is more information about this on page 29 of the Tools and Inquiries reference guide for the IB Diploma Biology Third Edition (2023), which you can access at www.hoddereducation.co.uk/ib-extras.

Writing your report

Your scientific investigation will be a written report with a maximum of 3000 words. The following are not included in the word count:

- charts, diagrams and graphs
- data tables
- equations, formulae and calculations
- citations/references
- bibliography
- headers.

The start of your report should contain the following:

- the title of the investigation
- your IB candidate code
- the IB candidate code for all group members (only applicable if the report is the result of collaborative work)
- a word count.

A cover page/contents page is not a requirement.

Structure and clarity

While there are no formal guidelines on font size or style, margins or paper size, the preferred format is Arial font size 12 with single spacing.

Your report must be coherent and relevant to the focus: the research question, the methodology, and the results and conclusion. It should resemble a research or review paper (without the abstract). Include headings and sub-headings throughout to give your report a logical sequence, allowing your teacher and the IB examiner to understand your thought processes throughout the report. Use diagrams or photographs to enhance understanding, with suitable referencing.

Relevance and conciseness

Your written work, including the background information, should remain closely connected to and relevant to the research question and topic of your scientific investigation. Be concise and check your work for unnecessary or repetitive (redundant) information. The description of your methodology should be detailed enough to allow someone else to repeat the investigation; however, simplistic, well-known and assumed aspects of your methodology do not need to be described.

Full calculations for processing all numerical data and all error propagation are not expected – selected examples will be sufficient and free up more space for your conclusion and evaluation.

Avoid repetitive data tables when one table would suffice. It may also be appropriate to combine multiple graphs into one – this will not only save space but also allow for comparisons to be made between data.

Terminology and conventions

Make sure you use the correct biological terminology (especially IB Biology terminology), scientific conventions (binomial species names should be underlined or italicised, for example) and mathematical symbols throughout your report. Remember to include units with your quantitative data and check your significant figures and any random uncertainties in the data.

SI and metric units should be used throughout the report (see the Tools and Inquiries reference guide, page 18, or the *Biology for the IB Diploma Third Edition Student's book*, page 185). The numbers of decimal places should be applied consistently and correspond to the precision of the data. Measurement uncertainties should be included.

All tables, graphs, charts and equations should be introduced by a sentence of explanation. They should also have an explanatory label. The labels should be applied using the same formatting and numbered sequentially throughout the report, for example, equation (1).

Use of artificial intelligence

The IB Academic Integrity policy has guidelines on the use of artificial intelligence (such as ChatGPT). The IB will not ban the use of AI software as it is an innovative technology that will become as routine as calculators and translation programs, but such technology must be used ethically. You need to know how to get the best out of AI tools, for example to edit text to personalize it, and to recognize the inherent bias in what is produced because of bias in the programming (and the material that the AI tool has been trained on by the software developers).

As when referencing sources of information that are not your own, and with any quote or material from another source, it must be clear when any text, image or graph included in your work has been generated by AI software. The software must be credited in the body of the text and appropriately referenced in the bibliography. If this is not done, you would be misrepresenting content (as it was not originally written by you), which is a form of academic misconduct.

Safety requirements and recommendations

Your report needs to describe and explain the safety, ethics and environmental impact of your investigation. As well as identifying potential areas where safety is an issue in your investigation, you also need to explain how the issue was avoided. If your investigation did not have ethical or environmental impacts then you need to state this and explain why (for example, when conducting a simulation there are no safety or ethical aspects to comment on).

Internal assessment marking criteria

There are four IA criteria for the scientific investigation; the marks and weightings are shown in Table 2.

Table 2 The inquiry processes and the IA marking criteria

Inquiry process	Criterion	Maximum number of marks available	Weighting (%)
Exploring and designing	Research design	6	25
Collecting and processing data	Data analysis	6	25
Concluding and evaluating	Conclusion	6	25
	Evaluation	6	25
	Total	**24**	

Source: *IB Diploma Programme Biology guide, page 120*

Inquiry skills and the IA

The IB Biology course encourages the acquisition of knowledge through inquiry. Throughout the textbook you are given the opportunity to practise inquiry skills so when you carry out your IA, you know which skills are needed and how they can be applied most effectively. In this chapter, the inquiry skills that relate specifically to the IA marking criteria are discussed, rather than all the skills (for full coverage, see the Tools and Inquiries reference guide, which can be found at www.hoddereducation.com/ib-extras).

Research design

In this section, you need to describe a research question within a specific biological context and explain the purpose of your methodology and how you are going to carry it out. Research design covers parts of Inquiry 1: Exploring and designing, particularly the skills Exploring and Designing. Table 3 sets out the marking criteria for this section.

Table 3 Marks and level descriptors for Research design

Marks	Level descriptor
0	The report does not reach the standard described by the descriptors below.
1–2	The research question is stated without context. Methodological considerations associated with collecting data relevant to the research question are stated. The description of the methodology for collecting or selecting data lacks the detail to allow for the investigation to be reproduced.
3–4	The research question is outlined within a broad context. Methodological considerations associated with collecting relevant and sufficient data to answer the research question are described. The description of the methodology for collecting or selecting data allows for the investigation to be reproduced with few ambiguities or omissions.
5–6	The research question is described within a specific and appropriate context. Methodological considerations associated with collecting relevant and sufficient data to answer the research question are explained. The description of the methodology for collecting or selecting data allows for the investigation to be reproduced.

Source: *IB Diploma Programme Biology guide, page 120*

Inquiry 1: Exploring and designing

Exploring

As well as describing and explaining your research question, you should include background information that provides context and reasons behind your investigation. This could be references to published work in books, papers and websites, or even a brief review of competing hypotheses or interpretations of data. Ensure you select relevant and sufficient sources of background information. This part of the report needs to be focused, contain relevant information, and provide a brief overview of the theory and current knowledge specific to your topic. Using evidence from sources will support the argument behind your report.

A research question should clearly state the variables that are to be manipulated, measured and analysed. Explorations of the relationship between variables should:

- identify the independent variable
- indicate the range of the independent variable
- identify the dependent variable (and/or derived dependent variable)
- describe the material being studied
- include a methodology
- include the scientific name of the organism, where relevant.

Many students lack a sufficiently focused research question. For example, the research question: 'How different amounts of dissolved sugar will affect anaerobic cell respiration in yeast' is insufficient because it should state what sugar will be used (for example, sucrose) and use a more specific word than 'amount' (for example, mass, volume or moles; moles are preferable since they are directly related to the number of particles in a unit volume of solution). This research question example should also have indicated the range of sucrose concentrations used, named the species of yeast (its biological name) and explained how the dependent variable will be measured. A better and more focused research question would be: 'What is the effect of different molar concentrations of sucrose solution on anaerobic respiration in baker's yeast (*Saccharomyces cerevisiae*), measured using the volume of carbon dioxide produced per minute?'

Designing

When designing an investigation, you should:

- ensure that the independent variable is the only major variable that is changed (manipulated)
- include controls and comparisons to show it is only the independent variable that causes the measured biological or biochemical effect (if there is one)
- where appropriate, select experimental subjects randomly to cancel out variation arising from biased selection (this is important in ecological investigations)
- keep the number of replicates as high as possible, given the time constraints of the scientific investigation
- carry out the same number of replicates for each value of the independent variable
- identify other factors that could affect the dependent variable and keep them constant (controlled variables such as temperature, pH, concentrations of solutions, light intensity, time for reaction, and so on). Variables that cannot be controlled, such as those in ecological investigations, need to be monitored.

Different types of investigation that you could design are mentioned on page 2. The approaches could be used in isolation or in conjunction with each other. If you are investigating a process that occurs over a long period of time or one that is difficult to study in your local area, such as the natural selection of peppered moths, a simulation may be appropriate.

A methodology is the justification for using a particular research method. Your methodology should not be a long list of detailed instructions, but it should explain why you chose certain techniques or apparatus/instruments, or a particular statistical approach to analysing the data. Any steps or procedures designed to minimize the systematic and random errors in all your measurements should be described. Your methodology needs to be written clearly and include a cross-sectional diagram where appropriate. You should also explain why alternative approaches were considered but not adopted. Any special precautions you took to increase the accuracy, precision or reliability of your raw data should be included.

You should provide enough detail so that another student could repeat your work without your presence. This means including actual quantities of substances and how these quantities are measured, concentrations, sizes and precision of apparatus, and the range of instruments. You are allowed to use a method from a published or online source, but you must reference this source and, ideally, adapt and modify it.

Make sure you identify and justify the independent variable and its range, as well as explaining the dependent variable. A discussion of controlled variables is needed to demonstrate that you understand and appreciate that other factors may impact on values of the dependent variable. Consider whether you can use a control experiment in your investigation. The variables could be classified and tabulated with an emphasis on explicitly identifying the controlled variables that affect the results.

Weaker reports tend to investigate a topic in which causal relationships are difficult to confirm and a large number of controls are missing, for example human physiology studies with limited data sets and poorly controlled variables.

Research design: final check

- ☐ My research question is explained within a specific context.
- ☐ I have given a concise description of the context for my research question, including relevant background theory.
- ☐ I have explained how the methods for measuring the dependent and independent variables were selected.
- ☐ I have explained how sampling of data was selected, and how the databases or model (if relevant) were chosen.
- ☐ I have explained how the scope, quantity and quality of measurements were selected (for example, the range, interval or frequency of the independent variable, repetition and precision of measurements).
- ☐ I have identified control variables and outlined the choice of method of their control.
- ☐ I have included safety, ethical or environmental issues that need to be considered in the form of a risk assessment, identifying hazards and risks, and control measures that need to be taken.
- ☐ My methodology is sufficiently detailed (for example, materials, chemicals, apparatus and instruments, with associated uncertainties and ranges used, and precise procedural steps) and avoids unnecessary or repetitive information.
- ☐ A reader can understand my methodology and could repeat my investigation.

Data analysis

In this section you record, process and present data in ways that are relevant to the research question. Data analysis covers parts of Inquiry 2: Collecting and processing data. Table 4 sets out the marking criteria for this section.

Table 4 Marks and level descriptors for Data analysis

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	The recording and processing of the data is communicated but is neither clear nor precise. The recording and processing of data shows limited evidence of the consideration of uncertainties. Some processing of data relevant to addressing the research question is carried out but with major omissions, inaccuracies or inconsistencies.
3–4	The communication of the recording and processing of the data is either clear or precise. The recording and processing of data shows evidence of a consideration of uncertainties but with some significant omissions or inaccuracies. The processing of data relevant to addressing the research question is carried out but with some significant omissions, inaccuracies or inconsistencies.
5–6	The communication of the recording and processing of the data is both clear and precise. The recording and processing of data shows evidence of an appropriate consideration of uncertainties. The processing of data relevant to addressing the research question is carried out appropriately and accurately.

Source: *IB Diploma Programme Biology guide, page 121*

Inquiry 2: Collecting and processing data

After your scientific investigation is planned, you need to collect and process your data to see whether your hypothesis is supported or not.

Collecting data

Data can be quantitative or qualitative.

- Quantitative information is collected through measurement and may be processed using statistical and other techniques. The focus is on numbers and such information can be displayed through tables, graphs and maps.
- Qualitative information, collected through observation and subjective judgement, is non-numerical and does not involve measurement. It can be used to comment on or assess quantitative data. Qualitative information may be processed or quantified (i.e. numbers assigned to observations) where appropriate, or it may be presented through images or as text.

Most students succeed in obtaining data that are relevant to the question or topic that is being studied, but lose marks by collecting data insufficient in quantity. Normally, five is the minimum number of samples required per site, treatment, repetition, and so on. For example, if you are measuring changes in rate of oxygen release in *Elodea* (pondweed) with respect to light intensity, it would be expected that you would take at least five readings for each level of light intensity. This means that the variation in the data (for example, standard deviation) can be calculated. Lack of sufficient data can have knock-on effects for other marking criteria; for example, if only a single measurement is collected per treatment, the data do not lend themselves for processing and, by extension, are not suitable for the presentation of processed data. When carrying out ecological fieldwork, time constraints can be problematic, and it is appreciated that in these cases you may need to collect fewer than five samples or transects. In such cases, three may be acceptable, but you need to explain in your report the time constraints you encountered.

Raw data are the data collected without any processing. They are just the values of each variable collected. They are often difficult to use for data analysis, and usually need to be processed in some way. Observations are another example of raw data. Later you will process these data, which can include transforming them so they are ready for analysis.

Raw data must be presented in tables with appropriate headings and units. The decimal places used for each variable must be consistent with the precision of the equipment used (for example, if a balance can measure to two decimal places, this is the precision that should be used to record the raw data). The same number of decimal places must be used consistently across all data for each variable.

When large amounts of data have been collected, for example when using data loggers, you should only present a representative sample of the raw data. You need to ensure that your sample size is large enough for data processing (this is covered on page 35 of the Tools and Inquiries reference guide).

You should identify and address issues that arise during data collection, for example reducing the number of repeats if there is insufficient time to do these in a field study. You need to note any issues and address these in the evaluation section, for example what the issues were, how they affected data collection, and how this may have affected your analysis and conclusion.

When presenting data, the method of processing needs to be shown so that it can be understood easily, including appropriate details such as the labelling of graphs and tables or the use of units, decimal places and significant figures, where appropriate.

Processing data

Raw data must be processed in some way. At its most basic, this will take the form of calculating means and standard deviations (provided this is suitable and appropriate, i.e. data are large enough and follow a normal distribution), calculating percentage changes, logarithms and reciprocals. You need to ensure that processed data are relevant to the research question, i.e. address the independent, dependent and controlled variables.

If carrying out a statistical test, your investigation should have both a null hypothesis and an alternative hypothesis. For example, if carrying out a test to see whether there is an association between two variables x and y:

- **Null hypothesis**: there is no association between variables x and y.
- **Alternative hypothesis**: there is a statistically significant association between variables x and y.

For more on statistical tests and which would be most appropriate to use, see the Tools and Inquiries reference guide, pages 11–17 at www.hoddereducation.co.uk/ib-extras or the *Biology for the IB Diploma Third Edition Student's book*, pages 572–4 and 757–9.

One of the most effective ways to communicate the results of your scientific investigation is by creating a visual representation (a graph) of the data that have been counted, measured and calculated. You can often see patterns in a graph that may not be as obvious in a table of data. Graphs show trends in data clearly and can be used to summarize complex relationships between independent and dependent variables. Different types of charts and graphs are described throughout the *Biology for the IB Diploma Third Edition Student's book* and in the Tools and Inquiries reference guide (www.hoddereducation.co.uk/ib-extras).

Graphs are sometimes reduced in size to ensure the report is the correct page length, however graphs should not be reduced to such a size that they become uninformative, simply to stay within the page limit.

Standard deviation and standard error help in our analysis of the data: these measurements indicate variation around the mean and can be presented on graphs as error bars (see *Biology for the IB Diploma Third Edition Student's book*, pages 686–7).

You are expected to appreciate the limitations of your instruments, and measurement uncertainties need to be presented and discussed. The experimental procedure and apparatus will result in measurements that vary from true values. These are known as 'uncertainties'. There are several different types of uncertainty (see the Tools and Inquiries reference guide, page 20).

Data analysis: final check

- ☐ In my report, data refer to quantitative data or a combination of both quantitative and qualitative data.
- ☐ My method for processing the data can be understood easily.
- ☐ I have followed scientific and mathematical conventions correctly (for example, for annotating graphs and tables, and for using units, decimal places and significant figures).
- ☐ I have considered uncertainties where relevant.
- ☐ There are no omissions, inaccuracies or inconsistencies that would prevent you reaching a valid conclusion that addresses the research question (see next section).

Conclusion

After collecting your data and processing it, you must analyse the data and draw relevant conclusions. Do not forget to ensure these conclusions relate directly to the research question and the accepted scientific context. You should not arrive at a conclusion to your experimental work without questioning any assumptions or possible competing explanations. This covers Inquiry 3: Concluding and evaluating, particularly in the skill Concluding.

Table 5 sets out the marking criteria for this section.

Table 5 Marks and level descriptors for Conclusion

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	A conclusion is stated that is relevant to the research question but is not supported by the analysis presented. The conclusion makes superficial comparison to the accepted scientific context.
3–4	A conclusion is described that is relevant to the research question but is not fully consistent with the analysis presented. A conclusion is described that makes some relevant comparison to the accepted scientific context.
5–6	A conclusion is justified that is relevant to the research question and fully consistent with the analysis presented. A conclusion is justified through relevant comparison to the accepted scientific context.

***Source**: IB Diploma Programme Biology guide, page 122*

Inquiry 3: Concluding and evaluating

Concluding

Your processed data should be correctly interpreted, for example the correct numerical relationship between the independent and the processed dependent variable deduced from a graph with data quoted to support the interpretation. Terms to describe graphical relationships, such as ‘directly proportional’, ‘exponential’ and ‘inversely proportional’, should be used correctly.

Do not overstate your findings and always be tentative in your conclusions. Use statements along the lines of: ‘The line graph suggests a possible relationship between variables *X* and *Y*.’ The conclusion should use your understanding of biology to explain the outcomes of your research. If there is no obvious pattern, trend or relationship, or the pattern was not what you were expecting, think laterally: is there a biological reason why this may have happened? Is there another variable affecting the dependent variable? Anything you are speculating on could be used in the evaluation as a possible area for further investigation.

After you have determined a result for your experiment, it is good practice to compare this result to published research. This allows you to see how well your experiment was designed and how well you carried it out. The IB asks that your literature value is ‘traceable’. This means you need to include a good amount of detail as to its source (i.e. your system of referencing and citation needs to be clear).

Your conclusion should also include a discussion of the uncertainties. What is the impact of these values? Are they small, meaning your measured uncertainties are well controlled, or are the uncertainties large, meaning your result could be inaccurate or biased? If the range of your uncertainties allows your calculated value to lie in the same range as the literature value, you may conclude that most of the uncertainties in the experiment have been accounted for.

Conclusion: final check

- ☐ My conclusion is fully consistent with the data, analysis and research question.
- ☐ My conclusion correctly interprets the processed data, including associated uncertainties.
- ☐ My conclusion refers to the scientific context.
- ☐ I have obtained information about the scientific context from published material (paper or online), published values, course notes, textbooks or other outside sources.
- ☐ I have cited published materials in sufficient detail to allow research sources to be traceable.

Evaluation

The final stage of your scientific investigation is to reflect on and evaluate your work: what went well and what needs improving? This covers Inquiry 3: Concluding and evaluating, particularly the skill of Evaluating.

Table 6 sets out the marking criteria for this section.

Table 6 Marks and level descriptors for Evaluation

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	The report states generic methodological weaknesses or limitations. Realistic improvements to the investigation are stated.
3–4	The report describes specific methodological weaknesses or limitations. Realistic improvements to the investigation, that are relevant to the identified weaknesses or limitations, are described.
5–6	The report explains the relative impact of specific methodological weaknesses or limitations. Realistic improvements to the investigation, that are relevant to the identified weaknesses or limitations, are explained.

***Source**: IB Diploma Programme Biology guide, page 122*

Inquiry 3: Concluding and evaluating

Evaluating

An effective evaluation will consider the major source or sources of error in the experiment (whether systematic or random) and explain how the suggested improvements will quantitatively impact on (i.e. reduce) that error. For example, in a calorimetry experiment, the major sources of error are heat loss and incomplete combustion (systematic errors); thus discussion of random errors such as temperature readings, water volumes, etc., is not relevant because if the random errors are reduced, this will not have an impact on the major sources of (systematic) error.

The evaluation should refer to the overall approach to the investigation of the research question as well as procedural steps. It can also include:

- identification and justification for the removal of any outliers
- an assessment of the confidence you have in the reliability of the conclusions
- an estimation of percentage uncertainties and identification of the main sources of random error.

The methodology must be evaluated thoroughly. You need to include the strengths as well as the weaknesses and limitations of the investigation. For example, a strength could be a small standard deviation in data for the dependent variable, indicating that measurements were precise. Weaknesses could include instances where other variables in an investigation were not sufficiently controlled or, if using an online simulation, the software may not have reproduced natural conditions accurately. Do not only restrict weaknesses to details of the practical, but include other aspects as well (for example, lack of secondary data or literature values for comparison). Clear and serious flaws in your methodology should have been removed at an early stage of your IA development; you should not use the evaluation as an excuse for any fundamental flaws in your methodology.

You also should explain realistic and relevant improvements to your investigation. For example, if a large range of pH values (pH 3–11) were tested during an investigation of the effect of pH on the digestion of casein (a protein) by neutrase (a protease enzyme), an improvement may be that a greater number of pH values at greater resolution (sensitivity) could be tested either side of the suggested optimum pH (pH 6) for the enzyme (i.e. pH 5–7 at 0.25 intervals).

Evaluation: final check

- ☐ I have identified sources of random and systematic error and discussed their impacts.
- ☐ I have evaluated my methodology by explaining the implications of weaknesses, limitations and assumptions on my conclusions.
- ☐ I have suggested realistic and relevant improvements to my investigation.