OCR Advanced Subsidiary GCE in Human Biology (3886)

OCR Advanced GCE in Human Biology (7886)

Teacher Support: Coursework Guidance

This Teacher Support: Coursework Guidance booklet is designed to accompany the OCR Advanced Subsidiary GCE and Advanced GCE in Human Biology for teaching from September 2004.

Foreword

This coursework guide has been written to support the OCR AS and Advanced GCE specifications in Human Biology and assist teachers in setting suitable coursework tasks and in assessing candidates' work. It aims to serve two functions:

- it is a 'stand-alone' pack for teachers who are unable to attend any of the OCR Coursework INSET meetings;
- it provides activities to be carried out and discussed at INSET meetings.

For the sake of continuity, this booklet follows the approach taken by the Awarding Bodies on the assessment of coursework skills at GCSE. There is also a common parity with the scheme of assessment of OCR AS Biology (3881). The coursework mark descriptors are common with AS Biology and are designed to facilitate the development of a range of skills that should be part of a candidate's education in Human Biology at GCE.

Whilst this guide is concerned with the assessment of coursework, it cannot be emphasised too strongly that before candidates are assessed on their Research and Laboratory skills, these skills must be taught. Candidates must be given the opportunity to practice and develop their abilities.

Section A gives guidance to Teachers on the teaching, assessment and moderation of investigative skills.

Section B comprises several Activities that are designed to be used at INSET meetings; these may also be used for training within departments.

The Appendices, in Section B, contain Frequently Asked Questions, a section on Ethics and the Law.

Contents

Section A: Guidance for Teachers

1 General Introduction

This coursework guide has been written to assist teachers in setting suitable coursework tasks and in assessing candidates' work. The guide should be read in conjunction with the specification itself. However, all sections of the specification relating to coursework assessment are included here.

While this guide is concerned with the assessment of coursework, it cannot be emphasised too strongly that before candidates are assessed on their investigative skills, these skills must be taught and candidates must have opportunities to practise and to develop their abilities.

Investigative skills will be assessed at AS in parity with OCR Biology (3881):

P Planning;

I Implementing;

A Analysing Evidence and Drawing Conclusions;

E Evaluating Evidence and Procedures.

At A2 a single Extended Investigation is required, to assess the same four skills at AS along with three additional skills:

S Searching for Background Information;

R Recording an Interview;

M Making a Presentation.

It is expected that candidates will have had opportunities to acquire experience and develop the relevant skills prior to assessment.

In AS, when a skill has been assessed on more than one occasion, the better or best mark for that skill should be submitted. However, centres are recommended not to assess the skills on more than **two** occasions since this may take up time that might be better devoted to other aspects of the specification.

All coursework is marked by the teacher and internally moderated by the centre. Marks are then submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures. The purpose of moderation is to ensure that the standard for the award of marks in coursework is the same for each centre, and that the teacher has applied the standards appropriately across the range of candidates within the centre.

In AS, the marks for Unit 2858 (Component 2), contribute towards Assessment Objective AO3: Experiment and Investigation.

In A2, the marks for Unit 2868 contribute equally to Assessment Objectives AO3 and AO4: Synthesis of Knowledge, Understanding and Skills. Assessment of AO4, which is synoptic assessment, is made because:

- candidates are required to use biological knowledge and understanding from other modules of the specification in planning their investigative work, and in analysing evidence and drawing conclusions;
- in the assessment of all seven skills in Unit 2868, taken at the end of the course of study, candidates are expected to draw on their experience of such work throughout the course.

Practical work provides many opportunities to develop key skills and to collect evidence that may contribute towards the assessment of key skills. Full details are given in Appendix A of the specification and links are identified throughout the content of the specification booklet. Teachers are advised to discuss such opportunities with colleagues and with the candidates concerned.

2 Coursework Assessment

Unit 2858/02 – Investigative Skills (60 Marks)
Unit 2868 – Extended Investigation (90 Marks)

In these components, assessment of candidates' investigative work is made by the teacher (as coursework) and moderated externally by OCR.

Skills **P** and **A** are each marked out of 8 and Skills **I** and **E** are each marked out of 7. One mark per skill must be submitted for each candidate for Advanced Subsidiary (Unit 2858/02) and for A2 (Unit 2868). Hence, a mark out of 30 is initially calculated for each component. The marks are then doubled so that the final mark submitted for each component is out of 60. In addition, **A2** also has a potential further 15 marks for the **three additional skills** (**S, R and M**), which are also doubled to give a final component total of 90.

When a skill has been assessed on more than one occasion in AS the better or best mark for that skill should be submitted. However, centres are recommended **not** to assess the skills on more than two occasions in AS since this may take up time which might better be devoted to other aspects of the specification.

The skills may be assessed at any time during the course using suitable practical activities, based on laboratory or field work, related to, or part of, the content of the teaching course. The context(s) for the assessment of the coursework for Unit of Assessment 2858/02 should be drawn from the content of AS Units 2856 and 2857; the context(s) for the assessment of the coursework for Unit of Assessment 2868 should be drawn from the content of A2 Units 2866 and 2867, in which the level of demand of the related scientific knowledge and understanding is higher.

In AS, the skills may be assessed in the context of separate practical exercises, although more than one skill may be assessed in any one exercise. They may also be assessed altogether in the context of a single 'whole investigation' in which the task is set by the teacher, or by using individual investigations in which each candidate pursues his or her own choice of assignment. In A2, the skills **must** be assessed as an extended investigation where one investigation is used to assess all seven skills. For this reason it is only anticipated that candidates will embark on one investigation. Investigative skills can be taught and developed using investigations within the content of the teaching course.

A similar set of mark descriptors is used for both AS and A2 in the common four skills (**P**, **I**, **A** and **E**). These descriptors have been written to provide clear continuity from the assessment of Sc1 in GCSE Science. The difference in standard of AS and A2 is a product of the level of demand of the related scientific knowledge and understanding expected and the complexity and level of demand of the tasks set. Also, the mark descriptors for Skills **P** and **A** at A2 include synoptic elements. The additional skill areas (**S**, **R** and **M**) are only to be assessed at A2.

Marks submitted for coursework assessment must have been generated from candidates' **individual** work. Group work is not suitable for assessment unless the work of the individual candidate can be quite clearly identified by both the teacher and the moderator.

The submission of proposed coursework tasks for approval by OCR is **not** a requirement of the scheme. However, centres wishing to obtain guidance on whether a coursework task is suitable should send details to OCR using the Coursework Enquiry Forms on the OCR website. There are separate forms for Unit 2858, Component 2 and for Unit 2868. The appropriate form should be used to request advice on the suitability of coursework tasks and specific mark schemes. It can also be used to request feedback and advice on the marking of candidates' work before marks are submitted to OCR and the moderator. Details of the task set and any background information should accompany any marked examples of candidates' work. Teachers are asked not to send large quantities of material at any one time. Feedback will be provided within approximately five weeks.

A programme of INSET meetings is arranged to provide detailed guidance on coursework assessment. Details are circulated to centres and a contact number for OCR Training and Customer Support is given on page 55.

The skills of Planning, Implementing, Analysing and Evaluating should be **taught** to candidates. This may be done in a variety of ways, for example by using a 'trial' investigation or by critically studying some exemplar material and discussing its strengths and weaknesses and the extent to which the work meets the skills' descriptors.

The length of time to be devoted to the assessment of investigative skills is entirely at the discretion of the teacher. However, it is anticipated that at AS, in most cases the report will not exceed 2,000 – 2,500 words (excluding tables and graphs); between 5 to 10 hours class time should be sufficient. At A2 it is anticipated that the report will not exceed between 3,000 – 3,500 words (excluding tables and graphs); between 10 – 15 hours of class time should be sufficient. The time allocation should include time for initial discussion, preliminary practical work, the main investigation and a discussion of the results (see FAQ 4 in Section B).

2.1 Standards at AS and A2

A similar set of assessment descriptors is used for the assessment of Planning, Implementing, Analysing and Evaluating in both AS and A2. These descriptors are also common with those used in the OCR Biology (3881) specification.

Assessments at AS and A2 are differentiated by the complexity of the tasks set and the contexts of the underlying scientific knowledge and understanding. In A2, candidates will be required to apply knowledge, understanding and skills from the AS and A2 parts of the specification in planning investigative work and in the analysis of results to reach conclusions as well as show evidence for three further assessment skills (**S**, **R** and **M**).

At AS, investigative work is likely to be qualitative or require processing in a context that is familiar to candidates.

- **Planning** exercises, although novel, focus on apparatus and techniques which have previously been encountered, based on knowledge and understanding from a limited part of the AS specification.
- **Implementing** involves the manipulation of simple apparatus and the application of easily recognised safety procedures; or collects and records sufficient data/observations in sufficient detail.
- **Analysing and concluding** involve simple data handling, reaching conclusions based on a limited part of the AS specification.
- **Evaluation** expects recognition of the main sources of error and direct methods for improving accuracy, precision and reliability.

At A2, assessments will expect a greater level of sophistication and higher levels of skill for the common skills **P**, **I**, **A** and **E**.

- **Planning** exercises require research to provide a satisfactory solution to a problem which can be addressed in more than one way. The underlying knowledge, understanding and skills are likely to be drawn from different parts of the AS and A2 specifications.
- **Implementing** involves a detailed risk assessment and the careful use of sophisticated techniques or apparatus to obtain results that are precise and reliable.
- **Analysing and concluding** involve sophisticated data handling and the synthesis of several strands of evidence. In developing conclusions, candidates will have the opportunity to demonstrate their skills in drawing together principles and concepts from different parts of the AS and A2 specifications.
- **Evaluation** requires recognition of the key investigative limitations and other sources of error as well as an understanding of the methods that may be used to limit their effect.

The essential difference in these skills between AS and A2 is that at A2, candidates should show a wider range of relevant scientific knowledge and understanding than at AS. The context in which the Extended Investigation is set at A2 should allow candidates to do this. A candidate who incorporates material from the AS and A2 specifications into their coursework may thus satisfy the synoptic descriptors in Skills **P** and **A**.

A2 candidates will also be assessed on the three additional skills, **S, R** and **M,** some of which are implicit in the four common skills. Candidates will be assessed on the skills of searching for information, recording evidence and making a presentation. A candidate who incorporates evidence to demonstrate these skills may thus satisfy these descriptors and gain further credit for work completed.

2.2 Demands of an Activity

The demand of an activity is an important feature of the assessment. From the bottom to the top of the mark range in a skill area the activity should involve increasing demands of associated scientific knowledge and understanding, manipulation, precision and accuracy and complexity.

The difference in standard of common Skills **P**, **I**, **A** and **E** at AS and A2 is a product of the level of demand of the related scientific knowledge and understanding, together with the complexity and level of demand of the tasks set. Also the mark descriptors for Skills **P** and **A** at A2 include synoptic assessment. Assessment at A2 uses three *additional* skills: **S, R and M** (see page 33 to 35).

In A2, candidates will be required to apply knowledge, understanding and skills from the AS and A2 parts of the specification in planning investigative work and in the analysis of evidence (synoptic assessment). Details of the way in which tasks can be differentiated are given in Section 2.8**.**

Further details concerning the demand of an activity can be found in Section 4.1 on page 20.

Further advice and guidance on the A2 Extended Investigation will be published on the OCR website (www.ocr.org.uk).

2.3 Using Secondary Data

When candidates use secondary data (data they have not collected themselves from practical or investigative work) in coursework, they must process the data themselves if credit is to be available in Skill **A** (not simply copy the analysis completed by others). The data may have been obtained from, for example, local sources, the Internet, scientific papers or be pooled from class data, but if candidates are to evaluate the data (and the techniques used to collect it) in Skill **E**, they will need to have available to them details of the procedures originally used. Candidates must provide detailed references to the sources of the data used (or copies of the data if not readily available) to the person marking the work and to the moderator.

It is recommended that if coursework is based on secondary data, more than one source of data is combined (two or more secondary sources, or secondary and primary). The task is then likely to be of an appropriate demand and candidates will have more opportunities to match the assessment criteria and attain the higher mark levels.

2.4 Assessment and Moderation

All coursework is marked by the teacher and internally standardised by the centre. Marks are then submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures. The purpose of moderation is to ensure that the standard for the award of marks in coursework is the same for each centre, and that each teacher has applied the standards appropriately across the range of candidates within the centre.

Coursework submissions should be clearly annotated by the centre to support the marks awarded to the candidates.

The sample of work that is submitted to the Moderator for moderation must show how the marks have been awarded in relation to the marking criteria. Any additional tick lists should also be included with the work sent for postal moderation along with a suitable context.

2.5 Minimum Coursework Requirements

If a candidate for a coursework component submits no work, the candidate should be indicated as being absent from that component on the coursework mark sheets submitted to OCR. Any work submitted by a candidate should be assessed according to the mark descriptors and marking instructions and the appropriate mark awarded, which may be 0 (zero).

2.6 Authentication of Coursework

As with all coursework, the teacher must be able to verify that the work submitted for assessment is the candidates' own. Sufficient work must be carried out under direct supervision to allow the teacher to authenticate the coursework marks with confidence. Form CCS160 (Centre Authentication Form for Coursework) should also be completed and sent to the moderator.

2.7 Special Arrangements for Coursework

For candidates who submit some coursework but are unable to complete the full assessment, or whose performance may be adversely affected through no fault of their own, teachers should consult the *Inter-Board Regulations and Guidance Booklet for Special Arrangements and Special Consideration*. In such cases, advice should be sought from OCR as early as possible during the course.

2.8 Differentiation

In coursework, differentiation is by task and by outcome. Candidates will undertake assignments which enable them to display positive achievement.

2.9 Some Definitions

Fair Test

Candidates should be well aware of the 'fair test' idea from KS2, KS3 and GCSE and this should determine how an investigation is planned and carried out. Candidates should show an awareness of the factors that they can control to ensure that their results are not distorted by those factors.

Factors / Variables

A variable is a factor that is measured or can be controlled. Candidates should identify the variables that may influence their investigation. The most important of these should be listed and described in candidates' plans. For candidates to identify and manipulate variables they need to know what to change (independent variable), and what to measure or judge (the dependent variable) for each value of the independent variable. In some studies, especially in physiology, candidates should show an awareness of factors which they cannot control but which may affect the outcome of their investigation.

Preliminary Work

This is work carried out by a candidate as part of planning which helps to clarify the strategy to be used in the main investigation. At AS, it may well involve a class practical or some preliminary work or a trial investigation carried out prior to the main investigation. It may also be some work carried out at GCSE. Candidates should report on the work that they have done and the results obtained. They should indicate in their reports how the preliminary work influenced their choice of apparatus or the strategy that they have employed. At A2, preliminary work may be any of the above or work done at AS.

Safety Aspects

Safety aspects are important features of the planning and the implementing of investigative work. Candidates should be encouraged to include a risk assessment in their plans. If there are no risks associated with their investigation, then there should be a statement to this effect.

Secondary Sources

These include books, articles, web sites and CD-ROMs. It should be clear how these secondary sources have been used to develop a strategy and they should be referenced somewhere in the work. Candidates should indicate in their work exactly where they have used their secondary sources. Details of the sources may be given at that point in their text or in a footnote or in a bibliography at the end of their work (see further details on page 15 in Planning).

Numerical Processing

This is assessed in Skill A. The descriptors for Skill A are given on page 31.

A1.a – simple numerical processing involving calculation of means will satisfy this descriptor e.g. averages, percentages.

A3.a – the use of a suitable graph will satisfy this descriptor. If a candidate does not present results as a graph, then some simple comment, such as identifying the range of results without any further calculation would be sufficient.

A5.a – this descriptor requires more detailed processing of results and this will depend on the investigation concerned and may involve any of the following:

- calculation of rates (e.g. cm^3, min^{-1} or $cm^3\ s^{-1}$)
- standard deviation
- calculation of gradients (e.g. for rates of reaction)
- use of intercepts
- use of error bars on the basis of standard error
- statistical tests (e.g. chi squared test, *t*-test).

Mathematical Requirements

Appendix D of the specification (page 89) lists the mathematical skills which candidates should apply at AS and A2. Several mathematical skills may need to be taught during the AS and A2 courses and teachers should note that the chi squared test and the *t*-test are listed in the section 'Mathematical requirements' in Appendix D (page 89) of the specification. Candidates at A2 may therefore be expected to use appropriate statistical tests in their coursework if they have collected sufficient data and the design of the investigation lends itself to statistical analysis. It should be noted that the chi squared test is very often applied in contexts when it is not appropriate. The use of a statistical test is **not** a requirement for A5.a; however, if a statistical test, such as the chi squared test or the *t*-test, is used appropriately then this descriptor is clearly satisfied.

Scientific Knowledge and Understanding

At AS, candidates are expected to draw on their knowledge of the relevant learning outcomes from the AS specification when planning investigations and analysing their results. They should also show understanding by applying their knowledge in appropriate ways. At A2, they are expected to use appropriate scientific knowledge and understanding from relevant learning outcomes across the AS and A2 specifications.

Hypothesis / Prediction

An hypothesis is a model, based on scientific knowledge and understanding, proposed to explain a particular problem or a set of observations or measurements. Having devised an hypothesis, it is possible to make predictions based on it, and these can be tested by experiment. The coursework descriptors for planning refer to 'predictions'. It is perfectly acceptable for candidates to make predictions without giving extensive theoretical support in an introduction to their investigation. However, **relevant** scientific knowledge and understanding should be evident in the planning for the award of descriptors **P.3a**, **P.5a** and **P.7a**. Candidates are advised to investigate the effect of one variable – both at AS and A2 – and to give a concise prediction that is testable. Candidates should be encouraged to make clear the prediction that they are testing. In some investigations it may be appropriate to give a null hypothesis.

The 'scientific method' is based on the idea that an hypothesis can be disproved by experiment (when predictions are found to be untrue) but can never be proved (since an experimenter may, in the future, disprove it). Thus, an hypothesis which is not disproved remains in place and, when it has general acceptance, may come to be called a theory or law.

Accuracy

The accuracy of an observation or measurement is the degree to which it approaches a notional 'true' value or outcome.

The accuracy of an observation or measurement depends on the investigative techniques used, the skill of the experimenter and the equipment (including measuring instruments) used. Removing or minimising sources of error improves accuracy and the degree of accuracy can be estimated by evaluating sources of error (either qualitatively or quantitatively as appropriate).

Precision is taken here as being that part of accuracy which is wholly in the hands of the experimenter. So, having devised an investigative technique and selected the apparatus, the experimenter may choose to take observations or measurements to different degrees of precision (or may do so through lack of skill or carelessness). Decisions about the precision with which observations or measurements are made may take into account the nature of the investigation and an assessment of the sources of error. For example: a low-power drawing from a microscope may address the task set; there may be little point in measuring a quantity to four significant figures if other quantities are measured to two significant figures.

Reliability

Reliability is a measure of the confidence that can be placed in a set of observations or measurements. The closer a set of observations or measurements approaches to conformity with an underlying model, process, structure etc. (which may be known or unknown), the more reproducible it is likely to be.

If the underlying model, process or structure is known, or a suitable hypothesis can be drawn up, reliability can be judged by reference to this. So, for example, the distance between data points and the line of a graph may provide evidence of reliability and statistical techniques may be used to provide a quantitative assessment of reliability in such cases. If observations or measurements are replicated, then the closeness of the replicates provides another way of judging reliability.

The reliability of a set of observations or measurements depends on the number and accuracy of the individual observations or measurements. Replicating observations or measurements increases the reliability of the set.

Validity

'Valid' implies that the outcome of an activity is not being distorted by extraneous factors. In some experiments, one factor is varied whilst other control factors are kept constant (e.g. rates of reaction).

The validity of a conclusion is a measure of the confidence that can be placed in it. The validity of an experiment or investigation depends upon factors such as the range and reliability of the observations or measurements that underpin it, any assumptions made in developing hypotheses or planning the investigation, and the nature of the investigation itself.

A conclusion may relate to whether or not a proposed hypothesis can be rejected or accepted. In such cases statistical techniques may be used to place a value on the reliability of data by generating a probability that the data do conform with the hypothesis. Such techniques should be used where appropriate and in Biology are identified in the specification for work in A2.

Anomalous Results ('Outliers')

Candidates are expected to **identify clearly** anomalous results in Skill **E**. They may do this in a variety of ways, for example by highlighting anomalous results in tables, graphs or in the text of their reports. Results that do not 'fit' the trend may be regarded as anomalous. If measurements are replicated and one or more of these are different from others, then they may be regarded as anomalous. **In order to satisfy marking criteria E1.b, candidates should state that they have no anomalous results if this is the case**.

'Where appropriate'

The words 'where appropriate' appear in a number of descriptors. It is expected that most investigations at AS and A2 will allow candidates to match the descriptors that follow these words. However, if there are reasons why this is not possible, moderators will expect to see some explanation on the work submitted. Section 4.1 (see page 20) should be born in mind when choosing an investigation.

3 Introduction to Each Skill

The investigative skills to be assessed are:

Skill P Planning

Candidates should:

- identify and define the nature of a question or problem using available information and knowledge of Biology;
- retrieve and evaluate information from multiple sources (including the Internet, computer databases, etc. where appropriate) and decide the measurements and observations likely to generate useful and reliable evidence (observations/data);
- choose effective and safe procedures, selecting appropriate apparatus and materials;
- consider ethical implications and safety aspects of the proposed procedures.

To achieve these objectives and satisfy the full demands of the mark descriptors for this Skill, candidates will benefit by providing evidence that they can:

- identify and define a problem capable of investigation and describe its biological content;
- plan a fair test or practical procedure, identifying the equipment required and making prediction(s) where appropriate;
- identify key factors to vary, control or take account of and select an appropriate number and range of observations and/or measurements;
- use and evaluate information from a variety of sources to develop and justify an appropriate strategy;
- take into account the need for safe working and accurate and reliable evidence (observations/data);
- use appropriate biological terminology and write up their plan ensuring correct spelling, punctuation and grammar.

For candidates to be able to achieve the highest marks for this Skill, tasks set must be sufficiently open-ended to allow more than one solution. The tasks must provide opportunities for candidates to gather information from a variety of sources (including perhaps text books, the Internet, preliminary experiments) to inform their plans and the scientific knowledge and understanding underpinning their work should be of a high standard. **All bibliographies should be in an appropriate format, for example:**

Author, Year of publication, *Title*, Publishers, ISBN

e.g. CADOGAN, A., SUTTON, R. 1994. *Maths for advanced biology.* Thomas Nelson and Sons, Walton-on-Thames. ISBN: 0-17-448214-0333333

For each task, it is suggested that candidates are asked to complete a preliminary plan which is assessed by the teacher, primarily to ensure that it is practicable and safe. The final mark awarded for planning should, however, take into account any additional work done during the implementation of the plan, i.e. to include any modifications or additions. Planning must be carried out individually and experience shows that candidates achieve higher marks if they carry out their plan. At AS, Skill **P** may be assessed as part of a 'whole investigation' or with Skill **I** and/or Skills **A** and **E**.

At A2, all four Skills (P, I, A and E) along with the additional three Skills (S, R and M) must be assessed in one Extended Investigation. There are additional statements in the **P** and **A** Skills that relate to synoptic assessment to take into account in the assessment of candidates work. Thus, to achieve the highest marks, the tasks set must offer opportunities for candidates to make use, in their planning, of scientific knowledge and understanding from modules in both AS and A2 modules.

Further guidance and advice on the A2 Extended Investigation will be published on the OCR website (www.ocr.org.uk).

Candidates are advised to make appropriate use of ICT techniques where these will allow objectives to be achieved more effectively and efficiently.

Skill I Implementing

This Skill involves implementing the plan created under Skill **P**, or assessed by a separate exercise (at AS only), implementing a plan created by teaching staff.

Candidates should:

- use apparatus and materials in an appropriate and safe way;
- carry out work in a methodical and organised way with due regard for safety and with appropriate consideration for the well-being of living organisms and the environment;
- make and record detailed observations in a suitable way, and make measurements to an appropriate degree of precision, using ICT where appropriate.

To achieve these objectives and satisfy the full demands of the mark descriptors for this Skill, candidates will benefit by providing evidence that they can carry out data gathering techniques and procedures:

1. safely
2. competently
3. accurately
4. systematically.

Candidates are expected to provide evidence that they can record observations and measurements:

5. clearly (e.g. spreadsheet or table)
6. accurately
7. systematically
8. with an appropriate level of detail
9. in an appropriate format (e.g. spreadsheets, tables etc.).

For candidates to achieve the highest marks for this Skill, the techniques used should be familiar and well understood. The tasks set should involve techniques that require precision and skill and that make sufficient demands on a candidate's ability to use a variety of data gathering techniques, procedures, and methods of recording observations and measurements.

Skill **I** may be assessed as part of a 'whole investigation', in isolation, or in combination with Skills **P** and/or Skills **A** and **E** at AS, but must be part of an Extended Investigation at A2.

Candidates are advised to make appropriate use of ICT techniques where these will allow objectives to be achieved more effectively and efficiently.

Skill A Analysing Evidence and Drawing Conclusions

This Skill involves analysing data (primary or secondary) collected under Skill **I**, or if assessed by a separate exercise (at AS only) analysing data provided by teaching staff. Candidates should:

- communicate biological information and ideas in appropriate ways, including tabulation, line graphs, histograms, continuous prose, annotated drawings and diagrams using biological nomenclature and terminology;
- recognise and comment on trends and patterns in evidence (observations/data);
- understand the concept of statistical significance where appropriate;
- draw valid conclusions by applying biological knowledge and understanding.

To achieve these objectives and satisfy the full demands of the mark descriptors for this Skill, candidates will benefit by providing evidence that they can:

10. process and present evidence (observations/data) collected during the investigation in an appropriate format (e.g. spreadsheets, charts);
11. use a variety of graphical and numerical techniques where appropriate (e.g. charts, statistical techniques);
12. use biological terminology correctly and write up work ensuring correct spelling, punctuation and grammar;
13. identify trends or patterns from the evidence collected and draw appropriate conclusions;
14. explain conclusions with reference to associated scientific knowledge and understanding.

For candidates to achieve the highest marks in this Skill, the tasks set must provide sufficient data or information to make the analysis demanding, and allow them to relate their results to scientific knowledge and understanding of a high standard.

Skill **A** may be assessed as part of a 'whole investigation', in isolation, or in combination with Skills **P** and/or Skills **I** and **E** at AS, but must be part of an Extended Investigation at A2.

At A2, there are additional statements that relate to synoptic assessment to take into account in the assessment. Thus, to achieve the highest marks, the tasks set must offer opportunities for candidates to make use, in their analysis, of scientific knowledge and understanding from both AS and A2.

Candidates are advised to make appropriate use of ICT techniques where these will allow objectives to be achieved more effectively and efficiently.

Skill E Evaluating Evidence and Procedures

This Skill involves evaluating the data collected under Skill **I**, the procedures and plan formed under Skill **P** (or provided by teaching staff at AS), and the outcomes of analysis conducted under Skill **A**.

Candidates should:

- assess the reliability and precision of investigative evidence (observations/data) and the conclusions drawn from it;
- evaluate the techniques used, recognising their limitations.

To achieve these objectives and satisfy the full demands of the mark descriptors for this Skill, candidates will benefit by providing evidence that they can:

1. recognise any anomalous results and suggest reasons for them;
2. assess the accuracy and reliability of the evidence (observations/data);
3. identify and assess the limitations of the techniques used an strategy followed and relate these to sources of error;
4. identify and recognise the effect of the main source of error;
5. suggest and justify how the techniques used and the strategy followed might be improved;
6. assess the significance of uncertainties in the evidence in terms of their effect on the final conclusions drawn.

For candidates to achieve the highest marks in this Skill it is advisable that they either carry out the investigation themselves or have seen the techniques demonstrated. Only in this way will they be able to evaluate investigative procedures effectively. The tasks set should be sufficiently complex to allow detailed analysis and the data or information collected should permit evaluation of error and reliability. There should also be the opportunity to suggest realistic changes to the procedures used that would improve the quality of the results.

Skill **E** is best assessed as part of a 'whole investigation' (a requirement at A2), or together with Skill **A**, in which case the investigative procedure should have been carried out by the candidates themselves, or demonstrated to them. Where the investigative procedures are such that individual working is not possible, candidates could carry out the investigation working in groups but then be assessed for Skills **A** and **E** on their individual work.

NB: Assessing this Skill on its own is not recommended at AS; and is not permissible at A2.

4 Coursework Submission & Assessment

These notes are intended to provide guidance for teachers in assessing investigative skills, but should not exert an undue influence on the methods of teaching or provide a constraint on the practical work undertaken by candidates. It is not expected that all of the practical work undertaken by candidates would be appropriate for assessment.

It is expected that candidates will have had opportunities to acquire experience and develop the relevant skills before assessment takes place.

4.1 The Demand of an Activity

The demand of an activity is an important feature of the assessment. From the bottom to the top of the mark range in a skill area the activity should involve increasing demands of associated scientific knowledge and understanding, manipulation, precision and accuracy and complexity. The difference in standard of common Skills **P**, **I**, **A** and **E** at AS and A2 is a product of the level of demand of the related scientific knowledge and understanding, together with the complexity and level of demand of the tasks set. Also the mark descriptors for Skills **P** and **A** at A2 include synoptic assessment. Assessment at A2 uses three additional Skills **S, R and M**.

In A2, candidates will be required to apply knowledge, understanding and skills from the AS and A2 parts of the specification in planning investigative work and in the analysis of evidence (synoptic assessment). Details of the way in which tasks can be differentiated are given in Section 2.8 (page 10).

Teachers should appreciate that the **choice of an activity that is comparatively undemanding** (primarily in terms of the level of the scientific knowledge and understanding that can be linked to the activity and in the range/complexity of the equipment/techniques used) **may prevent access to the highest marks**.

Teachers should be aware of this feature of the assessment so that, when considering the award of higher marks, the activity should require a sophisticated approach and/or complex treatment. Higher marks must not be awarded for work that is simplistic or trivial.

One of the factors that determine the demand of an activity is the level of guidance given to candidates. The use of a highly structured worksheet, for example, will reduce the number of decisions and judgements required by the candidate and will limit the range of marks available.

4.2 Using Secondary Evidence (observations/data)

When candidates use secondary data (data they have not themselves collected from practical or investigative work) in coursework, they must plan the investigative technique to obtain the data themselves for Skill **P** and process the data themselves if credit is to be available in Skill **A** (not simply copy the analysis completed by others). The data may have been obtained from, for example, local sources, the Internet, scientific papers or be pooled from class data, but if candidates are to evaluate the data (and the techniques used to collect it) in Skill **E**, they will need to have available to them details of the procedures originally used. Candidates must provide detailed references to the sources of the data used (or copies of the data if not readily available) to the person marking the work (and to the moderator).

It is recommended that if coursework is based on secondary data, more than one source of data is combined (two or more secondary sources, or secondary and primary). The task is then likely to be of an appropriate demand and candidates will have more opportunities to match the assessment criteria and attain the higher mark levels.

4.3 Marking Candidates' Work

The descriptors for Skills **P**, **I**, **A** and **E** have been written to provide clear continuity from the assessment of Sc1 for GCSE. This should ensure an effective continuation of the development of candidates' skills from GCSE to AS and A2.

The mark descriptors in the four common Skills **P**, **I**, **A** and **E** are similar to three in the OCR Biology Specification (3881) and consequently gives rise to the opportunity for centres to use appropriate investigations for both Human Biology and Biology at **AS**. **Care must be taken that the scientific knowledge and understanding is based on learning outcomes from the relevant specification.**

The mark descriptors within a skill area have been written to be **hierarchical**. Thus, in marking a piece of work, the descriptors for the lowest defined mark level should be considered first and only if there is a good match should the descriptors for the next level up be considered. When a teacher is considering awarding a mark, the work must have demonstrated a **good match** to **all** the mark descriptors below the mark to be awarded.

For each Skill, the scheme allows the award of intermediate marks 2, 4 and 6 that are between the defined mark levels. An **intermediate mark** may be awarded when the work of a candidate exceeds the requirements of a defined mark level but does not meet the requirements of the next higher defined mark level sufficiently to justify its award. Thus, an intermediate mark could be awarded if the work meets only one of the two descriptors at the higher defined mark level, or provides a partial match to both descriptors, or provides a complete match to one and a partial match to the other. For clarification of these points see the Activities in Section B and the commentaries.

In Skills **P** and **A**, a mark of 8 should be awarded for work which meets **all** the requirements (without doubt or hesitation) of the descriptors up to and including level 7 and is judged to be of **exceptional** merit in terms of originality, depth, flair, or in the use of novel or innovative methods. Work should be clearly annotated to explain to the moderator why a mark of 8 has been awarded. This may take the form of a check list of items that teachers considered appropriate for the group as a whole or annotations on each piece of work to indicate where there was material of exceptional merit.

A mark of zero should be awarded where there has been an attempt to address the Skill but the work does not meet the requirements of the lowest defined mark level.

The marks awarded should be based on the final written work and, in the case of Skills **I** and **M**, also on the teacher's knowledge of the work carried out by the candidate. In assigning a mark, attention should be paid to the extent of any guidance needed by, or given to, the candidate.

Work should not be marked and then returned to candidates to be improved. However, it may be appropriate to comment, in generic terms, on work in draft form before the final marking.

In defining the various mark descriptors it is recognised that investigative tasks vary widely, both in the procedures used, and in the nature of the evidence collected by the candidate. The mark descriptors for each defined level are intended to provide guidance to teachers on how to recognise levels of achievement. It is acknowledged that the balance between the statements provided for a particular level of performance will vary with the nature of the activity. Whilst both statements for a particular defined level **must** be considered in awarding the marks, it is clear that teachers will need to judge for themselves the relative weightings they attach to each of the statements. **This is particularly important where secondary data has been used.**

4.4 Synoptic Assessment

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced GCE course. Assessment Objective AO4 relates specifically to synoptic assessment and marks from the A2 Extended Investigation, 2868, contribute to the assessment of AO4.

During investigative work, synoptic assessment:

- allows candidates to apply knowledge and understanding of principles and concepts from different parts of the specification in planning investigative work and in the analysis and evaluation of evidence;
- allows candidates to apply skills and techniques learned during the course.

The Extended Investigation, assessed internally by centres for the A2 Unit 2868, should draw on the range of experience that the candidate has acquired during the AS and A2 courses. It is particularly important that an exercise used to assess Skill **P** should involve an element of research that goes beyond the repetition of a task conducted during the A2 part of the course. Likewise, the assessment of Analysing Evidence and Drawing Conclusions must require a candidate to use knowledge and understanding acquired outside the confines of a standard task recently practised. During the process of moderation, evidence will be sought that such breadth has been achieved.

The assessment descriptors for Skills **P** (Planning) and **A** (Analysing Evidence and Drawing Conclusions), include statements that relate specifically to synoptic assessment. **These are shown in bold and should be applied only when assessing A2 work**. **Thus, in A2, a candidate will not be able to achieve more than 2 marks in each of Skills P and A without demonstrating aspects of synoptic assessment**. Candidates will also bring to the assessment of Skill **I** (Implementing) their experience of practical and investigative work from throughout the course. In Skill **E** (Evaluating Evidence and Procedures), aspects of Skills **P** and **A** are evaluated. Overall, in A2, approximately 15 of the 45 available marks can thus be identified as contributing to an assessment of AO4 (synoptic assessment).

4.5 Quality of Written Communication

Coursework must include an assessment of candidates' quality of written communication. Candidates are required to:

- select and use a form and style of writing that is appropriate to the purpose and complex subject matter;
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate;
- ensure the text is legible and that spelling, grammar and punctuation are accurate, so that the meaning is clear.

The mark descriptors for Skills **P** and **A** have been written to include these aspects, and these Skills carry an additional mark each in recognition of this.

4.6 Annotation of Candidates' Work

Each piece of assessed coursework must be annotated to show how the marks have been awarded in relation to the relevant Skills.

The writing of comments on candidates' work can provide a means of dialogue and feedback between teacher and candidate, and a means of communication between teachers during internal standardisation of coursework. The main purpose of annotating candidates' coursework should be, however, to provide a means of communication between the teacher and the moderator, showing where marks have been awarded and why. The sample of work which is submitted for moderation **must** show how the marks have been awarded in relation to the marking criteria.

Annotations should be made at appropriate points in the margins of the text. The annotations should indicate both where achievement for a particular Skill has been recognised, and where the mark has been awarded. It is suggested that the minimum which is necessary is that the 'shorthand' mark descriptors (for example, **P.5aii**, **I.3bi**) should be written at the point in the text where it is judged that the work has met the descriptors concerned.

For Skill **I**, Implementing, more detail is necessary and the moderator will require evidence concerning candidates' use of practical techniques and safe working practice. This evidence could take the form of check lists or written notes which are **specific** to the investigation. For Skills **S**, **R** and **M**, where evidence is ephemeral, evidence must be provided to the moderator in the form of checklists (see page 39) or written notes to support the marks awarded.

A possible convention to use for annotating coursework is as follows:

Annotation	Meaning of annotation
Tick + descriptor, i.e. _ **P.3aii**	*Evidence found here for complete match with the descriptor*
Cross + descriptor, i.e. **X P.3aii**	*No evidence for this descriptor therefore overall mark for this skill limited at this point*
Descriptor in brackets, i.e. **(P.3aii)**	*Partial evidence found for this descriptor at this point in the work*

Brief comments written on the coursework where necessary are also helpful, especially where intermediate marks are awarded. Please also see the notes on the award of level 8 on page 22.

4.7 Health and Safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for GCE AS and A level this is likely to be the education authority or the governing body. Employees, i.e. teachers and lecturers, have a duty to cooperate with their employer on health and safety matters.

Various regulations, but especially the COSHH Regulations 1996 and the Management of Health and Safety at Work Regulations 1992, require that before any activity involving a hazardous procedure or harmful microorganism is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of *Safety in Science Education* (see below). For members, the CLEAPSS guide, *Managing Risk Assessment in Science* offers detailed advice.

Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X

Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2

Hazcards, 1995, CLEAPSS School Science Service*

Laboratory Handbook, 1988-97, CLEAPSS School Science Service*

Topics in Safety, 2nd edition, 1988, ASE ISBN 0 86357 104 2

Safety Reprints, 1996 edition, ASE ISBN 0 86357 246 4

Hazardous Chemicals, A Manual for Science Education, SSERC Limited 1997, ISBN 0 95317 7602.

* Note that CLEAPSS publications are only available to members or associates.

(Other publications have sometimes been suggested, e.g. the SSERC *Hazardous Chemicals Manual* or the DES *Microbiology, an HMI Guide for Schools and FE,* but both of these are now out of print).

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment. Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate, or that the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded, for example on schemes of work, published Teachers' Guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications these may well lead to the use of novel procedures, chemicals or microorganisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting the CLEAPSS School Science Service (or, in Scotland, SSERC).

When candidates are planning their own practical activities, whether in project work or for more routine situations, the teacher or lecturer has a duty to check the plans before practical work starts and to monitor the activity as it proceeds.

4.8 Ethical Working Practices

Many of the topics covered by these specifications concern issues with complex ethical considerations. It is important that guidance should be given by teachers on the ethical implications of any topic, particularly those considered for coursework. Collection of evidence from individuals including fellow candidates should be conducted with care and sensitivity. When candidates are planning their own investigative activities, whether in project work or for more routine situations, the teacher or lecturer has a duty to check the plans before the investigative work starts and to monitor the activity as it proceeds.

It is the responsibility of the teacher or lecturer to ensure that the guidelines which follow are adhered to.

Candidates **must**:

- understand that ethical guidelines are based on respect and care for the individuals involved
- appreciate the feelings and reactions of potential subjects to their investigations
- work with *positive* variables such as healthy eating, athletic performance
- investigate only legal activities, such as the use of data in the public domain
- make it clear to potential subjects what the investigation involves
- ask questions only about less sensitive issues (except where the person concerned is a professional in the area)
- maintain anonymity of the subjects.

Candidates **must not**:

- cause or risk stress, distress or embarrassment
- cause or risk potential harm to themselves or their subjects
- engage in or be party to any illegal activity such as breaching the Data Protection Act, use of controlled drugs
- use data from a workplace without permission
- deceive their subjects in any way
- manipulate a subject's behaviour for the sake of an investigation
- ask questions about sensitive issues such as suicide, abortion, risk of inherited disease, physical appearance, eating disorders, disease conditions (except where the person concerned is a professional in the area).

5 Mark Descriptors for Investigative Skills

In defining the various mark descriptors, it is recognised that practical tasks vary widely, both in the investigative procedures used and in the nature of the observations and measurements which may be made by the candidate.

The mark descriptors within each defined level are intended to provide guidance to teachers on how to recognise levels of achievement.

It is acknowledged that the balance between the statements provided for a particular level of performance will vary with the nature of the activity. Whilst both statements for a particular level **must** be considered in awarding the marks, it is clear that teachers will need to judge for themselves the relative weightings they attach to each of the statements.

All statements at a defined level must be satisfied in order that the mark for this level is awarded. All descriptors for lower defined levels must be satisfied before a higher mark is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, manipulation, precision, accuracy and complexity.

The mark descriptors for the seven Skills are given on pages 29 to 35. Teachers may also find it helpful when annotating their work to subdivide the descriptors within their mark schemes to ensure that candidates match all the points covered by each descriptor. The marking grids on pages 36 to 43 are set out in this way. The mark schemes for Skills **P** and **A** for A2 include descriptors that refer to the synoptic assessment and are given in dark type. Identifying each part of some descriptors using i, ii and iii etc. helps in annotating the work to ensure that every part of each descriptor is met in candidates' work.

AS marking grids - pages 36 to 39

A2 marking grids - pages 40 to 44

It is recommended that a tick list is used to assess Skill **I**. A proforma for such a tick list is on page 45. This should be customised for each investigation.

The synoptic descriptors are indicated in bold type. **These should only be used for coursework at A2.** In the marking grids on pages 40 to 44, they are indicated separately from the other descriptors at levels 3, 5 and 7. Candidates may use synoptic material in different ways. Teachers are advised to send the moderator a context for each investigation and itemise the learning outcomes from the AS and A2 specifications that they considered appropriate for their candidates to use when planning their investigations and analysing their results.

The relevant descriptors are as follows.

Level 3: '……**drawn from more than one area of the specification**'. If candidates refer to material from more than one learning outcome then they satisfy this requirement.

Level 5: '……**drawn from more than one module of the specification**'. If candidates refer to material from two modules of which at least one must be from the A2 specification (2866 or 2867) then they satisfy this requirement.

Level 7: '……**drawn from different parts of the AS and A2 specification**'. If candidates use **relevant** material from an AS module (2856 and/or 2857) to support material from an A2 module (2866 and/or 2867) then they satisfy this requirement **and the requirements at levels 3 and 5 as well**. It is important that the synoptic material is used in the context of the whole descriptor at each level.

Skill P – Planning **Total 8**

Mark	Descriptor	The candidate:
1	**P.1a**	develops a question or problem in simple terms and plans an appropriate investigation, making a prediction where relevant.
	P.1b	chooses appropriate investigative techniques.
2		
3	**P.3a**	develops a question or problem using scientific knowledge and understanding **drawn from more than one area of the specification**; identifies the key factors to vary, control or take account of.
	P.3b	decides on a suitable number and range of evidence (observations/data) needed for the investigation.
4		
5	**P.5a**	uses detailed scientific knowledge and understanding **drawn from more than one module of the specification** and information from preliminary work or a secondary source to plan an appropriate strategy to collect evidence, taking into account the need for safe and/or ethical working practices and justifying any prediction made.
	P.5b	describes a strategy to collect evidence, including choice of investigative techniques, which takes into account the need to produce precise and reliable evidence; produces a clear account and uses specialist vocabulary appropriately.
6		
7	**P.7a**	retrieves and evaluates information from a variety of sources*, and uses it to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding **drawn from different parts of the AS and A2 specification**; uses spelling, punctuation and grammar accurately.
	P.7b	justifies the strategy developed, including the choice of investigative techniques, in terms of the need for precision and reliability.
8		**8 marks** should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.

The statements in bold represent additional requirements when assessing Unit 2868 (A2); they are not to be used at AS.

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, and complexity. See page 15 for further clarification of these statements.

* For details on Bibliography requirements see page 15.

Skill I – Implementing Total 7

Mark	Descriptor	The candidate:
1	I.1a	demonstrates competence in the use of simple investigative techniques and an awareness of the need for safe and/or ethical working practices.
	I.1b	makes and records evidence (observations/data) that is adequate for the investigation.
2		
3	I.3a	demonstrates competence in the use of familiar investigative techniques.
	I.3b	collects evidence accurately; records evidence clearly and accurately.
4		
5	I.5a	demonstrates competence and confidence in the use of investigative techniques; adopts safe and/or ethical working practices throughout.
	I.5b	collects evidence accurately; records evidence in an appropriate format.
6		
7	I.7a	demonstrates skilful and proficient use of all investigative techniques.
	I.7b	collects sufficient evidence to meet all the requirements of the investigation; records evidence in appropriate detail and justifies the degree of precision to which evidence is recorded, in terms of the investigative techniques used.

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, and complexity. See page 16 for further clarification of these statements.

Skill A - Analysing Evidence & Drawing Conclusions Total 8

Mark	Descriptor	The candidate:
1	A.1a	carries out some simple processing of the evidence collected, such as the use of bar charts or histograms, or the calculation of means.
	A.1b	identifies trends or patterns in the evidence and draws simple conclusions.
2		
3	A.3a	processes and presents evidence gathered using appropriate graphical and/or numerical techniques.
	A.3b	links conclusions drawn from processed evidence with the associated scientific knowledge and understanding **drawn from more than one area of the specification.**
4		
5	A.5a	carries out detailed processing of evidence and analysis including the use of advanced numerical techniques such as (where appropriate) statistics, the plotting of intercepts or the calculation of gradients, or the use of error bars.
	A.5b	draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding **drawn from more than one module of the specification**; produces a clear account which uses specialist vocabulary appropriately.
6		
7	A.7a	uses detailed scientific knowledge and **understanding drawn from different parts of the AS and A2** specification to make deductions from the processed evidence, with due regard to nomenclature, terminology and the use of significant figures (where relevant).
	A.7b	draws conclusions which are well structured, appropriate, comprehensive and concise, and which are coherently linked to underlying scientific knowledge and **understanding drawn from different parts of the AS and A2** specification; uses spelling, punctuation and grammar accurately.
8		**8 marks** should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.

The statements in bold represent additional requirements when assessing Unit 2868 (A2); they are not to be used at AS.

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, and complexity. See page 17 for further clarification of these statements.

Skill E - Evaluating Evidence and Procedures Total 7

Mark	Descriptor	The candidate:
1	E.1a	makes relevant comments on the suitability of the investigative techniques used.
	E.1b	makes a relevant comment about the evidence, for example the occurrence of anomalous results.
2		
3	E.3a	recognises how limitations in the investigative techniques and/or strategies for collecting evidence may result in sources of error.
	E.3b	comments on the accuracy of the evidence (observations/data), suggesting reasons for any anomalous results.
4		
5	E.5a	indicates the significant limitations of the investigative techniques and/or strategies used, and suggests how they could be improved.
	E.5b	comments on the reliability of the evidence and evaluates the main sources of error.
6		
7	E.7a	justifies proposed improvements to the investigative techniques and/or strategies used in terms of increasing the reliability of the evidence and minimising significant sources of error.
	E.7b	assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, and complexity. See page 18 for further clarification of these statements.

Skill S – Searching for Background Information (Unit 2868 only) Total 5

Mark	Descriptor	The candidate:
1	S.1a	uses, and provides a bibliography for, a minimum of 5 sources related to the investigation, including both digital and written media.
	S.1b	records information clearly and concisely in a report of 500 – 1,000 words.
2		
3	S.3a	selects and uses relevant information from the sources identified and references these accurately within the report.
	S.3b	organises the information selected; uses several different presentational techniques, such as flow diagrams, graphs, drawings, photographs and text.
4		
5	S.5a	evaluates information from the sources identified, justifying the selection used.
	S.5b	integrates information from a variety of different sources in a coherent report, using a variety of appropriate presentational techniques.

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, and complexity.

Skill R – Recording an Interview (Unit 2868 only) Total 5

Mark	Descriptor	The candidate:
1	R.1a	devises a set of 10-15 questions linked clearly to the nature of the investigation.
	R.1b	records answers clearly and concisely.
2		
3	R.3a	devises well-constructed questions designed to elicit answers that will assist in the planning of the investigation or in the interpretation of the results or in an understanding of the work related relevance of any conclusions.
	R.3b	suggests supplementary questions to investigate areas of interest; evaluates the interview in simple terms, suggesting improvements.
4		
5	R.5a	devises a logical sequence of questions all of which clearly relate the nature of the investigation to the experience of the interviewee.
	R.5b	uses supplementary questions that assist in the development of the investigation; evaluates the interview in terms of its contribution to the investigation.

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, and complexity.

Skill M – Making a Presentation (Unit 2868 only) Total 5

Mark	Descriptor	The candidate:
1	M.1a	summarises the main aspects of the investigation: background information, interview, planning, implementing, analysis and evaluation.
	M.1b	uses an appropriate presentational technique such as: an A3 poster, a 10 minute talk with overhead transparencies, a PowerPoint Presentation or a 500 word article for a magazine; uses text and/or images that are clear and legible to an audience.
2		
3	M.3a	organises the presentation well, dealing with aspects of the investigation in a logical order.
	M.3b	presents information using relevant, carefully selected, text and/or images.
4		
5	M.5a	produces a well-structured, coherent presentation in which the key aspects of the investigation are identified.
	M.5b	makes good use of language and scientific vocabulary; produces a well-designed, imaginative presentation.

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, and complexity.

This skill is wholly teacher assessed.

Skill P – Planning for AS Coursework Total 8

The candidate:

Mark	General strategy	Level	Choices within plan	Level
0				
1	**P1.a** (i) develops a question or problem in simple terms and plans an appropriate investigation; (ii) makes a prediction where relevant.		**P1.b** chooses investigative techniques.	
2				
3	**P3.a** (i) develops a question or problem using scientific knowledge and understanding; (ii) identifies the key factors to vary, control or take account of.		**P3.b** decides on a suitable number and range of evidence (observations/ data) needed for the investigation.	
4				
5	**P5.a** (i) uses detailed scientific knowledge and understanding to justify any prediction made; (ii) uses information from preliminary work or a secondary source to plan an appropriate strategy to collect evidence; (*see page 15)* (iii) takes into account the need for safe and/or ethical working practices.		**P5.b** (i) describes a strategy to collect evidence, including choice of investigative techniques, which takes into account the need to produce precise and reliable evidence; (ii) produces a clear account and uses specialist vocabulary appropriately.	
6				
7	**P7.a** (i) retrieves and evaluates information from a variety of sources; (*see page 15)* (ii) uses information to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding; (iii) uses spelling, punctuation and grammar accurately.		**P7.b** justifies the strategy developed, including the choice of investigative techniques, in terms of the need for precision and reliability.	
8	**8 marks** should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill I - Implementing for AS Coursework **Total 7**

The candidate:

Mark	Manipulation		Level	Recording		Level
0						
1	**I1.a**	(i) demonstrates competence in the use of simple investigative techniques; (ii) shows an awareness of the need for safe and/or ethical working practices.		**I1.b**	makes and records evidence (observations/ data) that is adequate for the investigation.	
2						
3	**I3.a**	(i) demonstrates competence in the use of familiar investigative techniques.		**I3.b**	collects evidence accurately; records evidence clearly and accurately.	
4						
5	**I5.a**	(i) demonstrates competence and confidence in the use of investigative techniques; (ii) adopts safe and/or ethical working practices throughout.		**I5.b**	(i) collects evidence accurately; (ii) records evidence in an appropriate format.	
6						
7	**I7.a**	demonstrates skilful and proficient use of all investigative techniques.		**I7.b**	(i) collects sufficient evidence to meet all the requirements of the investigation; (ii) records evidence in appropriate detail and justifies the degree of precision to which evidence is recorded.	

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

See page 51 for guidelines in presenting results in the form of tables.

Skill A - Analysing Evidence and Drawing Conclusions for AS Coursework

The candidate: **Total 8**

Mark	Processing evidence	Level	Drawing conclusions	Level
0				
1	**A1.a** carries out some simple processing of the evidence collected, such as the use of bar charts or histograms, or the calculation of means.		**A1.b** identifies trends or patterns in the evidence and draws simple conclusions.	
2				
3	**A3.a** processes and presents evidence gathered using appropriate graphical and/or numerical techniques.		**A3.b** links conclusions drawn from processed evidence with the associated scientific knowledge and understanding.	
4				
5	**A5.a** carries out detailed processing of evidence and analysis including the use of advanced numerical techniques such as, where appropriate, statistics, the plotting of intercepts or the calculation of gradients, or the use of error bars.		**A5.b** (i) draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding; (ii) produces a clear account which uses specialist vocabulary appropriately.	
6				
7	**A7.a** (i) where appropriate, uses detailed scientific knowledge and understanding to make deductions from the processed evidence; (ii) shows due regard to nomenclature, terminology and the use of significant figures (where relevant).		**A7.b** (i) draws conclusions which are well structured, appropriate, comprehensive, and concise and which are coherently linked to underlying scientific knowledge and understanding; (ii) uses spelling, punctuation and grammar accurately.	
8	**8 marks** should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill E - Evaluating Evidence and Procedures for AS Coursework Total 7

The candidate:

Mark	Procedures		Level	Sources of error		Level
0						
1	**E1.a**	makes relevant comments on the suitability of the investigative techniques used.		**E1.b**	makes a relevant comment about the evidence, for example the occurrence of anomalous results.	
2						
3	**E3.a**	recognises how limitations in the investigative techniques and/or strategies for collecting evidence may result in sources of error.		**E3.b**	(i) comments on the accuracy of the evidence (observations/data); (ii) suggests reasons for any anomalous results.	
4						
5	**E5.a**	(i) indicates the significant limitations of the investigative techniques and/or strategies used; (ii) suggests how procedures / strategies could be improved.		**E5.b**	(i) comments on the reliability of the evidence; (ii) evaluates the main sources of error.	
6						
7	**E7.a**	justifies proposed improvements to the investigative techniques and/or strategies used in terms of increasing the reliability of the evidence and minimising significant sources of error.		**E7.b**	assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.	

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill P – Planning for A2 Coursework Total 8

The candidate:

Mark	General strategy	Level	Choices within plan	Level
0				
1	**P1.a** (i) develops a question or problem in simple terms and plans an appropriate investigation; (ii) makes a prediction where relevant.		**P1.b** chooses investigative techniques.	
2				
3	**P3.a** (i) develops a question or problem using scientific knowledge and understanding; (ii) identifies the key factors to vary, control or take account of; (iii) **uses information drawn from more than one area of the specification.**		**P3.b** decides on a suitable number and range of evidence (observations/ data) needed for the investigation.	
4				
5	**P5.a** (i) uses detailed scientific knowledge and understanding to justify any prediction made; (ii) uses information from preliminary work or a secondary source to plan an appropriate strategy to collect evidence (*see page 15)*; (iii) takes into account the need for safe and/or ethical working practices; (iv) **uses information drawn from more than one module of the specification.**		**P5.b** (i) describes a strategy to collect evidence, including choice of investigative techniques, which takes into account the need to produce precise and reliable evidence; (ii) produces a clear account and uses specialist vocabulary appropriately.	
6				
7	**P7.a** (i) retrieves and evaluates information from a variety of sources (*see page 15)*; (ii) uses information to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding; (iii) uses spelling, punctuation and grammar accurately; (iv) **uses information drawn from different parts of the AS and A2 specification.**		**P7.b** justifies the strategy developed, including the choice of investigative techniques, in terms of the need for precision and reliability.	
8	**8 marks** should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill I - Implementing for A2 Coursework — Total 7

The candidate:

Mark	Manipulation		Level	Recording		Level
0						
1	**I1.a**	(i) demonstrates competence in the use of simple investigative techniques; (ii) shows an awareness of the need for safe and/or ethical working practices.		**I1.b**	makes and records evidence (observations/ data) that is adequate for the investigation.	
2						
3	**I3.a**	demonstrates competence in the use of familiar investigative techniques.		**I3.b**	collects evidence accurately; records evidence clearly and accurately.	
4						
5	**I5.a**	(i) demonstrates competence and confidence in the use of investigative techniques; (ii) adopts safe and/or ethical working practices throughout.		**I5.b**	(i) collects evidence accurately; (ii) records evidence in an appropriate format.	
6						
7	**I7.a**	demonstrates skilful and proficient use of all investigative techniques.		**I7.b**	(i) collects sufficient evidence to meet all the requirements of the investigation; (ii) records evidence in appropriate detail and justifies the degree of precision to which evidence is recorded.	

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

See page 51 for guidelines in presenting results in the form of tables.

Skill A - Analysing Evidence and Drawing Conclusions for A2 Coursework

Total 8

The candidate:

Mark	Processing evidence	Level	Drawing conclusions	Level
0				
1	**A1.a** carries out some simple processing of the evidence collected, such as the use of bar charts or histograms, or the calculation of means.		**A1.b** identifies trends or patterns in the evidence and draws simple conclusions.	
2				
3	**A3.a** processes and presents evidence gathered using appropriate graphical and/or numerical techniques.		**A3.b** (i) links conclusions drawn from processed evidence with the associated scientific knowledge and understanding; **(ii) uses information drawn from more than one area of the specification.**	
4				
5	**A5.a** carries out detailed processing of evidence and analysis including the use of advanced numerical techniques such as, where appropriate, statistics, the plotting of intercepts or the calculation of gradients, or the use of error bars.		**A5.b** (i) draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding; (ii) produces a clear account which uses specialist vocabulary appropriately; (**iii) uses information drawn from more than one module of the specification.**	
6				
7	**A7.a** (i) where appropriate, uses detailed scientific knowledge and understanding to make deductions from the processed evidence; (i) shows due regard to nomenclature, terminology and the use of significant figures (where relevant).		**A7.b** (i) draws conclusions which are well structured, appropriate, comprehensive, and concise and which are coherently linked to underlying scientific knowledge and understanding; (ii) uses spelling, punctuation and grammar accurately; **(iii) uses information drawn from different parts of the AS and A2 specification.**	
8	**8 marks** should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill E - Evaluating Evidence and Procedures for A2 Coursework Total 7

The candidate:

Mark	Procedures	Level	Sources of error	Level
0				
1	**E1.a** makes relevant comments on the suitability of the investigative techniques used.		**E1.b** makes a relevant comment about the evidence, for example the occurrence of anomalous results.	
2				
3	**E3.a** recognises how limitations in the investigative techniques and/or strategies for collecting evidence may result in sources of error.		**E3.b** (i) comments on the accuracy of the evidence (observations/data); (ii) suggests reasons for any anomalous results.	
4				
5	**E5.a** (i) indicates the significant limitations of the investigative techniques and/or strategies used; (ii) suggests how procedures / strategies could be improved.		**E5.b** (i) comments on the reliability of the evidence; (ii) evaluates the main sources of error.	
6				
7	**E7.a** justifies proposed improvements to the investigative techniques and/or strategies used in terms of increasing the reliability of the evidence and minimising significant sources of error.		**E7.b** assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.	

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

HUMAN BIOLOGY

Additional A2 Coursework Skills

Teacher Record Sheet

The candidate:

Mark	Skill S	Skill R	Skill M*
1	(a) uses and produces a bibliography– minimum of 5 sources; ☐ (b) records information clearly and concisely. ☐	(a) devises 10-15 questions linked clearly to the investigation; ☐ (b) records answers clearly and concisely. ☐	(a) summarises the main aspects of the investigation; ☐ (b) using an appropriate presentational technique **and** makes clear and legible presentation. ☐
2	☐	☐	☐
3	(a) selects and uses relevant information from sources **and** uses accurate references; ☐ (b) organises information **and** uses more than one selected presentational technique. ☐	(a) questions are well-constructed; ☐ (b) supplementary questions are asked **and** questions are evaluated with improvements suggested. ☐	(a) produces a well organised presentation; ☐ (b) presents information using relevant text / images. ☐
4	☐	☐	☐
5	(a) evaluates information, justifying selection of material; ☐ (b) integrates information from a variety of sources into a coherent report **and** uses appropriate presentational techniques. ☐	(a) logical, relevant questions are used; ☐ (b) uses supplementary questions to develop the investigation **and** evaluates the interview. ☐	(a) produces a well-structured, coherent, presentation; ☐ (b) shows good use of language and scientific vocab; well-designed and imaginative presentation. ☐
	level achieved ☐	level achieved ☐	level achieved ☐

*****Skill **M** is wholly teacher assessed.

Note: the award of S.3a also allows the award of P.5a(ii) and P.7a(i).

All statements at a defined level must be fully satisfied in order that the mark for this level is awarded. From the bottom to the top of the mark range the activity should involve increasing demands of related scientific knowledge and understanding, and complexity. See part B for further clarification of these statements.

SUGGESTED PROFORMA FOR ASSESSING SKILL I

EXPERIMENT TITLE:_____ **DATE**: _____

	Competence in simple techniques	Works safely/ethically	Records observations	Competence	Systematic/clear & accurate	Competent & Confident	Safe/ethical throughout	Observes accurately	Records appropriately	Skilful & proficient	Detail & precision	Records with detail and
Descriptor	**1ai**	**1aii**	**1b**	**3a**	**3b**	**5ai**	**5aii**	**5bi**	**5bii**	**7a**	**7bi**	**7bii**
Candidate												

6 Suggested tasks for each module

6.1 Planning Coursework Tasks

The learning outcomes for each module identify key areas where practical skills are expected to be developed and candidates given the opportunity to carry out practical work. Many of these will provide occasions on which some or all of the four skills may be assessed. However, it is imperative that candidates are **taught** the four common investigative skills before they are assessed.

Access to marks depends upon the demand of the activity, which includes the associated increasing demands of scientific knowledge and understanding, manipulation, precision and accuracy and complexity. Teachers should realise that some tasks of a lesser demand may be set for those candidates who are only likely to achieve a low final grade, or for use as training exercises.

One strategy that can be usefully employed to assist in training candidates is to use a prompt sheet or check list, which identifies the key areas that are required to access the full range of marks in each of the four skill areas. Examples of these are given in Section B.

For AS assessments the teacher may assess the Skills in the context of separate practical exercises; more than one Skill may be assessed in any exercise. They may also be assessed altogether in the context of a single 'whole investigation' using a task set by the teacher, or by using individual investigations chosen by each candidate. *This 'whole investigation' approach is a **requirement** at A2 and candidates must complete an Extended Investigation.* At AS in situations where a Skill(s) has been assessed on more than one occasion the final four marks (one each for **P**, **I**, **A** and **E**) can be taken from any combination of the preceding practical approaches, e.g. a mark for **P** from a candidate chosen individual investigation, a mark for **A** from a teacher set practical task and marks for **I** and **E** from a teacher set 'whole investigation.' In all cases, the candidate's best marks for each Skill should be submitted to OCR for moderation.

Coursework will provide much scope for the use of ICT. However, both teachers and candidates must ensure that any software used, especially many of the graph-plotting packages, is used with caution, since it may not produce the most appropriate graphs, or graphs which conform to the guidelines published by the Institute of Biology. **Therefore, the use of such software could result in candidates failing to access specific marking descriptors**.

Skill **I** in particular requires evidence that the candidate has carried out various tasks at a suitable level. Whilst the candidates' results will, in some cases, demonstrate that this has happened, in most cases the centre will need to provide a tick-list as evidence that these aspects have been assessed. An exemplar tick-list is included (see page 45).

Suggested strategies for AS assessment

The coursework assessment uses skills which cover the same areas as those covered at GCSE and uses a similar form of mark descriptors. Therefore it is to be hoped that candidates will have some prior knowledge of practical work of this type from their work at GCSE. However, candidates will need additional training in order to meet the demands of an AS/A GCE course.

Within the two AS units, there are a number of opportunities for practical work. These can be used for training and formal assessment. As with all investigations, especially in Human Biology, there is a risk that an investigation may fail for one reason or another, often due to causes outside the candidate's control. Therefore it is strongly recommended that this is not the only route pursued by the centre in order to obtain a candidate's coursework assessment marks.

Suggested strategies for A2 assessment

Candidates who carry out statistical methods at A2 clearly meet the descriptor A5.a which requires 'more detailed processing' of results. Candidates can access level 5 and above for Skills **A** and **E** if they use non-statistical methods as appropriate to their investigations.

The A2 assessment will build upon the knowledge, understanding and skills acquired during the AS course. The tasks set, or approved, by the teacher should normally enable the candidate to demonstrate knowledge and skills from more than one area of the specification, including the AS specification. Candidates will, therefore, need to select any topic they wish to investigate with great care. As previously mentioned, it may benefit the candidates if they are provided with a prompt sheet which identifies the key requirements of the mark descriptors. This will then allow them to check that the investigation has sufficient scope and breadth to allow them to utilise knowledge, understanding and skills acquired from other units, including those from AS.

Types of practical work

A list of suggested tasks is provided in order to give teachers an idea of the practical work that could be used for assessment. The choice of practical work is dependent upon the centre's facilities, the number of candidates undertaking the course, the interests of the staff etc. In all cases, teachers must ensure that the work can be undertaken to a sufficient level of demand.

Microscopy can be used for assessment of Implementing and, possibly, Analysis. Dissections may be used for the assessment of Implementing.

6.2 Suggested assessment tasks relating to modules

The following practical tasks can be used for the assessment of the investigative skills. However, some of these practical tasks **may not** be sufficiently demanding to allow access to marks for descriptors at the higher defined levels. Please check with the Subject Officer at OCR in cases of doubt.

It should be pointed out that these are suggestions. There may be difficulties in using some of these suggestions because of large numbers of candidates or lack of appropriate apparatus or materials. It should also be noted that to satisfy the descriptor **I.5b** results should be recorded in a table. This means that practicals chosen to assess Implementing should generate numerical data.

6.3 Examples of possible coursework tasks

The following list is provided to show the wide range of tasks that are possible.

AS

- Semi-quantitative Benedict's test – to produce numerical data (e.g. by using a colorimeter).
- Effect of temperature on the rates of enzyme-catalysed reactions.
- Effect of pH on the rates of enzyme-catalysed reactions.
- Effect of enzyme or substrate concentration on the rates of enzyme-catalysed reactions.
- Effect of enzyme inhibitors on the rates of enzyme-catalysed reactions.
- Investigating enzyme activity in apple browning - to produce numerical data (e.g. by using a colorimeter).
- The effect of chloride ion concentration on activity of salivary amylase.
- Effect of, for example, temperature, detergents, solvents etc. on membrane permeability (using beetroot or blood).
- Effects of osmosis on various tissues (e.g. blood).
- The effect of different solutes of the same concentration on various tissues
- Investigating the elasticity of an artery and a vein.
- Heart dissection and drawing.
- Epidemiological investigation into the factors associated with coronary heart disease.
- Effect of noise on pulse rate.
- Analysis of the spirometer traces to investigate lung function.
- Analysis of the composition of inspired and expired air.
- Epidemiological investigation into smoking and lung disease.
- Analysis of preparations of slides of mitosis.
- Epidemiological investigation into the factors associated with cancer.
- Effect of birth time on circadian rhythm.
- Investigating the factors which affect human growth.
- Effect of hand span or gender on manual dexterity.
- The development of balance in four to five year old children.
- Investigating the effects of, for example, enzyme inhibitors, antibiotics and disinfectants on bacterial growth.
- Investigating growth requirements or growth rates of bacteria.
- Using epidemiological data to investigate the incidence and prevalence of infectious disease.
- Investigating the causes of death or age of death over time.

A2

The **P** and **A** Skills are synoptic. Therefore, the task chosen for the A2 Extended Investigation must be based on the A2 content of the specification and must be supported by knowledge and understanding from the AS specification in order to access the higher mark levels.

- Investigating the substrates used in respiration by calculating RQ values (primary and/or secondary data) and relating these to athletic performance.
- Physiological studies on training methods and the improvement of athletic performance.
- The effect of exercise on the body for different age groups.
- A comparison of fitness levels between smokers and non-smokers in the same age group.
- The effect of a fitness programme on the resting pulse rate.
- Investigating memory or learning.
- The effect of age on saying tongue twisters/matching playing cards.
- The effect of age on reaction time.
- The effect of age on short term memory.
- An investigation into smell and associative memory.
- Colour preferences in children in relation to age.
- The effect of age on personal space.
- Studies of the effects of drugs on the brain.
- Investigating the effectiveness of different methods of contraception.
- Using secondary data to investigate the factors affecting global warming.
- Investigating the occurrence and inheritance of inherited diseases, using pedigree analysis.
- Investigating the frequency of occurrence of alleles in human populations.
- Investigating the control of temperature, blood glucose levels or water balance in humans.
- The suitability of different snacks for diabetic children.
- Investigating the effectiveness of HRT in treating the symptoms of the menopause.

7 Guidelines for tables and graphs

These guidelines are taken from the Institute of Biology publication:

Biological Nomenclature: Standard terms and expressions used in the teaching of biology. 3rd Edition, 2000, edited by Alan Cadogan. ISBN 0-900490-36-5

Tables

The following guidelines should be followed when presenting numerical results in tables.

- Numerical values inserted in the table should not have units
- Columns should be headed with a physical quantity and appropriate SI unit.
- The slash, or /, meaning per should not be used in the unit symbol, e.g. 100 joules per kilogram can appear in the text as 100 joules per kilogram or as 100 Jkg^{-1}. In a table it should be shown as:

	Energy content / Jkg^{-1}	
	100	

- Note that the slash is here used to separate what is measured from the unit in which it is measured.
- When two or more columns are used to present data, the first column should be the independent variable (i.e. that variable which is chosen by the experimenter); the second and subsequent columns should contain the dependent variables (i.e. the readings taken by the experimenter).
- Tables should be given informative titles.

Bar charts and histograms

These are used when the dependent variable on the y-axis is discrete, i.e. whole numbers; fractions are impossible and the data under consideration deal with frequencies.

Bar charts

Bar charts are used when the independent variable is non-numerical, e.g. the number of different insect species found on trees. These data are discontinuous.

- They can be made up of lines, or blocks of equal width, which do not touch.
- The lines or blocks can be arranged in any order, but it can aid comparison if they are arranged in descending order of size.
- Each axis should be labelled clearly with an appropriate scale.
- There should be an informative title.

Histograms

These are used when the independent variable is numerical and the data are continuous. They are sometimes referred to as frequency diagrams.

- One axis, usually the x-axis, represents the independent variable and is continuous. It should be labelled clearly with an appropriate scale.
- The number of classes needs to be established. This will largely depend on the type and nature of the data. However, five times the log of the number of observations is one approach.
- The blocks should be drawn touching.
- The edges of the blocks should be labelled, so a block might be labelled '7' at the left and '8' at the right; this is expressed as a class range 7 — 8 units, but it is implied that 7.0 is included in this range but 8.0 is not. 8.0 will be included in the next class, range 8 — 9.
- The other axis, conventionally the y-axis, represents the number or frequency, and should be labelled with an appropriate scale.
- There should be an informative title.

Pie charts

These can be used when displaying data that are proportions or percentages.

- Sector angles are calculated by dividing their percentage by 100 and multiplying the answer by 360^{o} (if figures are proportions then just multiply by 360^{o}).
- When comparing two or more pie charts, the sequence of segments should be kept the same.
- The size of the pie circle can be made proportional to the size of the sample.
- Ideally pie charts should not contain more than 6 to 7 sectors, otherwise they become confusing.
- There should be labels or a key.
- There should an informative title.

Line graphs

Graphs are used to show relationships in data which are not immediately apparent from tables.

The term graph should be used to refer to the whole diagrammatic representation. The term curve should be used to describe both curves and lines which are used to join points.

The following guidelines should be followed.

- Each axis should be labelled clearly with the quantity and SI unit if appropriate, e.g. length of branch from trunk / m.
- Each axis should be marked with an appropriate scale. The data should be critically examined to establish whether it is necessary to start the scale(s) at zero.
- The independent variable should be plotted on the x (horizontal) axis.
- The dependent variable should be plotted on the y (vertical) axis.
- Plotted points must be clearly marked and easily distinguishable from the graph grid lines (dots on their own are not sufficient). Encircled dots or saltire crosses (x) should be used. When multiple curves are being plotted, vertical crosses (+) can be employed; when producing computer-generated graphs, it may not always be possible to impose a particular style of plotted point.
- A smooth curve should only be drawn if there is good reason to believe that the intermediate values fall on the curve, e.g. the effect of light on the rate of photosynthesis. Otherwise, straight lines joining the points should be drawn, thus indicating uncertainty about the intermediate values, e.g. numbers of ground beetles found at set distances from a hedge.
- If a graph shows more than one curve, then each curve should be labelled to show what it represents.
- There should be an informative title.

Scattergrams

These are used when investigating the relationship between two variables of a sample or replicate and observations are in pairs. The data can then be used to establish if there is a relationship between the variables. The relationship can be a positive correlation, a negative correlation or no correlation at all.

- The two axes of the graph are marked out with appropriate scales.
- The two variables are plotted for each sample as a point so that each point on the graph represents an individual.
- There should be an informative title.

8 Coursework forms

The coursework summary form should be used to record candidates' marks to be submitted to OCR. The marks for each Skill should be recorded and the total mark should be transferred to the computer printed mark sheet (MS1) supplied by OCR, or transferred to OCR directly (by EDI). A copy of the coursework summary form should be submitted to the moderator, together with the moderator copy of the MS1 form (or a printout of the EDI submission) and the Centre Authentication Form (CCS160). A centre wishing to use a computer to keep a record of marks (for example on a spreadsheet) may submit a printout to the moderator as an alternative to the coursework assessment form, provided that it includes all the necessary information.

The coursework cover sheet should be attached to the front of each candidate's portfolio of work submitted to the moderator. Cover sheets do not need to be completed for candidates whose work does not form part of the sample of work sent for moderation.

The coursework forms are provided on the OCR website (www.ocr.org.uk).

9 Contacts

Subject Officer for A Level Human Biology (syllabus-specific queries only)

OCR
1, Hills Road
Cambridge
CB1 2EU

Training and Customer Support (INSET enquiries)

OCR
Mill Wharf
Mill Street
Birmingham
B6 4BU

Tel: 0121 628 2950
Fax: 0121 628 2940
Email: tcs@ocr.org.uk

OCR Information Bureau (other queries)

Tel: 01223 553995
Email: helpdesk@ocr.org.uk

10 Resources for Practical Biology

Books

CADOGAN, A., SUTTON, R. 1994. *Maths for advanced biology.* Thomas Nelson and Sons, Walton-on-Thames. ISBN: 0-17-448214-0

CLEGG, C.J., MACKEAN, D.G. 1996. *Advanced Biology principles and applications. Study Guide.* John Murray, London. ISBH: 0-7195-5358-X

EDMONSON, A., DRUCE, D. 1996. *Advanced biology statistics.* Oxford University Press, Oxford. ISBN: 0-19-914654-3

ENNOS, R. 2000. *Statistical and Data Handling Skills in Biology*. Prentice Hall,

Harlow. ISBN: 0-582-31278-7

FREELAND, P.W. 1985. *Problems in Practical Advanced Level Biology.* Hodder and

Stoughton, Sevenoaks. ISBN: 0-340-33563-7

GARVIN, J.W. 1986. *Skills in advanced biology 1. Dealing With Data.* Stanley Thornes, Cheltenham. ISBN: 0-85950-588-X

GARVIN, J.W., BOYD, J.D. 1990. *Skills in advanced biology 2. Observing, Recording and Interpreting.* Stanley Thornes, Cheltenham. ISBN: 0-85950-817-X

GARVIN, J.W. 1995. *Skills in advanced biology 3. Investigating.* Stanley Thornes, Cheltenham. ISBN: 0-7487-2048-0

JONES, R. REED, R. WEYERS, J. 1999. *Practical Skills in Biology. 2nd Ed.* Longman, Harlow. ISBN: 0-582-29885-7

POWELL, S. 1996. *Statistics for science projects.* Hodder and Stoughton, London.

ISBN: 0-340-664096

ROCKETT, B., SUTTON, R. 1996. *Chemistry for biologists at advanced level.* John Murray, London. ISBN: 0-7195-7146-4

SIDDIQUI, S.A. 1999. *Comprehensive Practical Biology for A Level.* Ferozsons, Lahore. ISBN: 969-0-01572-9

WEBB, N., BLACKMORE, R. 1985. *Statistics for biologists: a study guide.* Cambridge University Press, Cambridge. ISBN: 0-521-31712-6

Institute of Biology Booklet

Biological Nomenclature: Standard terms and expressions used in the teaching of biology. 3rd Edition, 2000, Edited by Alan Cadogan. ISBN 0-900490-36-5

Web sites

A Dictionary of Pharmaceutical Medicine:	www.pharma-lexicon.com
Age Concern:	www.ace.org.uk
Alzheimer's Society:	www.alzheimers.org.uk
Association of the British Pharmaceutical Industry:	www.abpi.org.uk www.abpischools.org.uk
British Diabetes Association	www.diabetes.org.uk
British Medical Journal:	www.bmj.com
Cambridge University Press:	www.cambridge.org
Department of Health:	www.doh.gov.uk
MIND	www.mind.org.uk
NHS Direct:	www.nhsdirect.nhs.uk
OCR	www.ocr.org.uk
Schools science	www.schoolscience.co.uk
Your Genes	www.yourgenesyourhealth.co.uk
Biozone	www.biozone.co.uk/
Science and Plants for Schools (SAPS)	www.saps1.plantsci.can.ac.uk
National Centre for Biotechnology Education	www.ncbe.reading.ac.uk

Using a Search Engine like Google (www.google.com) can increase chances of finding appropriate information to support practical work in Biology.

Useful addresses

The Alzheimer's Society

Gordon House
10 Greencoat Place
London SW1P 1PH

tel: 020 7306 0606

fax: 020 7306 0808

e-mail: info@alzheimers.org.uk

Age Concern

1268 London Rad
London SW16 4ER

Adviceline: 0808 808 6060

tel: 020 8765 7200

e-mail: ace@ace.org.uk

The British Diabetic Association

10 Queen Anne Street
London W1M 0BD

Cancer Research UK

PO box 123
London WC2A 3PX

tel: 020 7269 3662

fax: 020 7269 2865

MIND

Granta House
15-19 Broadway
London E15 4BQ

Infoline: 0845 660 163

tel: 020 8519 2122

e-mail: contact@mind.org.uk

National Osteoporosis Society

PO Box 10

Radstock

Bath BA3 3YB

Helpline: 01761 472721

tel: 01761 471771

fax: 01761 471104

The Stroke Association

Stroke House

Whitecross Street

London EC1Y 8JJ

tel: 020 7566 0300

fax: 020 7490 2686

Advisory service 020 7566 0330

Section B: Activities for Training and Appendices

It should be noted that the examples used in this Section of this handbook are not intended as exemplars of good practice by candidates. The examples are for the purposes of training staff and candidates e.g. to show how coursework should be marked and annotated, to develop an internal moderation process, and the appreciation of the importance of the hierarchical mark scheme by staff and candidates.

Please note, updates and revisions to this section of the Coursework Guidance booklet will be published on the OCR website, **www.ocr.org.uk** as they become available.

Introduction

There are three different activities in this section. These involve investigations that are carried out as part of the AS course (see below).

Each of the activities is suited for training purposes at INSET meetings, but can also be adapted for use by teachers for internal moderation exercises within their departments. One Activity (No. 3) is designed to be used with students to develop their skills during the AS course.

There are two appendices in this section. The first is 'Frequently Asked Questions' (page 139) and the second is entitled 'Ethics and the Law' (page 143).

Activity 1: Coursework annotation review

This Activity provides an opportunity for teachers to consider the most appropriate style of annotation to support judgements made in the marking of coursework and the use of a contextualised mark scheme. This Activity also provides an opportunity to consider the application of the hierarchical mark scheme. Teachers may find this Activity useful when training staff new to setting, organising and marking coursework at AS. There is a commentary on the work on page 129.

Activity 2: Coursework marking exercise

This Activity consists of a piece of coursework on a different topic to Activity 1 and without any annotation or final mark. Teachers may use this Activity in training within their departments. There is a commentary on the work on page 132.

Activity 3: Student marking activity

This is an Activity that teachers may find useful for training their students in the requirements of the coursework scheme. It is designed to help students focus on the skills descriptors and see how work of poor quality fails to match those descriptors. These proformas are on pages 99 to 102. There is a commentary on page 135.

Activity 1: Coursework annotation review

Context:

The students investigated the effect of substrate concentration on the rate of reaction of catalase. Consider the annotation of the coursework and the use of the contextualised mark scheme.

The Task:

1. Use the annotations on the coursework to complete as much as possible of the mark scheme proforma on pages 84 to 87. It is recommended that you carry out this activity for five minutes, and restrict yourself to considering the planning skill only.

2. Consider the ease and effectiveness of completion of the mark scheme proforma in terms of:

   - The structure and logical layout of the student's work
   - The ease with which the material to which the annotations referred may be found
   - The extent to which careful teaching of the coursework module might improve the structure and logic of the student's work
   - The decision to award 7 marks for Skill P.

3. Use annotations on the coursework to complete the mark scheme proforma for Skills I, A and E. Use the information on the tick list provided (see page 83) to assess the mark for skill I. It is recommended that if you have attended an INSET course, this part of the task to be completed shortly after the course. If you have been unable to attend a course, complete it after tasks 1 and 2.

4. Consider how the hierarchical nature off the coursework assessment has been applied in this case.

5. Do you agree with the final decisions?

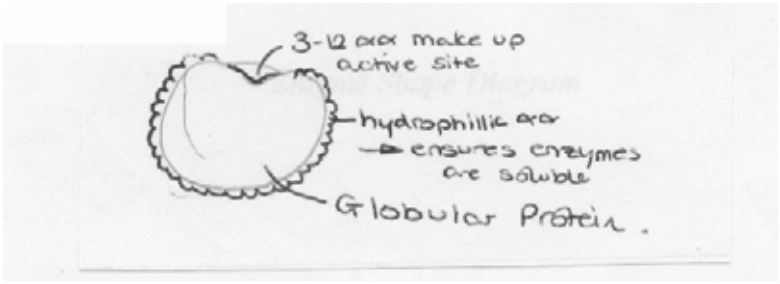
Please note that this piece of coursework has been reproduced with the use of Optical Character Recognition Software. Whilst every effort has been made to correct transcriptions errors some formatting and typing errors may be apparent. It should be noted that no such errors occurred in the original document.

An Experiment to discover how differing Concentrations of Substrate affect the Rate of Reaction between it and a fixed Concentration of Enzyme.

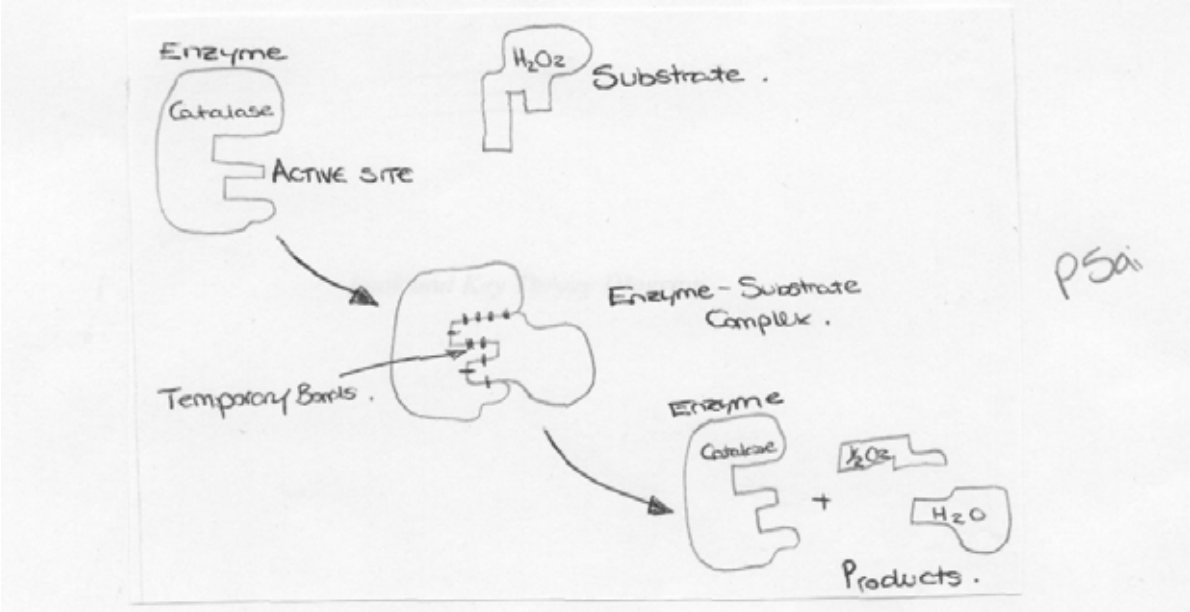
Aim: The aim of this practical is to assess how differing concentrations of Hydrogen Peroxide affects the rate of reaction when it is combined with the enzyme Catalase of a fixed concentration. With the results obtained it is hoped that accurate graphs will be able to be drawn displaying the rate of reaction and how it alters over a period of time. Ultimately I hope to prove my prediction and the theory associated with enzyme action through a set of accurate data.

Background Theory: All enzymes are biological catalysts, i.e. they speed up a chemical reaction by lowering the activation energy without being altered in the course of the reaction. Enzymes are specialised, Globular Proteins that is to say, the polypeptide chain is folded into a precise 3D shape. They are globular because Catalase, is found in the tissues of most living things, in tissues there is a substantial amount of fluid and therefore the proteins curl up so that their non-polar, hydrophobic R groups point into the centre of the molecule, away from their watery surroundings. The polar, hydrophilic, R groups remain on the outside of the molecule and therefore globular proteins such as Catalase are soluble in water. This is important to remember because it means that enzymes can be made into various concentrations.

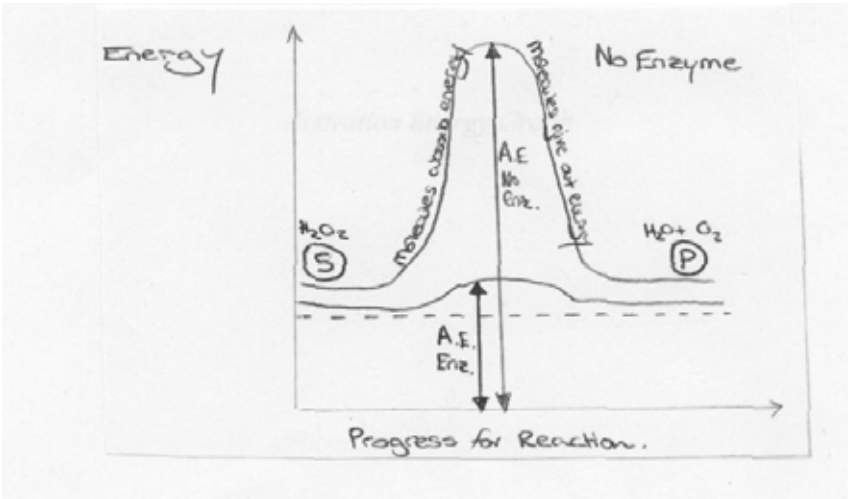
Enzymes are proteins made up of between 3,000 and 10,000 amino acids, however the most important area, the active site is only made up of between 3 and 12 amino acids, the remaining amino acids hold the enzyme in it's precise shape which enables it to be active.



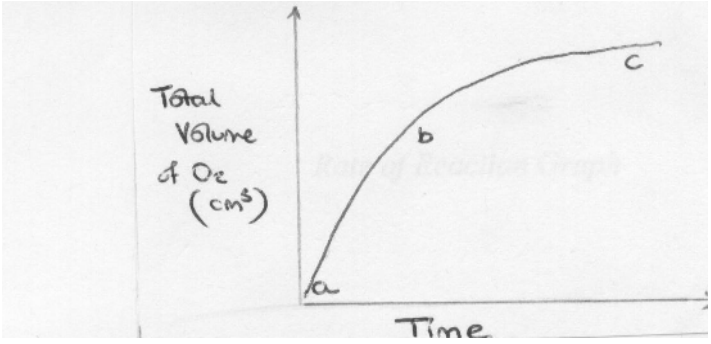
The Active Site is a depression on the surface of the enzyme, it is specific to that enzyme and complementary to its specific substrate. For example Catalase has an active site that is complementary to the Hydrogen Peroxide molecule, allowing it to enter and be broken down, no other molecule fits Catalase's active site. The shape of the active site allows the substrate to fit perfectly, and to be held in place by temporary bonds, which form between the substrate and some of the R groups of the enzyme's amino acids. This combined structure is known as an Enzyme-Substrate Complex. Catalase catalyses a reaction which breaks down Hydrogen Peroxide (H_20_2) into two separate products, water (H_20) and Oxygen (0_2). This is because Hydrogen Peroxide is toxic in tissue fluids in the human body and therefore it is imperative that it is broken down into two harmless products such as water and oxygen. When the reaction is complete the two products leave the active site leaving it unaltered and consequently it is available to receive another substrate molecule. The rate at which this happen can be quite rapid, Catalase can break Hydrogen Peroxide down at a rate of 10^7 molecules per second. The reason for this is that Catalase has 4 active sites per molecule, which allows it to be very efficient. It also contains a haem group (prosthetic group) which contains a Fe^{2+} **ion, which alters the** charge of the Active Site and promotes binding to the substrate. This is the Lock and Key Theory.



For a substrate to be broken down or joined together it needs a certain amount of energy to activate them to allow them to react, this is called the Activation Energy and is lowered by the presence of enzymes. They do this by holding the substrate with in close **proximity.** The greater the activation energy required the slower the reaction at a given temperature. Enzymes are used in the human body because they cannot gain the required energy from heat because an increase in temperature over 40^{o}C can cause irreversible damage to the human body. This lowering of the activation energy can be illustrated using the following diagram:



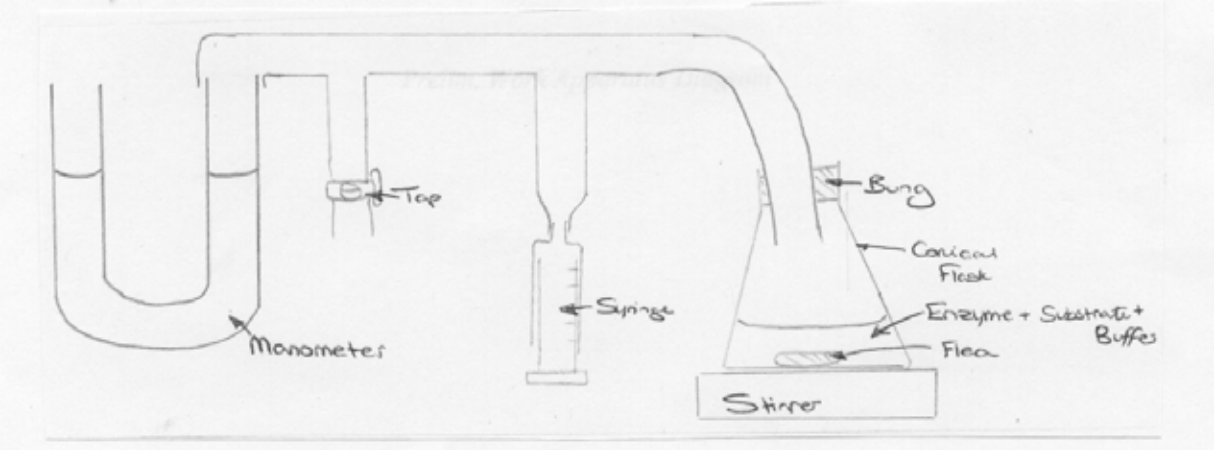
Within this experiment we are able to measure the rate of reaction through measuring the volume of oxygen gas given off. However most reactions involving enzymes have the same general pattern.



Initially, at a, there are lots of substrate molecules, the active sites are full and the reaction is rapid, this is the Initial Rate of Reaction. As the substrate is used up, there are fewer substrate molecules and there are spare, unused active sites, the reaction begins to slow (b). By the time we reach stage c all the substrate has been used up and the reaction has stopped.

Factors that affect this initial rate and subsequent speed of the reaction are numerous. Firstly enzyme concentration is directly proportional to the rate of the reaction, that is to say, if we double the enzyme concentration then the rate will double also. This is because the more enzyme there is the more active sites there are and the more likely that a successful collision between an enzyme protein and a substrate molecule is. However it is important remember that the total amount of product will remain the same as the substrate has not been altered, the curve will just be steeper. The second factor is substrate concentration, as this will determine the amount of product at the end of the reaction. The effect of this is that, if the enzyme concentration is kept the same the active sites will soon all fill up and become saturated. Therefore the graph will tail off as it reaches the maximum rate for that concentration of enzyme, this is the V Max, the substrate molecules are "queuing up" for an active site to be vacant.

Preliminary Work: Preceding the actual investigation it was necessary to undertake a preliminary investigation to determine what concentration of Catalase I would use when it came to the real investigation. It was also useful to familiarise myself with the apparatus that I would be using in the real thing. This was done using a simple method: Set up the apparatus as shown below.



1. Dilute the 10-vol H_20_2 to produce a concentration of 6-vol.
2. Pour 10.0 cm^3 of the H_20_2 into a conical flask placed on a magnetic stirrer.
3. Pour 10.0 cm^3 of 1.0 AU Catalase into the conical flask containing the H_20_2.
4. Insert the bung into the conical flask.
5. Close the tap, making a closed system.
6. Start the stop Clock.
7. Withdraw the syringe to the 2.0 cm^3 mark.
8. Note the time taken for the manometer levels to equalise again.
9. Continue steps 8 and 9 in 2.0 cm^3 intervals until 16.0 cm^3 of oxygen has been produced.
10. Repeat steps 1-9 twice more.
11. Repeat steps 1 - 10 using 0.5 AU Catalase.

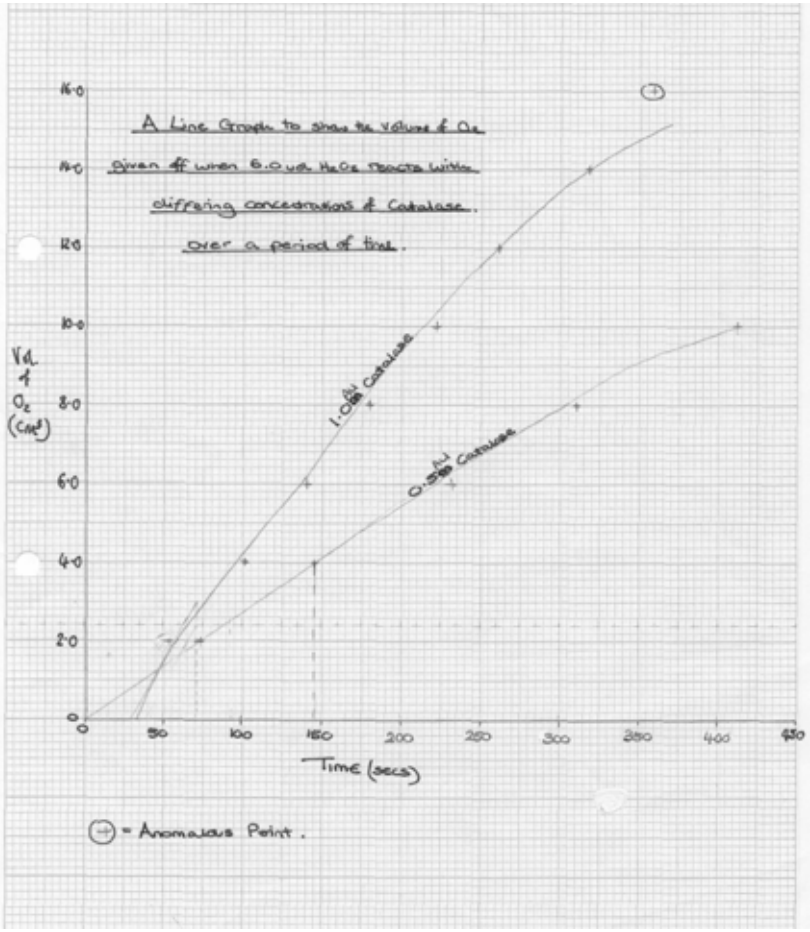
Results Table

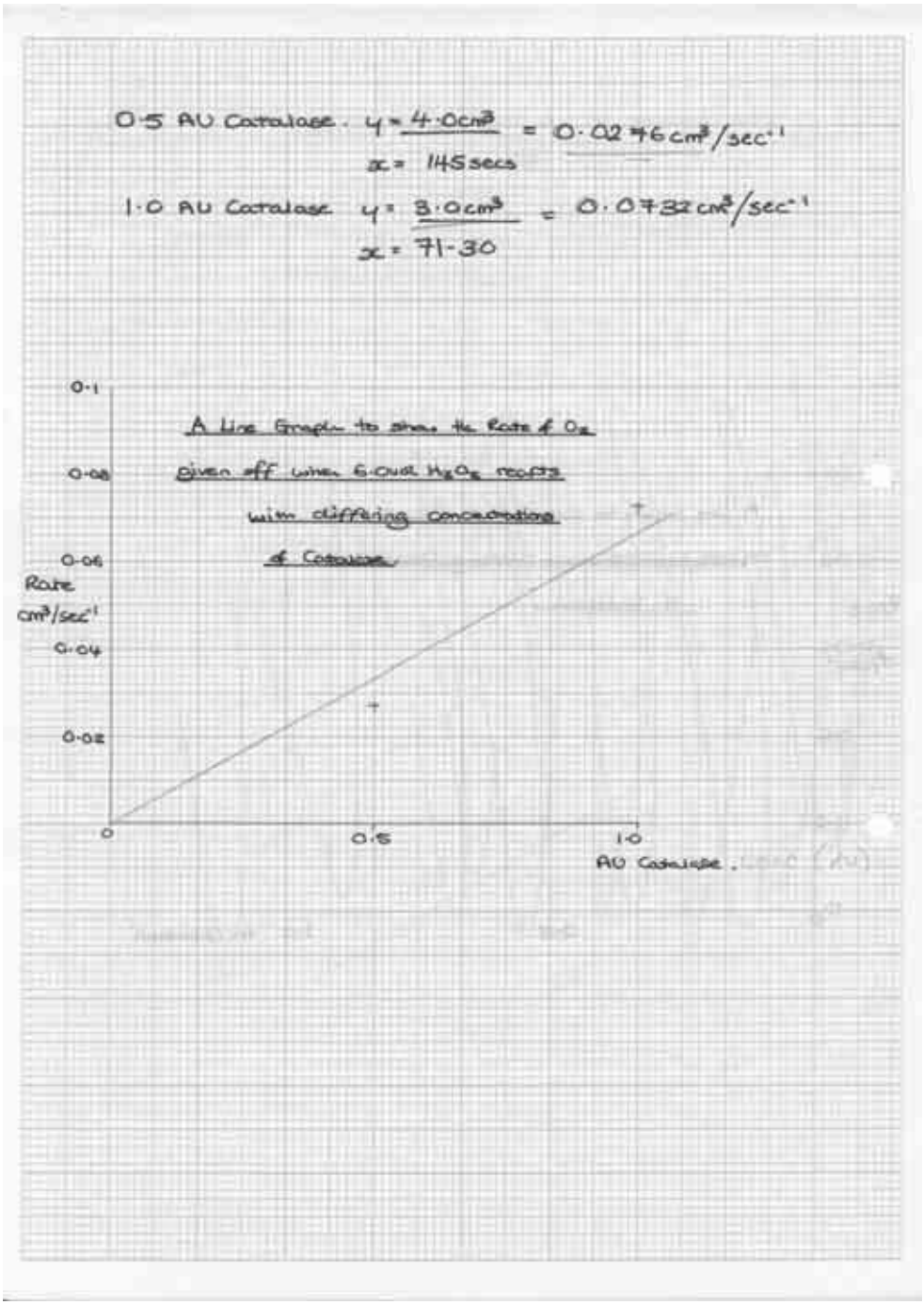
Catalase Conc. (AU)		Time (secs) taken to collect Oxygen (cm^3)							
		2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0
0.5	1	73	145	231	310	412	514		
	2								
	3								
	Av.	73	145	231	310	412	514		
1.0	1	51	105	145	184	225	275	325	378
	2	52	99	130	170	210	248	295	340
	3	60	100	145	186	230	276	332	375
	Av.	54	101	140	180	222	266	317	364

This preliminary work helped greatly as it allowed me to decide that when I carry out the investigation I will use Catalase of concentration 1.0 AU. The reason for this decision is that the rate at this concentration of enzyme was fairly rapid so that the rate could be measured accurately but at the same time was not too quick to make accurate recording impossible and it did not take excessive lengths of time to complete.

It has also helped me decide on the concentrations of the substrate I will use, in the preliminary experiment 6-vol H_20_2 was used, as I need six points on my graph I will use a series of concentrations ranging from 4-vol to 14-vol. This, I hope will give me a range of results that will allow an accurate graph to be drawn.

To ensure maximum accuracy it will be necessary to ensure I have three readings at each concentration of H_20_2, this means that I will be able to average out my results for each concentration meaning that the end result will be far more accurate and a more accurate conclusion can be drawn.

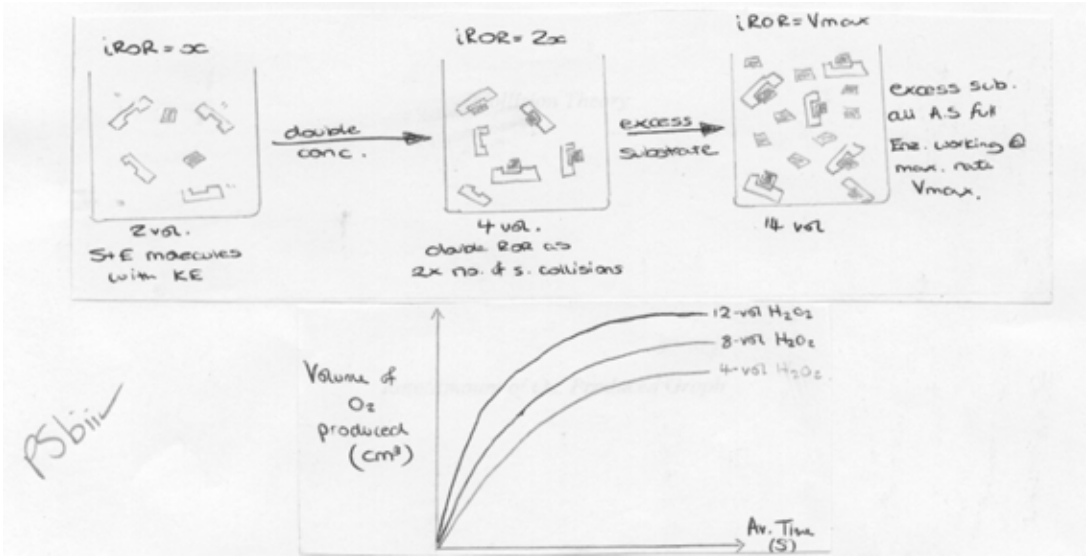




plain

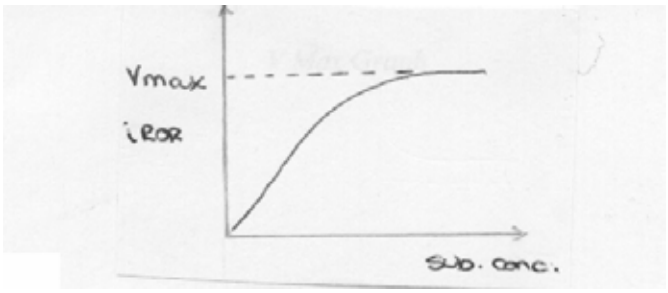
Prediction: I predict that the greater the concentration of the Hydrogen Peroxide the greater the rate of reaction. I would imagine that if we double the concentration from 2vol to 4-vol then there will be twice the amount of substrate molecules and therefore the rate of reaction will be twice as fast.

The reason for this prediction is due to some key theory that suggests for a successful collision to occur between an enzyme's active site and a substrate molecule, the molecules must possess a certain amount of kinetic energy. The more particles present in the solution the more collisions will occur, the more collisions occurring the more likely a successful collision is. As the substrate concentration increases the number of particles present will increase, therefore the number of successful collisions is likely to increase. This results in more enzyme-substrate complexes forming and subsequently the rate will increase proportionately.



This increase will continue until another factor limits the rise, this limiting factor will usually be the enzyme concentration, i.e. the number of active sites present. At a certain substrate concentration the enzyme will be working at its maximum rate, that is to say, the active sites are saturated and the enzyme is queuing up. This maximum rate of reaction for a specified enzyme concentration is called the Vmax, any further increase in substrate concentration will not result in an increase in the rate of reaction.

PSaiii



The rate of reaction can only be increased further through an increase in enzyme concentration- the provision of more active sites.

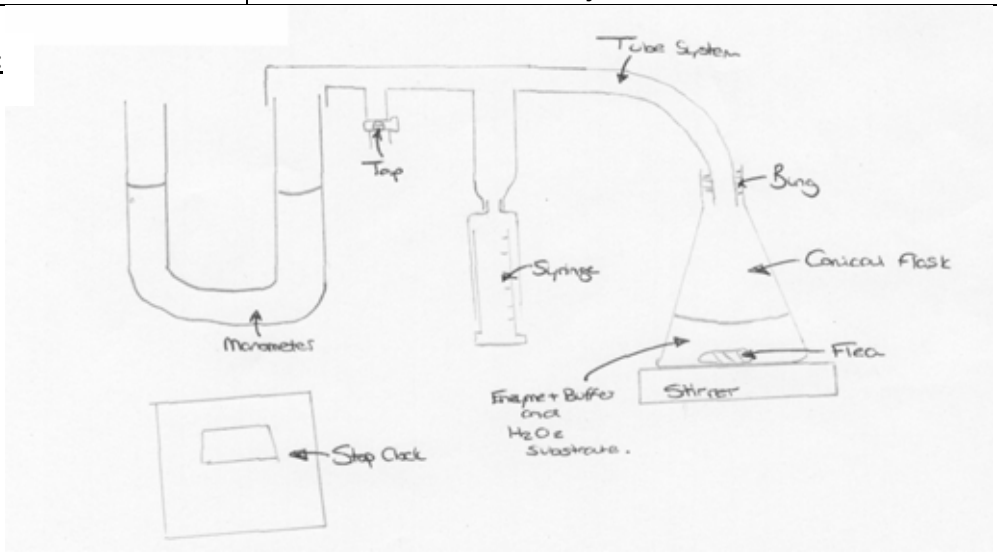
Safety: As with all experiments there are some hazards that precautions must be taken against. Firstly, goggles must be worn at all times to prevent any solutions coming into contact with the eye. The reason for this is that Hydrogen Peroxide is an irritant, therefore it is necessary to ensure that the chemical does not come into contact with the skin or eyes as it may cause redness and itchiness. However if the solution does come into contact with the eyes or skin it is necessary to immediately flood the area with water to dilute the solution and ensure that a reaction is kept to a minimum. Likewise precautions must be made to ensure that the enzyme Catalase does not come into contact with the skin as this can cause an allergic reaction. If it does, it is necessary to wash the area well with water as quickly as possible in an attempt to remove the enzyme from the skin. Also care must be taken when handling any glass apparatus such as conical flasks and measuring cylinders. If these are dropped they are likely to smash and the smashed glass may become embedded in the skin and cause abrasions. Having said that the experiment is relatively safe and as long as common sense prevails and care is taken there should be no problems.

PSaiii

Apparatus:

Apparatus	**Reason**
Hydrogen Peroxide Solution 20-vol.	The source of substrate at maximum strength: to be used to dilute by serial dilution to form other strengths
Magnetic Stirrer	To ensure constant (and therefore a fair test) mixing of enzyme and substrate
1.0 AU Catalase + Phosphate Buffer	Source of enzyme. Buffer used to ensure the pH remains constant (this is because pH changes can cause denaturing of the enzyme and therefore affect the reaction)
Flea	To aid mixing (see above)
Distilled Water	To rinse flea and conical flask in between runs. Excess water will be removed from them before they are re-used to ensure no contamination or dilution of the contents
2 Measuring Cylinders	To measure volumes of substance to 0.1 cm^3. NB I would like to use a micro-pipette but none are available
Conical Flask	To hold contents of the reaction
Gas Syringe	To drawn out volumes of gas in 2.0cm^3 intervals to enable the time to be determined to produce oxygen
Manometer	To accurately determine the point at which the volume of oxygen has been produced. This will be observed at eye level at all times to ensure accuracy and precision
2 Teat Pipettes	To add final solutions drop by drop to the measuring cylinder
Tubing System with tap and bung	To collect oxygen produced by the reactants in the conical flask and ensure air-tight delivery to the manometer. This is checked for leaks by emersing it in the sink of water and ensuring no bubbles are released. If this happens a new set of tubing will be selected
Stop Clock	To time the oxygen production to the nearest second. No further accuracy can be obtained due to human error and subjectivity of the manometer and human delay

Diagram:



Fair Test: To obtain accurate results it is imperative that the experiment is a fair test, this means that all factors should be fixed apart from one variable that is being tested, in this case the concentration of the substrate. The detailing of how these other factors will be kept constant and why they may alter my results are detailed below. However, these are not the only factors in making the experiment a fair test. While undertaking the experiment the same apparatus must be used throughout so that apparatus error is the same throughout so that this error can not alter the spread of the results. Also the volumes of both the Catalase and the Hydrogen Peroxide must be kept constant at 10.0 cm~ throughout so that there are the same number of active sites and substrate molecules at each of the concentration levels. To ensure that the Catalase concentration is kept the same a neutral buffer will be used to ensure that the enzyme concentration remains at 1.0 AU. If all this is done accurately then the test will be fair and accurate, reliable results should be obtained.

Variables:

	Variable	Why?	How?
Independent	Substrate (H_2O_2)		
Dependent	Time to Collect O_2		
Control	pH	Excess H+ ions Leads to denaturing Of Active Sites. This Means no reaction	Use buffer to make Up enzyme solution
	Temperature	Increase/Decrease In temperature will Affect the number of Collisions	Do the experiment at Room temperature to Prevent the use of Water baths, as they are unavailable.
	Final Volumes	It will affect the Concentrations of The substrate and Enzyme	Maintain the final Volume of 20.0cm^3 (10.0cm^3 of H2O2 + 10.0cm^3 of Catalase)
	Enzyme	The number of Active Sites must remain the Same	Keep 10.0cm^3 of 1.0 AU Catalase through-Out

To ensure that the results obtained are as accurate as possible and that they are obtained with the up most precision certain practises must be used. Firstly all volumes measured will be measured by reading the meniscus from eye level, this will be done when measuring volumes using the measuring cylinder and when viewing the manometer. Also when measuring these volumes a pipette will be used to add the last few drops to ensure the volume measured is as accurate as possible when making up the dilutions. Also when creating the closed system once the two solutions have been mixed it will be necessary to ensure that the bung is fitted to the conical flask tightly so that no oxygen "escapes" and that all of it actually reaches the gas syringe. Furthermore to ensure that the results I obtain are as accurate as possible I will take replicates at each concentration of Hydrogen Peroxide so that at the end of the experiment I can take an average for each concentration level of substrate. Consequently it is likely that my results will be more accurate and precise and are more likely to produce a smooth trend on my graph. When taking these replicates it will be necessary to rinse the conical flask out thoroughly each time to ensure that there is no residue left that could “throw out" my next result. Finally I will record all my times to the nearest second as this gives the most sensible degree of accuracy, anything greater would be inappropriate.

Method:

1. Set up the apparatus as shown in the diagram.
2. Dilute the 20-vol Hydrogen Peroxide to a concentration of 4-vol. This is done by using the measuring cylinder, firstly pour 2.0 cm^3 of the 20vol Hydrogen Peroxide into a measuring cylinder, then "top this up" to 10.0 cm^3 using distilled water. Ensure that as you reach the line the liquid is added by drops to improve accuracy.
3. Pour 10.0 cm^3 of the 4-vol Hydrogen Peroxide into the conical flask.
4. Place the conical flask on the metallic stirrer, place the flea in the conical flask and switch the stirrer on.
5. Place 10.0 cm^3 of 1.0 AU Catalase into a separate measuring cylinder.
6. Open the tap on the tubing system so it is parallel to the tube.
7. Tip the 10.0 cm^3 of 1.0 AU Catalase into the conical flask.
8. Secure the bung.
9. Close the tap so that it is at right angles to the tube.
10. Start the stopwatch.
11. Withdraw the syringe out to the 2.0 cm^3 marker.

(Steps 7. To 11. Should be done consecutively, as quickly as possible to ensure accurate results.)

12. Note the time taken for the manometer levels to equalise.
13. Withdraw the syringe to 4.0 cm^3. (This does not have to be instantaneous.)
14. Note the time taken for the manometer levels to equalise again.
15. Repeat steps 11-14. At 2.0 cm^3 intervals until 16.0 cm^3 of oxygen has been produced.
16. Repeat steps 1- 15. twice more.
17. Repeat steps 1-16. for differing concentrations of Hydrogen Peroxide at 2-vol. intervals up to 14-vol. (Details on preparing the concentrations are below.)

To produce the required concentrations of Hydrogen Peroxide, simple dilutions using a 20-vol concentration of Hydrogen Peroxide and some distilled water are required. These can measured in measuring cylinders and the following volumes of each liquid are required for each concentration. The total volume should be 10.0 cm^3 for each concentration.

Concentration of H_2O_2 (vol)	Volume of 20-vol H_2O_2 (cm^3)	Volume of Distilled water (cm^3)
4	2.0	8.0
6	3.0	7.0
8	4.0	6.0
10	5.0	5.0
12	6.0	4.0
14	7.0	3.0

To ensure that my results are both accurate and reliable it will be necessary to take three replicates/repeats at each concentration level of substrate. This means that at the end I can average out my times so that a better more precise value is given rather than just one record, which could be completely wrong due to human and/or experimental error. Consequently any anomalous recording I might make can be ignored and not included in my conclusion. Also great care will be taken to read volumes of solutions and the manometer along the meniscus at eye level so that accurate concentrations, volumes and times are used and recorded throughout. Also it is imperative that the volumes of the substrate and enzyme remain constant at 10.0 cm^3 to ensure that the number of active sites and substrate molecules remains the same throughout. Likewise great care must be taken when pulling out the gas syringe at 2.0 cm^3 intervals, as a small imprecision in the level to which it is pulled out will cause a great deal of disequilibrium in the water level of the manometer. It also must be ensured that when adding the last, small amounts of liquids when measuring the volumes a pipette is used and the liquid is added at a drop at a time. This will ensure accuracy when reading off the measuring cylinder so that precise volumes are used and my results remain correct. If all this is done and great care is taken while undertaking the experiment then all my results that are obtained should be both reliable and accurate, giving me a smooth general trend on my resulting graph(s).

References: All background Knowledge and information used in this plan came from one of three sources. These were:

1. Teachers Notes
2. Cambridge Advanced Sciences Biology 1 (Jones/Fosbery/Taylor)
3. www.clunet.edu

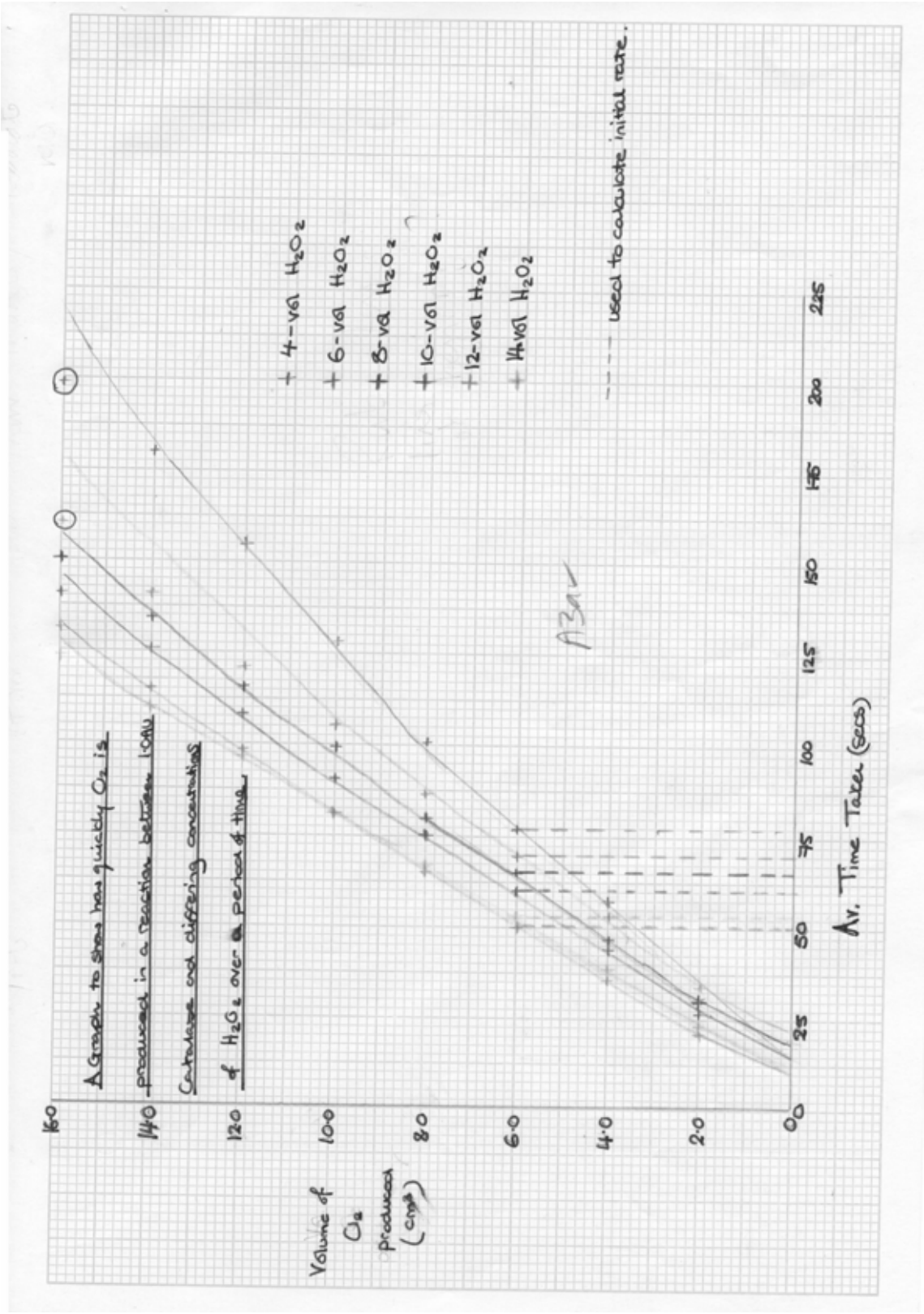
A Results Table to show the time taken (s) to collect certain volumes of Oxygen (cm^3) in a reaction between Catalase and various concentrations of H_2O_2

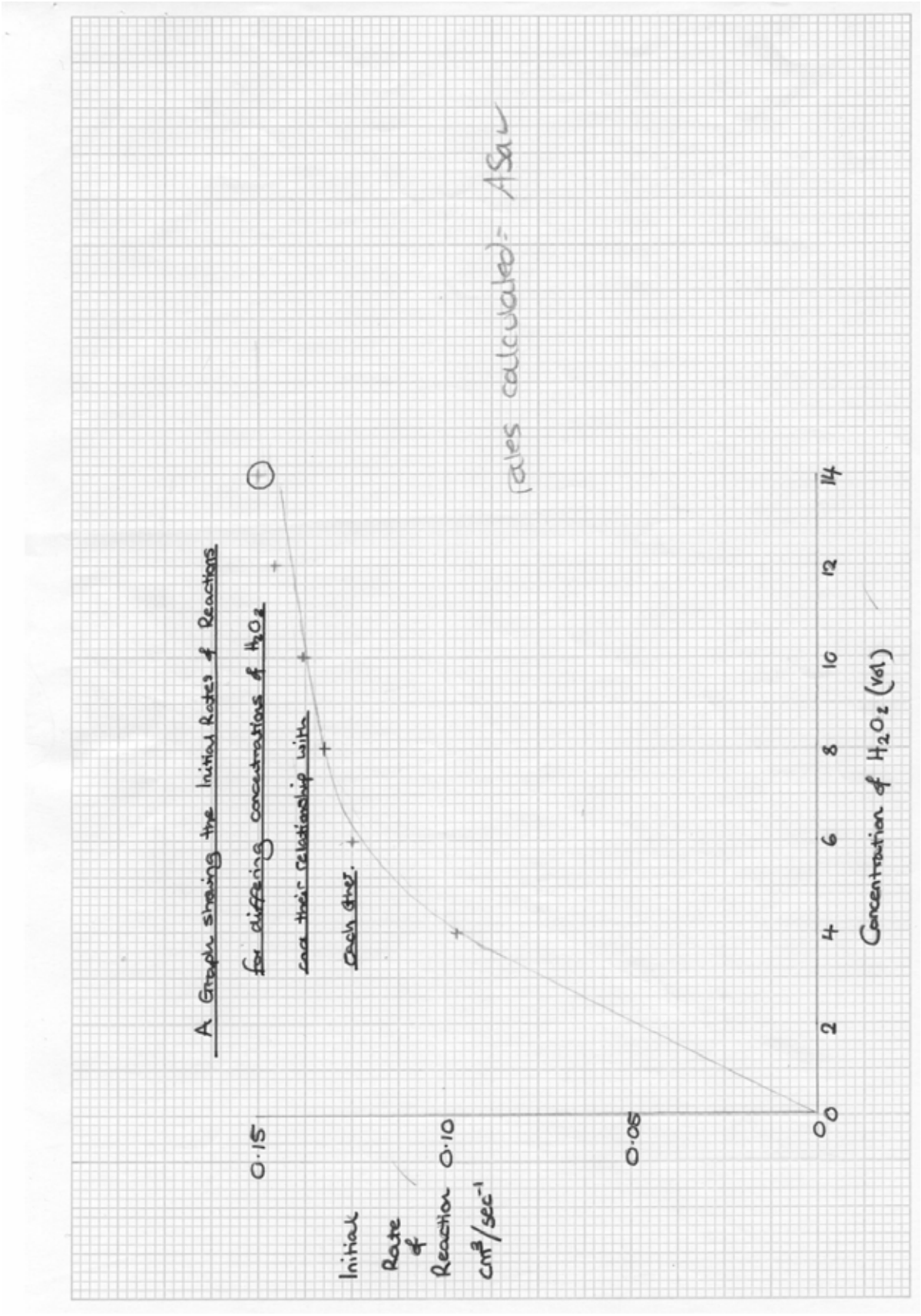
H_2O_2 Conc. (vol)		Time (s) taken to collect Oxygen (cm^3)							
		2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0
4	1	33	55	74	94	124	151	186	213
	2	30	60	81	105	129	155	182	212
	3	29	57	77	104	132	158	188	212
	Av.	31	57	77	101	128	155	185	212
6	1	33	54	74	90	106	116	134	154
	2	33	52	66	80	100	120	141	161
	3	33	53	71	91	111	128	147	165
	Av.	33	53	70	87	106	121	141	160
8	1	32	47	66	83	102	121	138	150
	2	29	49	66	80	99	117	136	155
	3	28	46	63	77	95	110	129	146
	Av.	30	47	65	80	99	116	134	150
10	1	28	46	63	78	93	109	127	143
	2	26	41	56	70	88	105	127	141
	3	27	46	61	77	93	109	124	140
	Av.	27	44	60	75	91	108	126	141
12	1	20	36	50	65	81	96	110	127
	2	24	38	53	68	85	101	117	131
	3	20	34	48	61	78	96	119	135
	Av.	21	36	50	65	81	98	115	131
14	1	25	40	55	70	84	96	114	129
	2	21	34	48	60	74	88	104	118
	3	24	40	56	70	86	95	112	125
	Av.	23	38	53	67	81	93	110	124

A Results Table to show the calculated initial rates of reaction for the reaction between Catalase and differing concentrations of H_2O_2

Conc. Of H_2O_2 (vol)	y-axis (vol. of O_2 produced cm^3)	x-axis (time Change in s)	Initial Rate of Reaction (cm^3/s)
4	6.0	62	0.968
6	6.0	48	0.125
8	6.0	46	0.130
10	6.0	44	0.136
12	6.0	40	0.150
14	6.0	42	0.143

O = Anomalous Result


A Graph to show how quickly O_2 is produced in a reaction between yeast & Catalase and differing concentrations of H_2O_2 over a period of time
+ 4-vol H_2O_2
+ 6-vol H_2O_2
+ 8-vol H_2O_2
+ 10-vol H_2O_2
+ 12-vol H_2O_2
+ 14vol H_2O_2
---- used to calculate initial rate.
Volume of O_2 produced (cm³)
Av. Time Taken (secs)
160
140
120
100
80
60
40
20
00
25
50
75
100
125
150
175
200
225


A Graph showing the Initial Rates of Reaction
for differing concentrations of H_2O_2
and their relationship with
each other.
Initial Rate of Reaction cm^3/sec^{-1}
0·15
0·10
0·05
0
2
4
6
8
10
12
14
Concentration of H_2O_2 (vol)
Rates calculated:- ASA

Conclusions

Conclusions that can be drawn from the results in my table and the trends displayed on the graphs are:

- As the time increases, over the course of the reaction a greater volume of oxygen is produced. This is the same for any concentration of Hydrogen Peroxide. For example for a concentration of 4-vol H_2O_2 it took 57 seconds to produce 4.0 cm^3 of oxygen whereas after 128 seconds 10.0 cm^3 of oxygen had been produced, this was an increase of 6.0 cm^3 in 71 seconds.

A1b

- As the substrate concentration increases the time taken for the reaction to produce 16.0 cm^3 decreased. For example when the concentration of H_2O_2 was 4-vol it took 212 seconds but when the concentration was 12-vol it took only 131 seconds a decrease of 83 seconds.

- All the lines on the graph display the same trend, in that they begin steep and then begin to level off towards the end of the reaction. This can be shown by the difference in times it takes for 2.0cm^3 of oxygen to be produced. With a concentration of 4-vol H_2O_2 it took 20 seconds to produce 2.0 cm^3 of oxygen towards the beginning of the reaction but towards the end it took 27 seconds to produce the same volume.

- As the concentration of the Substrate increases the initial rate of reaction increased. For example the initial rate of reaction when 4-vol Hydrogen Peroxide was used was 0.968 $cm^3/secs^{-1}$ whereas when the concentration was 12-vol the Initial rate had increased to 0.150 $cm^3/secs^{-1}$

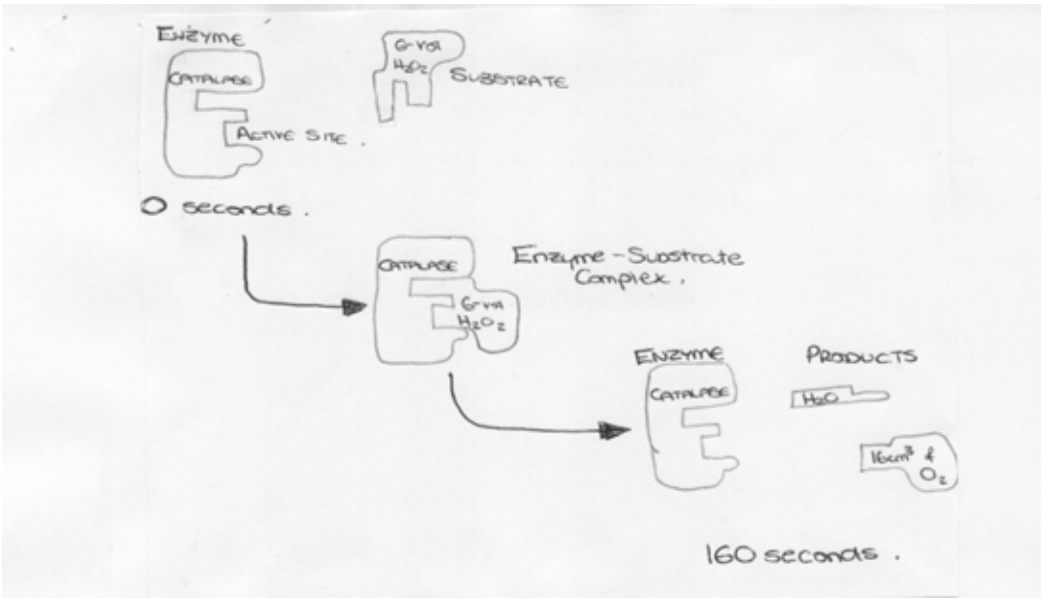
A1ai

  The increase in the initial rate of reaction becomes smaller as the initial rate increases. For example to begin with my graph shows that the initial rate roughly doubles from 1-vol to 2-vol from 0.025cm^3/sec^{-1} to 0.05 cm^3/sec^{-1}. However the subsequent increases are much smaller, the difference between 4-vol and 6-vol was only 0.843 cm^3/sec^{-1} (Just less than double)

A3b

Appropriate theory can be used to prove all the results and conclusions that have been made. Firstly at the beginning of the reaction the mixture contains the separate enzyme globular proteins and the H_2O_2 molecules. The presence of the Catalase enzyme lowers the activation energy by holding the molecules within close proximity of each other. The enzyme proteins contain a specific area called an active site, which is complementary to the H_2O_2 molecule's shape. Consequently the substrate molecules can fit perfectly into the 4 Catalase active sites on each enzyme forming an enzyme-substrate complex. The enzyme then breaks the Hydrogen Peroxide down into two harmless products, water and oxygen (in our experiment we collected the oxygen produced). Therefore as time progresses the total number of substrate molecules that have been broken down by the enzyme increases and therefore the amount of oxygen produces increases proportionately.

A5bii



As the substrate concentration increases the number of H_20_2 molecules within the 10.0 cm^3 increases. Therefore the number of collisions between the enzyme proteins and substrate molecules will increase, thus the number of successful collisions will increase and the rate of reaction will be greater. This explains why when the concentration of substrate increased the time taken to produce 16.0 cm^3 fell as there were more successful collisions breaking down more H_2O_2 and forming more oxygen and water more quickly.

All the curves display the same pattern because, initially there are lots of substrate molecules, therefore the active sites are full and the reaction is quick with lots of oxygen being produced at the start. However as the substrate is used up there are fewer substrate molecules and some of the active sites remain empty, the reaction began to slow. The curve will continue to level off until all the substrate had been used up and there were no substrate molecules left, at this point the reaction would have stopped. This pattern is the same for all substrate concentrations; the only difference is that the curve will level off higher the higher the concentration because there are more substrate molecules.

The increases in the rate of reaction occurs due to an increase in substrate molecules with the increase in substrate concentration. This increases causes more successful collisions to occur between H_20_2 molecules and the enzyme. Therefore more water and oxygen is produced at a faster rate. The doubling of the rate of reaction from 1-vol to 2-vol can be illustrated through the chemical equation.

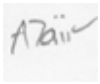
$$H_2O_2 \rightarrow H_2O + \tfrac{1}{2}O_2$$

If the amount of Hydrogen Peroxide is doubled then the volume of oxygen should double also.

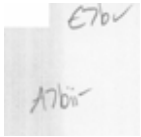
$$2H_2O_2 \rightarrow 2H_2O + O_2$$

This also explains why more oxygen is produced the higher the concentration of Hydrogen Peroxide because there are more substrate molecules, which creates more oxygen at a faster rate thanks to more successful collisions between the substrate molecules and the 4 active sites of the Catalase enzyme.

The reason for the “levelling off” of the rate of reaction graph is that the active sites of the enzyme were becoming saturated. As the substrate concentration increases the number of H_2O_2 molecules increases, increasing the number of successful collisions. However when the number of molecules reaches a certain maximum, i.e. at a certain concentration there will be too many H_2O_2 molecules for the active sites to cope with. This is to say that the active sites become saturated and the substrate molecules begin to “queue up”. This maximum rate of reaction for a specified enzyme concentration is called the Vmax, any further increase in substrate concentration will not result in an increase in the rate of reaction, the only way this could occur would be if more enzyme was added the provision of more active sites.



The accuracy of this experiment is not great, this comes about because, due to the method it was difficult to measure the time more accurately than just whole seconds. Due to the nature of the recording process it was very difficult to measure to any decimal places, therefore all my times are to the nearest second and this makes the results slightly inaccurate. However they are the most accurate that they realistically could have been. All volumes were measured and recorded to the nearest decimal place as this ensured greater accuracy and was relatively easy to measure using the apparatus provided. Finally all the initial rates of reaction were measured to three decimal places as I felt that this displayed a great deal of accuracy and the change could also been seen easily.



It is important to appreciate that these results and this conclusions are only adequate under the conditions of my experiment, if the experiment was repeated under slightly different conditions then the results and this conclusions could be very different. Examples of these alterations in conditions could be a slight altering in room temperature when the experiment was undertaken, the solution concentrations and volumes could differ very slightly with a different "batch" of enzyme being used, or the pH could have been slightly different. Also if I was to undertake the experiment again I would be more experienced and therefore my results might be slightly more accurate.

An example of this is that during my preliminary experiment I tested the reaction between 1.0AU Catalase and a concentration of 6-vol Hydrogen Peroxide, during my “real” investigation 1.0AU Catalase was used throughout and one of the concentrations of H_2O_2 was 6-vol. If both experiments had been entirely accurate giving precise conclusions then both sets of results should have been identical, and therefore the rates should have been the same also, however this was not the case. Both the rates were very different and therefore it shows that the experiment contains some errors. In the preliminary experiment the initial rate of reaction between 6-vol H_20_2 and 1.0 AU Catalase was 0.0732 cm^3/sec^{-1} whereas in the actual investigation the initial rate for the same reaction was 0.125 cm^3/sec^{-1} . This demonstrates clear error in the method of the experiment.

Evaluation

E1R

The experiment has been of sufficient quality for me to obtain a set of data, (raw data, average data and rates of reaction) that has allowed me to make accurate conclusions from the trends my graphs have shown.

E1a

Due to certain inaccuracies in the method of the experiment some anomalous results have been recorded. However these have been noted and circled in both my table and on the subsequent graphs. There are anomalous results in my raw data, average data and in the subsequent calculated rates of reactions. These have been circled in red.

	Error	Effect of Error in Results	Effect of error on Trend/Conc.
Source of Error	*Connections of Apparatus* i.e. the conical flask and bung may be loose and there fore the gas produced may escape	*The escape of the gas will* cause the first result to be too fast. That's to say that more than 2.0cm^3 of O_2 was Produced when the syringe Read 2.0cm^3.	*The graph will not be as steep* Initially as it should have been This will cause the initial rate of reaction will be slower than It actually was causing the 2nd graph to be less steep it should be!
	Interpreting the Manometer, for example the point at which it was judged to have met the mark may cause time to increase or decrease.	If the point at which the water level met the mark was Anticipated it is possible that the times will be faster but if the time was not recorded until the level passed the mark it is likely that the times will *be slower than they should be*	If the times were lower then the Graph will be steeper causing The initial rate to be greater but if the times were greater the Opposite would occur, the Graph would be less steep and the initial rate slower.
	Contamination of solutions in the conical flask could alter the concentration of the substrate downwards because the previous conc. was lower than that being used.	If the conc. Is slightly lower then the times will be slightly Slower as there are less Substrate molecules.	This will cause the graph to be less steep at the beginning Thus the initial rate will be Less and that graph will be shallower.
	Difficulty of pulling out the syringe, in that it was stiff causing air bubbles to appear *in the manometer.*	Air bubbles in the manometer will mean that it will take Longer for the levels to Equalize, *therefore the times* will generally be slower.	This will cause the graph to Be less steep throughout, Meaning that the initial rate *Will be slower at each conc.*
	The time delay between closing the tap and starting the stopwatch.	This will mean that the times *will be faster than they should* be because the offset of the Manometer will be less once the syringe is pulled out the longer the time difference is.	This will cause the graph lines to be steeper at first and Therefore the initial rate will be greater also. This error will cause the graph lines to be shallower
	A leak in the tubing system that is used linking the conical flask and the manometer.	This will make the times slower Because for each 2.0cm^3 Produced indicated by the Syringe more O_2 will actually Be produced.	Throughout meaning that the Initial rates will be slower.

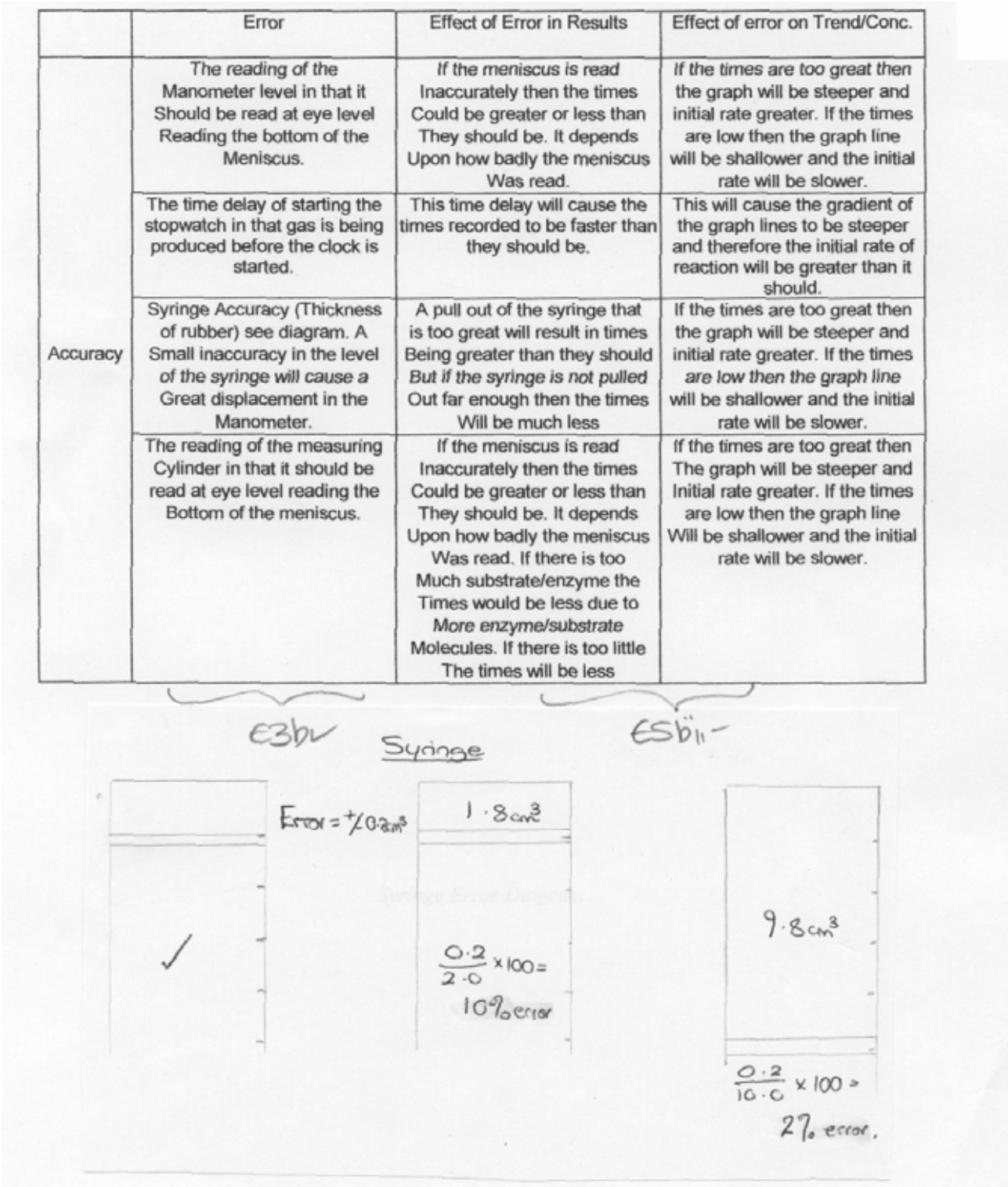
E3a

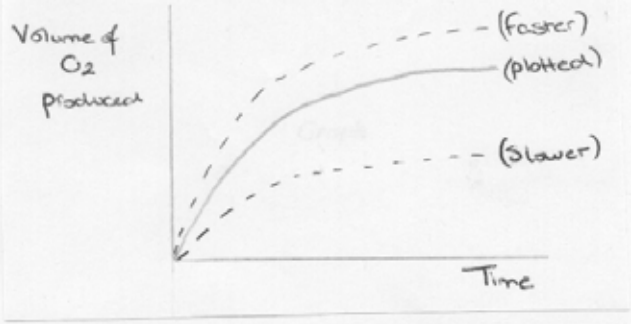
E5bii

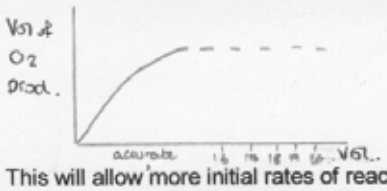
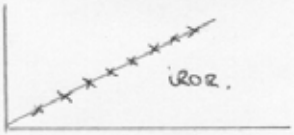
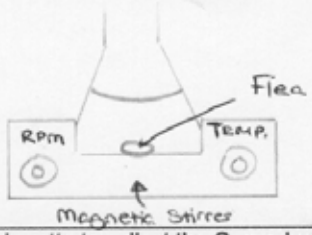
E5ai

The main error, in my opinion is the time delay of closing the tap and the subsequent actions because as soon as the two solutions are combined oxygen gas is being produced. Therefore the time taken to fit the bung, close the tap, start the stopwatch and pull out the syringe will mean that the first time at least will be inaccurate. This is likely to make the subsequent times recorded be inaccurate and therefore the trends and conclusions drawn will be incorrect.

	Error	Effect of Error in Results	Effect of error on Trend/Conc.
Accuracy	The reading of the Manometer level in that it Should be read at eye level Reading the bottom of the Meniscus.	If the meniscus is read Inaccurately then the times Could be greater or less than They should be. It depends Upon how badly the meniscus Was read.	If the times are too great then the graph will be steeper and initial rate greater. If the times are low then the graph line will be shallower and the initial rate will be slower.
	The time delay of starting the stopwatch in that gas is being produced before the clock is started.	This time delay will cause the times recorded to be faster than they should be.	This will cause the gradient of the graph lines to be steeper and therefore the initial rate of reaction will be greater than it should.
	Syringe Accuracy (Thickness of rubber) see diagram. A Small inaccuracy in the level of the syringe will cause a Great displacement in the Manometer.	A pull out of the syringe that is too great will result in times Being greater than they should But if the syringe is not pulled Out far enough then the times Will be much less	If the times are too great then the graph will be steeper and initial rate greater. If the times are low then the graph line will be shallower and the initial rate will be slower.
	The reading of the measuring Cylinder in that it should be read at eye level reading the Bottom of the meniscus.	If the meniscus is read Inaccurately then the times Could be greater or less than They should be. It depends Upon how badly the meniscus Was read. If there is too Much substrate/enzyme the Times would be less due to More enzyme/substrate Molecules. If there is too little The times will be less	If the times are too great then The graph will be steeper and Initial rate greater. If the times are low then the graph line Will be shallower and the initial rate will be slower.





Improvement	Why/How this improves the results
Take more results at higher concentrations  This will allow more initial rates of reactions to be calculated. 	These extra results will allow an estimation of the Vmax for 1.0AU Catalase to be More accurate It will make the initial rate of reaction graph more accurate as there will be more points to draw a trend through.
More replicates/repeats	This will make the data more reliable so that more accurate conclusions can be drawn on more reliable information.
Collect the amount of water produced in a separate experiment of the same reaction.	These times combined with the times taken to collect the same specified volume of O_2 will improve the accuracy and reliability of the results and conclusions drawn from Them.
Heated Stirrer 	The heated stirrer sets a precise temp. of the reactants. This means that all the molecules will have the same KE so that there is likely to be the same no. of successful collisions It can also set the speed at which the flea stirs and mixes the solution, ensuring an equal mixing. This improves the reliability and accuracy of the data collected meaning more accurate conclusions can be made. It is also possible to regulate the pH using this apparatus.
Use a burette to collect the O_2 produced instead of an equalizing manometer.	This method allows a more accurate way of measuring the volume produced. Also it removes the potential errors of the bung/ tap/clock/syringe process. Consequently it is likely more accurate data can be Obtained.

Even with the presence of these sources of error and inaccuracies it was still managed to collect concordant data on the whole. At each concentration of H_2O_2 I

E5ai✓ E7a✓

was able to collect at least one set of concordant times, these times are detailed below in a table.

Concentration of H_2O_2 (vol)	Concordant Data (s)		
	1	2	3
4	33	30	29
	213	2121	212
6	33	33	33
	54	52	53
8	32	29	28
	47	49	46
	66	66	63
10	28	26	27
	46	41	46
	93	88	93
	109	105	109
	127	127	124
	143	141	140
12	20	24	20
	36	38	34
	50	53	48
	96	101	96
14			

However, other results did not show this degree of concordance. For example, when using H_20_2concentration 14-vol my times were quite far apart, e.g. 70s, 60s and 70s. To rectify this problem it was necessary to ensure the bung was fitted properly and make sure my ability to undertake the method was more accurate. Also I made sure that more accuracy was taken when measuring out the dilutions!

It is important to appreciate that these results and thus conclusions are only adequate under the conditions of my experiment, if the experiment was repeated under slightly different conditions then the results and thus conclusions could be very different**.** An example of this is that during my preliminary experiment I tested the reaction between 1.0 AU Catalase and a concentration of 6-vol Hydrogen Peroxide, during my "real" investigation 1.0 AU Catalase was used throughout and one of the concentrations of H_20_2 was 6-vol. If both experiments had been entirely accurate giving precise conclusions then both sets of results should have been identical, however this was not the case.

Suggested proforma for assessing Skill I

Experiment title: Effect oF Substrate on catalase R.o.R

Date: A day in 2003

	Competence in simple techniques	Works safely/ethically	Records observations	Competence	Systematic/clear & accurate	Competent & Confident	Safe/ethical throughout	Observes accurately	Records appropriately	Skilful & proficient	Detail & precision	Records with detail and precision
Descriptors	**1ai**	**1aii**	**1b**	**3a**	**3b**	**5ai**	**5aii**	**5bi**	**5bii**	**7a**	**7bi**	**7bii**
Candidates Candidate 'activity 1'	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Skill P – Planning for AS Coursework — Total 8

The candidate:

Mark	General strategy	Level	Choices within plan	Level
0				
1	**P1.a** (i) develops a question or problem in simple terms and plans an appropriate investigation; (ii) makes a prediction where relevant.		**P1.b** (i) chooses investigative techniques.	
2				
3	**P3.a** (i) develops a question or problem using scientific knowledge and understanding; (ii) identifies the key factors to vary, control or take account of.		**P3.b** (ii) decides on a suitable number and range of evidence (observations /data) needed for the investigation.	
4				
5	**P5.a** (i) uses detailed scientific knowledge and understanding to justify any prediction made; (ii) uses information from preliminary work or a secondary source to plan an appropriate strategy to collect evidence; (iii) takes into account the need for safe and/or ethical working practices.		**P5.b** (i) describes a strategy to collect evidence, including choice of investigative techniques, which takes into account the need to produce precise and reliable evidence; (ii) produces a clear account and uses specialist vocabulary appropriately.	
6				
7	**P7.a** (i) retrieves and evaluates information from a variety of sources; (ii) uses information to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding; (iii) uses spelling, punctuation and grammar accurately.		**P7.b** (i) justifies the strategy developed, including the choice of investigative techniques, in terms of the need for precision and reliability.	
8	8 marks should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill I - Implementing for AS Coursework — Total 7

The candidate:

Mark	Manipulation	Level	Recording	Level
0				
1	**I1.a** (i) demonstrates competence in the use of simple investigative techniques (ii) shows an awareness of the need for safe and/or ethical working practices.		**I1.b** (i) makes and records evidence (observations/data) that is adequate for the investigation.	
2				
3	**I3.a** (i) demonstrates competence in the use of familiar investigative techniques.		**I3.b** (i) collects evidence accurately; records evidence clearly and accurately.	
4				
5	**I5.a** (i) demonstrates competence and confidence in the use of investigative techniques; (ii) adopts safe and/or ethical working practices throughout.		**I5.b** (i) collects evidence accurately; (ii) records evidence in an appropriate format.	
6				
7	**I7.a** (i) demonstrates skilful and proficient use of all investigative techniques.		**I7.b** (i) collects sufficient evidence to meet all the requirements of the investigation; (ii) records evidence in appropriate detail and justifies the degree of precision to which evidence is recorded,	

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill A - Analysing Evidence and Drawing Conclusions for AS Coursework Total 8

The candidate:

Mark	Processing evidence	Level	Drawing conclusions	Level
0				
1	**A1.a** (i) carries out some simple processing of the evidence collected, such as the use of bar charts or histograms, or the calculation of means.		**A1.b** (i) identifies trends or patterns in the evidence and draws simple conclusions.	
2				
3	**A3.a** (i) processes and presents evidence gathered using appropriate graphical and/or numerical techniques.		**A3.b** (i) Links conclusions drawn from processed evidence with the associated scientific knowledge and understanding.	
4				
5	**A5.a** (i) carries out detailed processing of evidence and analysis including the use of advanced numerical techniques such as, where appropriate, statistics, the plotting of intercepts or the calculation of gradients, or the use of error bars.		**A5.b** (i) draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding (ii) produces a clear account which uses specialist vocabulary appropriately.	
6				
7	**A7.a** (i) where appropriate, uses detailed scientific knowledge and understanding to make deductions from the processed evidence; (ii) shows due regard to nomenclature, terminology and the use of significant figures (where relevant).		**A7.b** (i) draws conclusions which are well structured, appropriate, comprehensive, and concise and which are coherently linked to underlying scientific knowledge and understanding; (ii) uses spelling, punctuation and grammar accurately.	
8	8 marks should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill E - Evaluating Evidence and Procedures for AS Coursework Total 7

The candidate:

Mark	Procedures	Level	Sources of error	Level
0				
1	**E1.a** (i) makes relevant comments on the suitability of the investigative techniques used.		**E1.b** (i) makes a relevant comment about the evidence, for example the occurrence of anomalous results.	
2				
3	**E3.a** (i) recognises how limitations in the investigative techniques and/or strategies for collecting evidence may result in sources of error.		**E3.b** (i) comments on the accuracy of the evidence (observations/data); (ii) suggests reasons for any anomalous results.	
4				
5	**E5.a** (i) indicates the significant limitations of the investigative techniques and/or strategies used; (ii) suggests how procedures / strategies could be improved.		**E5.b** (i) comments on the reliability of the evidence; (ii) evaluates the main sources of error.	
6				
7	**E7.a** (i) justifies proposed improvements to the investigative techniques and/or strategies used in terms of increasing the reliability of the evidence and minimising significant sources of error		**E7.b** (i) assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.	

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Activity 2: Coursework marking exercise

Context:

The students investigated the effect of temperature on the permeability of cell membranes. Consider the annotation of the coursework and the use of the contextualised mark scheme.

The task:

1. Use the annotations on the coursework to complete as much as possible of the mark scheme proforma on pages 97 to 100. It is recommended that you carry out this activity for five minutes, and restrict yourself to considering the planning skill only.

2. Consider the ease and effectiveness of completion of the mark scheme proforma in terms of:

   - The structure and logical layout of the student's work
   - The ease with which the material to which the annotations referred may be found
   - The extent to which careful teaching of the coursework module might improve the structure and logic of the student's work
   - The decision to award 6 marks rather than 7 for Skill P.

3. Use annotations on the coursework to complete the mark scheme proforma for Skills I, A and E. Use the information on the tick list provided (see page 96) to assess the mark for skill I. It is recommended that if you have attended an INSET course, this part of the task to be completed shortly after the course. If you have been unable to attend a course, complete it after tasks 1 and 2.

4. Consider how the hierarchical nature off the coursework assessment has been applied in this case.

Investigating the effect of alcohol concentration on the permeability of the plasma membrane.

Aim:
The aim of this investigation is to determine the effect of alcohol concentration on the permeability of cell membranes. In this investigation the tissue to be used is beetroot due to its availability, cost and coloured pigment anthocyanin.

Introduction:
All living things are surrounded by membranes. These membranes are permeable, so that cells can acquire and exchange substances with the environment by various transport mechanisms e.g. diffusion, active transport, facilitated diffusion etc. Cell membranes are made up of lipids called phospholipids; which belong to the triglyceride group, and other substances e.g. proteins. The structure of a phospholipid consists of a hydrophilic head and two hydrophobic tails. The hydrophobic regions prevent polar molecules and charged particles to pass through the membrane. When phospholipids are spread over water, the polar hydrophilic regions project into the water, whereas the non polar hydrophobic regions project out of the water.

When phospholipids are shaken in water, they can form round stable structures called micelles. The hydrophilic regions project out of the water and the hydrophobic tails point in towards each other. This causes the structure to become spherical. Further more structures called bilayers can form. The bilayer is very thin ≈ 7nm wide. As mentioned earlier the membrane also contains other substances for example proteins, glycoproteins, glycolipids and cholesterol. The model is called the fluid mosaic model.

The proteins in the bilayer can be fixed or motile. They have a range of important functions. They provide a passage for polar molecules/charged molecules to pass through the bilayer i.e. they are called transport proteins. Each of these transport proteins are specific for one type of molecule. So there will be plenty of transport proteins in the membrane, each of which controls the type of material entering or leaving the cell. Some protein molecules in the membrane can act as enzymes, which will catalyse many reactions in the cell. Protein molecules are insoluble in ethanol.

The glycoproteins and glycolipids are protein and lipid ,molecules with short carbohydrate chains attached to them. The help to stabilise the membrane structure. They form H-bonds with water molecules.

Cholesterol molecules have a similar structure to phospholipids. This allows them to fit into the bilayer perfectly. These molecules are important in maintaining the fluidity of membranes. They also help to maintain the membranes mechanical stability. Without cholesterol molecules cells would burst open.

Based on previous knowledge I think that lipids are insoluble in water, but soluble in ethanol (an alcohol). This is the basis of the emulsification test for lipids. So because the membrane is made of phospholipids, glycolipids, cholesterol when ethanol is added to the beetroot tissue the ethanol will begin to dissolve the phospholipids, some glycolipids and cholesterol in the membrane. This will consequently cause the intercellular membranes to break down.

The cholesterol molecules will also dissolve in ethanol so the membranes gradually loose mechanical stability, so the cells break and burst open releasing their contents. In the cells of beetroot tissue a purple pigment is present called anthocyanin. This gives the plant its purple colour. So when the ethanol is increased the membranes will be digested causing anthocyanin to bleed from the cells. This would cause the cytoplasm and other intercellular substances to leak out of the cell. So the cell has become permeable.

So I predict that an increase in ethanol concentration will increase the magnitude of damage done to the plasma membrane. The presence of more ethanol molecules will dissolve lipid

molecules in the plasma membrane and cause anthocyanin to leak out. The damage done to the plasma membrane will be detected as a colour change from light to darker purple. I also predict that dark purple will disappear at high concentrations as the high concentration of ethanol may damage and break down the anthocyanin. Also the solutions at higher ethanol concentrations will be more cloudy. This is due to the increased presence of protein molecules in the solution. Plasma proteins are immiscible in ethanol.

Materials to be used:

Beetroot plant, corkborer with a diameter of 5mm, absolute ethanol (to be diluted with distilled water to obtain various strengths), distilled water, 14 test tubes, test tube rack, 10cm3 pipette and tips, scale to measure out equal pieces of beetroot (graduated in cm and mm), sharp blade, cutting tile, stopwatch, 16 cuvettes (to ensure 3 repeats of each concentration), spectrometer (to be used as a colourimeter), spatula and pen.

Preliminary work:

This was carried out to find a suitable time to expose the beetroot to the ethanol.

I had set up 7 test tubes. One of which was a control so had 0% ethanol and 10 cm3 of distilled water. The control was to be used when obtaining numerical values from the colourimeter. With the remaining 6 test tube I set up two groups of 3 test tubes. In each group, the first test tube had 20% ethanol and 80% distilled water, the second had 60%:40%, the third 80%:20%. All of these tests were made up to a volume of 10cm3. In one group the beetroot (0.5cm) were exposed to the various ethanol concentrations for 15 minutes, the other for 20 minutes.

Preliminary results:

	Absorbance (units) at 540nm	
Ethanol concentration (%)	15 minutes	20 minutes
20	0.046	0.05
60	0.102	0.21
80	0.094	0.25

It was shown that the group which the beetroot was exposed to the ethanol for 20 minutes produced a darker colour. When readings were taken using the colourimeter the readings were higher as more light was absorbed by the substances. The test tubes from the other group which were exposed for 15 minutes had a lighter colour. The absorbance readings were low, as less light is absorbed by the solutions. The reason for the darker colour in the test tubes for 20 minutes was the fact the ethanol had more time to leave the tissue.

Based on preliminary work, it has been decided that the beetroots are going to be exposed to the ethanol for 20 minutes. This gives plenty of time for the ethanol to break the membranes down and the pigments to be released.

In my preliminary work I tested 3 different ethanol concentrations: low, medium and high. In my investigation I will investigate those concentrations and others in between them:

a) 20% ethanol
b) 40% ethanol
c) 60% ethanol
d) 80 % ethanol
e) 90% ethanol
f) 100% ethanol

Each of which will be made up to 10 cm^3 final volume.

The test tubes which were timed for 20 minutes, with 60% ethanol were looking cloudy. This may be because the ethanol had broken down all the lipids in the cell membranes but the proteins were insoluble in ethanol and made the solution go cloudy. This fact can be used to determine the ethanol concentrations to be used. So a range of readings could be investigated which cover the readings where this occurs least to where it has a large effect on the solution. As mentioned earlier I think a point will come where the ethanol will begin breaking down the pigment and the readings will fall.

So I have chosen the range of readings which will reflect when the pigment is broken down by high ethanol concentrations, and when the solutions begin to go cloudy due to the presence of proteins.

Method:

Take a tile, and place a beetroot on it. Then with the corkborer of diameter of 5mm extract some of the beetroot material. Then with a blade and a ruler (graduated in cm and mm) measure and cut 7 pieces of beetroot each of 0.5 cm. The pieces are 0.5cm pieces so the ethanol has a larger surface area to work on. This makes the investigation more effective. After this place the 6 test tubes in a test tube rack and label them appropriately. Then using a 10cm3 pipette and tip measure the amount of ethanol and distilled water to be added in each test tube using a different tip for each solution (all solutions will have been left at room temperature for an hour before to allow them to acclimatise).

Then pour some distilled water into a beaker and put the beetroot pieces in it. This will wash off the anthocyanin which bleed when the material was extracted from the beetroot organ using the corkborer and cut using the blade. Using a spatula get the pieces out of the beaker and put one in each test tube. Then start the stop watch and time for 20 minutes. At 3 minute intervals roll the test tubes vertically in your hands 4 times, to mix the solutions with the beetroot more. At the end of 20 mins stop the stopwatch, pour the solutions into 7 other test tubes (making sure the beetroot is not transferred, so use a spatula). Then transfer all the solutions through a filter from each of the test tubes into cuvettes. Place the central cuvette in the colourimeter and then add the other tubes and balance the colourimeter with the control cuvette. The control cuvette reading will be calibrated to zero at all times.

In this investigation I will be using a spectrometer (i.e. colourimeter) which measures the amount of absorbance. The colourimeter will allow me to obtain numerical readings and precise readings. Then using the numerical data I will be able to plot a graph and interpret the readings and the experiment as a whole.

To increase the reliability and accuracy of my investigation I will repeat each reading three times and calculate an average. There were anomalous readings in my preliminary work. If this occurs while carrying out the experiment the reading would be ignored.

A corkborer with a diameter of 5mm will be used to extract the beetroot and also ensures the pieces are the same size. The beetroot pieces will be cut into 7 pieces of 0.5cm. This provides a larger surface area for the ethanol to act on and break down the plasma membrane.

Variables:

The size of the beetroot i.e. 5.0mm will be the same in all test tubes
The amount of solution will be the same in each test tube i.e. 10.0 cm^3
I will be changing the concentration of ethanol by varying the amount of distilled water, but keeping the same end volume.
The solutions will all be acclimatised a room temperature as not enough water baths are available.

Safety:

Take care when using the blade
DO not inhale and avoid contact and spillage of the ethanol
Wear eye protection at all times

Results:

Ethanol concentration (% of 10.0 cm^3)	Absorbance (540 nm)		
	1	2	3
20	0.039	**0.042**	0.040
40	**0.058**	0.054	0.055
60	**0.129**	0.126	0.127
80	**0.182**	0.189	0.190
90	0.156	0.160	0.155
100	0.074	**0.068**	0.075

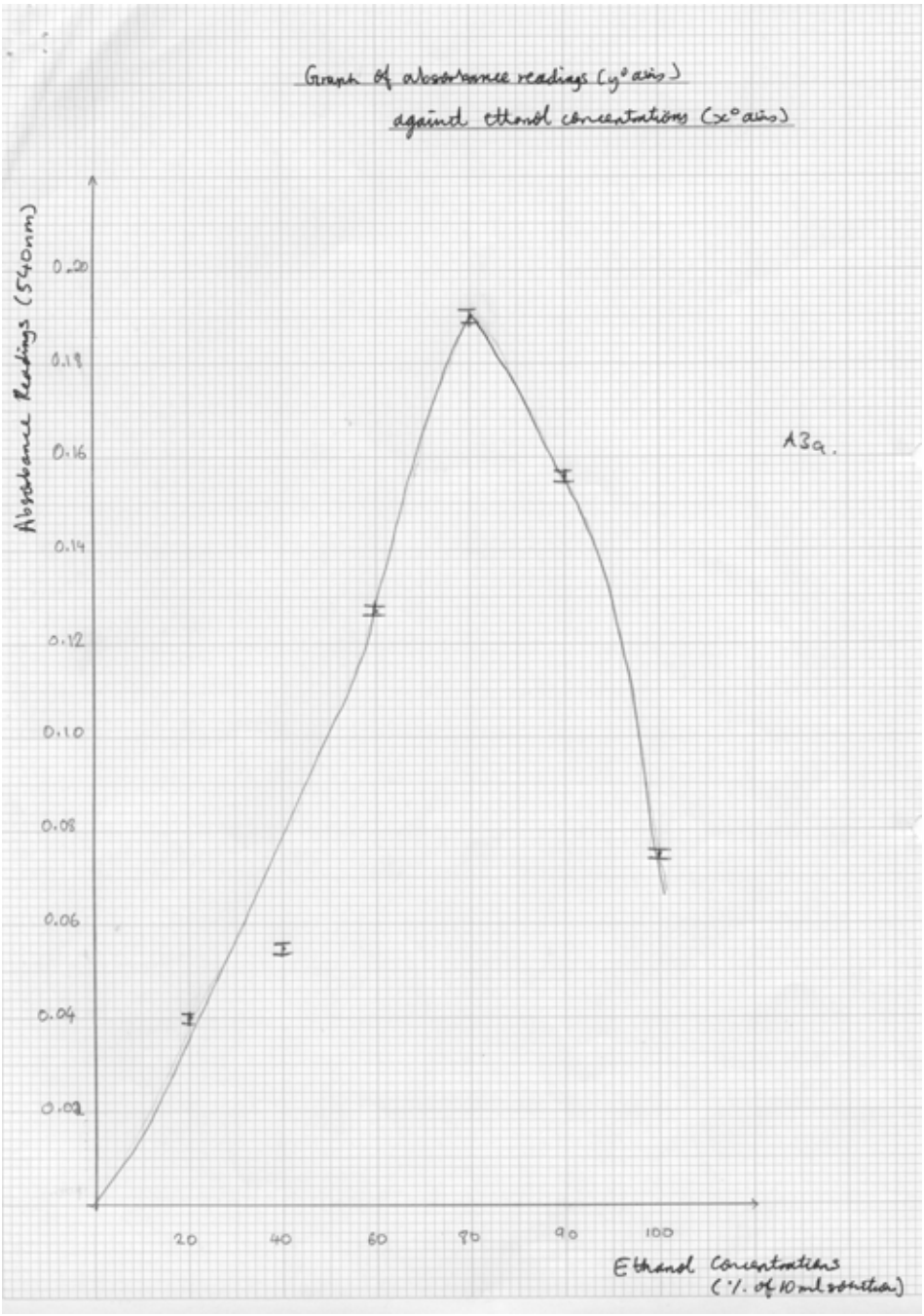
Bold indicates the reading was not used when calculating the average as it was not concordant with the other readings.

Calculated results:

Ethanol concentration (% of 10.0 cm^3)	Absorbance (540 nm)	Standard Error
20	0.040	0.001
40	0.055	0.001
60	0.0127	0.001
80	0.190	0.001
90	0.156	0.001
100	0.075	0.001

Using the data I plotted a graph of absorbance against ethanol concentration. The absorbance readings show that from 20% ethanol up to and including 80% ethanol the absorbance increased i.e. permeability increased. After this the pattern changed. The absorbance readings of 90 and 100% ethanol decreased.

Using the SE error bars were drawn on each of the plotted points. All the error bars drawn on the graph were +/- 0.001. This shows that all the errors in my investigation are very low, so my results are reliable and accurate. All my error bars were of the same size, this shows that all my results were concordant. This again shows the reliability and accuracy of the results. The absorbance readings were accurate to three decimal places, and the SE were also accurate to three decimal places. This is because the scale on my graph would permit this.



Conclusions:

My results support my prediction. An increase in ethanol concentration did damage the plasma membrane of beetroot cells, so causing the anthocyanin, cytoplasm and intercellular substances to leak out of the cells. This caused an increase in the absorbance readings. An increase in ethanol dissolved more of the lipids in the plasma membrane. When readings were taken using the colourimeter the readings increased, because the solutions got darker and therefore more light was absorbed by the solution. This pattern of absorbance readings changed after 80% ethanol. As mentioned in the hypothesis, this was because most of the lipids in the membrane would have been broken down by the ethanol, and cause the solution to go cloudy.
So as the ethanol increases from 80% the solution gets more cloudy as more proteins are present in the solution.

The high ethanol concentrations could have damaged the beetroot pigment, anthocyanin. This along with the increased presence of protein molecules causes the solutions to get more cloudy and less purple. This is because when the solutions are put into the colourimeter less light is absorbed by the solution.

Evaluation:

The method I used in this investigation gave the expected results and graph. The absorbance readings for the various ethanol concentrations support my original hypothesis. My results show that an increase in ethanol concentration will increase the magnitude of damage done to the plasma membrane. This caused an increased amount of anthocyanin (the beetroot pigment) to leak out of the beetroot cells therefore increasing the absorbance readings. My results show that this was the only pattern of absorbance readings from 20% to 80% ethanol. They also show that this trend changes as the absorbance readings decreased after 8-% ethanol. The pattern changed because the high ethanol concentrations damaged the beetroot cells. These are immiscible in ethanol, so an increased presence of these proteins occurs as ethanol concentration increases. When these solutions were placed in the colourimeter the absorbance readings fell because the solutions are more cloudy, less purple and so less light was absorbed.

I went up in steps of 20% ethanol at the start but then 10%. This was so that I could accurately tell when the absorbance readings began to fall. So it can be said that the range of readings I used in my investigation were a good choice. In my investigation the absorbance readings decreased after 80% ethanol.
In my results there are no anomalous readings. All my readings were concordant i.e. within 0.001 units. Readings were taken 3 times, the non-concordat reading was removed when calculating the average.

My readings are accurate and reliable. This is because I had minimal errors and carried out my method in a reliable manner. I attained a set of concordant results. All the error bars are 0.001 so this means that errors are low. A set of concordant results were attained as I carried out my investigation well.

The pieces of beetroot were kept small (0.5cm) so that the maximum surface area was available for the ethanol to work on. Before putting the beetroot pieces into the ethanol concentrations they were rinsed in distilled water. This was to wash off any pigment which had leaked out when the piece was cut. Also the tubes were shaken at three minute intervals. This caused an even distribution of pigment in the liquid.

A control used was very accurate, it had the same volume of distilled water and a 0.5 piece of beetroot. This was used to obtain the readings from the colourimeter. So even the slightest deviation in colour will be detected by the colourimeter. The above points helped in attaining a good set of results which were concordant as calculated the errors were all very low.

My results are reliable and accurate, so the final conclusions were able to be drawn (see conclusion). But there is a significant uncertainty in the evidence in terms of the above. Perhaps the ethanol only had an effect in dissolving some of the lipids in the plasma membrane. This causes damage in the membrane therefore making it more permeable. But if some of the ethanol can not dissolve some of the lipids in the membrane this statement is not true, so there is uncertainty in the results. Also ethanol may not have the same effect on all plasma membranes.
So as for improvements it is justified to say that other alcohols like methanol could be used instead of ethanol to see what effect they have on permeability of membranes. Also more non-polar substances may be used to see what effect they have on the permeability of membranes. They may have an effect on the proteins in the membranes. They may have an effect on the proteins in the membranes which are not affected by ethanol. So the solutions may be less cloudy, then it could be seen what absorbance readings would be like. Will more light be absorbed by the solution or less? This would determine whether the absorbance readings are high or low. If they are high, then plasma membranes are more permeable. Also different tissue may be used to see if ethanol has the same effect on all membranes.

Suggested proforma for assessing Skill I

Experiment title: Effect of Alcohol on permeability

Date: Another day in 2003

	Competence in simple techniques	Works safely/ethically	Records observations	Competence	Systematic/clear & accurate	Competent & Confident	Safe/ethical throughout	Observes accurately	Records appropriately	Skilful & proficient	Detail & precision	Records with detail and precision
Descriptors	**1ai**	**1aii**	**1b**	**3a**	**3b**	**5ai**	**5aii**	**5bi**	**5bii**	**7a**	**7bi**	**7bii**
Candidates Candidate 'activity 2'	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Skill P – Planning for AS Coursework **Total 8**

The candidate:

Mark	General strategy	Level	Choices within plan	Level
0				
1	**P1.a** (i) develops a question or problem in simple terms and plans an appropriate investigation; (ii) makes a prediction where relevant.		**P1.b** (i) chooses investigative techniques.	
2				
3	**P3.a** (i) develops a question or problem using scientific knowledge and understanding; (ii) identifies the key factors to vary, control or take account of.		**P3.b** (i) decides on a suitable number and range of evidence (observations/data) needed for the investigation.	
4				
5	**P5.a** (i) uses detailed scientific knowledge and understanding to justify any prediction made; (ii) uses information from preliminary work or a secondary source to plan an appropriate strategy to collect evidence; (iii) takes into account the need for safe and/or ethical working practices.		**P5.b** (i) describes a strategy to collect evidence, including choice of investigative techniques, which takes into account the need to produce precise and reliable evidence; (ii) produces a clear account and uses specialist vocabulary appropriately.	
6				
7	**P7.a** (i) retrieves and evaluates information from a variety of sources; (ii) uses information to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding; (iii) uses spelling, punctuation and grammar accurately.		**P7.b** (i) justifies the strategy developed, including the choice of investigative techniques, in terms of the need for precision and reliability.	
8	8 marks should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill I - Implementing for AS Coursework Total 7

The candidate:

Mark	Manipulation	Level	Recording	Level
0				
1	**I1.a** (i) demonstrates competence in the use of simple investigative techniques (ii) shows an awareness of the need for safe and/or ethical working practices.		**I1.b** (i) makes and records evidence (observations/data) that is adequate for the investigation.	
2				
3	**I3.a** (i) demonstrates competence in the use of familiar investigative techniques.		**I3.b** (i) collects evidence accurately; records evidence clearly and accurately.	
4				
5	**I5.a** (i) demonstrates competence and confidence in the use of investigative techniques; (ii) adopts safe and/or ethical working practices throughout.		**I5.b** (i) collects evidence accurately; (ii) records evidence in an appropriate format.	
6				
7	**I7.a** (i) demonstrates skilful and proficient use of all investigative techniques.		**I7.b** (i) collects sufficient evidence to meet all the requirements of the investigation; (ii) records evidence in appropriate detail and justifies the degree of precision to which evidence is recorded.	

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill A - Analysing Evidence and Drawing Conclusions for AS Coursework

Total 8

The candidate:

Mark	Processing evidence	Level	Drawing conclusions	Level
0				
1	**A1.a** (i) carries out some simple processing of the evidence collected, such as the use of bar charts or histograms, or the calculation of means.		**A1.b** (i) identifies trends or patterns in the evidence and draws simple conclusions.	
2				
3	**A3.a** (i) processes and presents evidence gathered using appropriate graphical and/or numerical techniques.		**A3.b** (i) inks conclusions drawn from processed evidence with the associated scientific knowledge and understanding.	
4				
5	**A5.a** (i) carries out detailed processing of evidence and analysis including the use of advanced numerical techniques such as, where appropriate, statistics, the plotting of intercepts or the calculation of gradients, or the use of error bars.		**A5.b** (i) draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding (ii) produces a clear account which uses specialist vocabulary appropriately.	
6				
7	**A7.a** (i) where appropriate, uses detailed scientific knowledge and understanding to make deductions from the processed evidence; (ii) shows due regard to nomenclature, terminology and the use of significant figures (where relevant).		**A7.b** (i) draws conclusions which are well structured, appropriate, comprehensive, and concise and which are coherently linked to underlying scientific knowledge and understanding; (ii) uses spelling, punctuation and grammar accurately.	
8	8 marks should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill E - Evaluating Evidence and Procedures for AS Coursework Total 7

The candidate:

Mark	Procedures	Level	Sources of error	Level
0				
1	**E1.a** (i) makes relevant comments on the suitability of the investigative techniques used.		**E1.b** (i) makes a relevant comment about the evidence, for example the occurrence of anomalous results.	
2				
3	**E3.a** (i) recognises how limitations in the investigative techniques and/or strategies for collecting evidence may result in sources of error.		**E3.b** (i) comments on the accuracy of the evidence (observations/data); (ii) suggests reasons for any anomalous results.	
4				
5	**E5.a** (i) indicates the significant limitations of the investigative techniques and/or strategies used; (ii) suggests how procedures / strategies could be improved.		**E5.b** (i) comments on the reliability of the evidence; (ii) evaluates the main sources of error.	
6				
7	**E7.a** (i) justifies proposed improvements to the investigative techniques and/or strategies used in terms of increasing the reliability of the evidence and minimising significant sources of error		**E7.b** (i) assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.	

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Activity 3: Candidate Training exercise

Context:

The candidates investigated the effect of temperature on the permeability of cell membranes. Consider the annotation of the coursework and the use of the contextualised mark scheme.

The Task:

1. Complete as much as possible of the mark scheme proforma on pages 113 to 116. It is recommended that you carry out this activity for **ten to fifteen** minutes, and restrict yourself to considering the **planning** skill only.

2. Consider the ease and effectiveness of completion of the mark scheme proforma in terms of:

    - The structure and logical layout of the student's work
    - The extent to which subheadings, tables and lists might improve the structure and logic of the student's work

3. Complete as much as possible of the mark scheme proforma for Skills I, A and E. Use the information on the tick list provided (see page 112) to assess the mark for skill I.

4. Consider version 2 of the same investigation and try to locate the areas which would enable the student to gain credit for the sub-descriptors of all 4 skills. Consider the extent the same piece of work was easier to follow and mark with the use of the headings and tables.

5. Consulting the mark scheme proforma draw up a list in logical order of subheadings which could be used for an investigation report.

Version 1

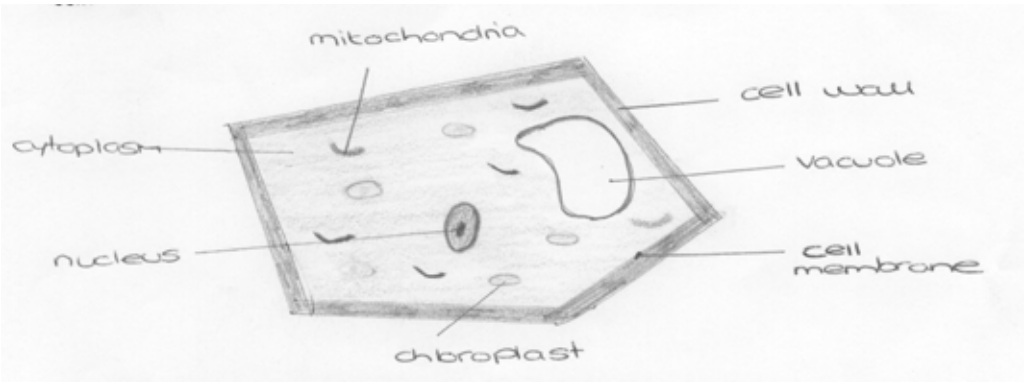
What effect does temperature have on cell membrane permeability.

Aim:

The aim of the experiment is to investigate the effects of temperature on the cell membrane of a plant cell.

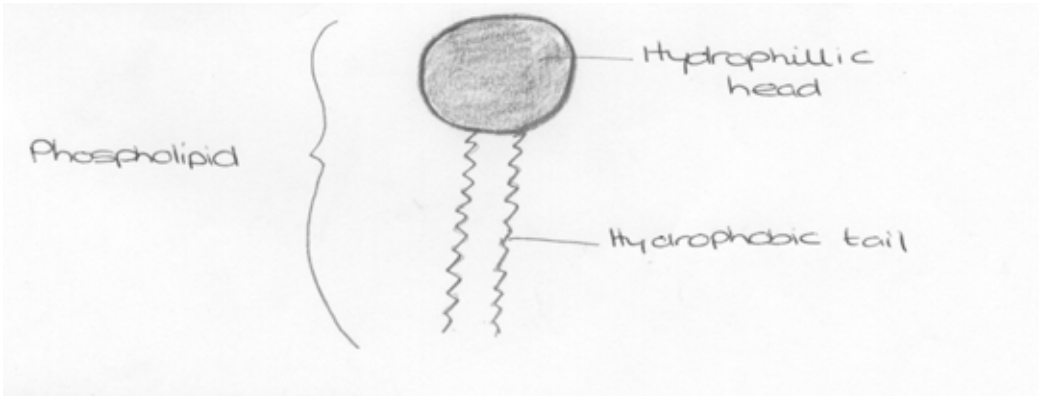
Introduction:

The cell membrane is a functional organelle. The membrane controls the exchange of material between the cell and its environment. The membrane is an extremely thin layer which is 8 to 10 nanometers thick. It is partially permeable, meaning it allows only some molecules into the cell. In our investigation we will find out what effect temperature has on the permeability of the cell membrane. Temperature may have a significant effect on the substances within the membrane, allowing it to become more permeable and therefore allow more substances in and out of the cell. Where is the cell membrane located?

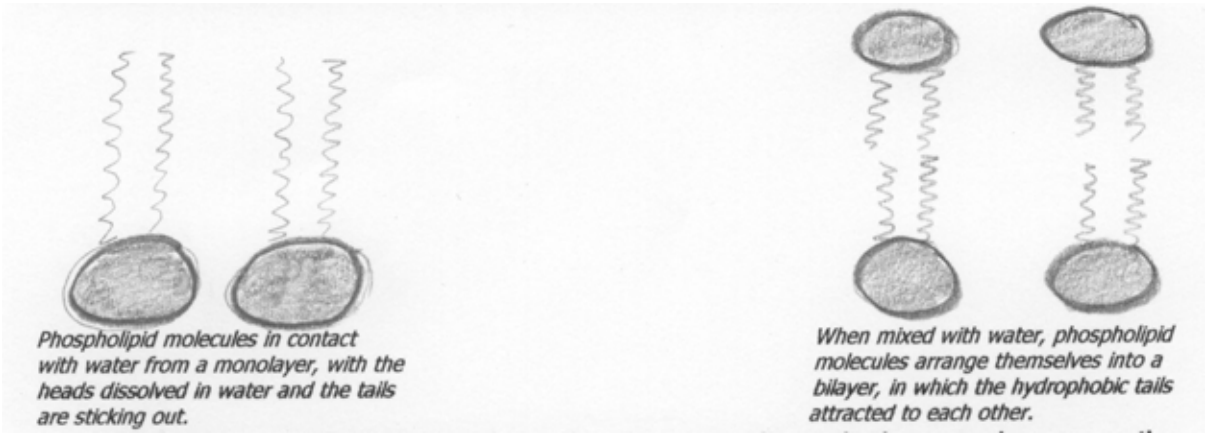


As the diagram shows, the cell membrane surrounds the contents of the cell i.e. the protoplasm. In our investigation we will be able to conclude the effect temperature has on the structure of the cell membrane.

The cell membrane is made up of two chemical groups, proteins and phospholipids.



Phospholipids have hydrophilic heads and hydrophobic tails, therefore if these molecules are placed over the surface of water they would form a single layer with their heads pointing inwards and their tails projecting outwards. A tightly packed bilayer of phospholipids makes up the structure of a membrane.

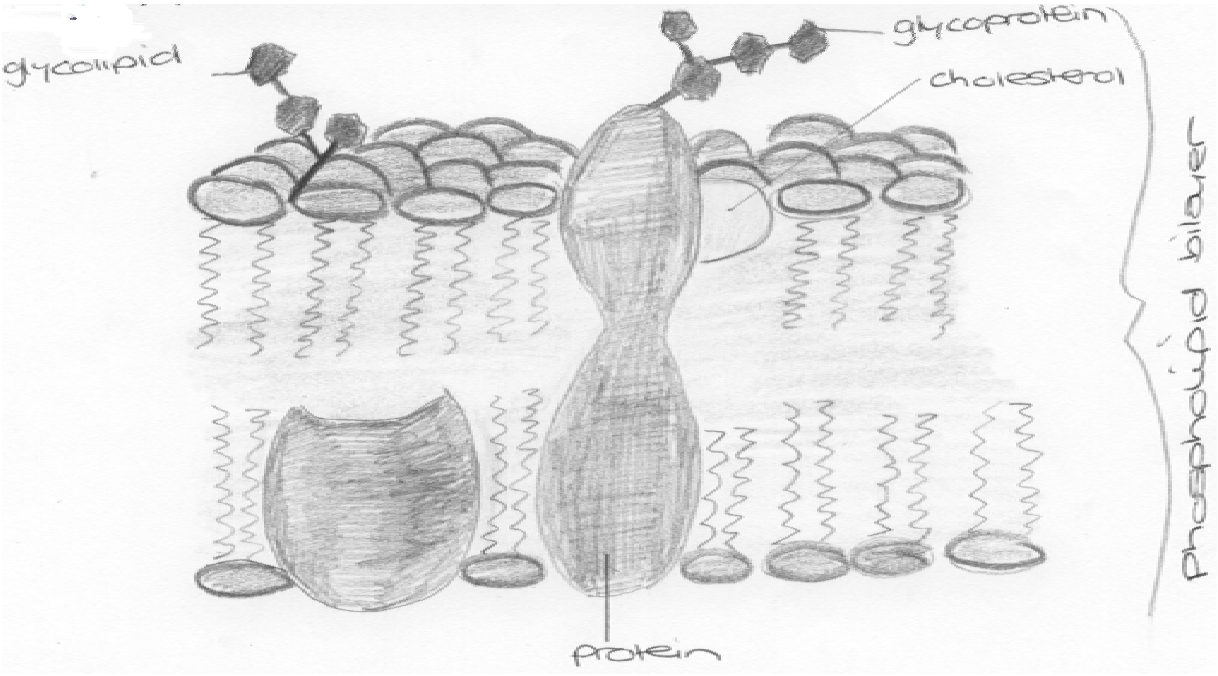


Phospholipid molecules in contact with water from a monolayer, with the heads dissolved in water and the tails are sticking out.

When mixed with water, phospholipid molecules arrange themselves into a bilayer, in which the hydrophobic tails attracted to each other.

Therefore small lipid-soluble molecules pass through the membrane easily because they dissolve as they pass through the phospholipids bilayer. I know that lipids are fats, and they compose the bilk of membrane mass. From my knowledge of fats, I think that temperature will cause the phospholipids to become more spaced out and the membrane will become more fluid. This loss in structure will mean larger molecules will be able to pass through the membrane.

Membranes also contain proteins, which vary in size. These proteins are channel proteins, carrier proteins and recognition proteins. Some proteins are present on the surface of the phospholipids layer, whilst others extend onto it. Channel proteins allow large molecules to pass through the membrane, carrier proteins carry molecules into the cytoplasm and recognition proteins help in cell recognition and cell interaction. A protein becomes denatured when its tertiary structure is altered. High temperature is a factor which can lead to a change in shape/denaturation. The denatured protein will change shape and therefore affect its properties. Proteins and phospholipids move around within their layer, therefore the structure of a cell membrane is called the fluid mosaic model.



Many proteins act as transport proteins, providing hydrophilic channels for ions and polar molecules. Other proteins act as enzymes, or assist active transport of the molecules across the membrane. The proteins within the membrane interact with the lipids and keep the cell membrane stable. However, when temperature is raised, these interactions between lipids and proteins may fall apart.

The phospholipid bilayer acts as a barrier against the movement of molecules. Some exchange in necessary, and diffusion, osmosis and active transport make this possible. Diffusion is the movement of molecules from a region of high concentration to an area of low concentration. Factors which may affect the rate of diffusion are surface area, the difference in concentration on either side of the membrane, the presence of pores within the membrane and the width of the membrane. Due to the characteristics of the phospholipids and proteins within the membrane, when the temperature is increased the membrane will begin to break down and become unstable, therefore the membrane will become more permeable.

Prediction:

I predict that an increase in temperature will damage and denature the cell membrane of the cell. I know that at high temperatures proteins will become denatured, this happens when its tertiary structure changes. This alters the shape and function of the molecule and at too high temperatures the protein is unable to perform its normal job. Proteins are very unstable over a range of temperatures. I predict that the lipids within the membrane will melt at high temperatures, therefore the membrane loses structure. The permeability of the bilipid layer increased due to the gaps appearing in the membrane. These gaps will appear when the temperature is increased because one of the phospholipid legs, the unsaturated ones get a kink in it and sticks out. The legs also vibrate a lot due to the increase in energy, caused by an increase in temperature. The legs will therefore slip between each other. The effect of this forces holes in the membrane. This results in larger molecules being able to pass through the membrane (more permeable). As the temperature increases the proteins and lipids interact to hold the structure of the membrane. Therefore, surely when the lipids melt and the proteins become denatured, the membrane will fall apart and at the same time the permeability of the membrane increase. Considering this information and scientific knowledge, I believe that the higher the temperature surrounding the cell is and increased amount of the cell membrane will be damaged and therefore more holes will appear in the membrane. This will be concluded by how much contents of the cell will leak out. The more leakage , the more holes in the membrane are present, therefore the more permeable the cell membrane is.

Plan:

In order for us to obtain accurate results, I have decided to use the cells from a beetroot to plan this experiment. Beetroot contains a substance called anthocyanin. It is a substance which makes the beetroot a deep purple colour. Beetroot is suitable to use in this experiment because if the cell in a beetroot is damaged and the membrane has broken, the anthocyanin leaks out of the cell. This allows me to collect the leakage and use it in my experiment to give us some accurate results. The anthocyanin is found in the vacuoles in cells. My results will show the effect of temperature on the cell membranes on the basis that the more pigment released out of the cell, the more membrane has ben broken down.

As the variable in this experiment is temperature, the procedure includes [lacing pieces of beetroot into water baths at the required temperature and then using a colourimeter to measure the colour change. This will tell me how the temperature effects the cell and I will be able to compare the effects of different temperatures on the cell membrane.

Method:

1. I took a beetroot, I used a beetroot because it contains a useful purple substance called anthocyanin. I used a cork borer to cut a cylinder of beetroot out, the borer allows you to get a piece of beetroot with the same diameter and surface area. I then used a ruler to measure seven pieces of beetroot 1 cm long so they are all the same size. I cut the beetroot using a clean razor blade so that I did not contaminate it.
2. When the beetroot is cut some of the cell membranes are damaged and the anthocyanin begins to leak out. I washed each piece of beetroot individually in distilled water, in order to keep the experiment fair.
3. I then heated a water bath to 80^0C, which is the highest temperature that I used in the experiment, and placed a thermometer in it. I placed the piece of beetroot into test tube with $10cm^3$ water and put it into the water bath at the required temperature. I left the test tube in the water bath for a required length of time (which I worked out in the preliminary work in order to get a suitable time).
4. I then removed the piece of beetroot from the test tube. I shook the test tube gently to get a spread of colour.
5. I analysed the colour of the fluid in the test tube using a colourimeter. I compared this against the control which is the test tube containing distilled water.
6. I then recorded my results an repeated my experiment at the other temperatures (20, 30, 40 , 50, 60 and 70^0C).
7. I repeated this twice in order to gain a mean reading of colour at each temperature.

Preliminary work:

I am doing preliminary work in order to find out the length of time the beetroot should be left in the water bath for. This preliminary will hopefully give me a suitable time to leave the beetroot for, so that I can collect reliable results. To do this I am going to carry out the following method:

1. I took a beetroot, I used a beetroot because it contains a useful purple substance called anthocyanin. I used a cork borer to cut a cylinder of beetroot out, the borer allows you to get a piece of beetroot with the same diameter and surface area. I then used a ruler to measure seven pieces of beetroot 1 cm long so they are all the same size. I cut the beetroot using a clean razor blade so that I did not contaminate it
2. When the beetroot is cut some of the cell membranes are damaged and the anthocyanin begins to leak out. I washed each piece of beetroot individually in distilled water, in order to keep the experiment fair.
3. I heated up two water baths of 20 and 400C.
4. I put a piece of beetroot into each test tube along with 10cm3 of distilled water. I placed five test tubes in each water bath, along with a test tube containing distilled water (the control).
5. I left one test tube in each water bath for one minute.
6. I then removed the piece of beetroot and shook the tube to get a spread of colour.
7. I then repeated this experiment for 5, 10, 15, 20 and 30 minutes.
8. I analysed the colour of the fluid in a colourimeter. The colours which are darkest are the ones which are successful and the corresponding times will be the ones used in the main experiment.

Results from preliminary work:

Time (min)	Absorbance units	
	Temp 20^0C	Temp 40^0C
1	0.021	0.058
5	0.043	0.146
10	**0.048**	**0.305**
20	0.082	0.320
30	0.037	0.327

Looking at these preliminary results the time which would produce the most accurate results would be 10 minutes. Therefore I am going to leave each piece of beetroot in the water bath for 10 minutes, as this result appears to be satisfactory and the experiment will not take too much time.

Safety:

When carrying out the practical work safety aspects have to be taken into account. In this experiment I will wear safety goggles at all times, this is because I will have a Bunsen burner on, and at high temperatures liquids could spit out of the test tubes into my eyes. I will also use forceps when removing the beetroot from the hot test tubes, and tubes from the beakers. This will prevent me from burning my hands. I will take extra care when cutting the beetroot not to cut myself.

Bibliography:

'Biology'; Mary and Geoff Jones

Advanced Biology Principles & Applications Study Guide; Clegg & McKean

Results:

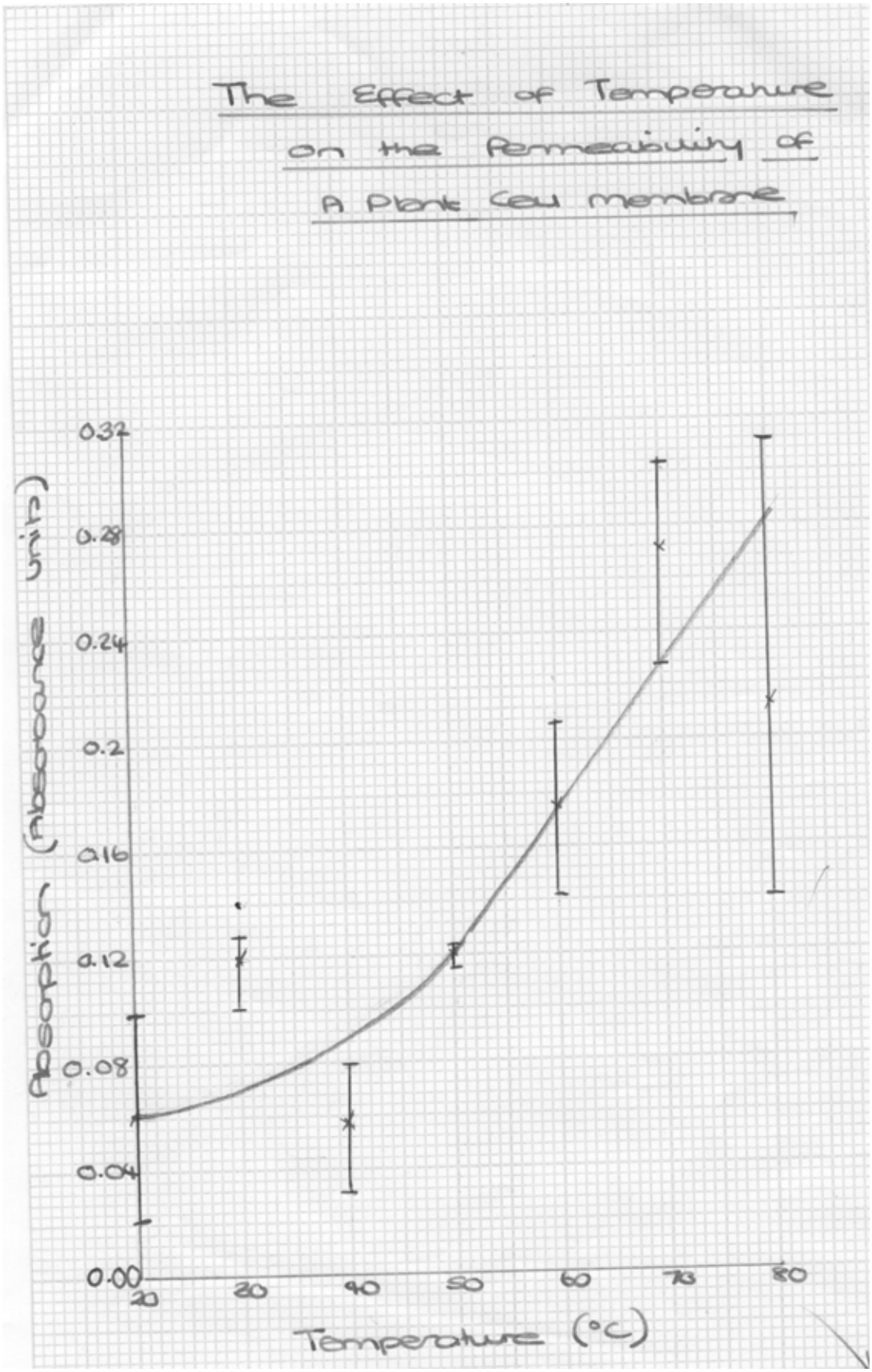
As I repeated each experiment twice, I recorded the two readings and took a mean reading. There were however results which I considered to be anomalous due to the fact that these readings were too low or too high. I have identified these readings by writing them in **bold** if they are too high and *italics* if they are too low.

Temperature	Absorbance reading 1	Absorbance reading 2	Mean Absorbance reading
20	0.088	*0.033*	0.0605
30	0.13	0.106	0.1185
40	*0.072*	*0.04*	0.056
50	0.121	0.118	0.1195
60	0.152	0.199	0.1755
70	0.24	**0.3**	0.2705
80	*0.174*	0.29	0.232

I then calculated the error boundaries in the above results and recorded them. The italic result indicates the result with the smallest error boundary and the bold indicates the result with the largest error boundary.

Temperature	Top error absorbance units	Bottom error absorbance units
20	0.099	0.022
30	0.128	0.112
40	0.079	0.032
50	*0.123*	*0.114*
60	0.208	0.141
70	0.305	0.227
80	**0.312**	**0.141**

I plotted the mean results for the absorbance readings and the error boundaries onto a suitable graph. I then plotted a suitable best fit line. This graph helps me to identify any patterns and analyse the results.


The Effect of Temperature on the Permeability of A Plant Cell membrane
Absorption (Absorbance Units)
0.32
0.28
0.24
0.2
0.16
0.12
0.08
0.04
0.00
20
30
40
50
60
70
80
Temperature (°C)

Analysis:

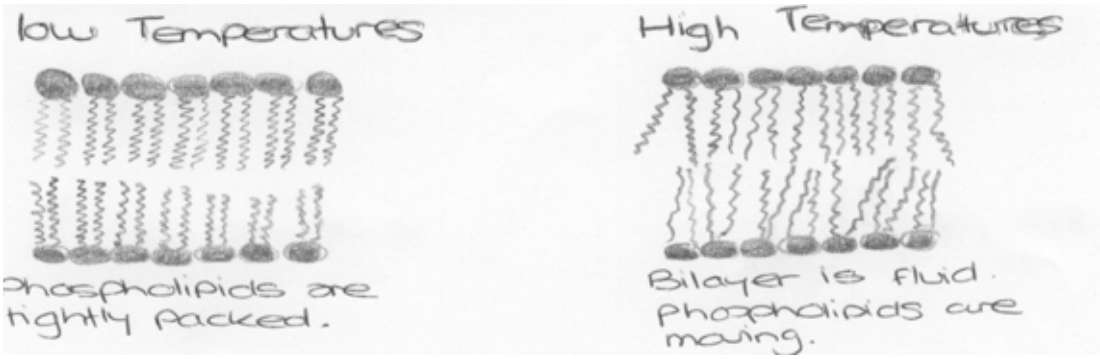
From the results I collected it is clear that temperature does have a significant effect on the permeability of a plant cell membrane. This was suggested by the shape of the graph, which showed a definite increase in the absorbance rates as the temperature increased.

When I plotted my graph, I appropriately plotted a line of best fit. This showed a definite pattern in the results, the higher the temperature, the higher the absorbance units. However, there were results plotted either side of the best line of fit, some of these results were thought to be higher than expected and others lower. This showed that there was quite a high degree of error in my experiment, we plotted these errors onto the graph. We found the standard error in my results by using a calculator. On the graph you are able to see the magnitude of these errors. It appears that at higher temperatures (60, 70n and 80^0C), the standard error was significantly larger than at the lower temperatures. On my graph there was also quite large differences in the absorbance readings between the two temperatures of 70 and 80^0C, this could possibly suggest that when the cell membrane reaches a certain temperature (in this case 70^0C), the substances stop leaking out of the cell so quickly. The explanation for this could be that the proteins within the cell have begun to denature, and blocked the pores in the cell membrane. This would prevent as much anthocyanin releasing from the cell. There were some patterns in the results, which were definitely notable. The absorbance reading for 30^0C was almost double that of 20^0C. The difference between readings for these temperatures was 0.056 AU. The difference between 50 and 60^0C was 0.058 AU. These values are both very close, suggesting a possible steady increase every 10^0C. Therefore, this pattern could suggest that a certain amount of cell membrane has been broken down every 10^0C, releasing a similar amount each time. There were results that I believe to be anomalous. I believe them to be anomalous because the AU appeared too high or too low, which consequently altered the mean causing it to be inaccurate and inconclusive. The anomalous results were evident when they were plotted on the graph as they were not close to the best fit line. The anomalies were result 2 for 20^0C and result 1 for 80^0C. If we ignored these anomalies the results appeared quite accurate and supported the initial prediction.

I have come to the conclusion that an increase in the temperature causes the phospholipid bilayer to become more fluid due to the 'melting' of the lipids and the cell membrane becomes denatured and damaged. The increase in temperature has a significant effect on the structure of the cell membrane, it becomes more unstable as proteins do not respond well to increasing temperatures. The permeability of the phospholipid bilayer increases when heated because the high temperatures cause gaps to appear in the membrane. This is due to the phospholipid's 'legs' developing a kink at high temperatures and the legs begin to vibrate more rapidly. These factors force holes into the membrane, and therefore larger molecules are able to pass through it. It is the proteins in the cell membrane which become denatured as higher temperatures. The proteins becomes denatured when their tertiary structure is altered. It is the high temperatures which cause the bonds holding the tertiary structure to break. Therefore the shape of the protein is changed and so is its properties. The proteins become unstable and because they are denatured they do not function properly. The interaction of proteins and lipids breaks up as temperature is raised. These changes in the phospholipids and proteins within the membrane causes the cell membrane to fall apart and become dysfunctional. The membrane is no longer stable and there is no semi-rigid structure packed tightly together like there is in a membrane at optimum temperatures. This increase in temperature produces large gaps in the cell membrane resulting in an increase in the amount of anthocyanin leaking out as the permeability increases. However, when the proteins denature they begin to block the gaps in the membranes and so leakage of anthocyanin begins to slow.

When we looked at our results, they do support the conclusion. Generally, the higher the temperature the larger the AU were. We can conclude that the more substances leaked out of the cell, the higher the temperatures. Obviously the results were not perfect, and errors found. In my prediction I stated that as temperature increases so will the absorbance units. This proved true apart from the result for 80^0C, as this was quite a bit lower than what was expected. This could be due to the proteins denaturing and then blocking the gaps in the membrane. This would explain the rapid decrease in the amount of anthocyanin released.

My interpretation of the results does show that my evidence does support my original prediction, as there is a definite pattern in the results and a positive correlation on the graph. I am able to make a concise analysis of the results I received from my experiment.



Evaluation:

When looking at the scientific evidence which supports my results and the general pattern of results which I gathered from my investigation, I can conclude that my method was reliable and produced satisfactory results.

However, when I look more closely at this particular set of results, in this experiment it can be said that the results 'could have been better' , as there were anomalies and quite considerable standard errors were calculated for some values. The anomalies were result 2 for 20^0C and result 1 for 80^0C. If we ignored these anomalies the results appeared quite accurate and supported the initial prediction. The mean absorbance reading for 30^0C appeared slightly too high, the reading for 40 ^{0}C appeared too low.

Obviously the colourimeters readings were accurate as there was nothing wrong with the machine. The errors must therefore have been caused by other factors. Although I tried to keep errors to a minimal. Controlling the variables was very difficult. I found it particularly awkward to maintain the temperature of the water bath as I was using a Bunsen burner, and sometimes I noticed the water bath was too high and I had to adjust it myself. This could have had an effect on the cell membrane, and caused these anomalies. If I did this experiment again then I would definitely use an electrical water bath which I could set at the given temperature. Another factor on the results was the size of the beetroot and using the corkborer, but there could easily have a small difference in the surface area and the length of the piece of the beetroot. One of the largest sources of error would be that I wouldn't extract all of the beetroot pigment at each temperature. Therefore this could possibly explain some of the readings which I considered to be lower than expected.

I would consider extending the experiment by taking readings for higher temperatures to see if the absorbance readings did decrease after 80 ^{0}C. On my graph the absorbance reading for 80^0C was significantly lower than that for 70^0C, and it would be interesting to see if absorbance readings did decrease after this temperature. Then, rather than the graph appearing as a straight line graph it would be more like a parabola.

I would like to repeat the experiment at 5^0C intervals so that there were more results on the graph. This would give me a more true shape of the graph, as on this graph I plotted a best fit line in my opinion. Also if I took a reading every 5^0C I would be able to analyse my results more accurately and draw a more valuable conclusion as I would have more results. I would like to repeat the experiment three times at each temperature instead of two. I would then ignore any anomalies when taking a mean result. I found in this experiment, my results would have been considered more accurate if I had ignored any anomalies. I am able to say that the control in the experiment was very accurate. I used distilled water, which is the clearest possible liquid. Therefore even the slightest deviation in colour could be detected by the colourimeter. I also found, using a beetroot was successful and gave us some accurate results which can be related to the theory behind cell membranes.

It would also be worthwhile considering using a variety of plant roots in order to extend the investigation, as a beetroot is not a good representation of all plant cells. I could also investigate the effect of temperature on animal cells e.g. blood cells.

There are different ways in which we could extend this investigation. We could carry out the same method at lower temperatures and higher temperatures. We would then be able to make a suitable conclusion to whether the higher temperature the higher the absorbance reading.

However I believe my method worked well and gave me overall, a set of competent results which I could analyse and evaluate. There were improvements which could be made next time to give me more accurate results if necessary. The were also suitable extensions which could be made, to make the experiment more complex.

Suggested proforma for assessing Skill I

Experiment title: Effect of Temp on Permeability

Date: Yet another day in 2003

	Competence in simple techniques	Works safely/ethically	Records observations	Competence	Systematic/clear & accurate	Competent & Confident	Safe/ethical throughout	Observes accurately	Records appropriately	Skilful & proficient	Detail & precision	Records with detail and precision
Descriptors	**1ai**	**1aii**	**1b**	**3a**	**3b**	**5ai**	**5aii**	**5bi**	**5bii**	**7a**	**7bi**	**7bii**
Candidates Candidate 'activity 3'	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X

Skill P – Planning for AS Coursework **Total 8**

The candidate:

Mark	General strategy	Level	Choices within plan	Level
0				
1	**P1.a** (i) develops a question or problem in simple terms and plans an appropriate investigation; (ii) makes a prediction where relevant.		**P1.b** (i) chooses investigative techniques.	
2				
3	**P3.a** (i) develops a question or problem using scientific knowledge and understanding; (ii) identifies the key factors to vary, control or take account of.		**P3.b** (ii) decides on a suitable number and range of evidence (observations/data) needed for the investigation.	
4				
5	**P5.a** (i) uses detailed scientific knowledge and understanding to justify any prediction made; (ii) uses information from preliminary work or a secondary source to plan an appropriate strategy to collect evidence; (*see page 13 'Bibliography)* (iii) takes into account the need for safe and/or ethical working practices.		**P5.b** (i) describes a strategy to collect evidence, including choice of investigative techniques, which takes into account the need to produce precise and reliable evidence; (ii) produces a clear account and uses specialist vocabulary appropriately.	
6				
7	**P7.a** (i) retrieves and evaluates information from a variety of sources; (*see page 13 'Bibliography)* (ii) uses information to develop a strategy which is well structured, logical and linked coherently to underlying scientific knowledge and understanding; (iii) uses spelling, punctuation and grammar accurately.		**P7.b** (i) justifies the strategy developed, including the choice of investigative techniques, in terms of the need for precision and reliability.	
8	8 marks should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill I - Implementing for AS Coursework Total 7

The candidate:

Mark	Manipulation	Level	Recording	Level
0				
1	**I1.a** (i) demonstrates competence in the use of simple investigative techniques (ii) shows an awareness of the need for safe and/or ethical working practices.		**I1.b** (i) makes and records evidence (observations/data) that is adequate for the investigation.	
2				
3	**I3.a** (i) demonstrates competence in the use of familiar investigative techniques.		**I3.b** (i) collects evidence accurately; records evidence clearly and accurately.	
4				
5	**I5.a** (i) demonstrates competence and confidence in the use of investigative techniques; (ii) adopts safe and/or ethical working practices throughout.		**I5.b** (i) collects evidence accurately; (ii) records evidence in an appropriate format.	
6				
7	**I7.a** (i) demonstrates skilful and proficient use of all investigative techniques.		**I7.b** (i) collects sufficient evidence to meet all the requirements of the investigation; (ii) records evidence in appropriate detail and justifies the degree of precision to which evidence is recorded.	

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

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Skill A - Analysing Evidence and Drawing Conclusions for AS Coursework Total 8

The candidate:

Mark	Processing evidence	Level	Drawing conclusions	Level
0				
1	**A1.a** (i) carries out some simple processing of the evidence collected, such as the use of bar charts or histograms, or the calculation of means.		**A1.b** (i) identifies trends or patterns in the evidence and draws simple conclusions.	
2				
3	**A3.a** (i) processes and presents evidence gathered using appropriate graphical and/or numerical techniques.		**A3.b** (i) links conclusions drawn from processed evidence with the associated scientific knowledge and understanding.	
4				
5	**A5.a** (i) carries out detailed processing of evidence and analysis including the use of advanced numerical techniques such as, where appropriate, statistics, the plotting of intercepts or the calculation of gradients, or the use of error bars.		**A5.b** (i) draws conclusions which are consistent with the processed evidence and links these with detailed scientific knowledge and understanding (ii) produces a clear account which uses specialist vocabulary appropriately.	
6				
7	**A7.a** (i) where appropriate, uses detailed scientific knowledge and understanding to make deductions from the processed evidence; (ii) shows due regard to nomenclature, terminology and the use of significant figures (where relevant).		**A7.b** (i) draws conclusions which are well structured, appropriate, comprehensive, and concise and which are coherently linked to underlying scientific knowledge and understanding; (ii) uses spelling, punctuation and grammar accurately.	
8	8 marks should be awarded if the work meets all the requirements for 7 marks and is judged to be of exceptional merit in terms of its originality, depth, flair or in the use of novel or innovative techniques.			

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded.

Skill E - Evaluating Evidence and Procedures for AS Coursework Total 7

The candidate:

Mark	Procedures	Level	Sources of error	Level
0				
1	**E1.a** (i) makes relevant comments on the suitability of the investigative techniques used.		**E1.b** (i) makes a relevant comment about the evidence, for example the occurrence of anomalous results.	
2				
3	**E3.a** (i) recognises how limitations in the investigative techniques and/or strategies for collecting evidence may result in sources of error.		**E3.b** (i) comments on the accuracy of the evidence (observations/data); (ii) suggests reasons for any anomalous results.	
4				
5	**E5.a** (i) indicates the significant limitations of the investigative techniques and/or strategies used; (ii) suggests how procedures / strategies could be improved.		**E5.b** (i) comments on the reliability of the evidence; (ii) evaluates the main sources of error.	
6				
7	**E7.a** (i) justifies proposed improvements to the investigative techniques and/or strategies used in terms of increasing the reliability of the evidence and minimising significant sources of error		**E7.b** (i) assesses the significance of the uncertainties in the evidence in terms of their effect on the validity of the final conclusions drawn.	

Both statements at a defined level must be fully satisfied in order that the mark for this level is awarded

Version 2:

This investigation has now been modified by the use of lists, tables and diagrams to aid the layout and structure of the work. These are both important in the awarding of the higher levels. Changes that have been made are indicated by lines in the right hand margin and boxes indicate the change that has been made. No additional work has been added to this report but information has been drawn out and rearranged to improve the coherence of the report.

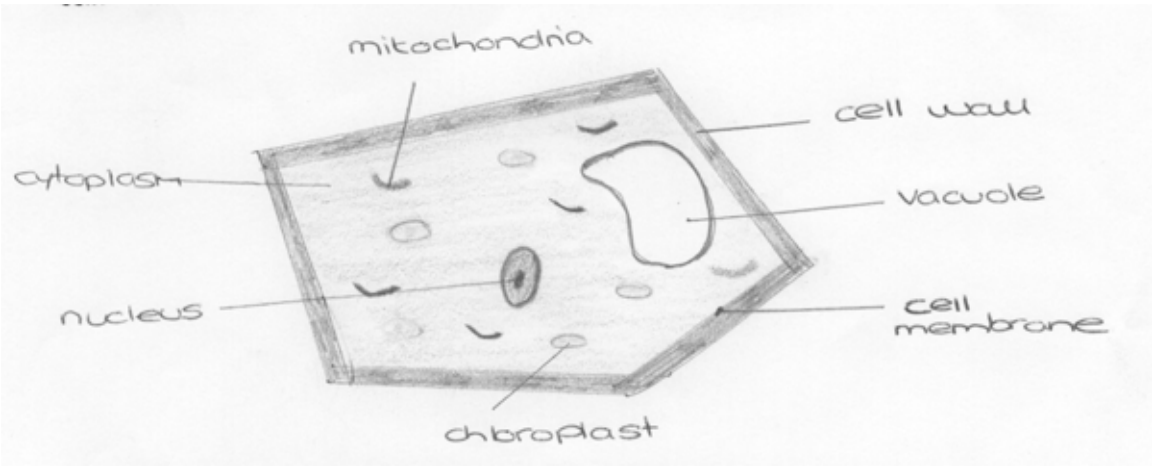
What effect does temperature have on cell membrane permeability

Aim:

The aim of the experiment is to investigate the effects of temperature on the cell membrane of a plant cell.

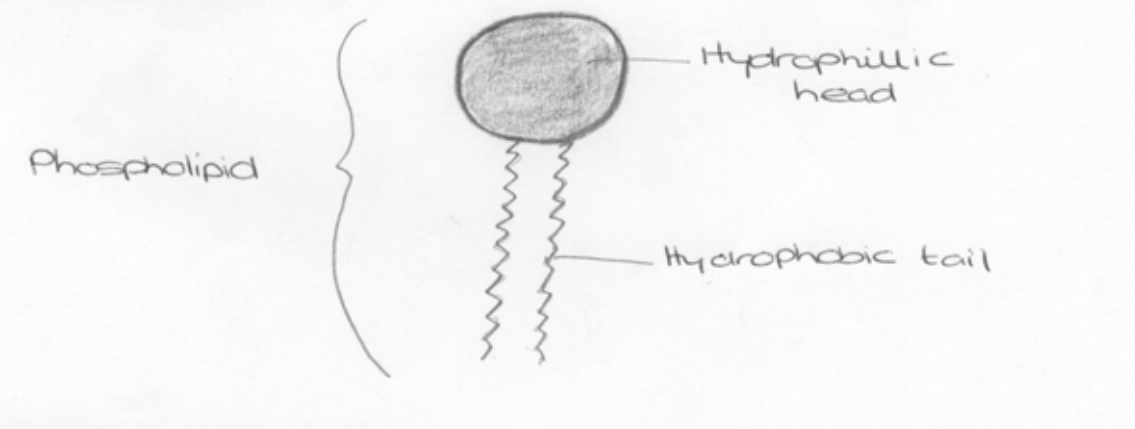
Introduction:

The cell membrane is a functional organelle. The membrane controls the exchange of material between the cell and its environment. The membrane is an extremely thin layer which is 8 to 10 nanometers thick[1]. It is partially permeable, meaning it allows only some molecules into the cell. In our investigation we will find out what effect temperature has on the permeability of the cell membrane. Temperature may have a significant effect on the substances within the membrane, allowing it to become more permeable and therefore allow more substances in and out of the cell. Where is the cell membrane located?



As the diagram shows, the cell membrane surrounds the contents of the cell i.e. the protoplasm. In our investigation we will be able to conclude the effect temperature has on the structure of the cell membrane.

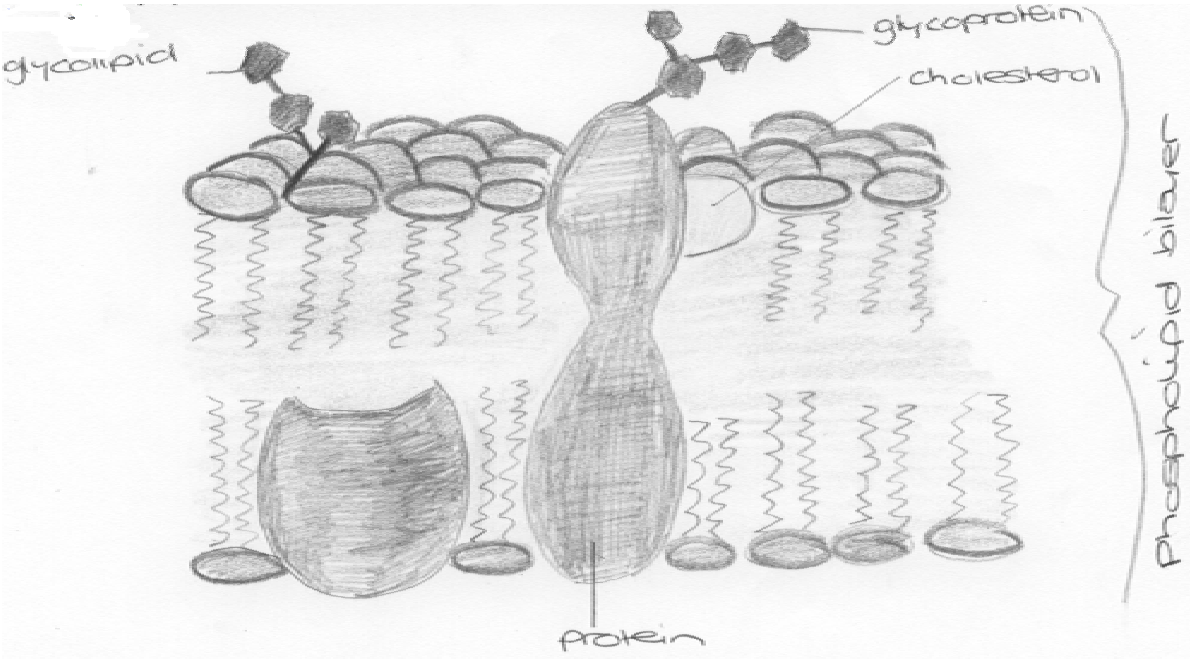
The cell membrane is made up of two chemical groups, proteins and phospholipids.



Phospholipids have hydrophilic heads and hydrophobic tails, therefore if these molecules are placed over the surface of water they would form a single layer with their heads pointing inwards and their tails projecting outwards. A tightly packed bilayer of phospholipids makes up the structure of a membrane[1].

Therefore small lipid-soluble molecules pass through the membrane easily because they dissolve as they pass through the phospholipids bilayer. I know that lipids are fats, and they compose the bilk of membrane mass. From my knowledge of fats, I think that temperature will cause the phospholipids to become more spaced out and the membrane will become more fluid. This loss in structure will mean larger molecules will be able to pass through the membrane[1].

Membranes also contain proteins, which vary in size. These proteins are channel proteins, carrier proteins and recognition proteins. Some proteins are present on the surface of the phospholipids layer, whilst others extend onto it. Channel proteins allow large molecules to pass through the membrane, carrier proteins carry molecules into the cytoplasm and recognition proteins help in cell recognition and cell interaction[2]. A protein becomes denatured when its tertiary structure is altered[1]. High temperature is a factor which can lead to a change in shape/denaturation. The denatured protein will change shape and therefore affect its properties. Proteins and phospholipids move around within their layer, therefore the structure of a cell membrane is called the fluid mosaic model[1,2].



Many proteins act as transport proteins, providing hydrophilic channels for ions and polar molecules. Other proteins act as enzymes, or assist active transport of the molecules across the membrane. The proteins within the membrane interact with the lipids and keep the cell membrane stable[1]. However, when temperature is raised, these interactions between lipids and proteins may fall apart.

The phospholipid bilayer acts as a barrier against the movement of molecules[1]. Some exchange in necessary, and diffusion, osmosis and active transport make this possible. Diffusion is the movement of molecules from a region of high concentration to an area of low concentration[2]. Factors which may affect the rate of diffusion are surface area, the difference in concentration on either side of the membrane, the presence of pores within the membrane and the width of the membrane. Due to the characteristics of the phospholipids and proteins within the membrane, when the temperature is increased the membrane will begin to break down and become unstable, therefore the membrane will become more permeable.

Prediction:

I predict that an increase in temperature will damage and denature the cell membrane of the cell. I know that at high temperatures proteins will become denatured, this happens when its tertiary structure changes[1]. This alters the shape and function of the molecule and at too high temperatures the protein is unable to perform its normal job. Proteins are very unstable over a range of temperatures. I predict that the lipids within the membrane will melt at high temperatures, therefore the membrane loses structure. The permeability of the bilipid layer increased due to the gaps appearing in the membrane. These gaps will appear when the temperature is increased because one of the phospholipid legs, the unsaturated ones get a kink in it and sticks out. The legs also vibrate a lot due to the increase in energy, caused by an increase in temperature[2]. The legs will therefore slip between each other. The effect of this forces holes in the membrane. This results in larger molecules being able to pass through the membrane (more permeable). As the temperature increases the proteins and lipids interact to hold the structure of the membrane. Therefore, surely when the lipids melt and the proteins become denatured, the membrane will fall apart and at the same time the permeability of the membrane increase[1]. Considering this information and scientific knowledge, I believe that the higher the temperature surrounding the cell is and increased amount of the cell membrane will be damaged and therefore more holes will appear in the membrane. This will be concluded by how much contents of the cell will leak out. The more leakage , the more holes in the membrane are present, therefore the more permeable the cell membrane is.

Cited references

Plan:

In order for us to obtain accurate results, I have decided to use the cells from a beetroot to plan this experiment. Beetroot contains a substance called anthocyanin. It is a substance which makes the beetroot a deep purple colour. Beetroot is suitable to use in this experiment because if the cell in a beetroot is damaged and the membrane has broken, the anthocyanin leaks out of the cell. This allows me to collect the leakage and use it in my experiment to give us some accurate results. The anthocyanin is found in the vacuoles in cells. My results will show the effect of temperature on the cell membranes on the basis that the more pigment released out of the cell, the more membrane has been broken down.

As the variable in this experiment is temperature, the procedure includes placing pieces of beetroot into water baths at the required temperature and then using a colourimeter to measure the colour change. This will tell me how the temperature effects the cell and I will be able to compare the effects of different temperatures on the cell membrane.

Preliminary work:

order

1. I am doing preliminary work in order to find out the length of time the beetroot should be left in the water bath for. This preliminary will hopefully give me a suitable time to leave the beetroot for, so that I can collect reliable results. To do this I am going to carry out the following method:
2. I took a beetroot, I used a beetroot because it contains a useful purple substance called anthocyanin. I used a cork borer to cut a cylinder of beetroot out, the borer allows you to get a piece of beetroot with the same diameter and surface area. I then used a ruler to measure seven pieces of beetroot 1 cm long so they are all the same size. I cut the beetroot using a clean razor blade so that I did not contaminate it
3. When the beetroot is cut some of the cell membranes are damaged and the anthocyanin begins to leak out. I washed each piece of beetroot individually in distilled water, in order to keep the experiment fair.
4. I heated up two water baths of 20 and 40^0C.
5. I put a piece of beetroot into each test tube along with $10cm^3$ of distilled water. I placed five test tubes in each water bath, along with a test tube containing distilled water (the control).
6. I left one test tube in each water bath for one minute.
7. I then removed the piece of beetroot and shook the tube to get a spread of colour.
8. I then repeated this experiment for 5, 10, 15, 20 and 30 minutes.
9. I analysed the colour of the fluid in a colourimeter. The colours which are darkest are the ones which are successful and the corresponding times will be the ones used in the main experiment.

Results from preliminary work:

table

Time (min)	Absorbance units	
	Temp 20^0C	Temp 40^0C
1	0.021	0.058
5	0.043	0.146
10	0.048	0.305
20	0.082	0.320
30	0.037	0.327

Conclusion form preliminary work:

Looking at these preliminary results the time which would produce the most accurate results would be 10 minutes. Therefore I am going to leave each piece of beetroot in the water bath for 10 minutes, as this result appears to be satisfactory and the experiment will not take too much time.

Main Investigation apparatus:

table

Apparatus	Reason for choice
Beetroot	Source of plant cells – used as the cells contain coloured pigment (anthocyanin)
Cork borer	To obtain sample of tissue with constant diameter and surface area
Ruler	To accurately measure length of beetroot samples
Water bath	Set at defined temperature (20 to 80^0C in 10^0C intervals). Regulates the one independent variable
Scalpel	To cut sections of beetroot samples
Safety goggles	For eye protection
Distilled water	To rinse beetroot when cut; to immerse beetroot when in the water bath to collect any released anthocyanin; to calibrate colourimeter (control)

Main investigation variables:

table

Variable	
Independent	Temperature
Dependent	Absorbance units (anthocyanin released)
Controlled	Type of plant cell, Surface area, length of cylinder, time of incubation, pH

Main investigation safety:

When carrying out the practical work safety aspects have to be taken into account. In this experiment I will wear safety goggles at all times, this is because I will have a Bunsen burner on, and at high temperatures liquids could spit out of the test tubes into my eyes. I will also use forceps when removing the beetroot from the hot test tubes, and tubes from the beakers. This will prevent me from burning my hands. I will take extra care when cutting the beetroot not to cut myself.

title

Main investigation method:

1. I took a beetroot, I used a beetroot because it contains a useful purple substance called anthocyanin. I used a cork borer to cut a cylinder of beetroot out, *the borer allows you to get a piece of beetroot with the same diameter and surface area*. I then used a ruler to measure seven pieces of beetroot *1 cm long so they are all the same size*. I cut the beetroot using a clean razor blade so that I did not contaminate it.

2. When the beetroot is cut some of the cell membranes are damaged and the anthocyanin begins to leak out. *I washed each piece of beetroot individually in distilled water, in order to keep the experiment fair.*

3. I then heated a water bath to 80^0C, which is the highest temperature that I used in the experiment, and placed a thermometer in it. I placed the piece of beetroot into test tube with 10cm^3 water and put it into the water bath at the required temperature. *I left the test tube in the water bath for a required length of time* (which I worked out in the preliminary work in order to get a suitable time).

4. I then removed the piece of beetroot from the test tube. I shook the test tube gently to get a spread of colour.

5. I analysed the colour of the fluid in the test tube using a colourimeter. *I compared this against the control which is the test tube containing distilled water.*

6. I then recorded my results an repeated my experiment at the other temperatures (*20, 30, 40 , 50, 60 and 70^{0}C).*

7. I repeated this *twice in order to gain a mean* reading of colour at each temperature.

Precision and reliability: *(these points are already stated and implied (see points highlighted in italics in the method but this section makes it more obvious to the marker and moderator!)*

Clarification of precision & reliability

1. Cut each section of beetroot to 10mm
2. Rinse the cut section in distilled water
3. Zero the colourimeter with a distilled water 'blank'
4. Incubate each beetroot section for 10 minutes in the water bath
5. Carry out the investigation at 5 temperatures (to enable a reliable graph of results to be plotted)
6. Repeat each temperature 3 times to calculate an average absorbance

Bibliography:

1. Mary and Geoff Jones; 2000; Biology; Cambridge University Press (0-521-48473-1)

2. Clegg & McKean; 1998; Advanced Biology Principles and Applications Study Guide; John Murray (0-7195-5358-X)

Results:

As I repeated each experiment twice, I recorded the two readings and took a mean reading. There were however results which I considered to be anomalous due to the fact that these readings were too low or too high. I have identified these readings by writing them in **bold** if they are too high and *italics* if they are too low.

title

Table to show raw data of absorbance units from beetroot tissue incubated at various temperatures for ten minutes

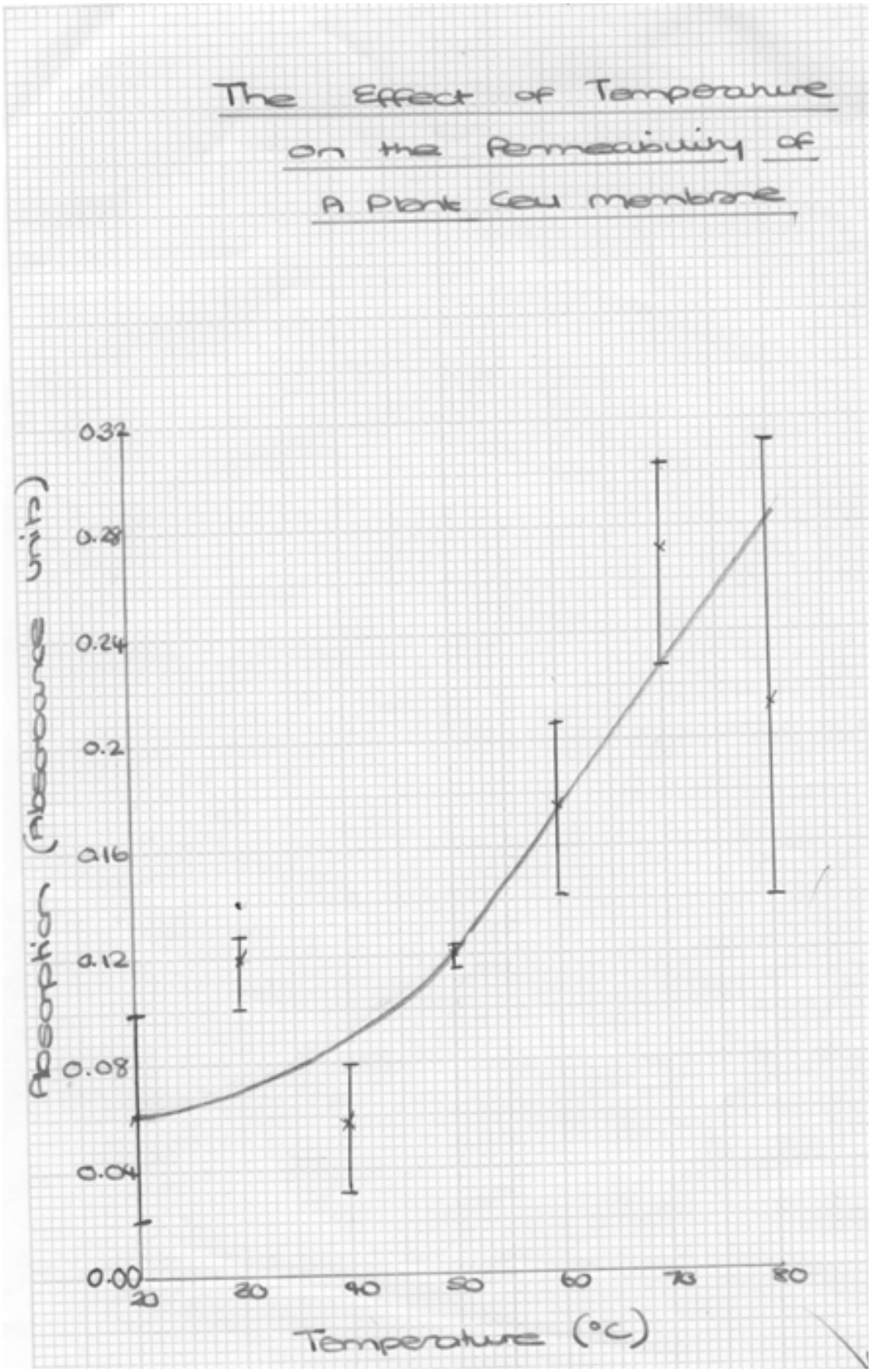
Temperature (^{0}C)	Absorbance reading 1	Absorbance reading 2	Mean Absorbance reading
20	0.088	*0.033*	0.0605
30	0.131	0.106	0.1185
40	*0.072*	*0.040*	0.056
50	0.121	0.118	0.1195
60	0.152	0.199	0.1755
70	0.240	**0.300**	0.2705
80	*0.174*	0.290	0.232

I then calculated the error boundaries in the above results and recorded them. The italic result indicates the result with the smallest error boundary and the bold indicates the result with the largest error boundary.

Table to show error ranges for absorbance units from beetroot tissue incubated at various temperatures for ten minutes

Temperature ^{0}C	Top error absorbance units	Bottom error absorbance units
20	0.099	0.022
30	0.128	0.112
40	0.079	0.032
50	*0.123*	*0.114*
60	0.208	0.141
70	0.305	0.227
80	**0.312**	**0.141**

I plotted the mean results for the absorbance readings and the error boundaries onto a suitable graph. I then plotted a suitable best fit line. This graph helps me to identify any patterns and analyse the results.


The Effect of Temperature on the Permeability of A Plant Cell membrane
Absorption (Absorbance Units)
0.32
0.28
0.24
0.2
0.16
0.12
0.08
0.04
0.00
20
30
40
50
60
70
80
Temperature (°C)

Analysis:

From the results I collected it is clear that temperature does have a significant effect on the permeability of a plant cell membrane. This was suggested by the shape of the graph, which showed a definite increase in the absorbance rates as the temperature increased.

When I plotted my graph, I appropriately plotted a line of best fit. This showed a definite pattern in the results:

Trends clearly stated and comments on anomalies replaced in the evaluation section

g) the higher the temperature, the higher the absorbance units. However, there were results plotted either side of the best line of fit, some of these results were thought to be higher than expected and others lower.

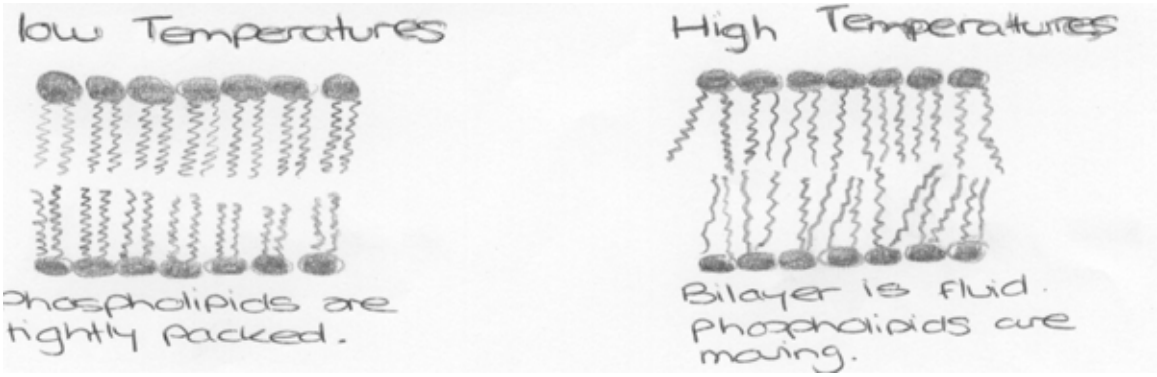
The explanation for this could be that the proteins within the cell have begun to denature, and blocked the pores in the cell membrane. This would prevent as much anthocyanin releasing from the cell.

h) The absorbance reading for 30^0C was almost double that of 20^0C. The difference between readings for these temperatures was 0.056 AU. The difference between 50 and 60^0C was 0.058 AU. These values are both very close, suggesting a possible steady increase every 10^0C. Therefore, this pattern could suggest that a certain amount of cell membrane has been broken down every 10^0C, releasing a similar amount each time.

I have come to the conclusion that an increase in the temperature causes the phospholipid bilayer to become more fluid due to the 'melting' of the lipids and the cell membrane becomes denatured and damaged. The increase in temperature has a significant effect on the structure of the cell membrane, it becomes more unstable as proteins do not respond well to increasing temperatures. The permeability of the phospholipid bilayer increases when heated because the high temperatures cause gaps to appear in the membrane. This is due to the phospholipid's 'legs' developing a kink at high temperatures and the legs begin to vibrate more rapidly. These factors force holes into the membrane, and therefore larger molecules are able to pass through it. It is the proteins in the cell membrane which become denatured as higher temperatures. The proteins becomes denatured when their tertiary structure is altered. It is the high temperatures which cause the bonds holding the tertiary structure to break. Therefore the shape of the protein is changed and so is its properties. The proteins become unstable and because they are denatured they do not function properly. The interaction of proteins and lipids breaks up as temperature is raised. These changes in the phospholipids and proteins within the membrane causes the cell membrane to fall apart and become dysfunctional. The membrane is no longer stable and there is no semi-rigid structure packed tightly together like there is in a membrane at optimum temperatures. This increase in temperature produces large gaps in the cell membrane resulting in an increase in the amount of anthocyanin leaking out as the permeability increases. However, when the proteins denature they begin to block the gaps in the membranes and so leakage of anthocyanin begins to slow.

When we looked at our results, they do support the conclusion. Generally, the higher the temperature the larger the AU were. We can conclude that the more substances leaked out of the cell, the higher the temperatures. Obviously the results were not perfect, and errors found. In my prediction I stated that as temperature increases so will the absorbance units. This proved true apart from the result for 80^0C, as this was quite a bit lower than what was expected. This could be due to the proteins denaturing and then blocking the gaps in the membrane. This would explain the rapid decrease in the amount of anthocyanin released.

My interpretation of the results does show that my evidence does support my original prediction, as there is a definite pattern in the results and a positive correlation on the graph. I am able to make a concise analysis of the results I received from my experiment.



Evaluation:

When looking at the scientific evidence which supports my results and the general pattern of results which I gathered from my investigation, I can conclude that my method was reliable and produced satisfactory results.

Anomalous results:

However, when I look more closely at this particular set of results, in this experiment it can be said that the results 'could have been better', as there were anomalies and quite considerable standard errors were calculated for some values. The anomalies were result 2 for 20^0C and result 1 for 80^0C. If we ignored these anomalies the results appeared quite accurate and supported the initial prediction. The mean absorbance reading for 30^0C appeared slightly too high, the reading for 40 ^{0}C appeared too low.

Clear titles

Reasons for anomalous results:

Obviously the colourimeter's readings were accurate as there was nothing wrong with the machine. The errors must therefore have been caused by other factors. Although I tried to keep errors to a minimal. Controlling the variables was very difficult. I found it particularly awkward to maintain the temperature of the water bath as I was using a Bunsen burner, and sometimes I noticed the water bath was too high and I had to adjust it myself. This could have had an effect on the cell membrane, and caused these anomalies. If I did this experiment again then I would definitely use an electrical water bath which I could set at the given temperature. Another factor on the results was the size of the beetroot and using the corkborer, but there could easily have a small difference in the surface area and the length of the piece of the beetroot. One of the largest sources of error would be that I wouldn't extract all of the beetroot pigment at each temperature. Therefore this could possibly explain some of the readings which I considered to be lower than expected.

Sources of error/Limitations in method:

a. Different sizes of beetroot samples – due to misuse of cork borer or inaccurate cutting with the scalpel

b. Different times in the water bath - tissue may not have reached correct temperature; higher temperatures may not have been reached as the tissue will take longer to acclimatise to this temperature

Clear titles

c. Difficult to maintain water bath temperature – manual adjustment was imprecise

Accuracy of data/results: *(This section was not clearly stated by the candidate in version 1 and may prevent the work reaching above a level 2)*

Improvements: *(This could further be amended to be completed as a table giving: improvement; justification of improvement (how it will improve accuracy, reliability or validity)*

I would consider extending the experiment by taking readings for higher temperatures to see if the absorbance readings did decrease after 80 ^{0}C. On my graph the absorbance reading for 80^{0}C was significantly lower than that for 70^{0}C, and it would be interesting to see if absorbance readings did decrease after this temperature. Then, rather than the graph appearing as a straight line graph it would be more like a parabola.

I would like to repeat the experiment at 5^{0}C intervals so that there were more results on the graph. This would give me a more true shape of the graph, as on this graph I plotted a best fit line in my opinion. Also if I took a reading every 5^{0}C I would be able to analyse my results more accurately and draw a more valuable conclusion as I would have more results. I would like to repeat the experiment three times at each temperature instead of two. I would then ignore any anomalies when taking a mean result. I found in this experiment, my results would have been considered more accurate if I had ignored any anomalies. I am able to say that the control in the experiment was very accurate. I used distilled water, which is the clearest possible liquid. Therefore even the slightest deviation in colour could be detected by the colourimeter. I also found, using a beetroot was successful and gave us some accurate results which can be related to the theory behind cell membranes.

It would also be worthwhile considering using a variety of plant roots in order to extend the investigation, as a beetroot is not a good representation of all plant cells. I could also investigate the effect of temperature on animal cells e.g. blood cells.

There are different ways in which we could extend this investigation. We could carry out the same method at lower temperatures and higher temperatures. We would then be able to make a suitable conclusion to whether the higher temperature the higher the absorbance reading.

Validity of the conclusion:

However I believe my method worked well and gave me overall, a set of competent results which I could analyse and evaluate. There were improvements which could be made next time to give me more accurate results if necessary. The were also suitable extensions which could be made, to make the experiment more complex.

Commentaries on coursework activities:

Activity 1:

The effect of substrate concentration on the rate of reaction of catalase:

Clear annotation in the margin showed where the descriptors and sub-descriptors had been met/partially achieved. The annotation used was in accordance with the suggested format on page 20 of this handbook.

Skill P:

Descriptor	Comment	Met?
P1ai	The candidate has developed an appropriate question which can be investigated.	✓
P1aii	The prediction is relevant to the question.	✓
P1b	The technique (oxygen production & manometer) is appropriate.	✓
P3ai	Scientific Knowledge & Understanding (SKU) used in the introduction is at least equivalent to grade A at GCSE.	✓
P3aii	The candidate indicates a need to keep the temperature, pH, enzyme concentration and total end volume constant. Only one variable has been altered.	✓
P3b	The range (4 to 14 vol H_2O_2) and number (minimum of 5 concentrations) is appropriate as well repeats.	✓
P5ai	The candidate has just used sufficient detailed AS SKU to justify their prediction.	✓
P5aii	The candidate has carried out and referred to their preliminary work in determining the enzyme concentration to be used. This descriptor could also be awarded for the information gathered from a text given in the bibliography.	✓
P5aiii	The candidate has identified the main safety considerations.	✓
P5bi	The candidate indicates the need to maintain a constant mixing, air tight seals, constant end volumes, pH, temperature, viewing at eye level etc. The volumes quoted indicate a final volume of 10.0 cm^3.	✓
P5bii	The candidate has used appropriate terminology and has given a clear account	✓
P7ai	The candidate has used two texts and one piece of preliminary work. The information is appropriately cited using superscripts or footnotes.	✓
P7aii	The pupil used clear sub-headings throughout the plan which means that it is well structured, logical and easy to follow and mark. This meant that P7aii could be supported at moderation.	✓
P7aiii	SPAG is satisfactory. The use of an electronic spell checker appears to have been used successfully.	✓
P7b	The candidate has given sufficient detail in some areas regarding accuracy and precision. The volumes stated are given to 1 significant figure etc.	✓

7 marks can be awarded.

An important point to note is that when teaching the coursework module pupils should be encouraged to write concisely. There is a fine balance between a detailed investigation with appropriate research and a report which is repetitive and verbose. If the candidate has provided additional theory and knowledge but in a concise manner this is acceptable. However, if the candidate has merely tried to rephrase theory on more than one occasion this would not be considered appropriate for P7aii. The same is true for A7bii.

Skill I:

Descriptor	Comment	Met?
I1ai	Assumed to be met as indicated on the Centre tick sheet.	✓
I1aii	Assumed to be met as indicated on the Centre tick sheet.	✓
I1b	Data recorded is adequate – number, range.	✓
I3a	Assumed to be met as indicated on the Centre tick sheet.	✓
I3b	Data recorded clearly and accurately.	✓
I5ai	Assumed to be met as indicated on the Centre tick sheet.	✓
I5aii	Assumed to be met as indicated on the Centre tick sheet.	✓
I5bi	Data is collected accurately – all are taken with the same degree of precision (nearest s).	✓
I5bii	Evidence is recorded in an appropriate manner. The table has appropriate column headings, units and all data within each column is to the same level of precision. *For reference: No units should be present in the body of the table at this level. If the skill is to be assessed as a stand alone skill the table must have a title, if it is in the main body of a report/whole investigation then it may not be necessary providing all column headings are informative and have appropriate units.*	✓
I7a	Assumed to be met as indicated on the Centre tick sheet.	✓
I7bi	Sufficient evidence has been collected to enable conclusions/trends to be identified.	✓
I7bii	Evidence is appropriate, precise and accurate.	✓

7 marks can be awarded.

Skill A:

Descriptor	Comment	Met?
A1a	Averages have been accurately calculated.	✓
A1b	Trends have been drawn correctly.	✓
A3a	Data has been averaged and presented in an appropriate graphical manner. The graph follows 'SALT' (Scale, Axis, Labels, Title) with an appropriate line of best fit.	✓
A3b	The conclusions have been linked to SKU at least equivalent to A grade GCSE.	✓
A5a	The addition and use of error bars has been shown.	
A5bi	Conclusions drawn have been linked to some AS SKU but there is insufficient detail to give a full match to this descriptor.	✓
A5bii	The account is clear and some specialist terminology has been used.	✓
A7ai	The determination of initial rates of reaction correctly supports level A5a. The use of graph 2 to estimate Vmax and use the data (i.e. rates) in the conclusions.	✓
A7aii	Within the discussion suitable terminology of AS standard has been used (e.g. ESC, successful collisions, excess substrate, saturation).	✓
A7bi	Conclusions are well structured and comprehensive as well as coherently linked to SKU.	✓
A7bii	SPAG is appropriate.	✓

7 marks can be awarded.

Skill E:

Descriptor	Comment	Met?
E1a	A relevant comment has been made.	✓
E1b	The identification of anomalous results has been made by the use of formatting in the table as well graphs.	✓
E3a	The limitations of the procedure/method are given in a clear table.	✓
E3bi	Table 2 (column 2) states reasons where accuracy could be affected..	✓
E3bii	Reasons for anomalous results have been suggested in table 1 and 2.	✓
E5ai	The main error in the candidate's view has been identified i.e. time delay in the closing of the tap and pulling of the syringe.	✓
E5aii	Improvements to the procedure have been clearly given in table 3 (column 1).	✓
E5bi	The candidate has discussed the reliability of the results by discussing concordancy.	✓
E5bii	The effect of the main error has been suggested in table 1 (row 6) and table 2 (row 3) as well as text.	✓
E7a	The candidate has justified their improvements in table 3 (column 2).	✓
E7b	This has been attempted by the candidate by comparing the rates between the preliminary and main investigation for comparable reactions. This was not felt to be sufficient for a full match of this descriptor.	**(E7b)**

A mark of 6 is awarded.

Activity 2:

The effect of ethanol concentration on the membrane permeability:

Skill P:

Descriptor	Comment	Met?
P1ai	The candidate has developed an appropriate question which can be investigated.	✓
P1aii	The prediction is relevant to the question.	✓
P1b	The technique (colourimetry) is appropriate.	✓
P3ai	Scientific Knowledge & Understanding (SKU) used in the introduction is at least equivalent to grade A at GCSE.	✓
P3aii	The candidate indicates a need to keep the size/surface area, incubation period, total end volume constant. Only one variable has been altered. This could have been improved by the use of a table to state independent, controlled and dependent variable(s). Temperature is accounted for by warming solutions at room temperature and no water baths are available.	✓
P3b	The range (20 → 100%) and number (minimum of 5 concentrations) is appropriate as well repeats.	✓
P5ai	The candidate has just used sufficient detailed AS SKU to justify their prediction – FMM model, effects of ethanol on lipids/proteins.	✓
P5aii	The candidate has carried out and referred to their preliminary work in determining the incubation period (20 min). This descriptor could also be awarded for the information gathered from a text given in the bibliography.	✓
P5aiii	The candidate has identified the main safety considerations.	✓
P5bi	The candidate indicates the need to maintain a constant surface area and size of beetroot (constant diameter 5mm and length 0.5cm). The volumes quoted indicate a final volume of 10cm^3. The intention to investigate each temperature 3 times is also stated. The candidate indicates a need to filter the solution to remove debris. As a colourimeter is used it is essential that candidates indicate that a blank is used to calibrate the machine. This has been stated.	✓
P5bii	The candidate has used appropriate terminology and has given a clear account.	✓
P7ai	The candidate has used two texts and one piece of preliminary work. The information should be appropriately cited using superscripts or footnotes.	✓
P7aii	The plan is well structured but is not coherently linked to SKU in places.	**(P7aii)**
P7aiii	SPAG is satisfactory. The use of an electronic spell checker appears to have been used successfully.	✓
P7b	The candidate has not given sufficient detail in some areas regarding accuracy and precision. The volumes stated are only given to 1 significant figure. This lacks accuracy and should ideally be given to at least 0.1cm^3. There is no indication of the precision of the readings to be taken. More adequate indication of temperature regulation could have been planned (even if this could not be implemented).	**(P7b)**

6 marks can be awarded.

Skill I:

Descriptor	Comment	Met?
I1ai	Assumed to be met as indicated on the Centre tick sheet.	✓
I1aii	Assumed to be met as indicated on the Centre tick sheet.	✓
I1b	Data recorded is adequate – number, range.	✓
I3a	Assumed to be met as indicated on the Centre tick sheet.	✓
I3b	Data recorded clearly and accurately.	✓
I5ai	Assumed to be met as indicated on the Centre tick sheet.	✓
I5aii	Assumed to be met as indicated on the Centre tick sheet.	✓
I5bi	Data is collected accurately – all absorbance readings are taken with the same degree of precision.	✓
I5bii	Evidence is recorded in an appropriate manner. The table has appropriate column headings, units and all data within each column is to the same level of precision. *For reference: No units should be present in the body of the table at this level. If the skill is to be assessed as a stand alone skill the table must have a title, if it is in the main body of a report/whole investigation then it may not be necessary providing all column headings are informative and have appropriate units.*	✓
I7a	Assumed to be met as indicated on the Centre tick sheet.	✓
I7bi	Sufficient evidence has been collected to enable conclusions/trends to be identified.	✓
I7bii	Evidence is appropriate, precise and accurate.	✓

7 marks can be awarded.

Skill A:

Descriptor	Comment	Met?
A1a	Averages have been accurately calculated.	✓
A1b	Trends have been drawn correctly.	✓
A3a	Data has been averaged and presented in an appropriate graphical manner. The graph follows 'SALT' (Scale, Axis, Labels, Title). A line of best fit has been drawn appropriately.	✓
A3b	The conclusions have been linked to SKU at least equivalent to A grade GCSE.	✓
A5a	The addition and use of error bars has been shown.	✓
A5bi	Conclusions drawn have been linked to some AS SKU but there is insufficient detail to give a full match to this descriptor.	**(A5bi)**
A5bii	The account is clear and some specialist terminology has been used.	**(A5bii)**

4 marks can be awarded as the partial match of both A5bi and A5bii prevents level 5 being awarded.

Skill E:

Descriptor	Comment	Met?
E1a	A relevant comment has been made.	✓
E1b	The identification of anomalous results has been made by the use of bold formatting in the table as well as written identification. The candidate unclearly also states there were no anomalous results – this was ***after*** the removal of anomalies in the raw data.	✓
E3a	Some limitations have been suggested but only just sufficient for a full match.	✓
E3bi	The accuracy of the data i.e. absorbance readings has not been clearly discussed.	**X**
E3bii	Reasons for anomalous results have been implied but are not implicit.	**X**
E5ai	The candidate has not clearly indicated what is perceived to be the main error.	**X**
E5aii	Some basic suggestions are made in terms of additional work which could be completed but these do not suggest how the significant errors/limitations could be improved.	**X**
E5bi	Error bars have been determined and drawn and partially discussed.	**(E5bi)**
E5bii	The effect of the main error has not been considered.	**X**

2 marks can be awarded as the partial match of A3bi and A3bii prevents level 3 being awarded

.

Activity 3:

The effect of temperature concentration on the membrane permeability:

Skill P:

Descriptor	Comment	Met?
P1ai	The candidate has developed an appropriate question which can be investigated	✓
P1aii	The prediction is relevant to the question	✓
P1b	The technique (colourimetry) is appropriate	✓
P3ai	Scientific Knowledge & Understanding (SKU) used in the introduction is at least equivalent to grade A at GCSE	✓
P3aii	The candidate indicates a need to keep the size/surface area, incubation period, total end volume constant. Only one variable has been altered.	✓
P3b	The range (20→ 100^0C) and number (minimum of 5 temperatures) is appropriate as well repeats	✓
P5ai	The candidate has just sufficient detailed AS SKU to justify their prediction – FMM model, effects of ethanol on lipids/proteins.	✓
P5aii	The candidate has carried out and referred to their preliminary work in determining the incubation period (10 min). This descriptor could also be awarded for the information gathered from a text given in the bibliography	✓
P5aiii	The candidate has identified the main safety considerations	✓
P5bi	The candidate indicates the need to maintain a constant surface area and size of beetroot (constant diameter and length 1cm). Ideally the length should have been more precise but sufficient evidence is present to support the awarding of this sub-descriptor. The volumes quoted indicate a final volume of 10cm^3. The intention to investigate each temperature 3 times is also stated. As a colourimeter is used it is essential that candidates indicate that a blank is used to calibrate the machine. This has been indicated.	✓ **(just)**
P5bii	The candidate has used appropriate terminology and has given a clear account	✓
P7ai	The candidate has used two texts and one piece of preliminary work. The information should be appropriately cited using superscripts or footnotes.	✓
P7aii	The plan is well structured but is not coherently linked to SKU in places.	**(P7aii)**
P7aiii	SPAG is satisfactory. The use of an electronic spell checker appears to have been used successfully.	✓
P7b	The candidate has not given sufficient detail in some areas regarding accuracy and precision. The volumes stated are only given to 1 significant figure. This lacks accuracy and should ideally be given to at least 0.1cm3. There is no indication of the precision of the readings to be taken.	**X**

5 marks can be awarded.

Skill I:

Descriptor	Comment	Met?
I1ai	Assumed to be met as indicated on the Centre tick sheet.	✓
I1aii	Assumed to be met as indicated on the Centre tick sheet.	✓
I1b	Data recorded is adequate – number, range.	✓
I3a	Assumed to be met as indicated on the Centre tick sheet.	✓
I3b	Data recorded clearly and accurately.	✓
I5ai	Assumed to be met as indicated on the Centre tick sheet.	✓
I5aii	Assumed to be met as indicated on the Centre tick sheet.	✓
I5bi	Data is collected accurately – all absorbance readings are taken with the same degree of precision.	✓
I5bii	Evidence is not recorded in an appropriate manner. The table shows all data within each column is to the same level of precision. However, units are missing from column 1 (temperature). *For reference: No units should be present in the body of the table at this level. If the skill is to be assessed as a stand alone skill the table must have a title, if it is in the main body of a report/whole investigation then it may not be necessary providing all column headings are informative and have appropriate units.*	**(I5bii)**
I7a	Assumed to be met as indicated on the Centre tick sheet.	✓
I7bi	Sufficient evidence has been collected to enable conclusions/trends to be identified.	✓
I7bii	Evidence is appropriate but different levels of precision limit this sub-descriptor to a partial match.	**(I7bii)**

4 marks can be awarded.

Skill A:

Descriptor	Comment	Met?
A1a	Averages have been accurately calculated.	✓
A1b	Trends have been drawn correctly.	✓
A3a	Data has been averaged and presented in an appropriate graphical manner. The graph follows 'SALT' (Scale, Axis, Labels, Title) with an appropriate line of best fit.	✓
A3b	The conclusions have been linked to SKU at least equivalent to A grade GCSE.	✓
A5a	The addition and use of error bars has been shown.	✓
A5bi	Conclusions drawn have been linked to some AS SKU and there is sufficient detail to give a full match to this descriptor.	✓
A5bii	The account is clear and some specialist terminology has been used.	✓
A7ai	Differences in average absorbencies only partially meets this descriptor. Processed data should be used/quoted to support deductions/trends/conclusions.	**(A7ai)**
A7aii	Within the discussion suitable terminology of AS standard has been used.	✓
A7bi	Conclusions are well structured but not comprehensive or coherently linked to SKU.	**x**
A7bii	SPAG is appropriate.	✓

6 marks can be awarded as the match of A7ai, A7bii and partial match of A7aii permits the awarding of an intermediate mark.

Skill E:

Descriptor	Comment	Met?
E1a	A relevant comment has been made.	✓
E1b	The identification of anomalous results has been made.	✓
E3a	The limitations of the procedure/method are given in paragraph 3.	✓
E3bi	The accuracy of the equipment is briefly mentioned but not sufficient for a full match as the accuracy of the ***data*** has not been discussed	**(E3bi)**
E3bii	Reasons for anomalous results have been implied but not clearly stated.	**(E3bii)**
E5ai	The main error in the candidate's view has been simply stated i.e. extraction of anthocyanin but this is not elaborated on.	**(E5ai)**
E5aii	Improvements to the procedure have been given.	✓
E5bi	The candidate has not discussed the reliability of the results i.e. plotting error bars in this section but has discussed it in the conclusion section.	✓
E5bii	The effect of the main error has not been suggested.	**x**
E7a	The candidate has not justified their improvements in terms of accuracy, reliability or precision.	**x**
E7b	This has been attempted by the candidate but this was not sufficient for a match of this descriptor.	**x**

Due to the hierarchical nature of the assessment criteria only 2 marks can be supported for this skill as both E3bi and E3bii are only partially met.

Suggested sequence for coursework structure:

Title

Aim

Background knowledge and theory

Prediction

Preliminary work – method, results and conclusion (how it has informed the plan)

Main method:

- Apparatus diagram (if required)
- Apparatus table – number required and justification of choice etc
- Variables – controlled, independent, dependent
- Method – detailed steps to allow repitition
- Precision and reliability

Results

- Raw data
- Processed data
- Graph (if appropriate)
- Statistical analysis (if appropriate)

Conclusions

Discussion

Evaluation

- General review
- Anomalous results – quoted, reasons for
- Limitations/errors in procedure
- Accuracy of data/results
- Reliability of data/results
- Main source of error – and effect on trend/conclusion
- Improvements – and reasons for improvements
- Validity of conclusion

Appendices

Appendix 1 Frequently asked questions (FAQs)

1. I am having trouble deciding whether my exercises properly address the demands of the skills listed in the specification. What advice is available?

A proposed task may be submitted to OCR on form OPF and a response on its suitability will be provided. Copies of form OPF may be obtained from OCR in Cambridge and should be sent to the subject officer (a contact address is given in Section 10). INSET courses are provided each year; details are sent to centres, and a contact address for the Training and Customer Support section is also given in Section 10.

2. Can a single coursework exercise be used to assess more than one skill?

Yes; skills may be assessed separately or in combination. However, it is the responsibility of candidates and their centres to ensure that it is clear where each skill is being covered. This should be achieved by the use of titles and sub-titles. At A2 a single coursework exercise **must** be used to assess all seven skills.

3. Is it advisable to test more than one skill in any one exercise?

This depends very much on the nature of the task and how it is set up. Generally, candidates achieve higher marks for planning if they are able to perform their investigation since this gives them opportunities to revise the plan in the light of experience. Thus, Skills P and I are often assessed together. Similarly, candidates who have not planned and carried out an investigation (or at least seen it demonstrated) will find it difficult to evaluate the investigation. Skill E may therefore be better assessed in a whole investigation. If all four skills are to be tested in one 'whole investigation', it is essential that it is clear to moderators, by means of titles, subtitles, teachers' comments, etc., which are being tested where.

4. Is it better to do laboratory work or use secondary data?

Assessment exercises can be based on either of these approaches. In practice, many centres may find that a mixture will offer greater flexibility.

5. Is there any size or word limit on coursework submissions?

No, but suggestions are given on page 7 of the Human Biology specification. There is absolutely nothing to be gained by submitting particularly large volumes of work for each assessment, especially where the same technique is repeated several times. Moderators will be looking at the quality of the work rather than the quantity and clear evidence that candidates have achieved the criteria listed under each skill.

6. Do centres need to show evidence of marking on candidate's work?

Yes; the minimum requirement is that the 'shorthand' mark descriptors (e.g. P.3b or A.5a) are written in the margin of the script at the point where the work has met the descriptors concerned. However, the more comments clearly written on submitted work, the easier it is for moderators to judge whether candidates have been fairly assessed.

7. Do centres need to submit copies of the worksheets, exercises and resources given to students?

Yes; moderators need to know exactly what candidates were asked to do, and what help they received.

8. Do centres need to submit mark schemes?

The general descriptors given in the specification (and in Section 5) may be used directly by centres to mark candidates' work. However, centres may choose to develop specific sets of descriptors for particular tasks, to allow consistency of marking from year to year, and from teacher to teacher. If such 'contextualised' descriptors are used, they must be very closely based on the standard descriptors and they must be sent to the moderator with the sample of work. It should be noted that the moderator will mark using the general set of descriptors (given in the specification), to ensure that the standard of work is the same from centre to centre. For Skills I, S, R and M, teachers should provide details of the aspects of the work that were scrutinised, in the form of check lists or written notes.

9. Some candidates find coursework very difficult. What advice can you offer which will increase candidates' prospects of achieving good marks?

It is clearly important that candidates are taught the skills and given opportunities to practice, before being assessed. Candidates may find it helpful if staff go through a worked exemplar showing how they themselves would tackle a particular topic, provided that candidates are not allowed to produce work on the same topic for submission. Candidates should be made aware of the descriptors used to assess their work, so that they can ensure that all aspects of the descriptors are addressed. Worksheets clearly give considerable assistance to candidates, but if they are too specific, the help which they give may prevent candidates making choices and so limit access to the highest marks, so they should be used carefully.

10. Do all candidates have to do completely different topics for Skill P assessments?

No; a single task may be set by the teacher for all candidates, but they must work individually.

11. In Skill P work at AS, do candidates have to put their plans into action and examine the results in order to evaluate and modify their plans?

No, but candidates who do not have the opportunity to carry out their plans and modify them in the light of experience will be at a considerable disadvantage.

12. Can candidates use the Internet during their investigations?

Yes; there is some excellent material available and the highest mark descriptors for Skill P require candidates to draw together material from several sources. All URLs should be listed (with any other sources) in a bibliography. It should be noted that unless this information is processed or modified in some way and **used** in the development of the strategy, it is unlikely to be worthy of credit.

13. Will candidates improve their chances of achieving high marks by making extensive use of Information and Communication Technology in their reports?

Computer generated material is not in itself worth any more marks than hand-written work. However, if the use of I.C.T. enables the mark descriptors for any of the skills to be more effectively addressed, then candidates could gain extra credit. It should be noted that many graph-plotting packages, if not used expertly, may not produce the most appropriate graphs and therefore that the use of such software may actually penalise candidates.

14. My candidates have completed several assessments in a field notebook that includes some unassessed work. Can I submit the book to the moderator?

No; only assessed work should be sent. Centres should avoid this practice because it adds to the cost of postage and makes unnecessary extra demands on moderators.

15. Does all coursework have to be carried out under the direct supervision of the teacher?

No; in order to meet the requirements of the descriptors, particularly for Skills P and A, candidates will need to carry out research which may require the use of library facilities, the Internet etc. Also, it may not be possible to devote sufficient time in the laboratory/classroom to allow candidates to write up their work. However, sufficient work must be completed under direct supervision to allow the teacher to authenticate the marks awarded, and this is left to the discretion of the Centre.

16. How much help can I give students with their coursework?

This is a difficult question to answer. In general terms, direct help in the form of suggesting to a student how to carry out an investigation, or how to interpret the results, is unacceptable, while it is acceptable to draw the attention of the student to aspects of the assessment descriptors that he or she has not addressed.

In some circumstances it may be necessary to give direct help to students, for example to ensure that they are working safely or to get them through a difficulty. Such help should be taken into account in the award of marks and details must be provided to the moderator.

If students are to be given the opportunity to choose their own coursework tasks, guidance should be given by the teacher to ensure that that the tasks are of appropriate demand and likely to generate results capable of analysis. In a whole investigation, or if students are to be asked to carry out an investigation that they have planned, it is suggested that the draft plans are submitted to the teacher for an initial assessment to be made of the suitability of the strategy. Such assistance is acceptable without penalty provided that candidates are not given direct guidance about what to do.

17. Can I take in the work of my students, mark it, and then give it back to them for any errors to be corrected before taking it in again for a final mark to be awarded?

No; once the work has been handed in for marking, the marks awarded should stand. Assistance can be given to students while they are carrying out their work provided that it is limited to the identification of aspects of the assessment descriptors that have not been addressed. However, it is suggested that work for Skill P should be collected in for an assessment of its suitability to be made before any practical work has been carried out, though Skill P should not be marked until the whole assessment has been completed.

18. Can I use worksheets to set the tasks that my students are to carry out?

Yes; worksheets are very helpful, particularly if students are not being asked to plan the investigation themselves. However, a worksheet used to set a planning task which gives too much guidance as to the method to be used or the number of readings to be taken etc. may reduce the level of demand of the task and so limit the marks which can be awarded to candidates.

19. Where more than one skill is being assessed on a single piece of work, for example in a whole investigation, is it acceptable for the skills to be given widely differing marks?

If the level of demand of the task is limited, this will have an effect on all four skill areas. The marks awarded for Skill P will relate closely to the other skill areas since it is unlikely that a poor plan will generate a good set of data and that such data can be analysed or evaluated to generate high marks. However, a good plan may produce good results but the analysis and/or evaluation may be poor.

20. Can work completed in the AS year be submitted for assessment for A2?

No; as A2 assessment is based on a single, A2-centred investigation it is highly unlikely that any AS investigations will be suitable.

21. If units 2858 and 2868 are re-taken, can the coursework marks be carried forward?

Yes; an entry for 2858 is for the written paper and the coursework component Entry options for these units are provided for coursework marks to be carried forward, but it should be noted that marks for the written paper component 2858 / 01 may not be carried forward.

22. Where can I get more information on the A2 Extended Investigation?

Additional guidance and advice will be published on the OCR website (www.ocr.org.uk).

Appendix 2 Ethics and the Law

In the Specification Aims, Section 2.1 covers Spiritual, Moral, Ethical, Social and Cultural Issues.' In addition, in planning an investigation it is important that the candidate 'considers ethical implications in the choice and treatment of organisms' as well as 'the environmental and safety aspects of the proposed procedures.'

Much biological practical work will involve ethical considerations. It is strongly recommended that appropriate guidance should be sought before working on any living organism. The following issues should be considered by Centres, as well as being discussed with candidates.

Animals — humans

Many biological experiments are carried out in Centres, where the subject is one of the candidates or other pupils in the school.

Most candidates will be aged under 18 during some or all of their course of study. Whilst a person aged 16 or 17 may give consent, without parental permission, to an experiment which will not harm them, either physically or mentally, the Centre and candidates should appreciate that for any experiment, the 16 or 17 year old can only give informed consent. This is dependent upon the competence of the person and the information provided. It is recommended that the Headteacher be informed of all such experiments and that full risk assessments are carried out. In addition, careful consideration should be given before any experiments are conducted where the subjects may be exposed to judgmental comments by their colleagues. This includes exercise experiments, reaction times, memory tests and testing for various genetic phenotypes. In all cases, subjects must be allowed to opt out of such activities. Under no circumstances would experiments where subjects are given cigarettes, alcohol or other drugs be acceptable.

In certain circumstances, candidates carry out experiments comparing different age groups. Again, great care must be taken to ensure that none of the subjects may be upset by the results of the experiment (e.g. slow reaction times or reduced memory in elderly people). All subjects should give their consent to any activities before they are undertaken. Any experiment involving children under the age of 16 must be carefully planned and must not involve any chance of harm. Within a school environment, the staff involved should ensure that the Headteacher or other person or persons acting in *loco parentis* are prepared to sanction the experiment. A person under 16 is rarely competent to give personal consent.

Any practical work involving questionnaires must ensure that none of the questions are of a personal nature and that there is always an option not to answer any or all of the questions if the person so desires.