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INTERNATIONAL ADVANCED LEVEL

BIOLOGY

PRACTICAL GUIDE
TEACHER SUPPORT

Pearson Edexcel International Advanced Subsidiary in Biology (XBI11)
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Introduction

This guide is designed to support you and your students through all elements of practical work in the new International A level specification. Although it will address assessment, its focus is to ensure that good quality practical work is at the heart of teaching and learning in Biology.

The over-arching aim of the specification is to help learners progress from being GCSE or International GCSE students towards becoming ready for the next stage of their development, whether that be university or the workplace. To some extent this can be through developing skills such as non-routine problem solving and ICT literacy but also by personal skills in communication, adaptability and self-management. In terms of practical work, the aim is for students to become capable of thinking independently. Part of this is developing confidence in their own competence to challenge accepted practice and ask 'How do I know that?', whilst thinking about the science behind the observations. This may be exhibited by e.g. working towards thinking independently in planning and evaluating for themselves the outcome of practical work.

Over the course of the International A level, students will develop a range of skills in practical work which will vary from the acquisition of specific practical techniques in a range of experiments (such as the use of a colorimeter or biological reagents), through to the development of some investigative techniques requiring some independent thinking (such as consideration of sampling techniques within fieldwork).

At one level, practical work undertaken by students can be simple, perhaps focusing on observational aspects of the subject (such as CP7, a study of plant histology), whereas other practical experiences may be truly experimental (such as CP4, the effect of temperature, pH and enzyme and substrate concentrations on the initial rate of reaction).

Many experimental activities will involve the collection of quantitative data and this provides opportunities for the development of mathematical skills, which are also required as part of the specification (see Appendix 6 of the specification).

There is a students' guide designed to be used alongside this teacher resource. It provides exercises to allow them to develop their skills. You will find the suggested answers to these exercises included in this teachers' guide.

Assessment of practical skills

Which skills will be assessed?

The International A level specification identifies two sets of practical skill that students should develop:

1. one of these sets of skills has been identified as suitable for assessment through written examinations;
2. and the other set of skills should be developed by students during laboratory work but will not be directly assessed.

Practical skills identified for assessment

- Solve problems set in practical contexts
- Apply scientific knowledge to practical contexts
- Comment on experimental design and evaluate scientific methods
- Present data in appropriate ways
- Evaluate results and draw conclusions with reference to measurement uncertainties and errors
- Identify variables, including those that must be controlled
- Plot and interpret graphs
- Process and analyse data using appropriate mathematical skills
- Know and understand how to use a wide range of apparatus, materials and techniques safely, appropriate to the knowledge and understanding of the specification
- Plan an investigation to test a hypothesis

Practical skills to be developed through teaching and learning

- Apply investigative approaches and methods to practical work
- Use a range of practical equipment and materials safely and correctly
- Follow written instructions
- Make and record observations
- Present information and data in a scientific way
- Use appropriate software and tools to collect and process data
- Use online and offline research skills, including websites, textbooks and other printed scientific sources of information
- Cite sources of information correctly
- Use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

The unit descriptions for Unit 3 and Unit 6 in the specification give more detail on the skills assessed in each Unit.

Preparing students for questions assessing practical understanding

Practical skills will be assessed on IAS Unit 3 and on IA2 Unit 6.

Unit 3 will be 20% of the IAS marks and 10% of the total IAL mark. The same applies to Unit 6 (20% of IA2, 10% of the IAL). In this way, practical skills will make up 20% of the marks of the whole IAL specification.

On each paper there will be a few marks (around 4 or 5) assigned to Assessment Objective 1 (AO1). So, of the 100 marks for Unit 3 and Unit 6 in the full IAL, up to only 10 may be on 'knowledge' and the remainder will address AO3 (Experimental skills in science, including analysis and evaluation of data and methods).

By far the most effective way to prepare students for written questions on these skills is to ensure that they have practised the skills required in the context of the core practicals. In this way it will become obvious that time spent on practical activities helps to prepare students for a substantial part of the examination. This needs to be taken into consideration when allocating time for practical work within your scheme of work.

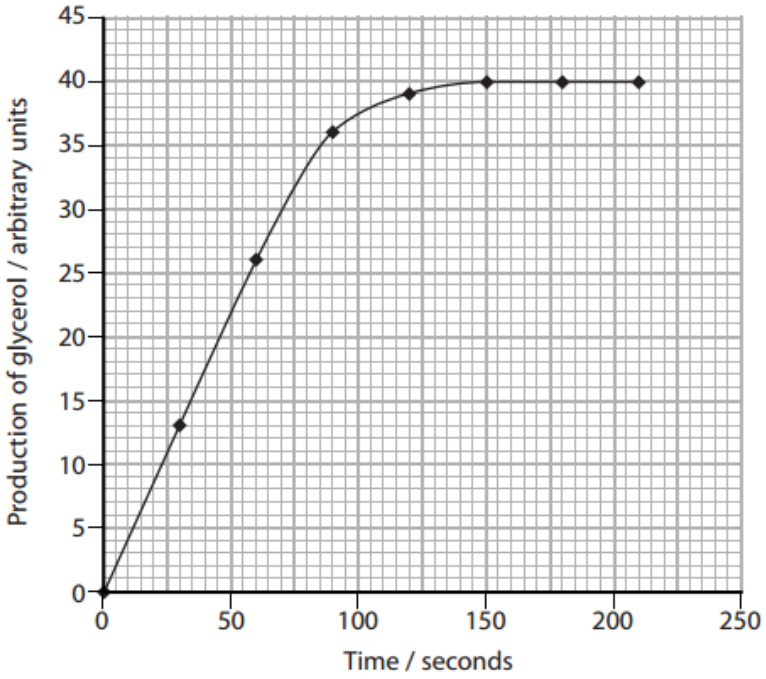
There are many suitable examples in the papers set on earlier specifications (WBI03 and WBI06) that could be used with students during their preparation for this type of question. Note, however, that skills in researching and reporting a scientific report, as tested on Question 2 of the old WBI03 papers, is no longer required in the new specifications. Questions of this type are not likely to appear as part of the assessment of Unit 3 or Unit 6 on the new IAL. Nevertheless, teachers should find some of the questions from these papers to be suitable for use with students preparing for the first papers in 2019.

Sample questions

1 Triglycerides from palm oil are added to ethanol in the production of biodiesel. The enzyme lipase can be used as a catalyst in the production of biodiesel.

This process is shown in the diagram below.

(b) The graph below shows the production of glycerol at one concentration of lipase.



Using the information in the graph, calculate the initial rate of reaction for this concentration of lipase.

Show your working.

(3)

Answer:

The initial rate is obtained by finding the gradient of the straight line part of the graph. This is from 0 to 60 seconds. So the change in glycerol production is from zero AU to 26 AU i.e. 26-0 AU. This happens in 60 seconds so rate is 26/60 AU sec^{-1}.

This is 0.43 AU sec^{-1}.

Commentary:

Maths skills will frequently be tested as part of the assessment of indirect practical skills as well. This is A.3.5 *Calculate rate of change from a graph showing a linear relationship.*

Likely problems here are doing the calculation but omitting the units and reading values off the wrong section of the graph. 1/time may also be calculated (in error) as a hangover from GCSE attempt at this type of work.

(Question taken from International A level Unit WBI03/01, January 2015)

1 A student read about the benefits of an increased intake of vitamin C in the diet. However, she disliked eating fruit and did not want to take vitamin tablets. Therefore she wanted to obtain most of her daily intake of vitamin C from vegetables. She also read that vitamin C in vegetables is destroyed when they are cooked.

She decided to do a project on the effect of temperature on vitamin C content.

She heated orange juice samples in boiling tubes at five different temperatures, in a water bath. In each case, the tubes were left in the water bath for fifteen minutes and then cooled in a beaker of ice for five minutes.

She determined the vitamin C content of each sample by titrating it with a 0.1% DCPIP solution (2,6-dichlorophenolindophenol). The vitamin C in the orange juice decolourises the DCPIP solution.

She repeated this procedure five times for each temperature.

(a) (i) State **two** variables that were controlled in this investigation.

(2)

Answer:

The heating time and concentration of DCPIP were both controlled.

(ii) Name **one other** variable, in her method, which should have been controlled. Describe how it could have been controlled.

(2)

Answer:

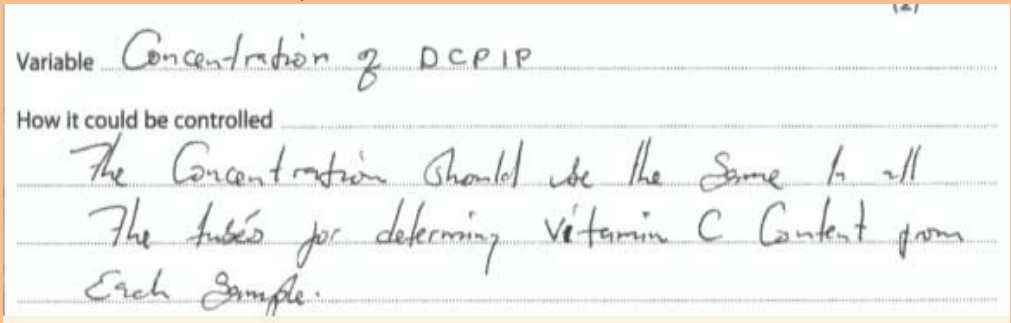
She should have controlled the volume DCPIP using a pipette

Commentary:

(i) This type of question, common on the WBI03 and WBI06 papers in the previous specification, tests one of the "Practical skills identified for assessment" highlighted in the list on 4: Identify variables including those that must be controlled.

The most common error is to just put down any variables, including ones that were not controlled or even the independent variable, as here:

(ii) Another common error is to quote variables that *are* controlled, as here:



(Question taken from International A level Unit 6BI07/01, January 2012)

Using Core Practicals to Teach Skills

The most important principle, which will be reiterated throughout this Guide, is that the assessments are based on testing how well students have developed appropriate skills. Whilst students are expected to have some knowledge of the techniques and procedures they encounter throughout the course, recalling small details is the simplest part of what is required.

Developing skills implies that there is significant progression in terms of independent thinking and understanding of the underlying science behind what they are undertaking.

We have selected core practicals to be included in our specification which are accessible to all students and provide opportunities to develop the skills listed, and not because they are 'perfect' examples of experimentation or can be used to demonstrate a textbook 'fact'.

Progression

As students move through the AS course and into the A2 course there should be evidence of skill development. This Guide should help to emphasise the level of progression expected and how it should look in terms of student ability.

A very good example of this can be seen in Core Practical 4. At GCSE or International GCSE level, simple investigations of how long it takes to reach an end-point are regarded as a satisfactory way of looking at enzyme action. This simple approach allows comparisons to be made - for example, the relative efficacy of an enzyme at different temperatures. What this approach does not do is to allow measurement of rate and, therefore, of initial rate. By extending something students know about in a simple way from to something much more sophisticated, the notion of progression can be clearly seen.

Planning practical lessons

It is a common belief that simply including practical sessions within the course is a 'good thing' which helps to motivate students. However, this is not always the case - as students will often say themselves! Like any other lesson, students are only engaged when they see clear aims and objectives which are relevant to their course. These aims must be relevant, achievable and explicit.

The core practicals should 'grow' naturally out of biological contexts in the specification. For example, the practical on the effect of enzyme concentration on initial reaction rate (CP4) could be linked to a consideration of the effect of a blockage to the pancreatic duct caused by thickened mucus in CF patients. Practical work on vitamin C content of various foods (CP2) could be as a follow-on from discussions of dietary effects on CHD.

In addition, and as mentioned, the core practicals are there to help embed practical skills in students. It can be very valuable to list the skills – practical, theoretical and mathematical – which each core practical may address. In this way, students have a clear understanding of why they are doing this particular piece of practical work and what they might be expected to learn from it.

As teachers, we know what is likely to happen during any one practical session. We also know that the time available for each practical is limited so it is vital to consider what our main objectives for the lesson are going to be in terms of the practical skills requirement.

This has two main advantages:

- It avoids student frustration and end of practical negativity ('It never works!', 'That was a waste of time.')
- It enables teachers to track practical skills development. Practicals with clear skills aims can be easily recorded for each group, thereby providing confirmation that all the skills are being covered within the scheme of work. This is especially important where more than one teacher is assigned to one teaching group.

Practical situations will form the contexts for assessment in written question papers (Units 3 & 6); and may frequently be associated with the assessment of mathematical skills. This needs to be reflected in teaching time during the International A level course and careful planning of the use of core practicals can play a vital part in developing the practical and mathematical skills required for success at this level, rather than simply concentrating on theoretical content.

Full details of the mathematical skills requirements can be found in **Appendix 6** of the specification along with exemplification of each assessment objective.

- All of the skills are to be examined at level 2.
- There will be 10% of the marks awarded at Advanced Level for mathematical skills.
- Mathematical skills will be expected in all papers

The next section of this Guide will consider how mathematical skills and practical skills link together as students complete core practicals and other practical activities.

Developing maths skills through core practicals

What level of mathematics is required?

IAL Biology will have questions that use mathematics at "Level 2". Effectively, this means that students are expected to have a knowledge of mathematics equivalent to the higher tier of GCSE or International GCSE. Not all mathematics in written exams will be at this level – as some questions may involve recall and use of simple formulae. However, even questions that involve simple mathematical operations may be viewed as Level 2 because the mathematics appears in a context, or involves a number of steps to be carried out with minimal structure of "scaffolding" of the question. Equally, questions where students must make decisions about which data or formulae to use can also be at Level 2. A good practical example would be requiring a student to draw a graph and select data from it to calculate a rate, as in calculating initial rates for enzyme investigations.

It is also useful to understand what is not regarded as mathematical skills. Questions often provide data from which candidates are expected to make conclusions by applying their biological knowledge and understanding. Even though data may be involved this would not be regarded as a mathematical skill, because mathematical operations are not involved in describing patterns. Similarly, simply defining mathematical terms or describing them would not be a mathematical skill.

The requirements for mathematics have obvious implications for planning schemes of work. It is common for biology teaching groups to contain students with varied mathematical ability and careful thought will be needed to meet their needs.

We cannot assume that even students who perform well at higher tier GCSE mathematics will retain their knowledge and competence at the end of two years without further practice and development.

Past examiners' reports show that there are several areas in which many students are not totally confident. These include:

- calculating percentage increase/decrease
- selection, application and accurate presentation of graphical formats
- manipulating formulae.

There are also areas, such as calculations using the Hardy-Weinberg relationship and statistical analysis, which will be new to students regardless of their mathematical background.

The implication of this is clear. There need to be specific learning opportunities integrated into the course which provide reinforcement and training in these mathematical areas, if students are to develop confident mastery; enabling them to perform to the best of their ability in the terminal examinations.

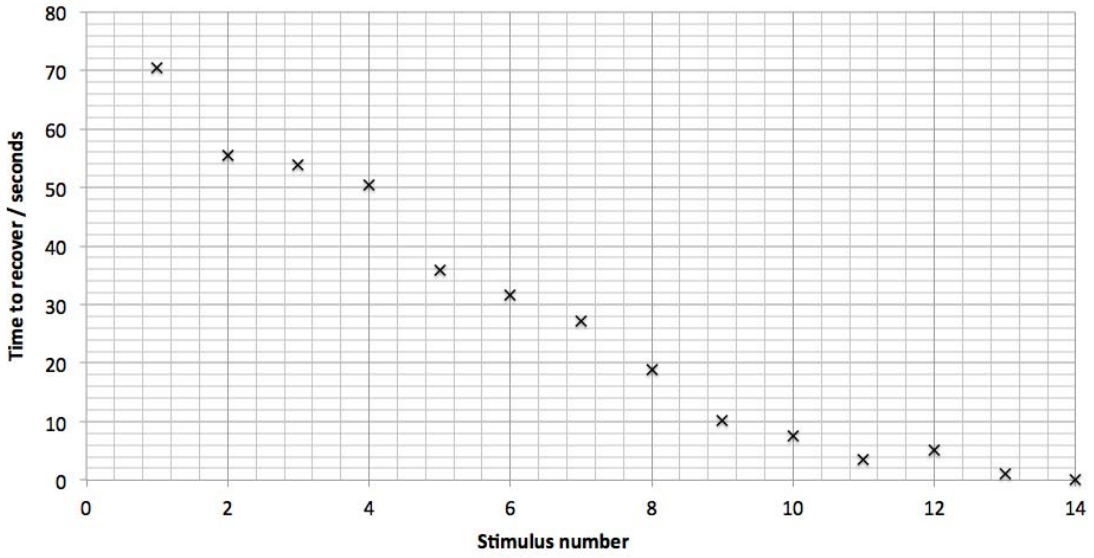
Practical activities offer an excellent framework for this, as they provide all the required elements within an applied setting which has been shown to be much more effective than a purely theoretical approach. Some illustration is given in the summary of core practicals.

Graphs

Graph plotting and interpreting skills will be relevant in the assessment of practicals.

Again, the 'Alternative to Practical' papers from the 'old' spec (WBI03 and 06) can provide very useful practice material for these skills.

Sample Graph: Recovery time for eyestalks in giant snails after a number of stimuli (Recommended additional practical at 8.9)



Axes: labelled with the measured quantity(ies) and the varied one (if appropriate) with units after a / (if appropriate).

Scale: chosen to occupy a significant proportion of the graph paper and to allow plotting to be reasonably easy and accurate. Multiples of odd numbers, except 5, should be avoided if possible. Think about the highest and lowest values when deciding on a scale.

Markers for data points: should be a x or a +. Error bars, if shown, may be drawn on either side of the marker which will show the mean in this case.

Lines: If a line of best fit is to be drawn it should be drawn in such a way that the number of points on either side of it is the same if possible. The line should be drawn, *not* sketched. It should not be extrapolated to go through the origin unless this makes sense.

Dot-to-dot is often appropriate in Biology where there is no knowledge of interim values and where the *x*-axis may not show a continuous variable.

Anomalous results: should only be ignored when graph plotting if there is good reason to do so.

Scatter graphs: should be drawn if a correlation is suspected but no causal reason for it is known.

Continuous data: should be graphed as a line graph or a histogram, in both cases the *x*-axis will show continuous data. In histograms the bars touch.

Discontinuous data: should be plotted as bar charts, with the bars not touching.

Gradient of a straight line: is calculated by dividing the change in y by the change in *x*. The initial rate example above can be used to demonstrate the method.

Equation of a straight line: should be known and the idea of intercept.

Statistics

Descriptive

Mean, median and mode and standard deviation: may need to be calculated in both the course of practicals and in written examinations. The formula for standard deviation will be provided in a written examination, if needed.

It is useful to know that ± 2 standard deviations encompasses 95 % of the data. It is als useful to have the idea that if SDs do not overlap, differences between two means are likely to be due to something other than chance.

Inferential

Chi-squared, Student's t-test and correlation coefficient: these may also need to be calculated in the practicals and in the exam. In a written examination, the formula for each of these will typically be given. These tests are part of the Maths requirement for Biology (Appendix 6)

Students should be aware that chi-squared and t-test are looking for significant differences: either between expected and observed values (chi-squared) or between means (t-test). The correlation coefficient is a test of association.

Use of significant figures

When writing tables all figures should be quoted to the same number of significant figures. e.g.

11.12
11.03
11.10
11.00
11.75

In the results of calculations, the number of significant figures should be that of the data used in the calculation with the least number of significant figures.

e.g. 17.8 × 4.6 = 82 (calculator gives 81.88)

When recording readings from a meter include all those displayed. e.g.

would be written as 2.89

Errors and uncertainty

Students studying chemistry and physics will be aware that calculations of uncertainties and errors plays an important part in understanding the accuracy of use of common laboratory apparatus such as pipettes, burettes, measuring cylinders and thermometers. In dealing more often with highly variable situations such as ecological investigations biologists are traditionally less concerned with this aspect but it is often very significant when collecting data in the field. However, several core practicals involve such processes as producing very dilute solutions by serial dilutions and accurate volume measurements, therefore it is important that those students not studying other sciences are introduced to these ideas.

Note, uncertainties are not errors. No matter how carefully we use a simple ruler there will still be significant uncertainties. Errors – which may be classified as systematic errors or random errors – arise through in-built precision of equipment, poor technique, unfamiliarity or simple lack of care.

Uncertainty: many pieces of apparatus have the level of uncertainty indicated e.g. a laboratory thermometer might have ± 0.5°C

When taking measurements it is important that students are aware of all of the possible uncertainties. With a ruler this includes placement of the ruler or specimen as well as the problems of discerning the actual gradations.

Where measurements are repeated using the same units then uncertainties are simply added.

e.g. A ruler has an uncertainty of ± 0.5 mm when reading the scale and ± 0.5 when lining up the specimen. The latter could be greater when the specimen is an awkward shape or in an awkward position on a living organism.

The total uncertainty is then ± 1 mm. For a total of 10 repeats this is ±10 mm.

Where readings are in different units the percentage uncertainty needs to be calculated. This is simply the uncertainty divided by the actual value multiplied by 100.

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{actual measurement}} \times 100$$

Percentage uncertainties can now be added together in the same manner as actual values.

A glossary of terms used with practical science can be found in the final section of this Guide.

Opportunities for skills development and their assessment.

This grid shows how the core practicals can be used to develop mathematical skills within Biology; and also makes some links to the skills that may be tested on question papers.

Biology Core Practical	Mathematical skills
1. Use a semi-quantitative method with Benedict's reagent to estimate the concentrations of reducing sugars and with iodine solution to estimate the concentrations of starch, using colour standards.	2.3
2. Investigate the vitamin C content of food and drink.	0.2, 1.2, 1.6, 2.3. 3.2
3. Investigate membrane properties including the effect of alcohol and temperature on membrane permeability.	1.2, 1.6, 3.2
4. Investigate the effect of temperature, pH, enzyme concentration and substrate concentration on the initial rate of enzyme-catalysed reactions.	0.3 3.2, 3.3, 3.6
5. (i) use a light microscope to make observations and labelled drawings of suitable animal cells (ii) use a graticule with a microscope to make measurements and understand the concept of scale	0.3, 1.8, 2.2
6. Prepare and stain a root tip squash to observe the stages of mitosis.	0.3, 2.3
7. Use a light microscope to: (i) make observations, draw and label plan diagrams of transverse sections of roots, stems and leaves (ii) make observations, draw and label cells of plant tissues (iii) identify sclerenchyma fibres, phloem, sieve tubes and xylem vessels and their location.	None
8. Determine the tensile strength of plant fibres.	3.1, 3.2
9. Investigate the antimicrobial properties of plants, including aseptic techniques for the safe handling of bacteria.	0.3, 3.2, 4.1, 2.3, 2.5
10. Investigate the effects of light intensity, light wavelength, temperature and availability of carbon dioxide on the rate of photosynthesis using a suitable aquatic plant.	1.2, 1.6, 1.10, 3.2
11. Carry out a study on the ecology of a habitat, such as using quadrats and transects to determine the distribution and abundance of organisms, and measuring abiotic factors appropriate to the habitat.	0.3, 1.3, 1.5, 1.7, 1.9, 1.11
12. Investigate the effects of temperature on the development of organism (such as seedling growth rate, brine shrimp hatch rates)	1.2, 1.6, 3.2
13. Investigate the rate of growth of microorganisms in a liquid culture, taking into account the safe and ethical use of organisms.	1.5, 2.3, 2.5, 3.2, 4.1
14. Investigate the effect of different antibiotics on bacteria	1.2, 1.6, 2.5, 4.1

Biology Core Practical	Mathematical skills
15. Use an artificial hydrogen carrier (redox indicator) to investigate respiration in yeast.	1.3, 1.5, 2.3, 2.5
16. Use a simple respirometer to determine the rate of respiration and RQ of a suitable material (such as germinating seeds or small invertebrates).	1.2, 1.6, 1.10, 2.4, 3.2
17: Investigate the effects of exercise on tidal volume, breathing rate, respiratory minute ventilation and oxygen consumption using data from spirometer traces.	2.4, 3.1, 3.6
18. Investigate the production of amylase in germinating cereal grains.	1.2, 1.6, 1.7, 1.9

Teaching approaches to the Core Practicals

The 18 core practicals, as well as the recommended additional practicals, should be used to allow students to develop their practical techniques and skills and to use their mathematical skills (Appendix 6).

It is expected that the course will include other practicals that also allow these techniques and skills to be introduced and practised but it is essential that the core practicals are covered as they from part of the specification.

In Core Practical 3 *Investigate membrane properties including the effect of alcohol and temperature on membrane permeability*, it is quite likely that colorimetry will be used, as it may also be in Core Practical 4, *Investigate the effect of temperature, pH, enzyme concentration and substrate concentration on the initial rate of enzyme-catalysed reactions.* A session on the principles and mode of operation of a colorimeter, if available, would thus seem to be a useful starting point prior to both of these.

Most of the core practicals should be able to be carried out in one laboratory session. Some, however, will need more sessions. CP9, *Investigate the antimicrobial properties of plants, including aseptic techniques for the safe handling of* bacteria and CP11, *Carry out a study of the ecology of a habitat, such as using quadrats and transects to determine the distribution and abundance of organisms, and measuring abiotic factors appropriate to the habitat,* are cases in point.

Practical skills and core practicals

The practical skills identified for assessment and to be developed through teaching and learning are listed on page 4 of this document, but can also be found in the specification on page 25 (for IAS) and page 39 (for IA2). These will be assessed in the context of the core practicals and additional practicals included in the Specification. As well as the assessment of practical skills, students should be gaining experience in techniques and, by completing all 18 core practicals, should be able to develop their skills to the level expected.

Choosing the Core Practicals

In most cases, we would expect that teachers will carry out the practicals and we have developed worksheets and instructions in our Lab Book to help with this. However, you are free to use other practical activities in place of the ones selected for the worksheet. For example there are a number of enzyme / substrate systems suitable for CP 4: *Investigate the effect of enzyme and substrate concentrations on the initial rates of reactions.*

Commentary on the Core Practicals

To help support you with Core Practicals, there is a Lab Book, published by Pearson, which has student worksheets for 18 practicals. Further Practicals support for teachers forms part of the Teacher Resource Pack for International A level.

1. Use a semi-quantitative method with Benedict's reagent to estimate the concentrations of reducing sugars and with iodine solution to estimate the concentrations of starch, using colour standards.

A good discussion could be initiated about the reasons why a quantitative method using a colorimeter, either a proprietary or home made one, could be used for the starch / iodine but not the Benedict's test.

Possible semi-quantitative colour standards could be made up, but there are many versions online. For example, for Benedict's reagent, there are: http://3.bp.blogspot.com/-lsv18C6OKzM/UNW_qSBz7sI/AAAAAAAAA_Y/fhdjoxAq-fI/s1600/Benedict%27s+test+for+reducing+sugars.jpg

or https://www.bioscience.pk/topics/pathology/clinical-pathology/item/820-tests-for-detection-of-glucose-in-urine

There do not appear to be colour standards online for starch so it might be a necessary to make your own.

2. Investigate the vitamin C content of food and drink.

Students should know that vitamin C is an antioxidant found in fruit and vegetables. They should also know that antioxidants oxidise lipoproteins which are more readily absorbed in the formation of plaques.

It is probably best presented as a technique which can then be applied to an investigation. This could take the form of comparing amounts determined in the experiment with those stated on product labels or looking at the effect of cooking on vitamin C content of food.

This is an opportunity for students to plan an investigation: teachers can decide the level of intervention required in relation to student abilities. It is likely however, that most will need some guidance on the actual titration method.

A simple worksheet may tell students that vitamin C decolourises DCPIP. How to actually carry out a titration and how to standardise it against known solutions is something with which they will need help. A procedure is provided in the Pearson Lab Book and this can be given to those who are struggling with their own method.

This investigation also provides opportunities for the development of mathematical skills as some calculations may be required.

The teacher sheet in the Teacher Resource Pack includes sample data to either substitute or supplement the data obtained by the students.

3. Investigate membrane properties including the effect of alcohol and temperature on membrane permeability

The most important point here is to set this practical in the correct context. Ideally, therefore, it should be carried out in direct conjunction with work on membrane *structure* and not work on *transport across membranes*. This is because students frequently interpret their results in terms of increases in rates of diffusion and/or osmosis, especially in relation to temperature effects. They then miss the point about the effect of temperature on membrane structure.

Some very interesting discussions can be entered into here. The relationship between temperature and rate of diffusion is a linear one, but the graph likely to be obtained in this investigation is *not* linear.

It is important that students understand the location of the pigment in beetroot cells. This is most satisfactorily achieved by looking at thin sections of the tissue through a light microscope. There are, however, resources showing that the pigment is in the vacuole.

(e.g. http://seniorbiology.com/beetroot_cell.jpg and page 27 of *Teaching Plant anatomy through creative laboratory exercises* by R. Larry Peterson, Carol A Peterson and Lewis H Melville, ISBN 9780660197982 or it can be viewed as a 'Google Book'.)

The investigation is best done using a colorimeter, but if numbers of these are limited or the school does not have them, other methods are available. The simplest way to do this is to place solutions in identical test tubes and compare them against a white card. This can be made quantitative by adding clear water to the more intensely coloured of two tubes until it looks the same as the one with which it is being compared. The height of liquid gives a measure of colour intensity. Relatively inexpensive colorimeters are now available from many biological equipment suppliers.

The worksheet in the Lab Book is a full recipe sheet for the practical. However, in this case students can be asked to write an hypothesis about what they think will happen with temperature and alcohol. If this is based on the knowledge that they have been given about the current model of membrane structure, it provides a very good example of experiments being carried out to support hypotheses. They should be encouraged to view their results in these terms rather than in terms of any 'proof' of the model of membrane structure proposed.

4. Investigate the effect of temperature, pH, enzyme concentration and substrate concentrations on the initial rates of enzyme catalysed reactions.

This practical is one of the most demanding in the AS part of the course. It shows real progression from simpler ideas at KS4. At that level finding out how long it takes for something to happen is sufficient in enzyme experiments. This practical requires a **rate** to be measured and this cannot simply be worked out by finding the reciprocal of the time taken. 1/t is not a measure of rate. Furthermore, at this level, it must be appreciated that the rate of an enzyme catalysed reaction changes as time goes by. The practical therefore requires an investigation of the **initial rate**. Students will find this challenging. The best way to do it is to follow the time course of the reaction, best done with a colorimeter (see core practical 3 for suggestions about colorimetry).

The context here is the reduction in digestive enzymes reaching the duodenum from the pancreas in individuals where the pancreatic duct is blocked due to thick mucus. Carrying the experiment out with a protease enzyme can reinforce this link, although other possibilities of course exist. Proteases will make a cloudy suspension of, for example, casein (found in dried milk powder) go clear. This can be followed quite simply in a colorimeter as mentioned above. Absorbance is measured and would be expected to decrease with time. When the time course has been followed for a few minutes a graph can be plotted of absorbance value against time. This graph will not be a straight line, as the rate of the reaction changes over time. The next step therefore is to get the initial rate from the straight-line part of the graph. This procedure will need to be repeated for a range of temperatures, pHs and enzyme and substrate concentrations. For example, if five enzyme concentrations were investigated, five time course graphs would be plotted. These will give initial rates which can then be plotted against enzyme concentration.

5. (i) use a light microscope to make observations and labelled drawings of suitable animal cells.

(ii) use a graticule with a microscope to make measurements and understand the concept of scale.

(i) The quality of drawings should be judged by:

- clear sharp single lines not sketched
- lines which do not 'hang' in mid-air or cross over too far
- lines which are proportioned to match the original
- lines which have a representative scale.

Drawings would be labelled or annotated to show important features.

Drawing a few cells in detail provides a much more productive exercise. Students often want to draw many tiny inaccurate cells when 3 or 4 are needed. Actual drawings should show cells at least 2-3 cm in size.

Remember that this is not an exercise in producing life-like artwork and so shading etc should be avoided. There are two main forms of drawing. Simple tissue plans with no cells to show arrangement of different tissues within an organ and drawings of a few cells.

(ii) Eyepiece graticules and stage micrometers will be needed for this exercise. These can prove expensive and it may be that only one of each can be acquired. The ones printed on to plastic film are the cheapest and are available from suppliers e.g. http://www.timstar.co.uk/mi84165-plastic-eyepiece-graticules.html

Stage micrometers can be much more expensive but a budget one is available at http://www.timstar.co.uk/mi170400-stage-micrometer-economy.html.

It is possible to get by with just one as each microscope can be pre-calibrated and a card stuck in its box or on it with the results of this exercise.

6. Prepare and stain a root tip squash to observe the stages of mitosis.

Students find this practical very rewarding if dividing cells are seen. The key, then, is to try to maximise the likelihood of this. Root tips between 2-5 days old yield the best results and midday is the best time to take the sample. If this does not fit with the timing of the practical, tips can be cut and fixed in ethanoic alcohol, ready for later use. To ensure uptake of stain, it is important not to rush this stage. If a few hours are left between application of stain and squashing, there will be better uptake of stain.

A webcam placed over a microscope can be used to show the class what they are looking for. This will also allow image capture which can alternatively be done with a mobile phone or digital camera. This can save a lot of time when students are first looking at their preparations. As always, it is worth having a 'one a prepared earlier' fall back if the practical fails.

Students should be encouraged to make drawings of what they observe and to include as many mitotic stages as possible. Sharing of preparations, or supplementing with pre-prepared slides should allow students to make drawings of all stages.

7. Use a light microscope to:

(i) make observations, draw and label plan diagrams of transverse sections of roots, stems and leaves

(ii) make observations, draw and label cells of plant tissues

(iii) identify sclerenchyma fibres, phloem, sieve tubes and xylem vessels and their location.

By far the most satisfactory way to conduct this work is to get students to cut and stain their own sections. Alternatives are to have pre-cut sections ('in-house' or from a supplier) which can then be stained by students, or simply permanent slides of relevant stems. Another possibility is to use photographs, many of which are available online.

Sunflower stem is one of the best to use. Plants can easily be grown from seed or preserved stems can be bought

(e.g. https://blades-bio.co.uk/shop/frozen-preserved/preserved-sunflower-stem/).

To stain for lignin, acidified phloroglucinol is recommended (recipe and safety notes are available through CLEAPSS www.cleapss.org.uk). Sections can be cut with a single-edged razor blade or a dedicated botanical razor

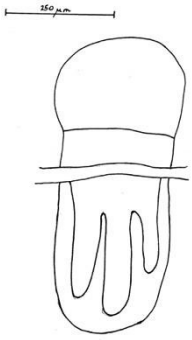
(e.g. https://www.timstar.co.uk/di06200-section-razor.html).

If prepared slides are used it is vital that students are made aware of the stains used and what colour they will cause the various tissues and cells to appear.

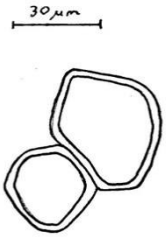
Students will need help with making appropriate drawing of their sections, however acquired. There is some guidance in "Techniques and Assessment in Biology by John Adds, Erica Larkcom, Ruth Miller and Robin Sutton", which can be found on Amazon (it is currently out of print).

Some examples

The format of a tissue plan (vascular bundle t.s.)



The format of a cell drawing (xylem vessels t.s.)



- Try setting some challenges. In a drawing of a xylem vessel is the proportion of cell wall thickness to lumen size about right? Can this be measured and then checked against the drawing? Is the detail of where cells join right showing a middle lamella or does it just merge two cell walls into one?
- Practical exercise in calculating actual size, manipulating formula and use of standard form.

8. Determine the tensile strength of plant fibres practically.

As with a majority of the CPs, this one is justified in terms of the context in which it is set, using plant fibres as a substitute for plastics and sustainability. Fibres can extracted by a process called water retting from such plants as nettle. Another useful plant is New Zealand flax, *Phormium* spp. In this case the fibres are easily extracted from the long strap like leaves by scraping away the surface tissue. Even more readily available is celery, from which fibres can also be easily pulled.

Again, the focus here is on experimental design. It is likely that it will have been addressed multiple times earlier but if not, this would be a good place to discuss error types, or to reinforce discussions from before.

9. Investigate the antimicrobial properties of plants, include aseptic techniques for the safe handling of bacteria.

Again, the practical is a natural adjunct to the work being done in other lessons about uses of plants, this time for medicinal drugs. This is a very important introduction to the use of aseptic technique, something which will be used at A level and beyond for those taking the subject further.

This might be a good opportunity, especially for the more 'ambitious', to consider the shortcomings of the disc diffusion method used in terms of diffusion and mo0lceualr size, plus other facts, which might affect diffusion rates. It is also worth discussing the various options for measuring the clear zone area, especially in the light of irregular shapes (not circles) if these arise.

10. Investigate the effects of light intensity, light wavelength, temperature and availability of carbon dioxide on the rate of photosynthesis using a suitable aquatic plant.

The standard method described in most worksheets involves counting bubbles coming from water plants (pondweed) or collecting the gas and measuring its volume. Teachers will need to explore the best pondweed in their area for this purpose. In the EU the most widely used species (Cabomba caroliniana) is banned, as it is an invasive in EU countries. Science and Plants for Schools (SAPS) lists alternatives but this a UK based list and may not be appropriate where you are. (http://www.saps.org.uk/secondary/teaching-resources/190-using-cabomba-to-demonstrate-oxygen-evolution-in-the-process-of-photosynthesis-)

If it is felt that pondweed is not the best option, the technique developed by SAPS may be worth considering

(http://www.saps.org.uk/secondary/teaching-resources/1224).

11. Carry out a study on the ecology of a habitat, such as using quadrats and transects to determine distribution and abundance of organisms, and measuring abiotic appropriate to the habitat.

This core practical is clearly best done on a field trip, if that is feasible.

There is clearly scope within this CP for a number of possibilities. It is probably best to use a combination of transects and quadrats to do a belt transect. Then, abiotic factors can be measured along the line of the transect and correlational questions can then be asked. Rocky shore, sand dune or salt marsh systems, perpendicular to a footpath through vegetation and woodland to meadow/open areas are all good places to do such work. Indeed, anywhere where there is an environmental gradient will suffice for this CP.

Within a stream, kick sampling can be used in conjunction with a quadrat. Here, comparisons could be made across the stream, but comparing one area of the stream with another may be a better option. The fauna of a stream under trees compared with that out in the open can yield some interesting results, links with allocthonous and autocthonous food sources being worth discussion.

The range of potential abiotic factors is, of course, huge but questions will be set in a way such as to allow students to discuss those they have measured in the correct context. It is worth remembering that it is not only going to be about the piece of equipment used but also how it is used, calibration and, very crucially, *exactly* where readings are taken. Opportunities for linking probes measuring such things as temperature, light intensity etc. to a data logger abound here.

If a transect is carried out on a sand dune or salt marsh system then succession can be explored at the same time. Having said this, experience shows that students can get very muddled about succession where there is an environmental gradient and end up thinking all such situations are successional. On balance, a better way to study successional change is via sites of different age, such as a quarry or mine waste tips. This allows a very good contrast to be made of random sampling using quadrats (where they are laid down at randomly selected sets of co-ordinates in a grid) with systematic (where the quadrats are laid down along a transect line).

12. Investigate the effects of temperature on the development of organisms (such as seedling growth or brine shrimp hatch rates), taking into account the ethical use of organisms.

Alternatives are given here but experience suggests that in practice brine shrimp hatch rate is the better one to do, as long as the 'eggs' can be sourced. The 'eggs' (in reality cysts) are usually easily and cheaply obtained, and are not difficult to handle. As suggested above, it is a good idea to link this experiment, looking at the effect of temperature on whole organisms, with that on effect on enzymes (CP4) and respiration rates (CP 16).

13. Investigate the rate of growth of microorganisms in a liquid culture, taking into account the safe and ethical use of organisms.

Any of the methods described in specification statement 6.2 can be used according to resources, but advantages and drawbacks of the chosen method need to be discussed - particularly the problems of distinguishing live and dead cells. It is also useful here to discuss the difficult problems involved in measuring 'growth'.

Depending upon your confidence in obtaining sufficient data, it is very useful here to have some sample data available for students to be able to gain maximum benefit from this investigation. It is the main example of the use of logarithmic functions and growth constants.

Plotting raw data on log graph paper is a good way to illustrate the principle of using logarithmic functions as exponential growth is converted into a straight line by the plot.

By the same argument some data can be used by students to calculate exponential growth rate constants.

14. Investigate the effect of different antibiotics on bacteria.

This exercise can use very similar techniques to those already encountered in CP9. It is, therefore, a good opportunity to rehearse the very important techniques learned there.

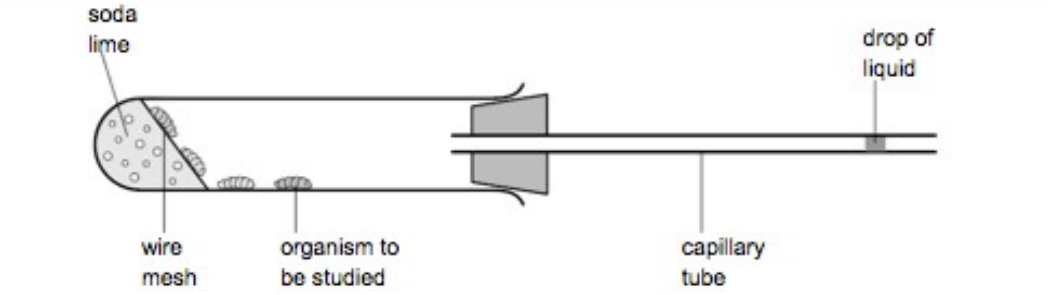
15. Use an artificial hydrogen carrier (redox indicator) to investigate respiration in yeast.

Although this is suggested as an opportunity to look at the effect of temperature on respiration rate, this is also covered in CP16, albeit using a different method. A useful further angle here is to focus on the use of the redox indicator, especially since the IAL does not require study of the Hill reaction. If TTC is not available DCPIP or methylene blue can be used.

16. Use a simple respirometer to determine rate of respiration and RQ of a suitable material (such as germinating seeds or small invertebrates.

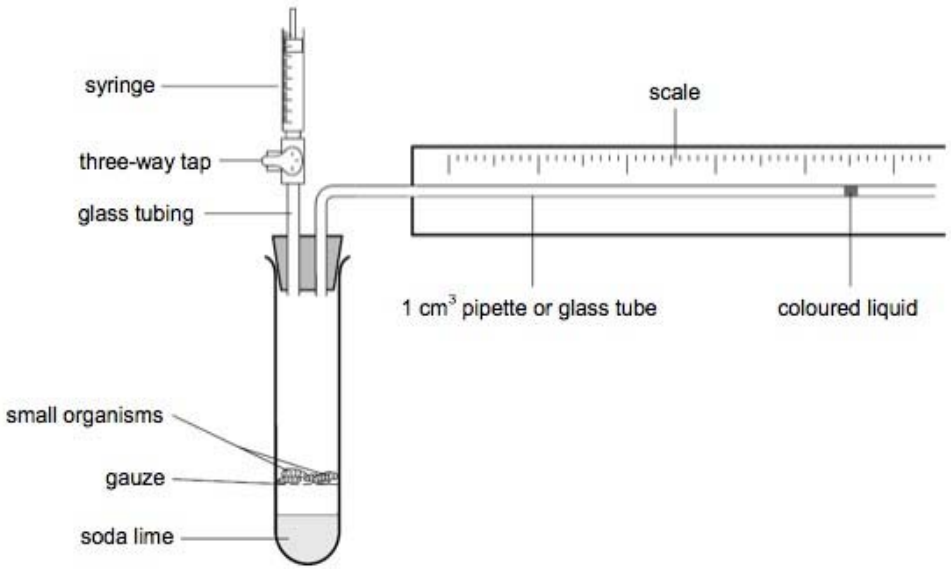
This practical uses a very familiar piece of equipment, a version of which learners are likely to have met at (International) GCSE. At that level though, the respirometer is likely to have been a 'simple' one and used without significant comment on any problems with the device. In this investigation, although a simple respirometer may still be used, the opportunity should be taken to discuss its shortcomings, and how they may be overcome.

A sequence of progressive improvement in the equipment can be traced. The very simplest device having this basic design:



The issues with this are the lack of any system to reset the liquid drop, so no possibility of easily repeating the investigation. There is also no control or method of controlling temperature.

The apparatus used by most schools for A level would be something like this:

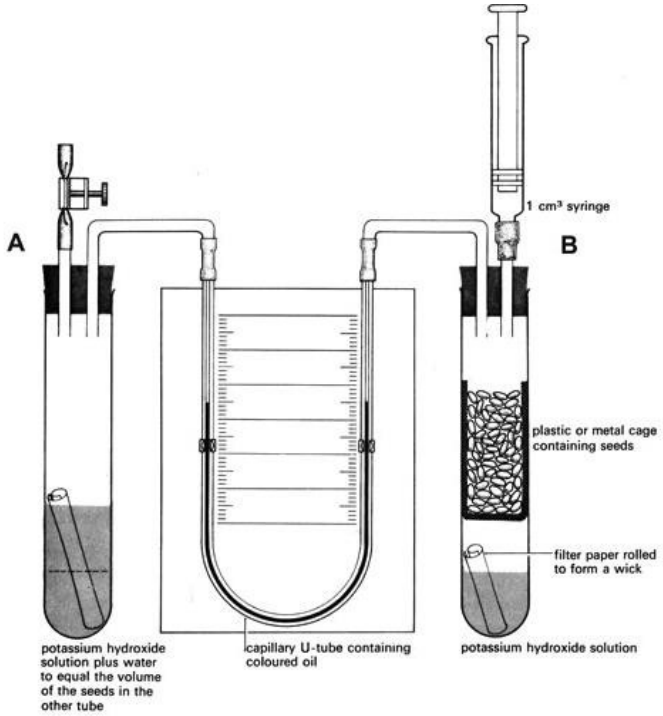


With its syringe and three-way tap, this design allows the return of the coloured liquid, so replicate measurements can be carried out. However, there is still no control, nor is any way shown of actually controlling the most important of the variables in this experiment, temperature.

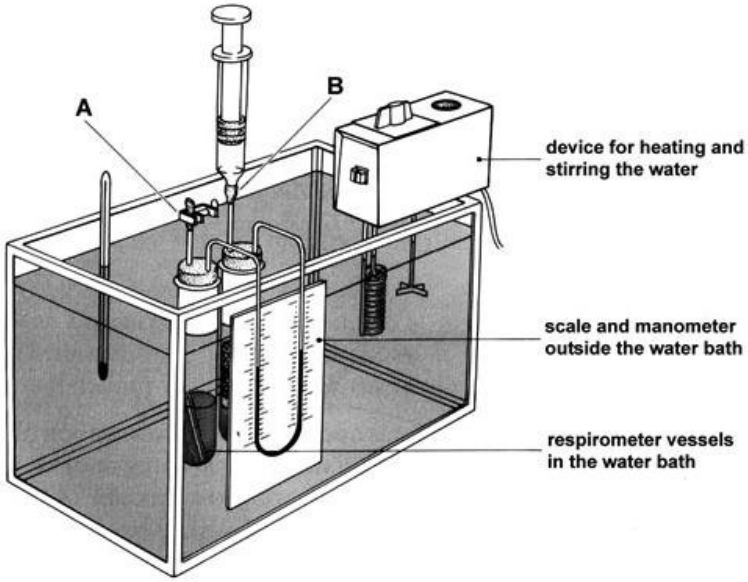
A discussion could now ensue about a good control, the most obvious being another set up like this with no 'small organisms' but some substitute, such as glass beads, or equal volume. This is necessary as the whole method relies on volume/pressure changes.

Temperature can be kept constant by immersing the test tube in a water bath, ideally one that is thermostatically controlled.

The most sophisticated respirometer likely to be met in a school is the device below.



This sometimes referred to as a Dixon–Barcroft apparatus. The left-hand tube is a compensating thermo-barometer, obviating the need for a control, as any changes in volume will be offset on both sides. The two tubes can easily be placed in water bath, viz,

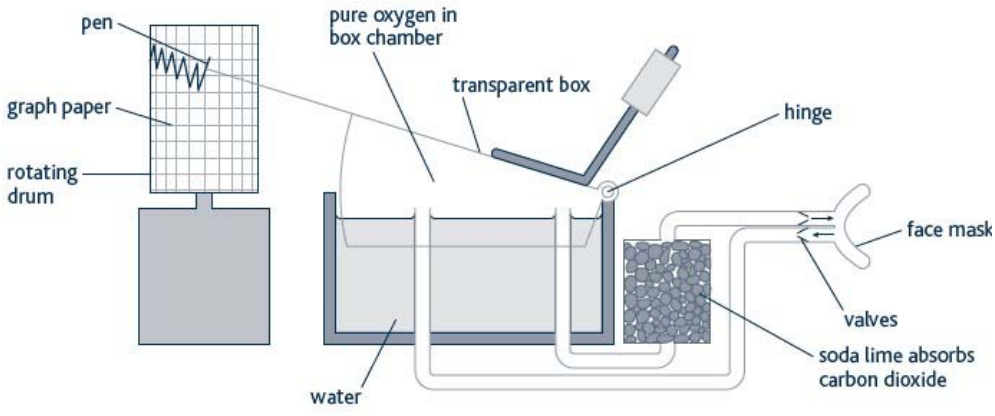


(from: http://www.nuffieldfoundation.org/practical-biology/measuring-respiratory-quotient)

An obvious extension of this CP would be to investigate the effect of temperature on respiration rate. The possibility then exists for links as suggested above under CP 12.

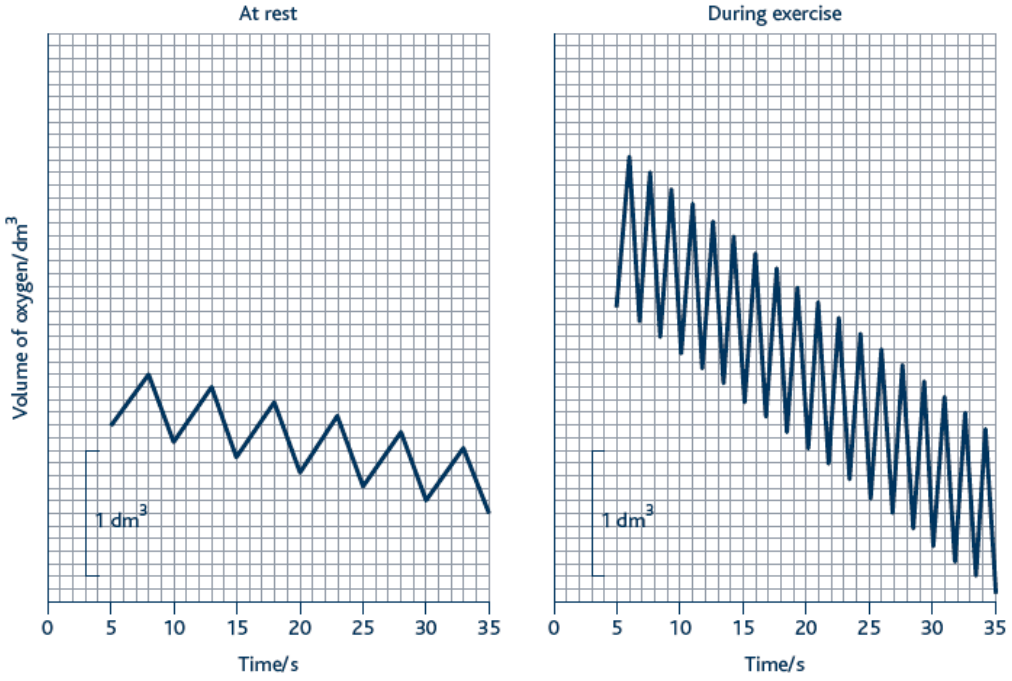
17. Investigate the effects of exercise on tidal volume, breathing rate, respiratory minute ventilation and oxygen consumption using data from spirometer traces.

A key point to bear in mind here is that there is **no requirement** to actually use a spirometer; it is interpretation of traces that is required.



Having said that, the basics of the equipment are worth knowing about.

This practical is very much a series of data interpretation exercises, and as such, very useful for some the maths skills. Suitable traces should be available from a number of sources but two are included here for convenience.



All the parameters listed in the CP can be worked out from these traces.

18. Investigate the production of amylase in germinating seeds.

Although possibly less well known this provides an interesting insight into the mechanisms of plant growth substances. Gibberellins stimulate the production of amylase in the initial stages of germination. If seeds are soaked in a Gibberellin solution for a short time then amylase is produced. Its presence can be detected by cutting the seeds in half and placing the cut surface onto a starch agar plate. After incubation at a fixed temperature the amylase diffuses through the starch agar hydrolysing the starch. Simply flooding the plate with agar will reveal a clear area around the seed providing a semi-quantitative assay of its concentration.

Using serial dilutions it is possible to investigate the effect of different concentrations of gibberellin this could be further enhanced by testing the antagonistic/synergistic effect of auxin on this system.

There is ample opportunity for independent thought. Is it better to measure simple diameters of the clear area or calculate/measure the area? Does this make a difference? Given that the area increases as the square of the dimension then differences will be larger.

Research and referencing

Students need to understand how scientific advances are communicated and reviewed. The process of peer-review, citations and attention to detail needed to present scientific papers should be understood, as should the role of scientific journals, conferences and the international nature of research. Evidence revealed by research might 'support the idea that' but is not described as 'proving'. Objective scientific language is cautious and often conditional and this needs to be reflected in students' own practical recording.

Independent objective research needs to be developed to incorporate this approach. The Internet is a wonderful resource but is often approached in a scientifically naive manner even by the most technologically aware students. Valid scientific information can be extracted easily but it is rarely found in the first few pages of a Google search or on an anonymous question and answer site. In contrast, Wikipedia is often carefully referenced or flagged where further corroboration of details are required. The simplistic view that it is weak, because anyone can edit it, needs to be investigated further.

For those able to start to engage with actual research papers, Google Scholar may be worth a look (https://scholar.google.co.uk).

Independent thinking and practical investigations

It is highly desirable that students are challenged to think more critically about a practical procedure from the start of the A level course. It is vital that they realise that what has served them well at GCSE needs to be developed to achieve the same success later.

As an example of this, consider the core practicals dealing with initial rates of enzyme reactions. Approaches to enzyme reactions need to be challenged, particularly the need to measure initial rates and to use S.I. units for rates. A simple challenge might be to use $1/t$ as a rate and investigate the effect of substrate concentration. In simple systems such as disappearance of starch increasing substrate concentration naturally increases the time taken for the substrate to be broken down and hence the rate decreases in direct contravention of the theoretical explanation. The problem, of course, is that the time does not increase to match the increase in starch and so the rate is actually faster. We can overcome this by measuring the quantity of starch (mass as we cannot ascertain molar concentrations) and dividing this by the time to achieve a more scientific measure of rate mg s^{-1}. But this still relies on the average rate of a rapidly changing system which again can be unreliable.

This is a really valuable example because students will quickly find that things are not as simple as first thought and there are some much more detailed ideas as well as conflicting suggestions. In other words, there is not necessarily some simplified answer paraphrased into an A level text. Whilst most students are not comfortable with uncertainty and often simply want to learn the 'right' answer, this approach, rather than simply being presented with a worksheet, is vital if we are to show students what we mean by progression to advanced level.

Independent thinking and evaluation

An objective discussion and reflection on the reliability and validity of their findings provides crucial evidence of a student's independent thinking and practical competence. This will vary according to the core practical, as some activities, such as dissection, are limited in this respect. Most others offer opportunities which can be based on a significant data set. In general those preceded with 'Investigate' offer the greatest potential.

Progression in evaluating practical investigations is characterised by:

- a move from descriptive comment and a subjective approach to evidence-based analysis
- cautious conditional language
- an accurate appreciation of exactly what the data shows (and what it does not)
- a clear understanding of the biological principles underlying the methodology applied
- an understanding of the limitations and advantages of statistical testing

When looking for evidence in evaluating, the obvious place to start is the data. There is little point in speculating about difficulties or mistakes if there is no evidence. Students need to appreciate that in a perfect investigation where all variables are accurately controlled then any repeats would be identical. When this is not the case then the size of these differences can provide useful information. This naturally leads to such measures as means, medians, standard deviation and standard error. Other differences may be more marked and be regarded as anomalies or outliers. All of this will provide good evidence for any judgements on the reliability of the findings. Only then is it possible to begin thinking about what might be causing these differences.

Where such variations lead to uncertainty this leads us naturally to statistical testing and the need for some basic rules agreed by all scientists. e.g. 5% significance levels.

So, one clear area of progression is from 'I think there is a difference' to 'there is a significant difference at the 5% confidence level'. Students do not need to know the detailed mathematical basis for all the statistical tests they might encounter. They do need to appreciate exactly what the test reveals. Statistical tests can only give us useful but limited conclusions. At this level these would be:

- 'There is a significant difference between....'
- 'There is a significant correlation between...'
- 'There is a significant association ('goodness of fit') between ...

What they do not tell us directly is why these might be significant. This is particularly important with correlations where even a perfect correlation does not indicate causation. The possibility of the variable under investigation being secondary and merely linked to another is an important consideration in many scientific investigations and especially in epidemiological studies.

In biology we often deal with variable data where it is very difficult to achieve the level on control often found in experiments in physics and chemistry. Analysis of data may well show obvious random errors well outside the range of uncertainty of the apparatus used and so such measures as standard deviation become important. Systematic errors may well have greater effects in some data ranges than others but are difficult to detect and quantify from the data alone. These may form part of the discussion but will be rather speculative.

In summary the practical assessment is not an isolated section of the specification and its assessment. A small part is simple direct learning of basic techniques and procedures as well as physical skill in handling apparatus. A far greater part will be testing students' ability to apply their skills to a wide variety of questions. In terms of assessment, practical skills will be encountered in Units 3 and 6; although the assessment of mathematical skills and interpreting data may be seen across all Units. In a wider perspective, the development of such skills is a key element in preparing students for higher education.

Terminology in Practical Biology

Integral to the study of biology is the collection of data and observations based on natural phenomena. The collection of data and empirical evidence can lead to concerns about the quality of evidence, especially if we base explanations on the data collected.

Although there is no practical examination in this qualification, a set of practical skills has been identified as appropriate for written assessment. In doing this it is clearly important that the words used in assessments have a precise and scientific meaning as distinct from their everyday usage.

Practical skills should be developed by carrying out practical work throughout the course. The assessment of appropriate skills will take place on written papers; and the others will simply be developed through teaching and learning (see page 4).

Practical terminology used in this specification and for its assessment can be found in the table below.

Glossary

Term	Meaning and notes
Validity	A measurement is valid if it measures what it is supposed to be measuring – this depends both on the method and the instruments.
True value	The value that would have been obtained in an ideal measurement – with the exception of a fundamental constant the true value is considered unknowable.
Accuracy	A measurement result is considered accurate if it is judged to be close to the true value. It is a quality denoting the closeness of agreement between measurement and true value – it cannot be quantified and is influenced by random and systematic errors.
Precision	A quality denoting the closeness of agreement (consistency) between values obtained by repeated measurement – this is influenced only by random effects and can be expressed numerically by measures such as standard deviation. A measurement is precise if the values 'cluster' closely together.
Repeatability	The precision obtained when measurement results are obtained by a single operator using a single method over a short timescale. A measurement is repeatable when similar results are obtained by students from the same group using the same method. Students can use the precision of their measurement results to judge this.
Reproducibility	The precision obtained when measurement results are obtained by different operators using different pieces of apparatus. A measurement is reproducible when similar results are obtained by students from different groups using different methods or apparatus. This is a harder test of the quality of data.

Term	Meaning and notes
Uncertainty	The interval within which the true value can be considered to lie with a given level of confidence or probability – any measurement will have some uncertainty about the result, this will come from variation in the data obtained and be subject to systematic or random effects. This can be estimated by considering the instruments and the method and will usually be expressed as a range such as 20°C ± 2°C. The confidence will be qualitative and based on the goodness of fit of the line of best fit and the size of the percentage uncertainty.
Error	The difference between the measurement result and the true value if a true value is thought to exist. This is not a mistake in the measurement. The error can be due to both systematic and random effects and an error of unknown size is a source of uncertainty.
Resolution	The smallest measuring interval and the source of uncertainty in a single reading.
Significant figures (SF)	The number of SF used depends on the resolution of the measuring instruments and should usually be the same as given in the instrument with the fewest SF in its reading.

This is a selection of terms from the list in *The Language of Measurement* published by ASE (ISBN 9780863574245).

Answers to student guide questions

Q1 (a) refers students to https://www.nhs.uk/news/Pages/Howtoreadarticlesabouthealthandhealthcare.aspx. This is an article which summarises lots of important points to consider when reading newspaper headlines. It is written in clear student-friendly language and encapsulates many of the ideas we want students to think about when considering scientific conclusions and evaluating. A really good example of illustrating to them what is meant by progression to A level. The same pages have a database of almost all the headlines that have appeared in the newspapers in the past few years and an evaluation of the scientific work behind them.

(b) Ideally students will quickly pick up that there is lots of evidence from genuine scientific papers to show garlic has antibacterial properties. But have they found the main drawbacks and have they asked why it is not normally prescribed by doctors?
e.g. the active ingredient allicin isn't normally absorbed into the bloodstream and is destroyed in cooking. So you need to eat lots of raw garlic! A really good point can be made about conclusions about investigations in vitro not being transferable to effects in vivo.

Manuka honey is very similar. It does have antibacterial properties and is used in some wound dressings but if some of its effect is slow release of hydrogen peroxide then what will happen in the stomach and the cells lining it long before the active ingredients can be absorbed?

Q2 (a) (i) The best examples might be surface area; mass; surface area:thickness.

(ii) There is a good opportunity here to discuss what this investigation is really investigating and the weakness of simple 'size' measurements. Hopefully some ideas about sun and shade leaves will lead to area and thickness then to think of better ways of expressing morphology such as ratios. Students need to be encouraged to think ahead and realise that very simple measurements might lead to very restricted scientific conclusions. The morphology of the leaf is changed by light in several ways which are matched to its function. This idea of overall shape should lead to the idea of plasticity and away from simplistic more photosynthesis = more sugars = more growth. Obviously this leads to the ideas of control of gene expression as the whole shape of the leaf is changed, not just 'gets bigger'.

(b) This section is directed at variable control and practical skills. So other important variables will be: Height of leaf on the bush; position of the leaf on the branch; age of leaf; avoiding possible shading by other leaves or surrounding buildings etc.

(c) Light is very difficult to measure reliably in the field and almost always involves making compromises. This is because:

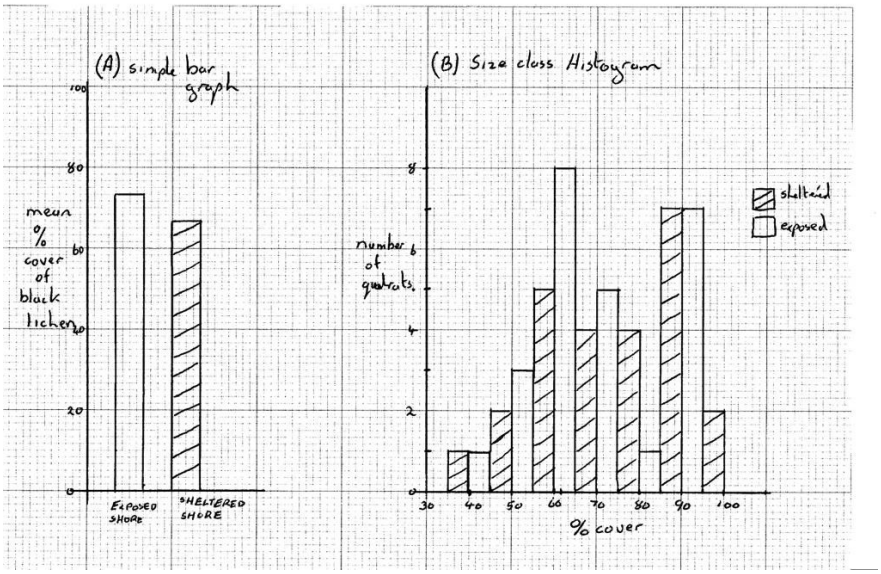
- Light changes with different times of day
- Light changes with different weather conditions (clouds etc)
- Light changes with the seasons (angle of sun in the sky)
- Aspect (E or W especially) needs to be controlled.

Q3 (a) (i) This is simply to get students thinking about graphical formats more carefully. The graph shown is meaningless because it has no clear labelling of the axes.

These are not paired samples so there is no scientific reason why a random sample called no.1 from the sheltered shore should be plotted alongside no.1 from the exposed shore.

If we plotted another set of data from random samples of the same two shores we would get a completely different pattern of coloured spikes therefore it does not show any general pattern or trend for analysis.

(ii) The sketch below shows two different formats for these data. Both are correct. The simple bar chart of means gives us a basic illustration of one important feature of these two populations. However by dividing the data into size classes we are able to present a much clearer picture of the actual distribution of these data and in doing so we are able to see more interesting trends and patterns.



Answers to core practical questions

Q4 Quantitative tests are ones which simply tell you if something (in this case sugar) is present or not. Quantitative give an accurate idea of much sugar. Semi-quantitative give some idea of how much but it no more than a rough guess.

Q5 Oxidation is the loss of electrons and reduction is the gain. Often remembered as OIL RIG.

Q6 (a) Betalain

(b) Betalain is stored in the vacuole.

(c) Pigment must cross the tonoplast around the vacuole and the plasmalemma (cell membrane) covering the cytoplasm.

(A good opportunity to check understanding of the plant cell structure. Could be followed up with questions concerning the cell wall to establish its freely permeable nature.)

(d) An example of more careful thinking about variables e.g. at higher temperatures the cells in the centre of the disc will take longer to reach the stated value. Therefore they will not all be treated for the same amount of time.

Q7 (a) Because enzymes catalyse rapid changes this means that variables such as substrate concentration change rapidly. If we are to measure the rate of reaction at the conditions we set up in our investigation then the initial rate is the only one which will give us an answer close to these initial conditions. The rate will slow quickly as the substrate is used up.

(b) mol dm^{-3} s^{-1}

(c) A rate cannot be expressed in terms of seconds only. What per second?

Q8 Use the low power objective lens locate the cells and also to get them into focus. Then move on to high power and focus with the fine focus knob.

Q9 (a) This will depend upon the actual stain you have used for the core practical, likely ones are Feulgen, acetic orcein, toluidine blue.

(b) To separate the cells so that chromosomes are visible.

To form a thin enough layer to allow sufficient light to pass through for viewing under the microscope.

(c) Various possibilities exist, but generally involve the use of concentrated acid, possibly with heating.

Q10 (a) 30 mm

(b) 32×10^{-6} m or 3.2×10^{-7} m

(c) Diameter of cell = 3.2×10^{-5} m

(d) You may need to check the drawing in the student guide as it could change depending on the print. The original has walls approx. 3.5 mm and a lumen approx.
42 mm. So the wall is thinner in proportion than the original cell.

Q11 (a) It might be suggested that temperature and humidity may have an effect. Fibre length is mentioned in the question, width might be even more important. Various aspects of fibre pre-treatment may be suggested.

(b) Again dependent on the variables mentioned. Suggestions should be sensible. Candidates commonly suggest a water bath for temperature control. Unless it is thermostatically controlled this would not suffice. In any case, a water bath would not be suitable in this case. It might be that the best that can be done is to carry out all trials in the same room and monitor any

fluctuations in temperature. There will be much more control over fibre width (measurable with Vernier callipers). Also, it should be feasible to standardise pre-treatment.

Q12 Likely suggestions are:

- use of sterile agar and Petri dishes, to stop the growth of unwanted species which might be pathogenic to humans and / or affect the results.
- use of flamed equipment (loops and the mouths of test tubes which contain the broth for example). This has the same purpose.

Q13 (a) Tissue Respiration

(b) Changes in temperature will cause large changes in the volume of gas produced making it difficult compare.

The effect of temperature on photosynthesis and respiration are not the same. Therefore more/less of the oxygen produced during photosynthesis will be used up e.g. photosynthesis and respiration have different temperature optima and the light independent phase of photosynthesis is much more temperature sensitive than the light dependent phase.

(c) An action spectrum is a graph of the rate of a reaction at different wavelengths of light.

(d) An absorption spectrum is a graph of the amount of light absorbed of a compound at different wavelengths.

(e) This is not a valid conclusion.

This may well support the idea that chlorophyll pigments absorb light which is used for photosynthesis but it does not 'prove' it.

Because this is a correlation only and there may be secondary links which would give this result.

There is no evidence in the investigation about carbohydrate so this cannot be supported.

There is plenty of evidence elsewhere that oxygen is a by-product of photosynthesis but not in this investigation.

Q14 (a) TWO methods of:

- simply count presence or absence of the organism in each of the 100 squares and use the count as a % cover.
- use the grid to estimate % cover by counting squares but only count a square when it is more than half covered by the organism.
- use the intersections of each square and record the presence or absence of the organism at each point where these cross.

(b) It is useful to compare simple visual estimates of a number of students to show just how varied these can be.

In **A** at least one part of a leaf appears in 56 squares. In **A** about 22 squares have more than half of the area covered. Note this will be variable and a good point for discussion as it is difficult to judge 'half covered' when there are different leaves and branches.

Which is better? Obviously this is just a subjective judgement but 56% is a very high estimate compared to how much sand is visible. A first impression without counts might put this lower but is unlikely to be lower than 22%.

Is it better to count the number of squares containing any of the plant, even though this might be an over-estimate it is the most consistent method for comparison? (a systematic error?)

So estimating % cover is highly variable and not easy and in any case is % cover a good idea? How many individual plants might there be? Is this a better measure?

Overall the idea here is to get students to think about the methods and to realise that there can be large errors which are not easy to eliminate.

(c) (i) A difficult exercise for those without rocky shore experience but a good one for testing observation. It would be reasonable to expect 4 or 5 for this.

For information there is at least:

- *Fucus vesiculosus* – Bladder wrack
- *Fucus serratus* – Saw wrack
- *Patella vulgata* – common limpet
- *Enteromorpha* species (bright green if viewed in colour)
- Barnacles – it is not possible to identify species from this but they are just visible on the rock surface.

It is also likely that the rock surface could have a coating of *Lithophyllum sp*.

(b) (ii) Included just to point out that clearly visible individuals are better counted as such not estimated as % cover. This could then lead to a discussion of the ACFOR scale, which can take account of different types of measurement but is not useful for quantitative analysis.

Q15 (a) Most would not object to the use of an animal in such an experiment.

There are some who would object to the use of an animal in such an experiment.

(b) The experiment would best be run in incubators set at the required temperatures. This can be problematic at temperatures below room. A refrigerator might be suitable, these usually run at about 5°C. If such equipment is not available, a thermostatically controlled water bath can be used. Failing both of these, flasks can be located in places, which are likely to experience different temperature regimes. In all cases it might be wise to monitor temperature. This is least necessary in an incubator where the set temperature should be maintained. In all cases it would best be achieved using temperature probes attached to a datalogger. If, again, such equipment is not available, regular readings can be taken to give some idea of the variation experienced.

Q16 (a) This is a useful exercise as the selection of a scale is possible but plotting of the first two numbers will be at best highly inaccurate.

(b)

Time (h)	Population Number	$\log_{10}$ population number
0	0	0
1	64	1.80
2	4096	3.61
3	262144	5.42

It should be evident that this is a straight line, illustrating the point of taking logs. This will then need to be supported by the concept of rate constants etc.

Q17 (a) No. It will also be affected by molecular size and solubility of antibiotic. These will both affect the speed at which it diffuses through the agar.

(b) No as the result is just a clear zone, it is not possible to tell whether this is due to death or a lack of reproduction.

Q18. (i) DCPIP, TTC, Methylene Blue.

(ii) DCPIP Blue to colourless,

Methylene blue, blue to colourless

TTC, colourless to red

Q19 (a) Potassium or sodium hydroxide, soda lime

(b) Assuming carbon dioxide output is equal to oxygen intake, then any change in volume must be due to oxygen intake. This is the case where carbohydrate is being metabolised as the equation is: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

(c) Students will have many and varied answers to this question and these can form the basis of useful discussion.

(d) The equation is: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

So when absorbent is present there would be no movement as there is no oxygen use to compensate for the carbon dioxide production. In the absence of absorbent the liquid would move away from the chamber containing the yeast. To investigate anaerobic respiration, therefore, no absorbent is used.

Q20 (a) Trace A is with the absorbent. As oxygen is used up, the curve slopes down as there is no equal volume of carbon dioxide to replace it. In B the line does not slope as the carbon dioxide produced replaces the oxygen used and there is no overall change in volume.
(b) The trigger for deeper and faster breathing comes from an accumulation of carbon dioxide in the blood. This does not occur when the CO_2 is absorbed and so the subject is unaware of the fall in oxygen availability and does not breathe faster or more deeply.
(c) In 11 small squares on the time axis (=55 seconds) the fall is about 2.5 squares on the y axis (= 2.5/4 x 1 dm^3 = 0.625 dm^3 in 55 seconds). This is 60/55 0.625 dm^3 per minute = 0.68 dm^3 per minute.

Q21 (a) Starch is insoluble and is therefore a common storage molecule in seeds. To be used as a respiratory substrate in germination it needs to be broken down into soluble sugars.

(b) The genes for α-amylase are present in the endosperm cell nuclei of the seed but not active.

Gibberellin is synthesised by the embryo in response to water entry etc. to the seed. Gibberellin is thought to stimulate the production of transcription factors necessary to activate the gene for α-amylase.

The binding of these transcription factors causes the production of m-RNA coding for the amylase.

The m-RNA is transported to ribosomes where it is translated to form the amylase molecules necessary to break down starch, initially into disaccharides. (Further details of protein synthesis could be expected here as revision for A level or consolidation for AS)

This also triggers active respiration in the seed to produce the ATP required for anabolic processes in the embryo which in conjunction with water uptake will cause the seed to germinate.

(c) This initial activation of amylases and hydrolysis of starch is used in brewing to produce a mixture of sugars which can be fermented anaerobically by yeast to produce ethanol in beers.