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AS and A Level Biology B

STUDENT GUIDE

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Contents

Introduction

What do we mean by practical skills?

It is really important to remember that the term practical skills covers a very wide range of requirements at A level. It does not mean just the ability to handle equipment in a school laboratory or know how to use some particular piece of apparatus. It ranges from using mathematics in a practical context to understanding how scientists investigate ideas, how they analyse their data and how they are very cautious when drawing conclusions. This guide will explain each of these in more detail.

These skills are not a separate part of your biology course, they are an essential part of all that you do and will be tested in your examination papers. In this course, there 16 core practicals which provide lots of opportunities to develop all of these skills.

How is this different from GCSE?

First of all you, are undertaking what is normally a two year course. Therefore you will be expected to have shown considerable development in this time. In simple terms there might be several familiar skills and theoretical topics, but you will be expected to have a much more detailed understanding of them. Above all you will be expected to develop into a more mature scientist. You will need to keep asking 'How do we know that?' You will also be expected to realise that, even at A level, you will only have part of the story and that science is constantly changing. It is not a pile of 'facts' it is just the best model we have at the present. Even at this level you can find many A level textbooks just 15 years old that contain information that we no longer accept, or at least has been significantly modified.

For example, for many years biologists believed in the 'one gene-one enzyme' hypothesis, but, as you will find in part of this course, we now know that there are several ways in which one gene can produce different products.

How can I use these skills in the future?

Almost all of the skills you will acquire during your course will be vital if you are thinking of continuing into higher education. Most are also what are called transferable skills. This means that they are extremely useful to a wide range of employers and in your own personal life. The most obvious example is that of research and analytical skills. Finding information that is reliable and accurate and using it to make decisions based on evidence is as applicable to buying a car as it is to making conclusions from experimental data. Exactly the same is true of all the mathematical skills where practical biology provides lots of opportunities to develop your skills.

How to use this guide

There are three main aims of this guide.

1. To explain what is meant by practical skills at Advanced Level.
2. To explain what is required to progress from GCSE to Advanced Level.
3. To provide questions to help you understand and develop your practical skills to the right level.

It is important to have a clear understanding of what you are trying to achieve at the beginning of the course. In this respect the introduction and the basic principles which follow need to be understood at the very start of your course. The questions and examples which link to particular practicals are more likely to be useful at the relevant points throughout your course and for consolidation before you sit the examinations.

How will practical skills be tested?

Practical skills in exam papers

There are 3 written papers at A level.

Paper 1: 1h 45mins. This paper tests content of topics 1–4 and 5, 6 & 7.

Paper 2: 1h 45mins. This paper tests content of topics 1–4 and 8, 9 & 10.

Paper 3: 2h 30mins. This paper tests content from all topics and questions may draw on material from two or more different topics. 50% of the marks in this paper will test your knowledge and understanding of experimental methods.

This means the following.

- Paper 3 will have lots of questions testing your practical skills and knowledge of the core practicals.
- This will include mathematical skills, as they are applied to practical work, but Papers 1 and 2 will also test your mathematical skills in other contexts. 10% of the total marks available on all papers will be allocated to mathematical skills.
- Papers 1 & 2 will contain questions which test your knowledge and understanding of the topics listed above but they can be presented in many different forms which are linked to your practical skills e.g. topic questions may well contain data tables or graphs which you might be asked to interpret and explain - in which case, you will need to use the skills you have developed throughout the whole course.

'The Practical Endorsement'

Your teachers will discuss this with you in more detail but the important features are as follows.

- It does not carry marks which count towards your final A level grade.
- It may be an important requirement for university entrance or your chosen career.
- There are only 2 grades; "Pass" or "Not classified," which will appear on your A level certificate.
- It will be assessed by your teachers throughout the course.
- The skills which are included in this assessment are:
    1. Following written procedures
    2. Applying an investigative approach
    3. Using a range of apparatus and equipment safely
    4. Making and recording accurate observations
    5. Researching, referencing and reporting

As you can see, these are just the skills that you would expect to develop when carrying out the range of core practicals in the specification and this is what will form the basis of this assessment.

Developing independent thinking

Whilst there are many individual skills to be developed it is very important to remember they are not isolated parts. All are linked to how we investigate things scientifically, so this is a good place to start.

We have already touched on what it means to be a scientist in the introduction. It is important to explain this a little more here.

Scientists work by creating models which are ideas about how and why things might happen. To form useful models they need imagination, ingenuity and a good deal of background knowledge. Almost all scientists work in groups, both together in one laboratory and with other groups worldwide. From these models they make predictions and only then do they design investigations to test these predictions. As the number of investigations which confirm these predictions increases then the model explanation becomes more widely accepted in the scientific community. However it only takes one well-designed investigation that contradicts expectations to destroy the idea.

Notice scientists are very careful not to claim they have 'proved' something and are very cautious in their language. They are very unlikely to refer to anything as a 'fact'.

Here is how Watson and Crick reported one of the most important discoveries of the 20th century: 'For the moment the general scheme we have proposed for the reproduction of deoxyribonucleic acid must be regarded as speculative. Even if it is correct then much remains to be discovered. Despite these uncertainties we feel that our proposed structure may help to solve one of the fundamental biological problems.'

Scientists are human. It is not uncommon for different groups to have conflicting ideas and to argue strongly. It then takes time for evidence to accumulate in support of one or the other.

So how does this affect you? Obviously you are unlikely to be involved in research at this level and be much more interested in achieving a good grade in your examinations. The answer is quite simple. You do need to begin to think like a scientist and to question things more carefully, even when carrying out simple core practicals. Your ability to do this will be tested in examination papers.

Question 1 – How do we know that? Thinking more scientifically.

(a) Read the article entitled 'How to read the health news' to be found at http://www.nhs.uk/news/Pages/Howtoreadarticlesabouthealthandhealthcare.aspx

(b) On the same web page you will find an archive with reviews of many claims made discoveries relating to health issues. Almost every week, newspapers report on new findings; often with remarkable claims. Take any one that you find and research the science behind it. What did the actual research really show? Does it match the claims in the newspaper?

If you cannot find your own question try the following:

(i) There are many scientific papers showing garlic has antibacterial properties but does this mean that this is a useful way of solving the problem of bacterial resistance to antibiotic?

(ii) If you wish the same question can be asked about 'Manuka' honey.

Biology practical skills: scientific methods and practices

This section of the Guide will consider a number of key skills and practices that you develop and use as you progress through your A level.

Designing investigations

Some of the core practicals offer you the opportunity to go beyond simply learning a technique by applying your knowledge to the design of an investigation. You will have met many of the requirements at GCSE level but during the two years of your A level course you will be expected to have a much more accurate understanding of the details. You might start as follows.

- Exactly what is to be measured? Is this the correct dependent variable, does it match the hypothesis and how can it be measured as accurately as possible?
- Can a single independent variable be measured or controlled accurately?
- Is it possible to control all other variables? If not, which ones are the most important to control and can we monitor others?
- How much data will be needed to come to some meaningful conclusions?

Now try the following.

Question 2 – Thinking about experimental design

A student decides to investigate the effect of light and shade on the size of leaves of one species of plant. Their initial plan is to measure the length of leaves on two sides of a single bush, one side which they can see is shaded and the other which is in full sunlight.

(a) The dependent variable chosen is length of leaf.

(i) Name three other possible leaf measurements which might provide information on size.

(ii) Which of these measurements would you select to provide the most useful scientific data? Give reasons for your answer.

(b) Name three other variables which need to be controlled when collecting these data.

(c) The student chose a bush with a shaded side and a sunlit side. Give three reasons why simply selecting differences in light intensity by observation might not give reliable information on 'light' and 'shade'.

Presenting data

Tables

Remember, the basic rules are really important.

- You must include all of your raw data even though you manipulate it in some way later.
- Think about designing your table to make any trends and patterns clear and show any data you might use to draw graphs.
- Include accurate S.I. units.
- Use a consistent number of significant figures. Remember figures such as 2 and 2.0 are not the same.
- The number of significant figures must be justified by the method of measurement. Calculating averages or means does not increase the number of significant figures that can be supported e.g. measuring with a 30 cm ruler allows a maximum accuracy of about 0.5 mm. Simply calculating an average of a set of measurements does not increase this to 0.05 mm or more.

Graphs

You will be expected to understand the use of different forms of graphs and be able to select the most appropriate, scientifically valid format. This means your choice must match your data but, above all, it must be directly linked to your hypothesis. You are drawing a graph to help analyse your data and illustrate important trends.

The main rules and uses of graphs do not change when you study biology, physics or chemistry but the type of graph you choose and the information we can get from it may be very different.

Bar graph	The simplest form of graph with separate columns but can only be used when the data is categorical. This means completely separate sets of counts e.g. counts of blood groups or flower colour.
Histogram	This is a special form of bar graph where the columns are touching each other. The horizontal axis is normally continuous and the columns represent sets of readings covering a small range.
Scattergram	This is simply a set of points on a pair of axes and is normally used to show a pattern of correlation between the two variables. Note this does not include a line.
Line of 'best fit'	This needs to be treated carefully. Where a scattergram shows a possible straight line relationship it might be relevant, but simply wobbling your ruler around until you think you might have the best place to draw a line is scientifically very dubious. You are simply guessing and it is unlikely that some other person with the same data will draw exactly the same line.
Line graph	In biology we often collect data where the values might rise and fall or show big variations. Drawing guesswork curves or links is not at all objective. In these cases, biologists sometimes simply join the points with straight lines. This might give some indication of important trends but it is normally a sign that we are not making any assumptions about them.

It is expected that all students will be aware of the basic rules of graph drawing.

- Axes are clearly labelled with units. The title and units are separated by a solidus (/).
- The scale is chosen to ensure the graph covers at least half of the paper and the *y*-axis intercept where appropriate.
- The axis shows the full scale with any breaks clearly indicated.
- The independent variable is on the *x*-axis and the dependent variable is on the *y*-axis.

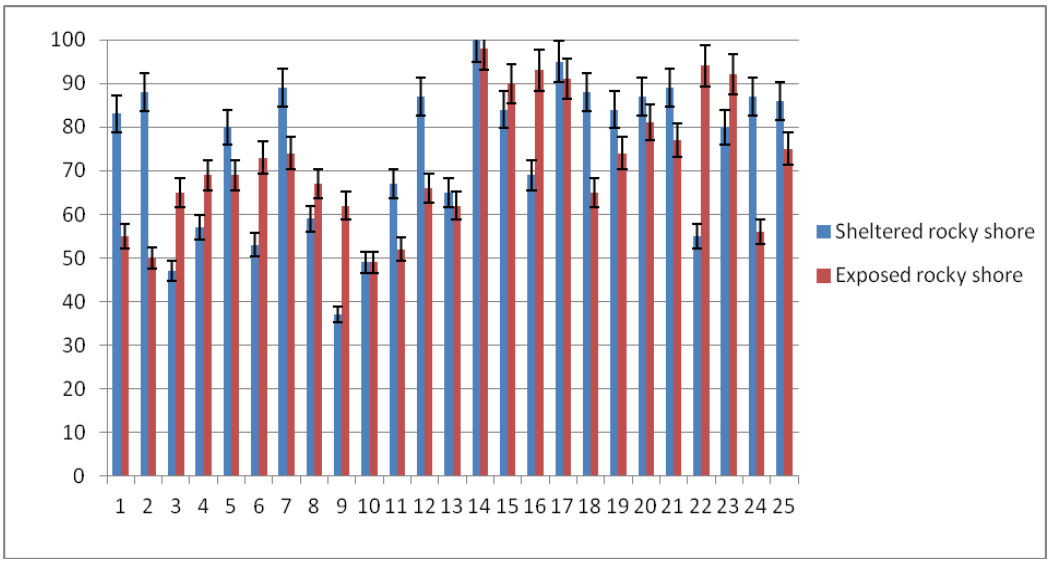
Question 3 – Spot the errors

The graph shown below was drawn by a student from data obtained from an investigation to compare the distribution of a black lichen on rocks in two different shores, one exposed to the waves and another sheltered. 25 random samples were taken on each shore. The horizontal axis is random sample number and the vertical axis is % cover. The bars at the top of each column are meant to show the variability in the data.

(a) The graph obviously has no labels or units which is a major error but not the most important one.

(i) Give two reasons why this graph is scientifically meaningless.

(ii) Sketch the format of graph which could be used to illustrate the difference in distribution of the lichen on the two shores.



Evaluating

This is one of the most important ways in which you will be expected to show progression to A level. Evaluating is not a simple process of offering an opinion. It is an **evidence-based analytical process**. You will certainly be expected to make a judgement but this must be expressed in terms of a reasoned argument.

So what evidence might be used when coming to a judgement?

- If you have all variables under control and a high level of accuracy then every repeat will be identical. Obviously this perfection is almost impossible to achieve so the variation in repeats can provide useful information. It is likely that means will have been calculated so we can consider how much the individual readings differ from this mean.

  Standard deviation is a measure of this variation. Where the data is normally distributed then the standard deviation is a measure of this distribution, about 68% of all the data will be within one standard deviation measure of the mean and about 95% of the data will be within 2 standard deviation measures of the mean. It is best calculated using programs such as Excel.

  Standard deviation is measured in the same units as your data. Do remember when considering whether you have a large or small standard deviation that you must compare it to the mean e.g. If the mean value was 0.5mm then a SD of 0.5mm is very large but if the mean was 50mm then a SD of 0.5mm is very small.

- **Outliers or anomalies** are another line of evidence when evaluating your findings. Be careful when suggesting that readings are anomalies and need to be removed from the data set. Highest and lowest values are not anomalies. Readings which are much larger or smaller than others obviously need to be investigated as do those which show a completely different trend to others. However, remember we are dealing with living things and they often show high levels of variability.

- If you have lots of anomalies or very high levels of variability then you need to take a careful look at your methodology. Big variations can arise from random errors in your methods. A random error is simply something that is different each time you take a reading and therefore is not under control. e.g. if you use a colorimeter to measure absorbance and some of the tubes you use are scratched but others are not, then the scratched ones will give a higher reading so increasing the variability in your data. **Systematic errors** are more difficult to detect. In this example this would mean using scratched tubes every time. The readings will not be correct but they will all be just a bit higher than they should and therefore have little effect on the overall pattern.

- **Uncertainties of measurements** – all measuring apparatus has some level of uncertainty which affects the precision of the final data. Where several measuring devices such as thermometers, pipettes or balances etc. are used these uncertainties accumulate to affect the precision of the final readings.

- Even statistical evidence of a strong correlation does not tell us anything about what is causing this. There are very many linked factors which give the same results e.g. you can get a strong correlation between number of ice creams eaten and skin cancer but this is obviously nothing to do with the cause. Similarly you need to take great care in understanding exactly what the tests for a significant difference show (and do not show).

Biology practical skills: use of mathematics

Significant figures

There is no fixed number that can be applied sensibly. Many core practicals will offer opportunities for you to make a decision on the most appropriate number of significant figures.

To do this, you should take account of the nature of the data and, most of all, the level of precision of the measuring apparatus. Remember the following pointers:

- Figures such as 2 and 2.0 do not mean the same thing.
- Consistency of significant figures is important.
- Simply calculating a mean does not improve the level of precision of the data.
- It is important to make a reasoned decision, not just copy down a figure from a calculator or spreadsheet.

Statistical testing

This is another good example of progressing from GCSE to A level. Having designed a sound investigation and collected data in a reliable way how do we make a decision? It is likely that, before this stage, this decision has been a matter of opinion. Where there is a lot of overlap between two sets of data you might feel there is a difference but someone else might not. Obviously this is not a scientific way of making important decisions, so we need some rules agreed by all scientists.

The general rule is quite simple. If there is less than 5 chances in 100 (a probability of 0.05) that the data could be from the same population then scientists state that there is a **significant** difference between them. The word significant is important here because other scientists will understand exactly what rules you have applied when making your judgement.

The complicated part of the statistics is exactly how we calculate the overall probability from the measurements we take. This has some difficult mathematics but if this is not your strong point you need not worry! Provided that you understand the basic idea then you can simply use some basic instructions and formulae to carry out the calculation to find a statistical test value and then look up the probability in a table. You will learn more about the individual tests during your course but what follows is a description of the basic rules. (Question 19 will help you to check if you have understood what you have learned.)

Statistics - the basic principles

Most statistical tests can be used to measure the probability that your two sets of data are from the same population. In other words there is no significant difference between them. For this reason it is usual to start with a **null hypothesis**. It is important to understand that this is not saying that the two sets of data are identical! On the contrary, most data you will deal with as a biologist is likely to show significant variation. The tests show how likely it would be to obtain the data you collect if these were just random variations within the same populations.

Having formed a null hypothesis we then select a suitable test and input the measurements we have taken into the chosen formula. This gives us our test statistic which we can then check in a table to find the probability of this occurring simply by chance from the same population.

If the probability is less than 0.05 (5%) then we reject the null hypothesis and we can state that there is a significant difference.

Exactly the same rules apply if we are testing for a significant correlation or a 'goodness of fit / association.

Common tests

The common tests you will meet are:

- tests for a significant difference – t-test, z-test or Mann-Whitney U test
- test for a significant correlation – Spearman's rank correlation test
- test for a 'goodness of fit' or association – Chi-squared test.

So you must learn to substitute your data into the correct formula and calculate the result: but it is not necessary to understand all of the mathematics used to devise that formula. What is really important is that you understand what the results of your statistical analysis show (and do not show!)

Some common terminology in statistics

Mean	The average value calculated as the total of the samples divided by the number of measurements.
Median	This is the value above which half of the sample lie and below which the other half lie – in other words, the middle value. Where there is an even number of samples this is calculated as the mid-point between the pair of values to which this applies.
Mode	The value which occurs most frequently in a set of measurements.
Standard deviation	This provides a numerical value for the average spread of data from the mean.
Range	This is a much simpler measure of the spread of data in a sample: simply, it is the difference between the highest and lowest values.

A simple example

A student uses a quadrat to count the number of clover plants in a fixed area. The student uses the quadrat 10 times in a field and records the number of plants in each quadrat. His results are:

12, 6, 7, 4, 11, 8, 5, 9, 11, 13

MEAN = (12 + 6 + 7 + 4 + 11 + 8 + 5 + 9 + 11 + 13) ÷ 10 = 8.6

MEDIAN = 8.5 (the middle two numbers are 8 and 9)

MODE = 11

Notice that the mean and median are similar. Why is this? What sort of data might produce very different values for the mean and the median?

Errors and uncertainties

The terms error and uncertainty are often confused.

An error arises in a practical work through:

- in-built precision of equipment, or a consistent design fault (systematic error)
- poor technique or lack of careful measurement (random error).

Uncertainties arise whenever a measurement is taken because, even with careful use of equipment, measuring instruments we use have a particular level of precision e.g. a laboratory thermometer might have +/- 0.5°C.

Some useful definitions when considering errors and uncertainties appear in the table.

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.
Accuracy	A measurement result is considered accurate if it is judged to be close to the true value. It is influenced by random and systematic errors.
Precision	A quality denoting the closeness of agreement (consistency) between values obtained by repeated measurement. It is influenced by random effects and can be expressed numerically by the standard deviation. A measurement is precise if the values 'cluster' closely together.
Repeatability	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	A measurement is reproducible when similar results are obtained by students from different groups using different methods or apparatus.
Uncertainty	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.
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.

Core practicals

The core practicals are an integral part of your course. They are not there to get you to demonstrate some text book 'fact' or recall some simple information. They are there to help you develop the whole range of practical and mathematical skills which are essential to biologists and which will be tested in the written assessments.

List of core practicals

1. Investigate a factor affecting the initial rate of an enzyme controlled reaction
2. Use of the light microscope, including simple stage and eyepiece micrometers and drawing small numbers of cells from a specialised tissue
3. Make a temporary squash preparation of a root tip to show stages of mitosis in the meristem under the light microscope
4. Investigate the effect of sucrose concentrations on pollen tube growth
5. Investigate the effect of temperature on beetroot membrane permeability
6. Determine the water potential of a plant tissue
7. Dissect an insect to show the structure of the gas exchange system
8. Investigate factors affecting water uptake by plant shoots using a potometer
9. Investigate factors affecting the rate of respiration using a respirometer
10: Investigate the effects of different wavelengths of light on the rate of photosynthesis
11. Investigate the presence of different chloroplast pigments using chromatography
12. Investigate the rate of growth of bacteria in liquid culture
13. Isolate individual species from a mixed culture of bacteria using streak plating
14. Investigate the effect of gibberellin on the production of amylase in germinating cereals using a starch agar assay
15. Investigate the effect of different sampling methods on estimates of the size of a population
16. Investigate the effect of one abiotic factor on the distribution or morphology of one species

Questions on core practicals

1. Investigate a factor affecting the initial rate of an enzyme controlled reaction

Question 4

(a) Why is it important to test the initial rate of enzyme-controlled reactions?

(b) What are the SI units of rate of reaction?

(c) Why is 1/t not recognised by scientists as a rate?

There are many ways of investigating enzymes so the exact method you use will depend upon your teacher.

Question 5

Some bacteria are found living in hot springs at temperatures as high as 80 °C. How does this compare with your ideas about the effects of temperature on enzyme activity?

Try researching the properties of the enzymes in these bacteria.

2. Use of the light microscope

This is a very important opportunity to practise some mathematical skills. Some examples are given below.

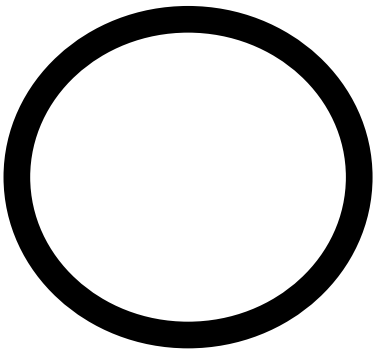
Question 6

(a) How many mms are there in 3×10^{-2} m?

(b) Write 32 μm as a measurement in standard form expressed in metres

(c) A student draws a single cell of diameter 2.8 cm. She calculates that this is a magnification of ×870. What is the size of the original cell?

(d) The diagram below represents a student's drawing of a single xylem vessel. His teacher shows him that the original cell has a lumen (hole) in the centre of the vessel which is approximately ×20 larger than the thickness of the wall. Use measurements of the diagram to calculate if the student has drawn a cell which matches the proportions of the original xylem vessel.



3. Making a temporary squash preparation

Question 7

(a) Name one suitable stain which could be used to show the chromosomes clearly.

(b) Explain why it is necessary to squash the root tip before viewing under the microscope.

4. Investigate the effect of sucrose concentrations on pollen tube growth

Question 8

(a) Explain why increasing the sucrose concentration might be expected to increase the growth of the pollen tube.

(b) Explain one reason why increasing the concentration of sucrose might be expected to decrease the growth of the pollen tube.

(c) In this investigation 'growth' is measured as an increase in length of the pollen tube. Why might a biologist consider that this was not really growth?

5. Investigate the effect of temperature on beetroot membrane permeability

Question 9

(a) Name the red pigment found in beetroot cells.

(b) Where exactly in the cell is the pigment stored?

(c) Name the membranes that the pigment must cross in order to pass into the surrounding water.

(d) The following is an extract from a student's report explaining how they controlled variables in this investigation.

'I used identical discs of beetroot and placed them in temperatures from 15 – 80 °C for exactly 5 mins.'

Explain why this might mean that the discs at different temperatures were not treated in exactly the same way.

6. Determine the water potential of a plant tissue

Water potential can be difficult to understand, so it is important to remember the basic rules.

- Water potential is the tendency of water molecules to move from one place to another.
- Water will always move from a region of higher to a region of lower water potential
- Pure water has the highest possible water potential which is zero.
- Adding solutes to water means there will be less water present so all solutions have a lower water potential. But as pure water is zero then all solutions will have negative water potentials.
- Water potentials are pressures so measured in Pascals (Pa).
  1000 Pa = 1 kPa

So the actual water potential of a system (ψ) such as a cell will depend on two things. (a) the concentration of the solutes dissolved in it (called the solute potential (ψ_S) which tends to draw water into the cell, and (b) any external pressures pushing the water in one direction (called the pressure potential (ψ_P) In plants this pressure potential tends to force water out of the cell.

ψ is the Greek letter psi.

Overall then $\psi = \psi_S + \psi_P$ where ψ_S is a negative number and ψ_P is usually positive.

To check if you understand this try the following questions.

Question 10

(a) Which is the higher water potential: -1250 kPa or -800 kPa?

(b) Calculate the water potential of a cell with a solute potential of -770 kPa and a pressure potential of 240 kPa.

(c) Explain why the pressure potential of a plant cell will rise as water enters by osmosis and what happens to the overall water potential of the cell as water continues to enter.

(d) Explain why it is much more important for animals to have very accurate control of their internal body fluid concentrations than plants.

7. Dissect an insect to show the gas exchange system

Your teacher will give you instructions on how to do this but don't miss the opportunity to investigate the structure of the spiracles which you can see clearly on the outside of the abdomen of most insects and simply cutting a small piece of exoskeleton around the spiracle will allow to pull out a series of tubes called trachaea which you can simply mount in water on a microscope slide to examine their structure more carefully. Look for rings around the tube made of a protein called chitin. The function of these tubes is very similar to thickened rings in some xylem vessels and the rings of cartilage in mammalian trachea.

8. Investigate factors affecting water uptake by plant shoots using a potometer

Make sure you understand exactly what is measured by the potometer.

Question 11

(a) Why is the volume of water taken up by the plant stem not the same as the volume lost in transpiration?

(b) Why is it necessary to cut the stem under water before attaching it to the potometer?

(c) The following data were obtained from an investigation measuring the uptake of water by a plant shoot attached to a potometer.

Time (mins)	Distance moved by the liquid in the capillary (mms)	Volume of water taken up (cm^3)
0	0	
1	7	
2	16	
3	25	
4	34	
5	39	

(i) If the diameter of the capillary tube was 1.5 mm complete the table to show the volume of water taken up each minute.

(ii) Draw a suitable graph to show the volume of water taken up each minute.

(iii) Use your graph to determine the rate of uptake of water between 1 minute 30 seconds and 4 minutes.

(iv) Calculate the average rate of uptake over the whole 5 minutes.

(v) Use your knowledge of this investigation and the data in the table to explain why there is a difference between the figures you have obtained in (iii) and (iv).

9. Investigate the factors affecting respiration using a respirometer

Question 12

(a) Name a compound which could be used to absorb carbon dioxide in the apparatus.

(b) Explain why removing the carbon dioxide and then recording the change in volume of gas in the respirometer chamber gives a measure of the oxygen taken up in respiration.

(c) Blowfly larvae (maggots) are often used in this investigation without restrictions. Maggots are also often used as fishing bait by piercing them with hooks. Using higher animals in this way is illegal and would cause a public outcry. Do you feel that invertebrate or cold-blooded organisms should have the same protection as other animals? Describe three reasons why you feel this way.

10. Investigate the effects of different wavelengths of light on the rate of photosynthesis

This investigation depends upon the assumption that the volume of oxygen given off by the plant is proportional to the rate of photosynthesis.

Question 13

(a) Name one other physiological process that will change the volume of oxygen given off.

(b) Give two reasons why this method would not be suitable for investigating the effect of temperature on the rate of photosynthesis.

Question 14

(a) What is meant by an action spectrum?

(b) What is meant by an absorption spectrum?

(c) A student investigating the effect of different wavelengths on the rate of photosynthesis drew an action spectrum from his results. When he compared this with the absorption spectrum of the pigments found in the same plant he found a close correlation between the two. He therefore wrote the following in his conclusions. 'The close correlation between the absorption of different wavelengths of light and the rate of photosynthesis proves that this mixture of pigments absorbs light energy which is used to manufacture carbohydrate and give off oxygen as a waste product.'

Is this a valid conclusion from these data? Explain your answer.

11. Investigate the presence of different chloroplast pigments using chromatography

This is an important biological technique so you will need to know some of the important details such as the solvents used and the need to get a concentrated spot of chlorophyll extract.

Remember that several of the pigments fade quickly in light so you may need to draw around the spot in pencil and label it. The distance travelled by the solvent is also important and will need to be marked as soon as you remove the paper or plate from the solvent bath.

Compound are often identified by their Rf values. These are calculated as;

Rf = Distance travelled by the spot ÷ distance travelled by the solvent front.

The Rf value is different according to the solvent used but can be looked up in tables for common solvents to find the name of the compound.

12. Investigate the rate of growth of bacteria in a liquid culture

There are several ways to carry out this investigation but all show why it is necessary to think about logarithmic growth when displaying results.

To understand why we need to use logarithms consider how a single bacterium grows by dividing into two often every few minutes.

2 > 4 > 8 >16 > 32 > 64 > 128 >256 and so on. Notice that not only is the population increasing but the speed at which it is getting bigger is also increasing. This creates problems.

Question 15

The table below shows some typical results of bacterial growth.

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

(a) Using an ordinary sheet of graph paper try to plot the increase in population numbers against time. How easy would it be to choose a suitable scale for the population number axis?

Why logarithms?

Common logs use a base of 10 which is written as $\log_{10}$.

The logarithm of a number is simply the power to which we need to raise the base to make that number.

So If the number is 100 then $10^2 = 100$ so the log of 100 is 2.

Similarly for 1000, $10^3 = 1000$ so the log of 1000 is 3.

Now for the sequence 10 > 100 > 1000 the logs would be 1 > 2 > 3. We have converted a rapidly increasing series of numbers into a linear scale which is ideal for plotting and for applying other formulae to describe it.

(b) Now complete the table above to include the logs of the population numbers. These can be found on any scientific calculator, online or even on some smart phone calculators. Plot time as the horizontal axis and $\log_{10}$ population numbers as the vertical axis on ordinary graph paper to see the effect.

13. Isolate individual species from a mixed culture of bacteria using streak plating

You will need to learn the basic details of this technique from your practical work in class. The principle of streak plating is to spread out the original culture so much that single bacteria are left in the final streak. These will grow into single species colonies after incubation. To spread out the culture enough to do this the wire loop is passed through the thin line of the previous streak several times.

Do check the final result very carefully. What features of each colony could be used to identify the actual species present?

14. Investigate the effect of gibberellin on the production of amylase in germinating cereals using a starch agar assay

Do think carefully about the biology behind this investigation before carrying it out.

One of the key events in a seed when it starts to germinate is the mobilisation of respiratory substrates. Seeds contain a variety of compounds as substrates but most cereals have starch stores.

Question 16

(a) Why must starch be 'mobilised' before it can be used as a respiratory substrate?

(b) There is no amylase present in cereal seeds before germination starts. Describe the sequence of events which must take place to produce an active amylase in the cereal seeds including the role of gibberellin.

(c) Explain how these events in a barley seed are used in brewing beer.

15. Investigate the effect of different sampling methods on estimates of population size

Quadrats are one of the most common ways in which to sample ecological sites. However, they can be used in several ways so it is very important to choose the one which will be most appropriate to the organism and the site you are investigating.

The two quadrats shown are parts of transects. A is taken from a sand dune transect close to the sea and B is taken from a rocky shore.

Quadrat A: Sand dune

Quadrat B: Rocky shore

continued

Question 17

Both quadrats are formed of a grid.

(a) Describe two ways in which the grid could be used to estimate the percentage cover of one of the organisms present.

For the next questions it would be useful to view the quadrats in more detail and you can find Quadrat A http://www.takeyouvirtuallyeverywhere.com/sanddunetour/skegness_transect/003.JPG and Quadrat B at http://www.takeyouvirtuallyeverywhere.com/0085.JPG.

Don't worry at this stage if you cannot recognise the organisms in the photos.

Question 18

(a) Quadrat A has one main plant species. First of all look at the picture overall and make a visual estimate of the % cover of this plant without any further counting. Next count all the squares that contain at least some of this plant. Finally count all the squares that are at least half covered by this plant. How do your estimates differ? Which do you think is the best measurement of % cover? Explain your answer.

(b) (i) How many different species can you see in Quadrat B?

(b) (ii) The cone shaped cells are limpets. How would you measure the distribution of limpets using a quadrat of this size?

16. Investigate the effect of one abiotic factor on the distribution or morphology of one species.

Remember that when planning such an investigation you should think very carefully about how you are to sample and measure your dependent variable and how you are going to select, measure or monitor your chosen independent abiotic variable. We have looked at this in **Ex.2** with regards to light but if we are working in the field then any abiotic variable will need some careful thought e.g. moisture content will vary with the weather, depth of soil might be very variable if the underlying rock is not level and so on.

Question 19

A student investigated the hypothesis that limpets on a sheltered shore would have larger diameters than those found on an exposed shore.

The data in the table shows her measurements of the diameter of limpets such as those shown in quadrat B.

22 samples were measured on a sheltered shore and 22 on a second shore which was very exposed to wave action.

continued

	Sheltered shore	Exposed shore
Sample number	**Diameter of *Patella Sp*. (mm)**	**Diameter of *Patella Sp*. (mm)**
1	27.2	14.9
2	28.0	17.5
3	19.6	20.6
4	26.9	18.4
5	24.3	16.0
6	29.0	20.3
7	27.6	17.4
8	23.2	18.5
9	24.3	16.7
10	28.1	15.3
11	26.4	18.4
12	34.4	19.2
13	29.2	24.5
14	32.6	17.3
15	25.9	22.4
16	24.0	23.3
17	29.0	24.4
18	26.6	21.2
19	32.5	18.3
20	31.6	19.8
21	38.0	21.6
22	34.0	19.3

(a) Name 3 other factors that would need to be controlled in order to ensure that the measurements could be compared.

(b) Calculate the mean and median for each set of data.

(c) Look carefully at the data for both shores. Identify the measurements, if any, which you consider to be anomalies or outliers. Explain your choice.

(d) Draw a suitable graph which would be useful to help analyse these data. Look back at the section on graphs before making your choice.

(e) Write a suitable null hypothesis for this investigation.

(f) Use a suitable statistical test to analyse these data with respect to the null hypothesis. Explain fully what conclusions can be drawn from the results of your test.

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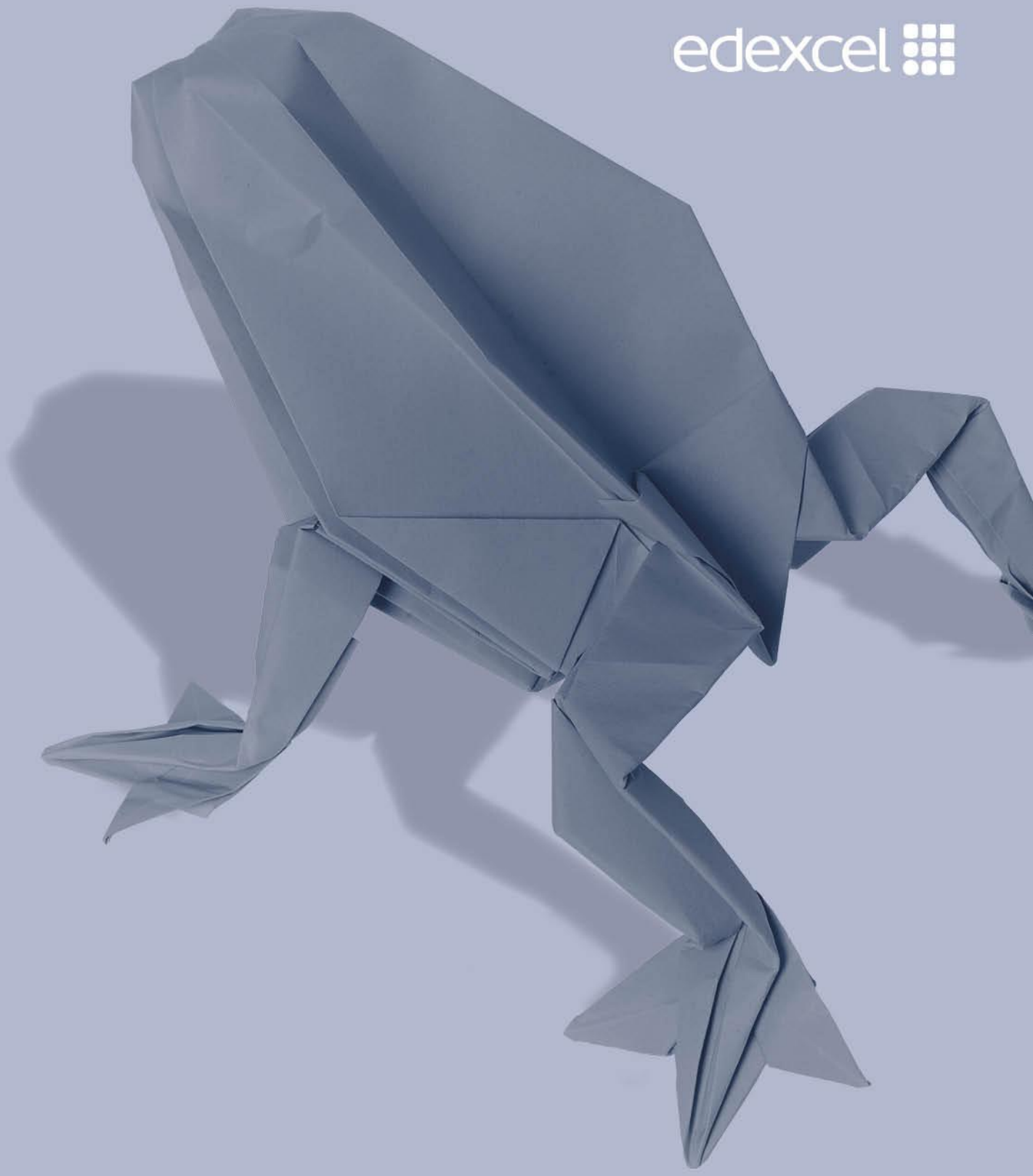

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