OCR
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14-19 CHANGES
A LEVEL

# *Support Materials*

## A2 Level Human Biology H423:

## Teacher Support: Extended Investigation

Version 2.0

AS/A Level Human Biology

OCR
RECOGNISING ACHIEVEMENT

# A Level GCE

# Teacher Support: Extended Investigation

## GCE Human Biology

OCR Advanced GCE in Human Biology H423

This *Teacher Support: Extended Investigation* handbook is designed to accompany the OCR Advanced GCE specification in Human Biology for teaching from September 2008.

A separate *Practical Skills Handbook* for AS Unit F223 is available from the OCR website (www.ocr.org.uk).

**Version 2.0 (July 2009)**

***OCR will periodically update this document. Please check the OCR website (www.ocr.org.uk) at the start of each academic year to ensure that you are using the latest version.***

# Contents

# 1 Introduction

This *Teacher Support: Extended Investigation* handbook has been published to assist teachers with the administration and marking of GCE Human Biology Extended Investigations (Unit F226).

This handbook plays a secondary role to the specification itself. The specification is the document on which assessment is based, and this handbook is intended to elaborate on the content of the specification to clarify how skills are assessed and what practical experience is necessary to support an assessment. This handbook should therefore be read in conjunction with the specification.

In keeping with its context-based approach to teaching and learning, Human Biology has developed a scheme for the assessment of candidates' practical skills that emphasises the progression from separate practical skills at AS to the application of these skills in the context of a coherent investigation at A2. At AS level, practical skills are assessed in separate practical Tasks; at A2 level, candidates are assessed in the context of a **single** Extended Investigation in which each candidate pursues his or her own investigation.

During their study of Human Biology, candidates are expected to acquire experience of planning, carrying out, interpreting, analysing and evaluating experiments, and it is important to recognise that these aspects of practical work require both teaching and continual practice. Experience has shown that evaluating experiments and suggesting improvements to the procedures employed are difficult skills for candidates to master.

Unit F226 *Extended Investigation in Human Biology* includes synoptic assessment. Synoptic assessment requires the explicit drawing together of knowledge, understanding and skills learned in different parts of the Advanced Subsidiary and Advanced GCE Human Biology courses. The inclusion of synoptic assessment is designed to encourage development of the understanding of the subject as a discipline.

Synoptic assessment requires candidates to make and use connections within and between different areas of GCE Human Biology at AS and A2 by:

- applying knowledge and understanding of more than one area to a particular situation or context;
- using knowledge and understanding of principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data;
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

# 2 Unit F226: Extended Investigation in Human Biology

## 2.1 The assessment model

Practical and investigative skills developed within contexts encountered during Advanced Subsidiary and Advanced GCE Human Biology (Units F221, F222, F223, F224 and F225) are the basis for meeting the criteria for the A2 Extended Investigation (Unit F226).

Candidates are required to carry out a single Extended Investigation made up of three connected sections, each of which assesses a particular group of skills:

**Skill A – Designing a data collection strategy** [15 marks]

- Use knowledge and understanding to pose scientific questions and define scientific problems.
- Describe safe and skilful practical techniques and processes, selecting appropriate methods of data collection.

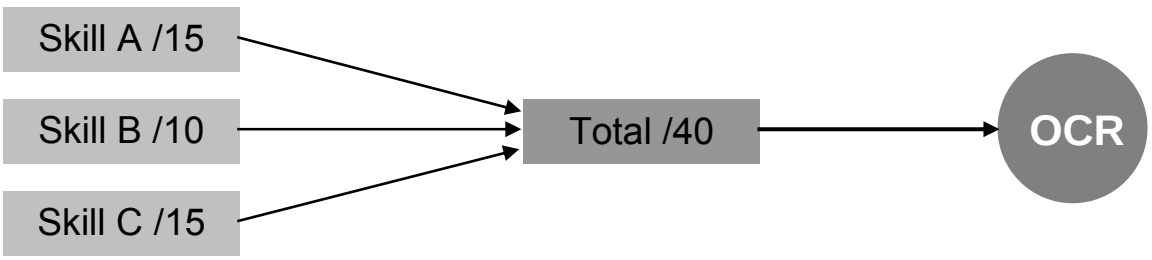
**Skill B – Collecting and processing raw data** [10 marks]

- Make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy.

**Skill C – Analysis and evaluation** [15 marks]

- Analyse, interpret, evaluate and explain the methodology and results of the investigation.

Each Extended Investigation is teacher assessed and then externally moderated by OCR. For each candidate, Centres will supply OCR with a single mark out of 40. Although Extended Investigations can be carried out throughout the year, entry for the A2 unit is available only in the June session of each year.



## 2.2 Administration and regulations

### 2.2.1 Assessment dates

The first assessment session for Unit F226 will be June 2010. Assessment will be available each June thereafter; it is not possible to submit a Unit F226 mark for assessment in January.

### 2.2.2 Scheduling the Extended Investigation

Extended Investigations may be undertaken at any time during the A2 teaching programme. However, it cannot be emphasised strongly enough that before candidates are assessed on their investigative skills within the Extended Investigation, the requisite skills must be taught and candidates must have opportunities to practice and develop their abilities. The work must be marked and the final mark for each candidate must be submitted to OCR by 15 May each year.

### 2.2.3 Time allowed for Extended Investigations

Extended Investigations are not time-restricted, however 10-15 hours of class time should be sufficient. Candidates are expected to spend approximately 4 hours collecting data as part of their investigation, and are also required to spend an appropriate amount of time designing their data collection strategy and analysing and evaluating their results.

Candidates within the class should be given similar time allowances to complete each Skill, although the time required for Skill B may be less than that for Skills A and C.

### 2.2.4 Word limits

There is no word limit for Extended Investigations, but it is anticipated that the completed report will not exceed 3 500 words (excluding tables and graphs). Experience has shown that **concise** reports, focused on the criteria, often gain more credit than very long reports.

### 2.2.5 Suitable Extended Investigation topics

Extended Investigation topics are not prescribed by OCR, rather they are devised by candidates individually. **The topic must be taken from an area of the A2 Human Biology specification**. The submission of proposed Extended Investigation topics/titles for approval by OCR is not a requirement of the scheme. However, Centres wishing to obtain guidance on whether a coursework topic or title is suitable may send an e-mail to GCEsciencetasks@ocr.org.uk for guidance from the senior moderating team. Please include the Centre number in all e-mails. OCR will acknowledge all e-mails but will only respond in detail within 4 weeks of acknowledgement of receipt. Centres should retain copies of any correspondence with OCR and forward copies to the Moderator with the sample of candidate work.

In Centres with a large number of candidates, it is permitted for all candidates in the Centre to undertake Investigations with the same title in order to help the Centre to plan and manage the provision of apparatus, materials and laboratory time. However, in such circumstances the Centre **must** ensure that candidates work individually to design their own data collection strategy for Skill A, collect and process their own data for Skill B, and analyse and evaluate for Skill C (see section 2.2.6). A common method may be issued **after** candidates have completed Skill A and before they start Skill B, but this **must** be noted to the Moderator when the sample is sent for moderation and candidates **must** work individually to collect and process their own data.

### 2.2.6 Group work

Candidates must work **individually** and must collect **their own** data. In some cases candidates may need to share equipment or apparatus and the Centre must make arrangements for this to take place without advantaging or disadvantaging any candidates.

### 2.2.7 Supervision

All practical work should be carried out under the supervision of the teacher. However, there is no requirement for 'examination conditions' to be imposed. Candidates may need to interact as they collect materials or use particular pieces of apparatus. The teacher must ensure that candidates do not copy from or assist each other, so that s/he can with confidence authenticate the work of each candidate.

*The safety of all candidates and participants involved in any Investigation remains the responsibility of the Centre and the teacher who approved the Investigation/data collection strategy (see Chapter 4 of this handbook).*

### 2.2.8 Centres with more than one teaching group

It is recognised that some Centres are likely to have more than one group with lessons timetabled at different times. In these circumstances, Centres are asked to ensure that all candidates are given similar time allocations to complete each Skill that contributes to the Extended Investigation.

### 2.2.9 Absence during the time of assessment

If a candidate is absent from a Centre when Extended Investigations are being carried out then an alternative time should be provided at the Centre if practicable. In these circumstances, Centres are asked to ensure that all candidates are given similar time allocations to complete each Skill.

### 2.2.10 Candidates with access arrangements

Candidates who are eligible for access arrangements and need additional time for the Extended Investigation may be given up to 25% extra time and their name should be recorded on the Interchange Access Arrangements site. Where other access arrangements are required, applications should be made to OCR at the beginning of the course using the standard forms and procedures in the Joint Council regulations and guidance document. However, it should be remembered that the Extended Investigation is intended to assess planning, practical and analytical skills. Credit is given to those skills which the candidate has performed independently. The Disability Discrimination Act lays no duty on awarding bodies to make reasonable adjustments with respect to the application of a competence standard or, in this case, the assessment objective being tested.

### 2.2.11 Unexpected circumstances

If an unexpected problem (such as a fire alarm or other circumstance beyond the teacher's control) occurs while an Extended Investigation is taking place, the investigation may be resumed subsequently provided the teacher ensures that no candidate is likely to have been advantaged or disadvantaged by doing so.

### 2.2.12 Support allowed for candidates

Teachers may provide additional safety instructions (including written advice) if this is felt to be necessary. If it becomes necessary for a teacher to provide a candidate with assistance during the course of an Extended Investigation, the work may still be marked but must be annotated to indicate the assistance given. The teacher should use their professional judgement to award marks appropriately.

### 2.2.13 Authentication

It is the responsibility of the Centre to ensure that the work submitted for assessment is that of the candidates involved, and is authenticated as such by the teacher using form CCS160 (available to download from www.ocr.org.uk).

### 2.2.14 Internal standardisation

Centres **must** set up an internal standardisation process to ensure that all teachers at the Centre are applying the criteria in the same way. This process could include double marking of a sample of candidates' work, or the remarking of work by a senior member of staff. Marks may be adjusted during moderation or work may be returned to the Centre be remarked if there is no evidence of internal standardisation.

### 2.2.15 External moderation

All Extended Investigations must be marked internally by teachers at the Centre; a sample will then be externally moderated by OCR. 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 teachers have applied the standards appropriately across the range of candidates within the Centre.

### 2.2.16 Submission of Extended Investigation marks

For each candidate, the marks awarded for each of the three Skills should be added to together and a total mark out of 40 submitted to OCR.

***Candidates' marks must be submitted to OCR to by no later than 15 May in the year of assessment.***

Following the submission of marks, the Moderator will request a sample of candidate work – the request will be sent by e-mail, so Centres must ensure that the Interchange e-mail account registered with OCR is checked regularly for communications from the Moderator. If there are ten or fewer candidates entered, all work should be sent to the Moderator.

The following paperwork must be included with the sample sent to the Moderator:

- Centre authentication form (CCS160)*;
- any tick sheets (or similar) used during marking and internal standardisation;
- copies of any correspondence with OCR regarding the Extended Investigations.

* If the CCS160 form is not received, the publication of candidates' results may be delayed. The CCS160 is available to download from www.ocr.org.uk.

Coursework submissions should be clearly annotated by the teacher 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.

## 2.3 Marking advice for teachers

The mark descriptors for Skills A, B and C are set out in Appendix B of the specification. The descriptors for each Skill have been made as explicit and as easy to apply as possible. Teachers should note that the mark descriptors are **not** hierarchical.

Mark candidates' work clearly in red ink and in accordance with the mark descriptors.

The descriptors are reproduced in Chapter 3 of this handbook together with additional guidance outlining what is required to award each descriptor.

A measure of professional judgement may be necessary in deciding whether or not a candidate has met the necessary requirements for a mark descriptor to be awarded. Teachers should not be hesitant to apply professional judgement when marking candidates' work, and should add annotations to explain to the Moderator why mark descriptors have or have not been awarded when professional judgement has been used. Annotations will also help other staff in the Centre who are checking the marking as part of internal standardisation.

Appropriate annotations include, but are not limited to:

| | |
|---|---|
| **A1 ✓** | Mark descriptor has been met |
| **B3 ×** | Mark descriptor has not been met |
| **(C7)** | Mark descriptor partly met |
| **bod** | Benefit of the doubt has been given |
| **nbod** | Benefit of the doubt has not been given |
| **g** | Given mark – where you wish to acknowledge evidence for a descriptor, but the mark has already been given |
| **con** | The candidate has contradicted themselves |

It is also useful to use a few words or phrases of explanation when this will help to demonstrate why a mark descriptor was or was not awarded.

The annotations described above will be more helpful to the Moderator and to other staff than simple ticks and crosses.

Once the work has been collected in, it must be marked by the teacher as it stands.

**Under no circumstances can a candidate be allowed to change or elaborate upon work that has already been marked or annotated.**

### Coursework consultancy

OCR offers a free coursework consultancy service in which Centres can send up to three **photocopies** of marked work to OCR for feedback from a senior Moderator. If a Centre wishes to make use of this service, the photocopied work should be posted to OCR with a Coursework Enquiry Form **no later than 15 March** each year (i.e. 8 weeks before the annual coursework submission deadline of 15 May). OCR will return completed coursework consultancies within 6 weeks. The Coursework Enquiry Form is available to download from www.ocr.org.uk.

## 2.4 General requirements for A2 practical work

### 2.4.1 Apparatus

All candidates will be expected to have access to standard laboratory apparatus. However, for certain Investigations other more specialised equipment may be required.

Advice about specialist equipment that may be suitable for candidates eligible for access arrangements (e.g. talking thermometers, talking scales, notched syringes) can be obtained from the RNIB (www.rnib.org.uk) and other specialist organisations. Before approving the use of such equipment in an Extended Investigation, the Centre must contact OCR to ensure that the equipment does not interfere with the competence standards being assessed.

### 2.4.2 Practical skills

Suggested practical activities have been included within the specification at the end of each module. Carrying out these practical activities is not a requirement of the course, but allowing candidates to undertake them will ensure that the skills required for assessment will have been covered. Alternative experiments may be chosen, but Centres should consider carefully whether candidates will have been afforded sufficient practical experience before the Extended Investigation is undertaken.

There are generic skills that should be developed during the study of AS and A2 Human Biology. The sophistication required of candidates should increase throughout the course, partly as their practical experience grows, but also through the extra demands expected by more complex experiments.

At both AS and A2 levels, candidates should:

- demonstrate good laboratory technique;
- demonstrate knowledge of laboratory safety and safe working;
- make and record accurate and precise measurements and observations;
- use and record the correct units for all measurements taken;
- process and present data in an appropriate format;
- construct or interpret appropriate graphs from data collected or provided;
- use a simple statistical test where appropriate;
- interpret the results of experiments and draw conclusions;
- establish whether data collected from experiments is valid and reliable;
- evaluate experimental technique and scientific method in light of practical experience.

During teaching, teachers should focus on the key areas listed above whilst developing the candidates' skills through a coherent practical programme.

In carrying out classroom practical activities and the AS Practical Skills Assessment Tasks in Unit F223, candidates should acquire the necessary experience to be able to carry out the Extended Investigation.

# 3 Mark Descriptors

## 3.1 Skill A – Designing a data collection strategy

Skill A is marked out of 15 marks, according to the 15 mark descriptors set out in Appendix B of the GCE Human Biology specification.

The descriptors have been reproduced below, together with additional guidance outlining what is required to award each descriptor.

In this skill area candidates should:

- identify and describe the aims of the investigation;
- describe the biological knowledge that they have researched in order to help them devise their data collection strategy;
- describe and justify the choice of the equipment, materials and experimental procedures that they will use to achieve the aims of the investigation;
- produce a risk assessment;
- include a list of references to the key sources that they have used to help them devise their data collection strategy;
- use knowledge and understanding to pose scientific questions and define scientific problems;
- describe safe and skilful practical techniques and processes, selecting appropriate methods.

Candidates must complete and hand in their report for Skill A **before** they begin Skill B (i.e. before they begin to collect data). A **copy** must then be returned to the candidate. The original copy of the report handed in by the candidate is marked by the teacher.

The planned procedure may need to be amended to ensure that a safe and valid experiment is carried out by the candidate. Such amendments may be made on advice from the teacher, but **must not contribute to the mark**. Any amendments to the planned procedure should be noted in the candidate's report for Skill B. **Under no circumstances can a candidate be allowed to change work that has already been marked or annotated.**

| Mark | Descriptor |
|---|---|
| | The candidate: |
| **A1** | States a scientifically valid question that can be answered by the investigation.<br><br>*<u>Additional guidance</u>:*<br>*The **aim** of the investigation should be outlined. The candidate must not simply repeat the title of the investigation. A problem may be described briefly, leading to a stated question.*<br><br>*The question should be based upon an area of the A2 specification. A question based upon the AS specification will limit the candidate's ability to access descriptors A4 and C4.* |
| **A2** | States a testable **quantitative** prediction.<br><br>*<u>Additional guidance</u>:*<br>*The prediction must be quantitative, not qualitative. Numerical measurements must be made to enable data processing (simple and advanced, see **A14**) to be performed. Colour observations are qualitative and hence must not be used; however, a colour change measured using a colorimeter generates quantitative data and would be appropriate.*<br><br>*Candidates are advised to investigate the effect of **one** independent variable; no additional credit can be given for investigating more than one independent variable.*<br><br>*A prediction that simply states an expected increase or decrease is not sufficient. The increase or decrease must be given numerical values related to stated values of the independent variable (for example: 'A rise of 10 °C would cause the time for the colour to change to halve' or 'A 5% increase in heart rate after 10 minutes of aerobic exercise'). A prediction in graphical form can be credited if appropriate, but a sketch graph without numerical values for both axes would not meet this descriptor.* |

| Mark | Descriptor |
|---|---|
| **A3** | Uses detailed, relevant scientific knowledge and understanding from Unit F221 and/or F222 to justify the stated question and/or prediction.<br><br>*Additional guidance:*<br>*The candidate must include **relevant** scientific knowledge from the **AS** specification. Key terms must be used appropriately The scientific knowledge and understanding must be of a sufficiently detailed AS standard. It is essential that the scientific knowledge and understanding has been used to **justify** the prediction.*<br><br>*This descriptor must **not** be awarded if the material presented includes:*<br>- *excessive and/or irrelevant theory from the AS specification not used to justify the question/prediction;*<br>- *material not **linked** directly to the question/prediction.*<br><br>*A description of the scientific knowledge relevant to the question being considered should include evidence of research by means of reference(s) within the text of the plan to the source(s) used. The candidate must also provide a detailed bibliography of the research source(s) referenced in the text.*<br><br>*The candidate must reference sources clearly **within** the text by use of superscript numbers with bibliography or footnotes. The inclusion of a bibliography or footnotes **without** references in the text of the plan will not allow this descriptor to be awarded.*<br><br>*Ideally, books should be referenced in the bibliography in the following format:*<br><br>*1* Author, Year, *Title*, Pages, Publisher, ISBN<br><br>*Class notes referenced in the bibliography should indicate the source clearly, and web pages should include the URL and the date of access.*<br><br>*For example:*<br><br>1 Hayward J.J., Hart R.M. & Moore A.M., 2001, *Methods in Practical Biology*, pp. 44-45, Heinemann, ISBN 0-24-031980-1<br>2 Class notes (Teacher: Mr D. Patterson, 2009, Community High School)<br>3 www.useful-biology.com/enzymes.html (accessed 21 September 2009) |

| Mark | Descriptor |
|---|---|
| **A4** | Uses detailed, relevant scientific knowledge and understanding from Unit F224 and/or F225 to justify the stated question and/or prediction.<br><br>*Additional guidance:*<br>*The candidate must include **relevant** scientific knowledge from the **A2** specification. Key terms must be used appropriately. The scientific knowledge and understanding must be of a sufficiently detailed A2 standard. It is essential that the scientific knowledge and understanding has been used to **justify** the prediction.*<br><br>*This descriptor must **not** be awarded if the material presented includes:*<br>- *excessive and/or irrelevant theory from the A2 specification not used to justify the question/prediction;*<br>- *material not **linked** directly to the question/prediction.*<br><br>*A description of the scientific knowledge relevant to the question being considered should include evidence of research by means of reference(s) within the text of the plan to the source(s) used. The candidate must also provide a detailed bibliography of the research source(s) referenced in the text, as in **A3**.* |

| Mark | Descriptor |
|---|---|
| **A5** | Identifies an independent variable, a dependent variable and factors to be controlled or taken into account.<br><br>*<u>Additional guidance</u>:*<br>*All relevant factors in the investigation must be categorised by the candidate into:*<br>- *independent variable (i.e. the variable that will be changed/investigated);*<br>- *dependent variable (i.e. the data that will be collected);*<br>- *factors to be controlled (i.e. the factors that will be kept the same).*<br><br>*This descriptor requires only a **list** of relevant factors in the appropriate categories. This can be achieved easily by use of a table, e.g.:*<br><br>Factor/variable: Description<br>Independent variable: Length of exercise period<br>Dependent variable: Heart rate<br>Factors to be controlled: Gender, age, ethnicity, BMI, smokers/non-smokers, diet, medical history/health, level of fitness, alcohol/caffeine intake, time of day, peak flow<br><br>*Note: physiology investigations should be considered carefully before being selected for assessment purposes due to the number of factors to be controlled when implementing an investigation of this type.* |

| Mark | Descriptor |
|---|---|
| **A6** | Proposes an appropriate range for, and number of values of, the independent variable and an appropriate number of measurements of the dependent variable.<br><br>*Additional guidance:*<br>*The candidate must state clearly each of the following:*<br>- *appropriate range for the **independent** variable;*<br>- *the number of values of the **independent** variable;*<br>- *appropriate number of measurements of the **dependent** variable.*<br><br>*The range proposed for the independent variable must be **appropriate** (for example, a range of 5 – 45 °C for an investigation of yeast respiration at different temperatures) and should be determined using information gained from research.*<br><br>*There must be a minimum of **five** values of the independent variable, unless gender is being investigated (in which case it will be **two**).*<br><br>*There must be a minimum of **three** replicates for each value of the independent variable, or a minimum of **ten** participants in each category for a human physiology investigation. If the candidate plans (in **A14**) to carry out a t-test, they must plan to collect at least 20 pieces of data in each category.* |
| **A7** | Uses, appropriately referenced, material from one secondary source to design an appropriate data collection strategy.<br><br>*Additional guidance:*<br>*'Data collection strategy' refers to the planned method, not to the prediction and theory parts of the investigation.*<br><br>*'Uses' means that the source (e.g. text or data) must be **used to inform** the planned method (e.g. to justify or determine a range for the independent variable, or to indicate the necessity of including a particular step/chemical/piece of apparatus, etc.).*<br><br>*The candidate must reference **one** secondary source clearly **within** the text of their plan by use of superscript numbers with bibliography or footnotes, as in **A3**. The inclusion of a bibliography or footnotes **without** references in the text of the plan will not allow this descriptor to be awarded.* |

| Mark | Descriptor |
|---|---|
| **A8** | Uses, appropriately referenced, material from a second secondary source or uses data collected from preliminary studies to design an appropriate data collection strategy.<br><br>*Additional guidance:*<br>*The candidate must reference an **additional** secondary source clearly **within** the text of their plan by the use of superscript numbers with bibliography or footnotes as in **A3**;*<br>***OR***<br>*the candidate must use data collected from their own preliminary experimental work to develop the data collection strategy (e.g. deciding the range for the independent variable). In the context of this descriptor, the word 'studies' can refer to repeats of the same experiment, and does not imply that more than one preliminary investigation should be carried out.* |
| **A9** | Produces a written risk assessment for the data collection strategy.<br><br>*Additional guidance:*<br>*The candidate should clearly identify the risks and state how these risks will be minimised.*<br><br>*This could be presented in a table, e.g.:*<br><br>Hazard identified \| How risk can be minimised<br>Scalpel \| Keep blade in cork when not in use; cut on cutting tile<br><br>*Hazcards and CLEAPSS® should be consulted as necessary; see Chapter 4 of this Handbook for guidance.* |

| Mark | Descriptor |
|---|---|
| **A10** | Describes, in detail, a strategy for collecting precise and accurate data.<br><br>*<u>Additional guidance</u>:*<br>*To meet this descriptor, the data collection strategy (i.e. method) written by the candidate must:*<br><br>- *be sufficiently detailed to enable the method to be repeated by another student and produce comparable data;*<br><br>- *give clear details of how precise data will be collected (e.g. by stating the precision of apparatus used);*<br><br>- *give clear details of how accurate data will be collected (e.g. by giving details of the techniques and apparatus that will be used to measure out materials and measure the independent and dependent variables, by highlighting instances where special care or speed will be needed, or by detailing how limitations and sources of error will be minimised or removed);*<br><br>- *include details of how the key factors identified in **A5** will be controlled or regulated.*<br><br>*Note: precision is the number of decimal places to which any measurement can be recorded, as determined by the apparatus used, e.g. a 1 $cm^3$ graduated pipette has the smallest measuring unit of 0.01 $cm^3$, therefore the precision is limited to 0.005 $cm^3$ (half the smallest measured unit); however, a timer cannot be used to record data to this level of precision because human reaction time does not allow the timer to be used this precisely (only to the nearest second or half second).*<br><br>*Note: accuracy is an assessment of how close the obtained value is to the true value. Accuracy can be assessed by the calculation of (or a comment on) the % error, or comment on the accuracy of pieces of apparatus. Accuracy can also be assessed by commenting on how the trend line obtained compares with the theoretical trend line.* |
| **A11** | Sequences the steps in the data collection strategy in a clear, logical manner.<br><br>*<u>Additional guidance</u>:*<br>*The method may be described in continuous prose, bullet form or by means of a flow diagram of events, and must allow the exact procedure to be repeated by another student.* |

| Mark | Descriptor |
|---|---|
| **A12** | Justifies the proposed data collection strategy in terms of maximising the validity of the data that will be collected.<br><br>*Additional guidance:*<br>*The candidate must **justify** the following:*<br><br>- *selection of apparatus;*<br><br>*The candidate must explain their selection of the apparatus used to measure volume, time, mass, (blood) pressure, length, temperature, etc. This could take into account consideration of the percentage error of different pieces of apparatus.*<br><br>- *measurement/control of variables;*<br><br>*This could be set out in a table. For example:* |

| Factor/variable | Description | Justification of how variable will be measured/controlled |
|---|---|---|
| Independent variable | Length of exercise period | |
| Dependent variable | Heart rate | Use of a heart rate monitor rather than counting using radial pulse – this eliminates error from counting |
| Factors to be controlled | Gender<br><br>Age<br><br>etc. | Five male subjects and five female subjects will be used in each category – this reduces variation between gender<br><br>All subjects will be between the ages of 16 and 17 years – this reduces the variation between individuals in different stages of puberty |

- *critical points within the strategy.*

*Key points in the method should be identified and an explanation given as to why the chosen method is the best approach in the circumstances of the work. The justification can be integral to the steps or to the controls. For example, 'All tubes will be incubated in a water bath at 25 °C so any difference in colour change will only be due to the difference in the sugar present'.*

*The candidate should appreciate that results, measurements and procedures will vary in the extent to which they actually measure or carry out what they were designed to do.*

| Mark | Descriptor |
|---|---|
| **A13** | Proposes an appropriate format for recording the raw (independent and dependent variable) data that will be collected.<br><br>*Additional guidance:*<br>*The candidate must plan to display their data in a single table with:*<br>- *ruled lines and border;*<br>- *independent variable in the first column;*<br>- *informative column and row headings;*<br>- *SI units for independent variable and dependent variable;*<br>- *an appropriate number of rows and column so that sufficient data can be collected to meet **A6**.* |
| **A14** | States how the raw data collected will be processed in order to answer the question asked or test the prediction made.<br><br>*Additional guidance:*<br>*The key idea at this stage is for the candidate to indicate how they **intend** to analyse their data. An essential part of planning an investigation is to consider how the raw data will be processed in order to **address the prediction**.*<br><br>*The candidate must state what processing of the data they will carry out, including:*<br>- *a simple numerical process (e.g. mean/gradient/percentage);*<br>***AND***<br>- *a detailed numerical process (e.g. standard deviation/standard error/other appropriate statistical test).*<br><br>*If a suitable statistical test is proposed, it can be assumed that this also encompasses simple processing such as calculating the mean.*<br><br>*Following the collection of data, implementing the planned processing will allow candidates to access B6, B7, C5, C6 and C14; the candidate may plan to perform more than one type of simple processing and more than one type of detailed processing.* |

| Mark | Descriptor |
|---|---|
| **A15** | Proposes an appropriate format for presenting the processed data graphically.<br><br>*<u>Additional guidance</u>:*<br>*The candidate must propose how they will present the **processed** data that will be generated by the processing proposed in **A14**. In the majority of investigations this will be in the form of a graph of means or mean rates. Candidates may choose (ideally) to sketch the proposed format, and/or to describe it in words.*<br><br>*The proposed graph, whether sketched or described in words, must:*<br>- *be of an appropriate type;*<br>- *be orientated appropriately;*<br>- *have both axes labelled;*<br>- *have SI units for the independent variable and dependent variables.* |

## 3.2 Skill B – Collecting and processing raw data

Skill B is marked out of 10 marks, according to the 10 mark descriptors set out in Appendix B of the GCE Human Biology specification.

The descriptors have been reproduced below, together with additional guidance outlining what is required to award each descriptor.

In this skill area candidates should:

- make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy;
- record, in an appropriate format, the raw data collected;
- ensure that there is a sufficient number of good quality measurements;
- process their raw data and present the processed data in an appropriate format.

The report, table and graph **must** be collected in by the teacher and validated as the candidate's work. The originals or copies should then be returned to the candidate.

Should a **detailed** common method be given to candidates to enable a common strategy for Skill B to be used, teachers should report this to the Moderator when the sample is sent for moderation. Note that the following marks may not be supported by the Moderator if too much guidance has been given: **B2**, **B4**, **B5**, **B6**, **B7**, **B8** and **B10**.

In the event of a candidate failing to generate their own valid data in Skill B, the Centre may provide a table of raw and processed data and appropriate graph to the candidate to continue with the assessment of Skill C. This **must** be reported to the Moderator when the sample is sent for moderation. **The candidate must not be awarded Skill B marks using the sample data and graph.**

| Mark | Descriptor |
|---|---|
| | The candidate: |
| **B1** | Collects data in a safe manner and, if appropriate, in an ethical manner.<br><br>*Additional guidance:*<br>*The planned data collection strategy proposed in Skill A should have considered safe working. It is the Centre's responsibility to ensure the safety of all candidates and participants involved in the investigation.* |
| **B2** | Collects and records data sufficient to answer the stated question and/or prediction.<br><br>*Additional guidance:*<br>*This should comply with the candidate's plan and must be consistent with the minimum requirements of **A6**.* |
| **B3** | Produces a report summarising how the effects of uncontrolled variables and other factors were minimised during the collection of data.<br><br>*Additional guidance:*<br>*This must be a written report of **at least** 100 words, separate from Skill A and Skill C, giving details of how the uncontrolled variables were taken into account.*<br><br>*The candidate must record any modification they make to the initial data collection strategy planned in Skill A, and explain the reason for modification. This may include modifications made as a result of generic advice given by the teacher or technician.*<br><br>*e.g.*<br>- *use of an upturned measuring cylinder in place of the burette planned for collecting gas over water;*<br>- *extension of independent variable range or number of replicates.* |
| **B4** | Records raw data with appropriate precision and accuracy.<br><br>*Additional guidance:*<br>*All raw data should be recorded consistently, either as whole numbers or to one or two decimal places. The number of decimal places used should be appropriate to the precision of the apparatus used to collect the data (see **A10**).* |

| Mark | Descriptor |
|---|---|
| **B5** | Records raw data in an appropriate format.<br><br>*<u>Additional guidance</u>:*<br>*The candidate must record their raw data in a **single** table with:*<br>- *an informative title;*<br>- *ruled lines and border;*<br>- *independent variable in the first column;*<br>- *informative column and row headings;*<br>- *SI units for independent variable and dependent variable;*<br>- *no units in the body of the table;*<br>- *all raw data recorded to the same number of decimal places.*<br><br>*The candidate may transcribe their raw data into a neat copy for marking.*<br><br>*A table of pooled raw data **must no**t be used to award B5. Teachers **must not** provide a template for any candidate to record data – all decisions regarding the presentation and formatting of the raw data table must be made by the candidate.* |
| **B6** | Carries out simple processing of the raw data.<br><br>*<u>Additional guidance</u>:*<br>*Mean values, or rates, or percentages or gradients must be presented, and rounded correctly according to the mathematical rules. The calculated figures could be incorporated into the table presented for **B5**. Allow up to one calculation and/or rounding error but no more.* |
| **B7** | Carries out detailed processing of the raw data.<br><br>*<u>Additional guidance</u>:*<br>*A suitable statistical test may be carried out, and/or standard error or standard deviation may be calculated. Credit SE or SD plotted as error bars on a graph. Allow up to one calculation and/or rounding error but no more. Allow error carried forward from **B6** (i.e. credit SE or SD calculated correctly from incorrect mean or rate etc.).*<br><br>*Range bars **must not** be used to award this descriptor.* |

| Mark | Descriptor |
|---|---|
| **B8** | Uses significant figures appropriately when processing the raw data.<br><br>*Additional guidance:*<br>*Processed data (e.g. means, standard deviations, etc.) should be recorded to the **same** number of decimal places as the raw data **OR** to **one additional** decimal place. All processed data within a set (i.e. all means or all rates) must be recorded to the same number of decimal places.* |
| **B9** | Identifies, using an appropriate method, anomalous values (outliers) in the raw data.<br><br>*Additional guidance:*<br>*Anomalous values should be indicated clearly in the table of raw data and/or on the graph.*<br><br>*Suitable methods of identifying anomalous values include, e.g.:*<br>- *values greater than ± 2 standard deviations from the mean;*<br>- *values greater than ± 10% of the mean;*<br>- *the use of interquartile ranges.* |
| **B10** | Plots, **by hand**, an appropriate graph of the **processed** data.<br><br>*Additional guidance:*<br>*All graphs must be drawn by hand and:*<br>- *have an informative title;*<br>- *be of an appropriate type;*<br>- *be scaled appropriately (make good use of the available space and have appropriate intervals on the axes);*<br>- *be orientated appropriately (independent variable on the $x$-axis);*<br>- *have labelled axes;*<br>- *have appropriate SI units for independent variable and dependent variable;*<br>- *have correct plots (± half a small grid square).*<br><br>*Line graphs must:*<br>- *include a plot-to-plot line drawn with a ruler and not extending beyond the range;*<br>- *include a line/curve of best fit.*<br><br>*Error bars or range bars may also be plotted, and may help the candidate to access **C5**, **C6**, **C7** and **C14**. Note: an error bar is plotted by the addition and subtraction of one standard deviation from the mean; a range bar plots the highest and lowest readings for each set of data.* |

## 3.3 Skill C – Analysis and evaluation

Skill C is marked out of 15 marks, according to the 15 mark descriptors set out in Appendix B of the GCE Human Biology specification.

The descriptors have been reproduced below, together with additional guidance outlining what is required to award each descriptor.

In this skill area candidates should:

- analyse, interpret, evaluate and explain the methodology and results of the investigation;
- describe and explain the trends and patterns in their data, using appropriate scientific knowledge and understanding;
- relate the data collected to the original aims of the investigation;
- evaluate the limitations of their data collection strategy;
- assess the validity of the conclusions that they have made.

Candidates must complete and hand in their report for Skill C after they have completed their analysis and evaluation of the whole investigation. The report should be authenticated and marked by the teacher.

In the event of a candidate failing to generate their own valid data in Skill B, the Centre may provide a table of raw and processed data and appropriate graph to the candidate to continue with the assessment of Skill C. This **must** be reported to the Moderator when the sample is sent for moderation.

| Mark | Descriptor |
|---|---|
| | The candidate: |
| **C1** | Describes the trends and patterns in the processed data.<br><br>*Additional guidance:*<br>*The trends/patterns in the **processed** data need to be clearly identified in the text of the report. The candidate must quote processed data in support of the trends/patterns they describe.* |
| **C2** | Makes a valid statement about the trends and patterns in the processed data and the original question asked and/or prediction made.<br><br>*Additional guidance:*<br>*The candidate should make a statement identifying whether their original prediction was supported or undermined, or their question was answered, by the data collected. Trends and patterns must be drawn from the **processed** data.* |
| **C3** | Uses detailed scientific knowledge and understanding from Unit F221 and/or F222 to explain the trends and patterns in the processed data.<br><br>*Additional guidance:*<br>*The candidate must include **relevant** scientific knowledge from the **AS** specification. Key terms must be used appropriately. The scientific knowledge and understanding must be of a sufficiently detailed AS standard. It is essential that the scientific knowledge and understanding has been used to **explain** the trends and patterns described in **C1** and **C2**.*<br><br>*This descriptor must **not** be awarded if the material presented includes:*<br>- *excessive and/or irrelevant theory from AS not used to explain the trends and patterns;*<br>- *material not **linked** directly to the trends and patterns.* |

| Mark | Descriptor |
|---|---|
| **C4** | Uses detailed scientific knowledge and understanding from Unit F224 and/or F225 to explain the trends and patterns in the processed data.<br><br>*Additional guidance:*<br>*The candidate must include **relevant** scientific knowledge from the **A2** specification. Key terms must be used appropriately. The scientific knowledge and understanding must be of a sufficiently detailed A2 standard. It is essential that the scientific knowledge and understanding has been used to **explain** the trends and patterns described in **C1** and **C2**.*<br><br>*This descriptor must **not** be awarded if the material presented includes:*<br>- *Excessive and/or irrelevant theory from A2 not used to explain the trends and patterns;*<br>- *material not **linked** directly to the trends and patterns.* |
| **C5** | Comments on the reliability of the raw data collected.<br><br>*Additional guidance:*<br>*Mentioning terms such as 'reliable' or 'reliability' is not sufficient in itself to meet this descriptor. The candidate must use the term(s) **appropriately** and must describe **why** they believe the data are reliable or not reliable.*<br><br>*Considering the reliability of the data is to consider the spread of the raw data from the mean.*<br><br>*The candidate could assess the reliability of the data by:*<br>- *considering the concordancy of the replicates;*<br>- *considering the standard deviation and/or standard error;*<br>- *commenting on range bars (or the range of the raw data);*<br>- *commenting on error bars.*<br><br>*The candidate may also consider whether some data sets are more reliable than others.*<br><br>*The criteria for assessing accuracy (see **C6**) must **not** be used to award this descriptor.* |

| Mark | Descriptor |
|---|---|
| **C6** | Comments on the accuracy of the raw data collected.<br><br>*Additional guidance:*<br>*Mentioning terms such as 'accurate' or 'accuracy' is not sufficient in itself to meet this descriptor. The candidate must use the term(s) **appropriately** and must describe **why** they believe the data are accurate or not accurate.*<br><br>*Accuracy is an assessment of how close the obtained value is to the true value.*<br><br>*The candidate could assess the accuracy of the data by commenting on any of the following:*<br>- *the percentage error of pieces of equipment;*<br>- *how the obtained trend line compares with the theoretical trend line;*<br>- *how close the data point(s) is/are to the line of best fit.*<br><br>*The candidate may also consider whether some data sets are more accurate than others.*<br><br>*The criteria for assessing reliability (see **C5**) must **not** be used to award this descriptor.* |
| **C7** | Comments on the reliability of the data collection strategy.<br><br>*Additional guidance:*<br>*To be awarded this descriptor, the candidate must discuss the reliability of the **data collection strategy** rather than the data itself, although they may do this in the context of explaining which elements of the practical work led to the effects on the data described in **C5**.*<br><br>*A reliable data collection strategy produces concurrent replicate results. A data collection strategy can be made less reliable due to errors and limitations. Limitations will be considered in later descriptors, so **C7** must be awarded on the basis of a discussion of **errors**.*<br><br>*An error is not a design fault of the procedure, but is a single or 'one off' incident or event caused by the candidate during their working. The candidate must discuss whether any errors during the practical work will have affected the reliability of the data collection strategy.*<br><br>*Errors may include, for example:*<br>- *using an incorrect mass/volume of material;*<br>- *contaminating a solution during use;*<br>- *dropping/spillage that reduced the number of replicates that could be performed.* |

| Mark | Descriptor |
|---|---|
| **C8** | Lists three significant limitations in the data collection strategy that will have affected the accuracy and/or precision of the raw data collected.<br><br>*Additional guidance:*<br>*Limitations are factors that have not been controlled or taken into account in the design of the procedure; limitations can be thought of as 'design faults', and will affect each run and replicate equally throughout the investigation.*<br><br>*The candidate must identify **three** limitations of the procedure. These may be presented in a table.*<br><br>*Limitations may include, for example:*<br>- *using a piece of apparatus that is insufficiently precise (e.g. using a measuring cylinder with a precision of 0.5 $cm^3$, instead of a syringe with a precision of 0.05 $cm^3$);*<br>- *using school year groups in an age-related investigation (cohort does not necessarily correspond to chronological age);*<br>- *failure to adequately control temperature (e.g. providing insufficient time for the temperature of samples to equilibrate in a water bath).*<br><br>*This descriptor **must not** be awarded for a discussion of **errors** (see C7).* |
| **C9** | Explains the effect one significant limitation will have had on the accuracy and/or precision of the raw data collected.<br><br>*Additional guidance:*<br>*The candidate must consider one **limitation** in detail to explain its effect on the raw data, and the effect must be quantified.*<br><br>*For example:*<br><br>The carbon dioxide was collected in a 50 $cm^3$ measuring cylinder instead of a gas syringe, so the value recorded for the volume of gas evolved was less precise – only to the nearest 0.5 $cm^3$ instead of to the nearest 0.05 $cm^3$.<br><br>*This explanation may be presented in a table with C8 and C10.* |
| **C10** | Explains the effect a second significant limitation will have had on the accuracy and/or precision of the raw data collected.<br><br>*Additional guidance:*<br>*A second **limitation** must be considered in detail to explain its effect on the raw data, and the effect must be quantified. This explanation may be presented in a table with C8 and C9.* |

| Mark | Descriptor |
|---|---|
| **C11** | Lists three improvements to the data collection strategy that would improve the accuracy and precision of the raw data collected.<br><br>*Additional guidance:*<br>*The improvements suggested need to be realistic and practical within the context of the investigation (e.g. using standard school apparatus). These improvements may be presented in a table.*<br><br>*The improvements must relate specifically to improving the strategy in terms of improving the **accuracy** and/or **precision** of the **raw** data. To that end, reference to performing more replicates will not in itself be sufficient, nor will references to increasing the accuracy of the mean (as the mean is **processed** data and the descriptor specifically requires the improvements to consider the **raw** data).* |
| **C12** | Explains the effect one improvement would have on the accuracy and precision of the raw data collected.<br><br>*Additional guidance:*<br>*Is the improvement likely to bring data points closer to a line of best fit or bring the trend line closer to the predicted trend line? This explanation may be presented in a table with C11 and C13.* |
| **C13** | Explains the effect a second improvement would have on the accuracy and precision of the raw data collected.<br><br>*Additional guidance:*<br>*Is the improvement likely to bring data points closer to a line of best fit or bring the trend line closer to the predicted trend line? This explanation may be presented in a table with C11 and C12.* |

| Mark | Descriptor |
|---|---|
| **C14** | Comments on the validity of the outcome of the investigation.<br><br>*<u>Additional guidance</u>:*<br>*The candidate can meet this descriptor by:*<br><br>- *commenting on:*<br>  - *confidence levels in any statistical tests carried out;*<br>  - *the accuracy and precision of the data collected;*<br>  - *the reliability of the strategy and data collected;*<br>  - *sources of error and limitations within the strategy;*<br>  - *reference to appropriate published data.*<br><br>- *and then assessing the confidence that can be placed in the conclusion drawn in **C2**.* |
| **C15** | Uses appropriate technical terms, spelt correctly, throughout the investigation.<br><br>*<u>Additional guidance</u>:*<br>*Scientific and technical terms should be spelt correctly and used in the correct context **throughout the whole investigation** (i.e. in all three Skills). An isolated mistake should not prevent this mark being awarded.* |

# 4 Health and Safety

## 4.1 Laboratory health and safety

Candidates are expected to be familiar with the standard hazard symbols illustrated below.

**Oxidising**

**Harmful**

**Highly Flammable**

**Corrosive**

**Toxic**

**Irritant**

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for AS and Advanced GCE, this is likely to be the local 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 2002 and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful micro-organisms 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 at www.ase.org.uk/htm/teacher_zone/safety_in_science_education.php.

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 *(now out of print but sections are available at: www.ase.org.uk/htm/teacher_zone/safety_in_science_education.php)*;
- Topics in Safety, 3rd edition, 2001, ASE ISBN 0 86357 316 9;
- Safeguards in the School Laboratory, 11th edition, 2006, ASE ISBN 978 0 86357 408 5;
- CLEAPSS® Hazcards*;
- CLEAPSS® Laboratory Handbook*;
- Hazardous Chemicals, A Manual for Science Education, 1997, SSERC Limited, ISBN 0 9531776 0 2 (see www.sserc.org.uk/public/hazcd/whats_new.htm).

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 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.

Certain Extended Investigations may involve the use of novel procedures, chemicals or organisms that 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 CLEAPSS® (or, in Scotland, SSERC).

* These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications CD-ROM issued annually to members. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to www.cleapss.org.uk. In Scotland, SSERC (www.sserc.org.uk) has a similar role to CLEAPSS® and there are some reciprocal arrangements.

## 4.2 Investigations using human participants

**It is the Centre's responsibility to ensure the safety of all candidates and participants involved in any Investigation.**

OCR does **not** permit Investigations that involve the administration of alcohol, caffeine, nicotine and other similar substances to human participants. Further, the administration of glucose and other sugars to human participants is also prohibited due to the risk of undiagnosed diabetes.

No Investigation that potentially causes harm to participants should be undertaken (e.g. exposure to inhaled particulates/air pollution). Harm resulting from administration of substances such as those listed above could result in prosecution under Health and Safety legislation by the appropriate authorities.

# 5 Data Presentation

The guidelines in this chapter are adapted from the following publication:

Cassidy, M., Lakin, L., Madden, D., Meatyard, B., Roberts, R., and Tribe, M. (2009) *Biological Nomenclature: Standard Terms and Expressions used in the Teaching of Biology (Fourth edition),* Institute of Biology.

## 5.1 Tables

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

- All raw data in a single table with ruled lines and border.
- Independent variable in the first column; dependent variable in columns to the right.
- Processed data (e.g. means, rates, standard deviations) in columns to the far right.
- No calculations in the table, only calculated values.
- Each column headed with physical quantity and correct SI units; units separated from physical quantity using either brackets or a solidus (e.g. “mass / g”).
- No units in the body of the table, only in the column headings.
- Raw data recorded to a number of decimal places and significant figures appropriate to the least precise piece of apparatus used to measure the data.
- All raw data recorded to the same number of decimal places and significant figures.
- Processed data recorded consistently to up to one decimal place more than the raw data.

## 5.2 Graphs

The following general guidelines should be followed when presenting data in graphs.

- The type of graph used (e.g. bar chart, histogram, line graph, pie chart or scattergram) should be appropriate to the data collected.
- The graph should be of an appropriate size to make good use of the paper.
- There should be an informative title.

Guidelines for specific types of graphs are given on the following pages.

**Histograms**

Histograms are used when:

- the independent variable is:
  - continuous;
  - numerical (e.g. age in years);
  - divided into classes;

- the dependent variable:
  - is discrete (i.e. the data are recorded in whole numbers);
  - records frequencies.

Histograms are sometimes referred to as frequency diagrams, and are plotted as a series of blocks.

- The x-axis (horizontal) represents the independent variable; the scale is numerical and continuous but is divided into classes. The number of classes will largely depend on the type and nature of the data, though five times the log of the number of observations is one approach.

- A block is drawn for each class. The blocks may not be the same width, depending on the sizes of the classes, and must be drawn touching. The width of the block must be related to the size of the class.

- The edges of the blocks are labelled, so a block may be labelled '7' at the left-hand edge and '8' at the right-hand edge; this block represents class range 7 - 8 units but it is understood that 7.0 is included in this range but 8.0 is not; 8.0 is included in the next class range, 8 - 9.

- The y-axis (vertical) represents the dependent variable (the number or frequency), and has ascending equidistant whole number intervals. The height of the bar therefore represents the number or frequency recorded for the class.

- Each axis must be labelled clearly to describe what it represents, and have an appropriate scale. Axis labels are written horizontally in lower case.

**Bar charts**

Bar charts are used when:

- the independent variable:
  - is discontinuous;
  - is divided into descriptive categories (e.g. school year groups, genders, substrates, etc.);

- the dependent variable is:
  - continuous.

Bar charts are used to illustrate relationships between the independent variable and the dependent variable, and are plotted as a series of lines or blocks.

- The x-axis (horizontal) represents the independent variable, and is divided into discrete descriptive categories. Each category must be labelled clearly.

- A line or block is drawn for each category. The lines or blocks must be drawn with equal width and separate from each other (i.e. the edges do not touch).

- The lines or blocks can be arranged in any order, but it can aid comparison if they are arranged in ascending order.

- The y-axis (vertical) represents the dependent variable, and has ascending equidistant intervals. The axis should be a labelled with SI units where appropriate, either abbreviated (e.g. “s”) or written out in full (e.g. “seconds”).

- Each axis must be labelled clearly to describe what it represents, and have an appropriate scale. Axis labels are written horizontally in lower case.

**Line graphs**

Line graphs are used when:

- the independent variable is:
  - continuous;
  - numerical;

- the dependent variable is:
  - continuous.

Line graphs are used to illustrate relationships between the independent variable and the dependent variable, and are plotted as a series of data points joined by a line or curve.

- The independent variable is plotted on the x-axis (horizontal) and the dependent variable is plotted on the y–axis (vertical).

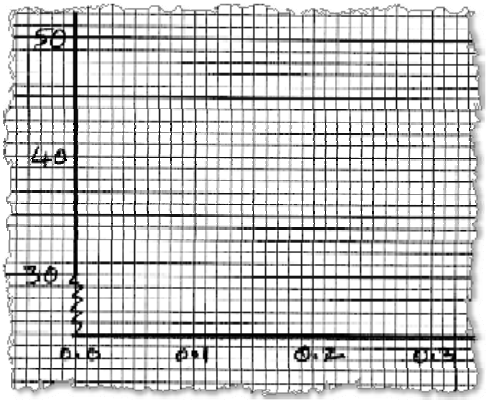
- Data should be plotted using encircled dots ( ⊙ ) or saltire crosses ( x ). Vertical crosses ( + ) may also be used, providing that they can be distinguished easily from the grid lines.

- Plots should be joined by straight plot-to-plot lines drawn with a ruler (a smooth curve is only drawn if there is reason to believe that intermediate values fall on the curve).

- Both axes must have an appropriate scale with ascending equidistant intervals. Axis labels are written horizontally in lower case, with SI units where appropriate (either abbreviated or written out in full).

- If the origin (0,0) is not included on an axis, the axis should be broken.

e.g.



- If a graph shows more than one line, then each line must either be labelled to show what it represents or the data plotted using different symbols and identified by a key.

- A line or curve of best fit can be drawn to illustrate the trend. It must **not** be assumed that a straight line drawn between the first and last data plots is the most appropriate line of best fit.

**Scatter graphs**

Scatter graphs are used when investigating the relationship between two variables of a sample or replicate, and the measurements are in pairs. The relationship can be a positive correlation, a negative correlation or no correlation at all.

- The two variables are plotted for each sample or replicate as a point. The measurement of one of the variables gives the $x$-axis co-ordinate, and the measurement of the other variable gives the $y$-axis co-ordinate. Each point on the graph represents an individual, a sample or a replicate.

- Both axes must have an appropriate scale with ascending equidistant intervals. Axis labels are written horizontally in lower case, with SI units where appropriate (either abbreviated or written out in full).

**Pie charts**

Pie charts are used when displaying data that are proportions or percentages, and are plotted as a circle divided into sectors.

- Sector angles are calculated by dividing the percentage by 100 and multiplying the answer by $360^{o}$; if the data are proportions then just multiply by $360^{o}$.

- When presenting two or more pie charts for comparison, the order of the segments should be the same.

- The size of the pie circle can be made proportional to the size of the sample.

- Pie charts should not contain more than 6 or 7 sectors, otherwise they become confusing.

- There should be sector labels (or a key), written horizontally in lower case, identifying each sector and the proportion or percentage it represents.

# 6 Resources

There are many resources available to help teachers provide support to candidates. Some suggestions are listed below.

## 6.1 Books


Cadogan, A. and Ingram, M., 2002, *Maths for Advanced Biology*, Nelson Thornes, ISBN 0748765069

Cassidy, M., Lakin, L., Madden, D., Meatyard, B., Roberts, R., and Tribe, M., 2009, *Biological Nomenclature: Standard Terms and Expressions used in the Teaching of Biology (Fourth edition)*, Institute of Biology, ISBN 090049039X

Clegg, C. J. and Mackean, D.G., 2000, *Advanced Biology Principles and Applications*, Hodder Murray, ISBN 0719576709

Edmondson, A. and Druce, D., 1996, *Advanced Biology Statistics*, Oxford University Press, ISBN 0199146543

Ennos, R., 2006, *Statistical and Data Handling Skills in Biology*, Prentice Hall, ISBN 0131955845

Jones, A., Reed, R. and Weyers, J., 2007, *Practical Skills in Biology*, Benjamin Cummings, ISBN 0131755099

Geatrell, B., Lowrie, P. and Tilley, A., Series editor: Fuller, F., 2008, *AS/A2 Human Biology (OCR endorsed textbook)*, Heinemann, ISBN 0435692100


## 6.2 Websites

The following list of websites has been compiled from suggestions by teachers at training events, and may be helpful in classroom teaching as well as during Extended Investigations. While these websites may be useful, OCR does not endorse them, does not contribute to or regulate them in any way, and is not responsible for any of their content or the way in which they are used.

**Statistics**

- www.theseashore.org.uk/theseashore/Stats%20for%20twits/Distressed%20twit%20advice.html
  – *'Stats for Twits', an accessible student guide to selecting and performing statistical tests for different data types, provided by the Field Studies Council*

**Images**

- www.sciencephoto.com – *science images*
- medphoto.wellcome.ac.uk – *medical and historical scientific images*
- www.drjastrow.de/ProdukteE.html – *microscopy and anatomy*
- www.istockphoto.com – *general (good for flowers, food, scenery, animals, objects etc.)*

**Animations**

- www.sumanasinc.com – *general biology animations*
- multimedia.mcb.harvard.edu – *includes 8-minute animation 'The Inner Life of the Cell'*
- www.hybridmedicalanimation.com – a *range of biology animations (e.g. heart)*
- www.maxanim.com – *genetics, biochemistry, immunology, physiology, microbiology*
- www.fredonia.edu/Athletics/health/Davis/HLTH_300/AP%20Interactive%20Animations.htm – *anatomy and physiology interactive animations*
- www.johnkyrk.com – *cell biology animations*
- library.med.utah.edu – *'Hyperheart' and other animations*

**General**

- www.ncbe.reading.ac.uk – *National Centre for Biotechnology Education*
- www-saps.plantsci.cam.ac.uk – *Science and Plants for Schools*
- www.biology4all.com – *includes the 'BioTutor' discussion list/support forum for teachers*
- www.biology-resources.com – *educational materials, presentations and practicals*
- www.biology.arizona.edu –*University of Arizona Biology Project, good range of topics*
- nobelprize.org/educational_games – *go to 'Nobel prize in medicine' for most of the biology*
- www.dnalc.org – *DNA learning center*
- learn.genetics.utah.edu – *University of Utah genetics learning center*
- www.accesexcellence.org – *good for biotechnology*
- www.nhs.uk – *National Health Service, good for health data*
- www.blood.co.uk – *National Blood Service (Blood Transfusion Service)*
- www.hpa.org.uk – *Health Protection Agency, good for health data and statistics*
- ec.europa.eu/environment/nature/index_en.htm – *biodiversity policies*
- www.beep.ac.uk – *Bio Ethics Education Programme*

## 6.3 INSET

OCR offers a full programme of training events for teachers related to the new GCE Human Biology specification, and these include sessions either wholly or partly in support of the AS Practical Skills Assessment Tasks (Unit F223) and the A2 Extended Investigation (Unit F226).

Further details are available from the 'Training' section of the OCR website (www.ocr.org.uk).

# 7 Frequently Asked Questions

**Can OCR provide a list of suitable Extended Investigation titles?**
OCR has not published a list of recommended titles, in order to encourage candidates to undertake a diversity of investigations of their own choosing. However, section 2.2.5 of this handbook gives guidance on choosing a suitable Extended Investigation topic.

**Can candidates investigate any topic of their choice?**
While it is technically possible to choose any topic, the selection of a topic from an AS learning outcome will prevent candidates from accessing some of the mark descriptors. Hence, it is advised and expected that topics from an A2 learning outcome are chosen.

**Can human subjects be used in an Extended Investigation?**
Yes in principal, though investigations involving the administration of certain substances are specifically prohibited by OCR – see section 4.2 of this handbook for guidance. Physiology investigations in general should be considered carefully before being chosen due to the number of factors that need to be controlled when implementing an investigation of this type.

**Can all candidates in the class use the same investigation title?**
Yes, but certain procedures **must** be followed – see sections 2.2.5 and 2.2.6 of this handbook.

**Can a common method be given to all candidates in the class?**
For reasons of safety or practicality, a common method may be given to candidates **after** they have submitted Skill A, but details **must** be supplied to the Moderator when the sample is sent for moderation. Note that if too much assistance has been given candidates may be denied access to one or more mark descriptors.

**Can I give out sample data?**
In the event of a candidate failing to generate their own valid data in Skill B, the Centre may provide a table of raw and processed data and appropriate graph to enable the candidate to continue with the assessment of Skill C. This **must** be reported to the Moderator when the sample is sent for moderation. The candidate **must not** be awarded any Skill B marks using the sample data and graph.

**Can I contact OCR for guidance on administering and planning Investigations?**
Teachers can e-mail queries not answered by this handbook to GCEsciencetasks@ocr.org.uk for guidance from the senior moderating team. Please include your Centre number in all e-mails. OCR will acknowledge all e-mails but will only respond in detail within 4 weeks of acknowledgement of receipt. Centres should retain copies of any correspondence with OCR and send copies to the Moderator with the sample of candidate work. See also section 6.3 for details of OCR's INSET events.

**Is there a time limit for completion of the Extended Investigation?**
See section 2.2.3 of this handbook.

**Can candidates work on their Extended Investigation outside the laboratory?**
Yes, and in order to gain maximum marks candidates will need to carry out some research in their own time. Completion of Skill C (analysis and evaluation) could be done under supervision or in the candidates' own time. It is the responsibility of the Centre to ensure that all submitted work is the candidate's own, and to ensure the health and safety of all participants at all times in any investigation.

**Is there a word limit?**
See section 2.2.4 of this handbook.

**Does a statistical test have to be carried out as part of the Extended Investigation?**
A well-planned investigation should include an appropriate statistical test. Candidates will not be able to access all of the mark descriptors if they do not plan and carry out simple and detailed processing of their data.

**Can candidates word process their reports?**
Yes. Just as with handwritten reports, candidates should be warned against copying significant sections of text from books, websites or other sources instead of describing in their own words the scientific knowledge and understanding required to devise, implement and evaluate their data collection strategy.

**Can candidates submit a computer generated graph?**
All graphs **must** be drawn by hand. No credit can be given for a computer-generated graph.

**How should candidates display their scientific knowledge and understanding?**
By describing in their own words the scientific knowledge and understanding required to devise, implement and evaluate their data collection strategy. Sources that have been researched should be used in support of the strategy, and fully referenced using superscript numbers and a detailed bibliography or footnotes.

**Should candidates classify errors as random or systematic?**
Not necessary – the emphasis is on discussing errors carefully rather than classification.

**Can candiates hand in a single report covering all three Skills at the same time?**
No. A report on the plan (Skill A) **must** be completed and handed in to the teacher for marking prior to the commencement of Skill B. A copy (not the original) must then be given back to the candidate to enable data collection to begin. A report on Skill B **must** be handed in when data collection is complete and prior to the commencement of Skill C. A copy must then be returned to the candidate so that they can complete and submit Skill C.

**Can candidates be given feedback by the teacher after submitting their plan?**
Teachers can indicate in general terms the areas of the assessment criteria that have not been addressed by candidates, but reference to specific mark descriptors must not be made. *Under no circumstances can a candidate be allowed to change work that has already been marked.*

**Can I award half marks?**
No. Award 1 mark per descriptor. If there is insufficient evidence to support the award of a descriptor, then no mark should be awarded.

**Should candidates' work be annotated during marking?**
Yes. See section 2.3 of this handbook for guidance.

**Will my marking be moderated?**
Yes. Following the submission of marks on 15 May each year, the Moderator will request a sample of candidate work – the request will be sent by e-mail, so Centres must ensure that the Interchange e-mail account registered with OCR is checked regularly for communications from the Moderator. If there are ten or fewer candidates entered, all work should be sent to the Moderator.

**Can I get guidance on my marking prior to moderation?**
See section 2.3 of this handbook for general guidance and for details of OCR's free coursework consultancy service.

**How can I ensure the same standard is applied to all candidates?**
A process of internal standardisation must be implemented within the Centre – see section 2.2.14 of this handbook.

# 8 Example Candidate Work and Marking Commentaries

The marked examples of candidate work presented in this chapter are designed to assist teachers with marking Extended Investigations.

Three examples are provided:

**Candidate 1** – 'Does the respiration rate of yeast vary with different sugars?'

**Candidate 2** – 'Is the recovery rate of human hearts influenced by gender?'

**Candidate 3** – 'Does human memory decline with increasing age?'

The three investigations are **not** perfect exemplars of Extended Investigations; they have been chosen deliberately because they **do not** meet all of the mark descriptors for Skills A, B and C, and are therefore useful as marking exercises. It is essential that the Investigations are read in conjunction with the accompanying marking commentaries, and they must not be taken as perfect exemplar Investigations.

Candidate 1

## F226 Extended Investigation

## Does the respiration rate of yeast vary with different sugars?

### SKILL A

Yeast (*Saccharomyces cerevisiae*) is an example of a heterotrophic single-celled eukaryotic organism. This means it requires an external organic carbon source for respiration as it cannot produce its own. The carbon source metabolised by yeast are usually carbohydrates in the form of sugars. Yeast cells absorb glucose needed for respiration by facilitated diffusion via protein channels in the plasma membrane. Yeast can respire aerobically forming the products of adenosine tri-phosphate (ATP), carbon dioxide ($CO_2$) and water ($H_2O$), or anaerobically forming significantly smaller numbers of ATP molecules as well as ethanol. ATP is the universal energy molecule, and is formed by substrate level and oxidative phosphorylation in aerobic respiration via a series of enzyme-controlled redox reactions in glycolysis, the Krebs cycle and the electron transport chain. In order for these processes to be carried out, hydrogen acceptors are required to accept electrons for use in the electron transport chain. The natural ones available in most organisms are usually NAD and FAD (1).

Sugars come in different forms known as isomers, for example glucose and fructose, and also in differently sized molecules. A monosaccharide is a sugar molecule, such as glucose, that cannot be broken down in hydrolysis to form a simpler sugar. Whereas, a disaccharide, such as lactose, is a form of sugar that composes of two monosaccharides joined together by a 1-4 glycosidic bond, for example lactose is composed of the monomers glucose and galactose. As the sugars have to be taken into the yeast cell via its protein channels, the size of the molecule would be important (2). The smaller monosaccharides would be absorbed faster, with glucose being the fastest of all due to it being the preferential respiratory substrate of most organisms, as they cannot be broken down further and so the protein channels would have to be adapted for diffusion of molecules of this size. However, the larger disaccharides would firstly need to be broken down to their component monosaccharides by hydrolysis of glycosidic bonds in order for facilitated diffusion to take place, therefore increasing the time taken for disaccharides to be absorbed. An exception being lactose; lactose cannot be broken down by yeast because it does not produce the required enzyme needed to hydrolyse the disaccharide into its constituent monosaccharides.

In order to test to see whether the different sizes of the molecules alter the rate of respiration in the yeast, an artificial hydrogen acceptor called triphenyl tetrazolium chloride (TTC) will be used. TTC behaves in the same way as NAD or FAD does in that it accepts hydrogen during respiration and becomes reduced. However, when reduced, TTC changes from a colourless liquid to pink. The time for this colour change to occur can be used to measure the rate of respiration when the TTC is mixed with a respiring yeast suspension.

In the investigation, TTC will be used to find out if the rate of respiration in *S. cerevisiae* changes when different sugars are used as the respiratory substrate. The sugars used to investigate this will include the monosaccharides glucose and fructose, as well as the disaccharides sucrose and lactose. The yeast source will be Allinson Dried Active Yeast mixed with distilled water.

The hypothesis is that the yeast cells will respire the monosaccharides faster, the time for TTC to turn pink will be half compared to a disaccharide being respired at the same temperature of 35 °C . The null hypothesis is that there is no significant difference between the rates of respiration of the yeast using monosaccharide or disaccharide as a respiratory substrate.

It is predicted that glucose and fructose will cause the TTC to change colour the fastest, with the disaccharide sucrose causing it to undergo the colour change in about half the time taken for a monosaccharide. Furthermore, it can be predicted that the disaccharide lactose will not cause a colour change of the TTC at all. This being due to under normal circumstances yeast cannot break down the lactose into its monosaccharides and so should not be able to be absorbed; meaning no respiration should take place.

The results of the tests will be analysed using the Student's T-test to provide a statistical examination of whether the hypothesis and predictions are correct.

**Bibliography**

1. Biological Science 1&2 Green Stout Taylor CUP 1991 ISBN 0 521 38380 3
Pages 19 170-4

2. Advanced Biology Jones & Jones CUP 1997 ISBN 0 521 48473-1 page 33-35

3. Yeast website

**Method and equipment**

The equipment required to carry out the investigation include:

- Allinson Dried Active Yeast
- Distilled water
- 17.5 g each of glucose, fructose, lactose and sucrose
- Balance
- 0.5% TTC solution
- Spatula
- 5 x 250 $cm^3$ conical flasks
- Glass rod
- 100 $cm^3$ measuring cylinder
- Water bath at 35 °C
- Thermometer
- Stopwatches (accurate to ± 1 second)
- 10 $cm^3$ graduated pipette
- 1 $cm^3$ syringe
- Test tubes
- Test tube rack
- Bunsen burner
- Tripod
- Heat proof mat
- Glass beaker for second water bath (at 100 °C)
- Tongs
- Incubator at 35 °C
- Chinagraph pencil



Risk assessment of equipment:

TTC is an irritant if it comes into contact with the eyes, skin or if it is ingested. It is also sensitive to light in that the light can cause the TTC to change colour. In order to reduce these risks, gloves, apron and goggles shall be worn at all times when handling the TTC. As well as this, the TTC will remain covered by aluminium foil at all times prior to testing to reduce risk of colour change not induced by the respiring yeast. TTC can also be combustible when exposed to a naked flame. To avoid this, the TTC will be kept a safe distance away from the Bunsen burner at all times.

Due care will be given when using the Bunsen burner and the water bath in the glass beaker to avoid burns or other injury. Tongs shall be used to remove any test tubes from this water bath as the water in it will be boiling.

Standard laboratory practices including avoiding spillages, handling equipment with precision and care, washing hands after handling any substances or chemicals and keeping work area clean and free of obstacles must be observed at all times.

All tests will be conducted in a well ventilated area to reduce the risk of damage by inhalation of chemical fumes or particles from the various other substances.

Method:

A yeast suspension will be produced in a conical flask using 10 g of the dried yeast to 100 $cm^3$ of distilled water. To this will then be added 2.5 g of a sugar and stirred thoroughly using a glass rod. This will be carried out four times so that each yeast suspension contains one of the four sugars being tested. Another yeast suspension will be produced without any sugar being added. This shall be used as a control test. These flasks will then be placed in an incubator for one hour before the tests begin. During this time, five test tubes will be labelled for each of the four sugars as well as one for the control yeast. Another five test tubes will be labelled for the TTC solution. Next, using a 1 $cm^3$ syringe, 1 $cm^3$ of TTC will be measured out and placed into each of the labelled test tubes. After one hour, the yeast suspensions will be removed from the incubator and 10 $cm^3$ of each yeast placed into its corresponding test tube using a graduated pipette. All ten of the test tubes will then be placed in a test tube rack in the water bath for two minutes so they come to the correct temperature. During this time, the temperature will be checked regularly using a thermometer to ensure the water bath remains at a steady 35 °C. After equilibration, the TTC solution will be added to the yeast suspensions and timed using a stopwatch until the TTC turns pink. This process will then be repeated five times for each yeast suspension.

Variables:

*Dependent Variable*: respiratory substrate molecules (mono or disaccharides)

*Independent Variable*: time for TTC to turn pink

*Variables that need to be controlled*:

Temperature needs to be controlled as the rate of respiration of yeast may vary considerably in different temperatures, due to the action of enzymes at different temperatures. For example, a respiratory enzyme such as dehydrogenase enzyme may have an optimum temperature of 40 °C, and at this temperature would ensure rapid respiration rates. Whereas, at 50 °C, the same enzyme may be denatured and so respiration may not be able to take place at all, if not at a slower rate. Due to the nature of the investigation being carried out, it is very important that the temperature remains constant throughout.

Another variable that should be considered is that for all tests the same volumes of TTC solution and the same masses of the yeast and sugars are used. Using the same volumes of TTC each time will ensure that the colour change of the TTC is not affected by how much TTC is used. The same masses of yeast and sugars will ensure that the respiratory rate of the yeast is not affected. This point is important as if there is a larger mass of either sugar or yeast, the respiratory rate will rise accordingly and this will have a large impact on the investigation. Controlling these variables will therefore ensure that minimum error can occur to within a decent degree of accuracy.

All the yeast suspensions used will be of the same age. This will reduce the risk that the yeast has been able to respire any sugars used for a longer period which could alter the results dramatically, especially in the case of the disaccharides.

Finally, the oxygen concentration during the investigation needs to be controlled as much as is physically possible. This is because the rate of respiration of the yeast may be different in anaerobic conditions than it is in aerobic conditions. To try and prevent anaerobic conditions, the yeast will be stirred thoroughly to try and give aerobic conditions throughout. Also the tests will be carried out in a well ventilated area.

**Control test**

To test whether the TTC changed colour without being reduced by the respiring yeast cells, a control test was carried out. Each yeast suspension was produced with boiling distilled water in order to kill the yeast cells. This was also then incubated for an hour. Following this, 10 $cm^3$ of each suspension was put into a boiling tube by pipette and placed in a water bath at 100 °C, over a Bunsen burner. These were then left at 100 °C for five minutes to ensure that the yeast cells were dead. Then, 1 $cm^3$ of TTC was added to each. The solution was then timed to see whether any colour change of the TTC occurred.

After 20 minutes, there was no colour change in any of the yeast suspensions and it was concluded that the TTC required live respiring yeast cells in order to become reduced and therefore change colour. This meant using the TTC in the investigation was a valid test of the rate of respiration.

**Preliminary test**

This was carried out to ensure the method outlined would be suitable to gather usable and reliable results.

During this test, a problem arose; the TTC in all of the yeast suspensions was turning pink within 120 seconds of being added regardless of whether the sugar used was a monosaccharide or disaccharide. A repeat of this test under the same conditions gave similar results again. This showed that the method being used was not correct for the investigation.

These results were thought to be because the yeast suspensions were being incubated for too long a period before testing. If this was the case, the yeasts may have had enough time to hydrolyse the disaccharides into their constituent monosaccharides. This would mean during testing, all the yeast suspensions would be respiring at a similar rate (apart from the lactose and control suspensions) as there would only be monosaccharides available as a respiratory substrate.

The proposed method was altered so that the incubation period would only be 600 seconds for each suspension.

The results following this change of method were more satisfactory, so it was decided this was the most reliable method to use.

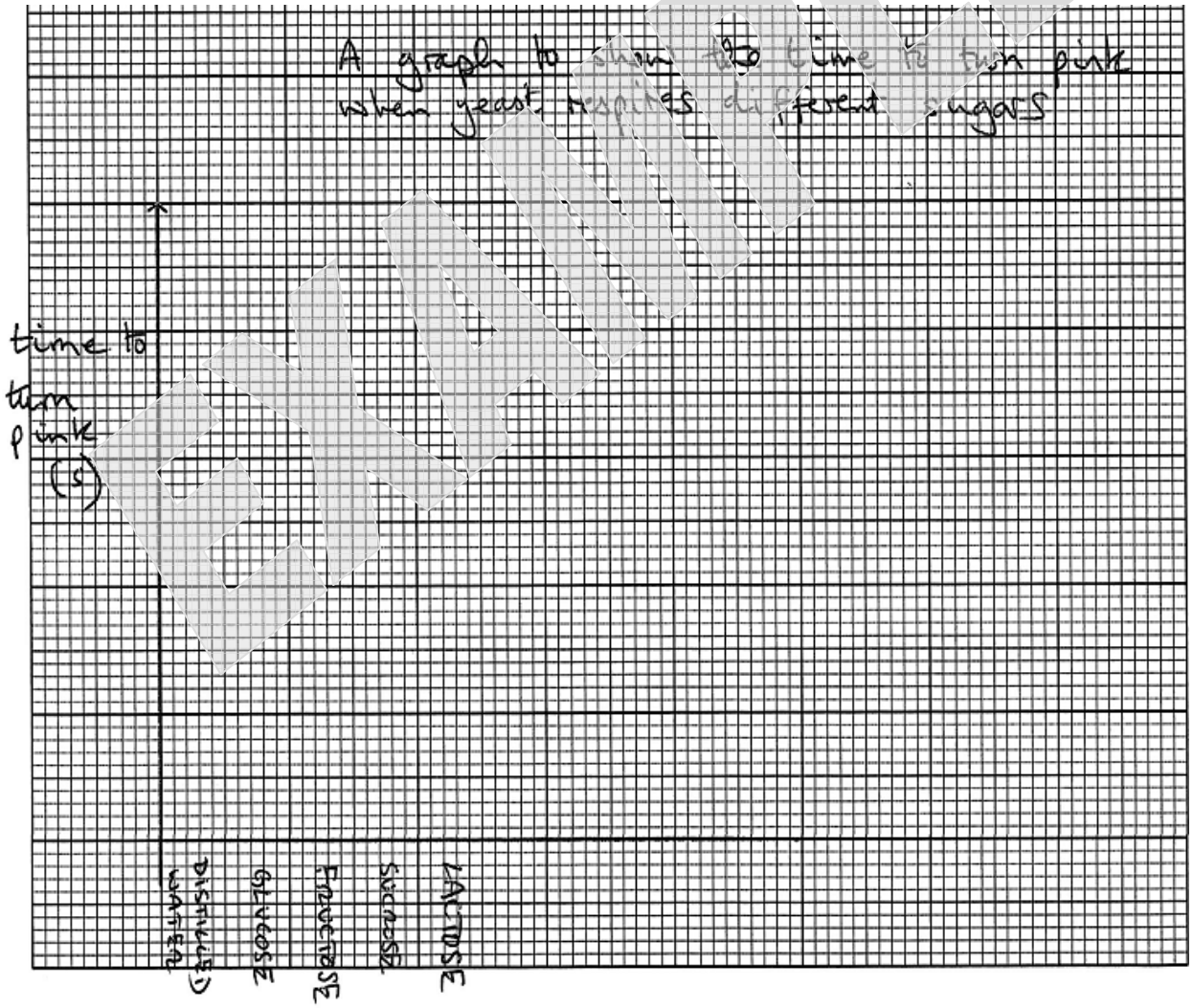
The results should be recorded in a table as shown on the next page.

Candidate 1

Time (s) for TTC to turn pink

| sugar | Test one | Test two | Test three | Test four | Test five |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

A bar graph will be plotted of named sugar on x axis and time (s) to turn TTC pink on the y axis as shown below.



**SKILL B**

**Results**

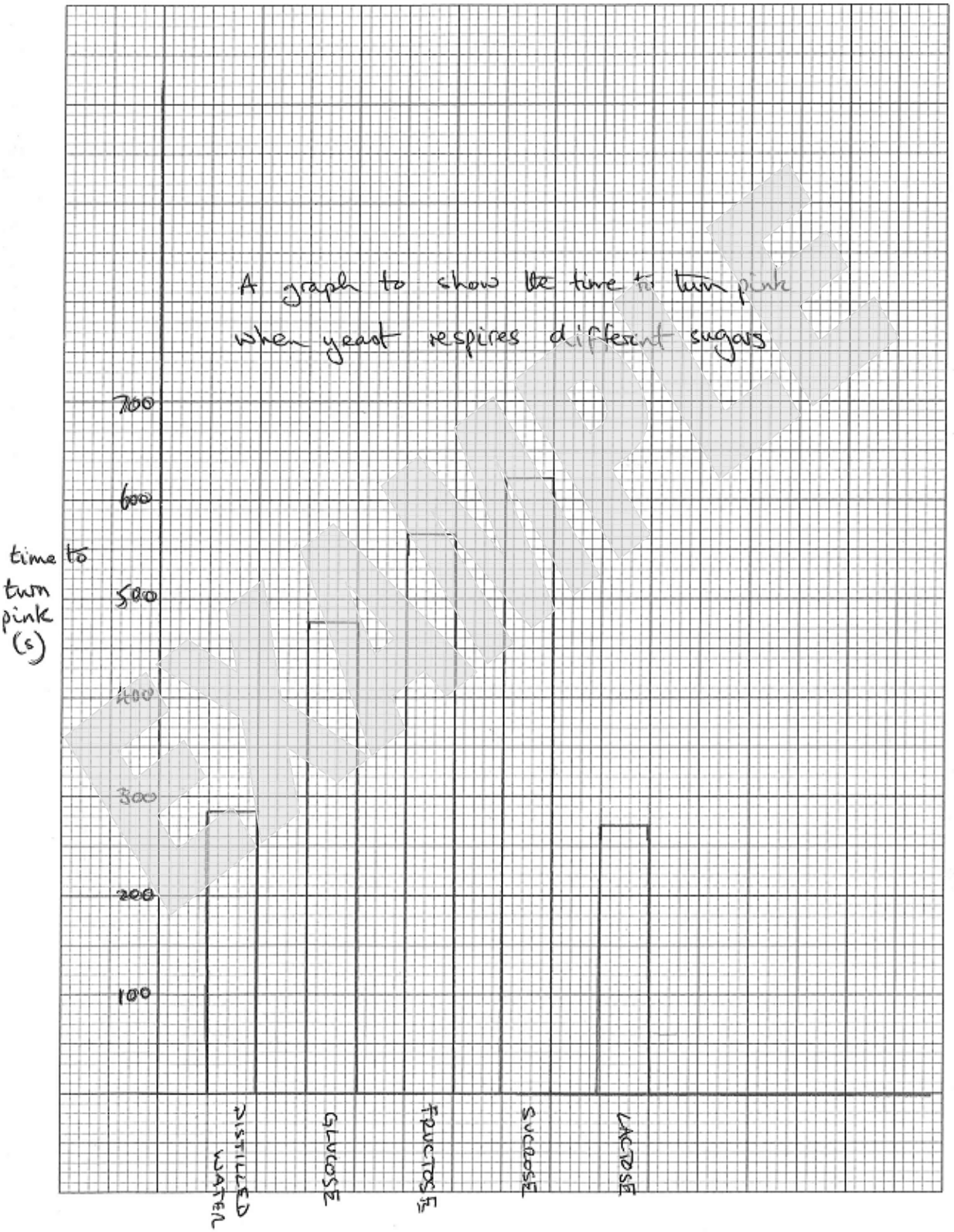
The results from the tests are as follows:

| Sugar | Test 1 (seconds) | Test 2 (seconds) | Test 3 (seconds) | Test 4 (seconds) | Test 5 (seconds) |
|---|---|---|---|---|---|
| Glucose | 484 | 477 | 473 | 476 | 482 |
| Fructose | 569 | 563 | 563 | 565 | 568 |
| Lactose | 252 | 277 | 280 | 273 | 276 |
| Sucrose | 625 | 620 | 619 | 625 | 621 |
| Distilled Water | 283 | 283 | 282 | 288 | 286 |

The averages and the standard deviations of the results are as follows:

| Sugar | Average (seconds) | Standard Deviation |
|---|---|---|
| Glucose | 478.4 | 4.5 |
| Fructose | 565.6 | 2.8 |
| Lactose | 271.6 | 11.2 |
| Sucrose | 622.0 | 2.8 |
| Distilled Water | 284.4 | 2.5 |

This data was then poltted into a bar chart as shown on the next page.



**SKILL C**

**Analysis**

In order to statistically analyse this data to check its reliability, the Student's T-test was carried out. This test shows whether or not there is a significant difference between two pieces of data. Therefore, in this investigation it will show whether there is conclusive evidence to suggest that the rates of respiration varies with different sugars.

First of all t-values had to be calculated for all the data being compared. It was because there were more than two variables to be considered, various T-tests would be carried out to compare different relationships. The chosen tests would be carried out between glucose and fructose in order to compare monosaccharides and between glucose and sucrose to compare a monosaccharide with a disaccharide. It was also decided that because lactose had given an unexpected result, it would be compared with distilled water. This would show whether there was a relationship between the two as neither were expected to turn the TTC pink.

The following equation is used in calculating the t-value:

$t = (X_1 - X_2) / \sqrt{(S^2_1/n_1 + S^2_2/n_2)}$

Where:

**X = mean**

**$S^2$ = standard deviation**

**n = number of samples.**

The calculated t-values were as follows:

| Sugars | t-value |
|---|---|
| glucose and fructose | 72.17 |
| glucose and sucrose | 118.57 |
| lactose and distilled water | 7.6 |

After viewing a stats table, it was discovered that the critical value for t in this investigation was 2.31. This was using the 95% confidence level.

A comparison between the t-values of the investigation to the critical value shows that there is a highly significant difference between the rates of respiration of yeast with glucose and fructose. This is evident because the t-value is considerably larger than the critical value of t. Therefore, the null hypothesis can be discarded on this particular relationship. This supports the prediction that glucose would be respired by yeast faster than another monosaccharide.

Comparing the t-value of the glucose and sucrose with the critical value shows an even more significant difference between the two of 116.26 than that apparent with the glucose and fructose of 69.86. Again, this means that the null hypothesis can be discarded and that there is a significant difference between the rates of respiration of the yeast respiring monosaccharides and disaccharides. This data also supports the prediction that not only will yeast respire monosaccharides faster than disaccharides, but also supports the idea that glucose is respired

faster than any other respiratory substrate investigated.

Looking at the t-value of the lactose and distilled water as well as the critical value also highlights a significant difference between the respiration rates with lactose and distilled water. However, the t-value of this relationship is considerably smaller than that of the other two relationships; approximately 16 times smaller than the relationship between glucose and sucrose and approximately 9 times smaller than the relationship between the two monosaccharides. This could be due to the unexpected nature of the results gained in this particular relationship

The unusual relationship highlighted in the results may be due to unexpected characteristics in the yeast used for the investigation. Yeast is not usually able to respire lactose due to it not being able to produce the enzyme β-galactosidase which is needed to break down lactose into its constituent monosaccharides (4). This means lactose is too large a molecule to be diffused into the yeast cell and so it is not used as a respiratory substrate. However, some strains of yeast have been genetically modified so that they are able to produce this enzyme and so respiration of lactose by yeast becomes possible. This may be a reason as to why the yeast used in the investigation reduced the TTC and turned it pink as the yeast used may have been a strain that has been modified.

However, this theory does not explain why the yeast with only distilled water also reduced the TTC and caused its colour change. This, and the lactose result, could be attributed to the fact that the yeast used was dried active yeast. This means the yeast was grown at a previous time and then dried. Because of this, the yeast may already have contained residual sugars from its previous growth period and so may well have been respiring this sugar content rather than the lactose.

A few accuracy issues became apparent during the investigation that could have been the cause of error. The tests involved using the colour change of TTC to measure the rate of respiration of the yeast. However, this may have been a cause of significant human error because of colour determination. It was difficult to try to distinguish an end point using only the human eye each time when the TTC was reduced. This meant that the timing of each test may have differed slightly from each. In future tests, a better method may be to measure the volume of carbon dioxide emitted by the yeast as this is a more reliable test.

Also, each sample of yeast may have included varying numbers of yeast cells which could have affected the results. This was caused because the yeast cells in the original samples made may have settled to the bottom, even after stirring. To prevent this, a haemocytometer could be used to measure the number of yeast cells per sample and this could be aided by stirring the yeast samples throughout the testing.

he water bath used may also have given a degree of error to the investigation because it was an unstirred water bath. This means that although a thermometer was used to measure the water temperature, this temperature may not have reflected the temperature throughout the water bath as different areas may have been warmer than others. Using a stirred water bath could help to resolve this issue in future tests.

The oxygen content in the samples may have varied. Whilst in the test tubes, the yeast sample may have become more anaerobic at the bottom of the tube than at the top. This could mean that the respiration rates of the yeast within a single sample may have varied as the rates at the top of the tube in more aerobic conditions may have been higher than those at the bottom.

In order to extend the investigation, tests could be carried out with different strains of yeast, including some that are genetically modified, to explore how well different yeasts respire lactose. This would also give more insight into the unexpected results in this investigation concerning the lactose yeast sample. Also, investigations could be carried out to examine whether the yeast used do contain residual sugars.

In conclusion, the tests mainly provided evidence to support the hypothesis that yeast respires monosaccharides at a faster rate than it does disaccharides. The results also agree with the prediction that glucose is respired faster than all the other respiratory substrates investigated. However, the prediction that lactose is not respired by yeast was not supported by the results due to unexpected reduction of TTC in these samples. On the other hand, the yeast containing just yeast and distilled water also gave an anomalous result which could contribute to ideas as to why the lactose sample reduced TTC as well.

**Candidate 1 – Skill A marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| A1 | Aim given in third paragraph 'to see whether different sizes of the molecules alter the rate of respiration', and clear from surrounding paragraphs that sugars are the molecules. | 1 |
| A2 | Predictions given in fifth paragraph, and quantified. | 1 |
| A3 | Second paragraph – information on membranes and glycosidic bonds, linked to the prediction, and referenced with bibliography. | 1 |
| A4 | Paragraph 1 and 3 – some relevant knowledge from A2 used to link TTC change to detailed respiration but **not** linked to the prediction in enough detail. | 0 |
| A5 | Control variables identified; however, independent and dependent variables are stated the **wrong way around**. | 0 |
| A6 | Sufficient replicates (i.e. five, which is more than the required three), but **insufficient** values of the independent variable (i.e. only four sugars tested – needs to be five). | 0 |
| A7 | (More than) one secondary source referenced in the text with numbers and bibliography, but it is not clear how the sources have been **used to inform** the data collection strategy. | 0 |
| A8 | "Preliminary test" used to develop the strategy (though ideally the data should have been presented – benefit of the doubt has been given on this occasion). | 1 |
| A9 | Risk assessment included. | 1 |
| A10 | Strategy is detailed and includes sufficient information on control of variables; however, the end point is being judged subjectively – "timed using a stopwatch until the TTC turns pink" does **not** sufficiently consider how to gather precise and accurate data. | 0 |
| A11 | Sequence is clear; benefit of the doubt given for repeatability (see comment in A10 on difficulty in judging end point). | 1 |
| A12 | Selecton of apparatus and measurement techniques is not justified, but some justification of critical steps in the strategy (e.g. allowing tubes to equilibrate to correct temperature, and importance of controlling variables); preliminary study also used to devise "the most reliable method". | 1 |
| A13 | Suitable table format proposed for recording data, **however** the dependent variable and units (s) should have been given in the column headings rather than in the title. | 0 |
| A14 | Simple processing not explicitly identified, but inferred by plan to perform T-test; appreciation that this will allow hypothesis to be tested statistically. | 1 |
| A15 | Suitable graphical method suggested, with appropriately labelled sketch. | 1 |

**MARK FOR SKILL A: 9/15**

**Candidate 1 – Skill B marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| B1 | Validated by teacher. | 1 |
| B2 | For a valid t-test, more repeats are needed (ideally 20 in each category). | 0 |
| B3 | No report of how effect of uncontrolled variables was minimised. | 0 |
| B4 | All raw data recorded to the nearest second – an appropriate level of precision for a stopwatch, due to impact of human reaction time. | 1 |
| B5 | Table meets all requirements of B5 **except** for the inclusion of an informative title. | 0 |
| B6 | Means calculated and rounded correctly (benefit of the doubt allowed for references to "average" rather than "mean"). | 1 |
| B7 | Cannot award this descriptor for the t-test, as this was performed in the report for Skill C; however correct calculation of standard deviations in Skill B means the descriptor **can** be awarded. | 1 |
| B8 | Decimal places used appropriately and consistently. | 1 |
| B9 | Anomalous values/outliers **not** identified in Skill B. | 0 |
| B10 | Appropriate graph plotted by hand, all plots correct, correct scaling and SI units; error bars may have helped the candidate analyse the data later and the x-axis should have had a label, but the candidate has done just enough for the mark here. | 1 |

**MARK FOR SKILL B: 6/10**

**Candidate 1 – Skill C marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| C1 | Trends described when considering the results of the t-test, however these are 'sweeping' – talking about monosaccharides and disaccharides rather than the specifics of the study – and presented more in the form of conclusions rather than a discussion of trends in the processed data; the descriptor can not be awarded if there is not **clear** evidence in support of it. | 0 |
| C2 | Mark given for the statements made in the final paragraph ("In conclusion…") of the analysis and evaluation. | 1 |
| C3 | Theory of hydrolysis of glycosidic bonds discussed as possible explanation for lactose results. | 1 |
| C4 | No detailed discussion of respiratory co-enzymes, so the mark has **not** been given. | 0 |
| C5 | Although standard deviation has been calculated, there is no comment on what this implies about the reliability of the raw data. | 0 |
| C6 | Paragraph discussing "A few accuracy issues…". | 1 |
| C7 | No **clear** comment on the reliability of data collection strategy; this could be inferred from the discussion of the timing issue or the "number of yeast cells" issue, but these are not related to reliability of the data collection strategy explicitly; the descriptor can not be awarded if there is not **clear** evidence in support of it. | 0 |
| C8 | Discussion of TTC and timing issue, varying yeast cells issue and unstirred water bath and oxygen content. | 1 |
| C9 | The effect of varying oxygen concentration on the dependent variable explained. | 1 |
| C10 | The effect of a second limitation is **not** discussed. | 0 |
| C11 | Three improvements needed; accept measuring evolved carbon dioxide to improve reliability of results and stirring water bath so that measured temperature is true reflection of actual temperature; however, it is **not** made clear how using a haemocytometer to "measure the number of yeast cells" or stirring the yeast suspension would be used to overcome the issue of variation in the number of yeast cells per sample; the descriptor can not be awarded if there is insufficient clear evidence in support of it. | 0 |
| C12 | Does not clearly explain effect of any improvement on the accuracy and precision of the raw data. | 0 |
| C13 | | 0 |
| C14 | Descriptor awarded for comments on significance levels following the t-test. | 1 |
| C15 | Spelling, punctuation and grammar good on the whole; one or two isolated mistakes do not prevent this descriptor being awarded. | 1 |

**MARK FOR SKILL C: 7/15**

**TOTAL MARK FOR EXTENDED INVESTIGATION: 22/40**

Candidate 2

**Extended Investigation**

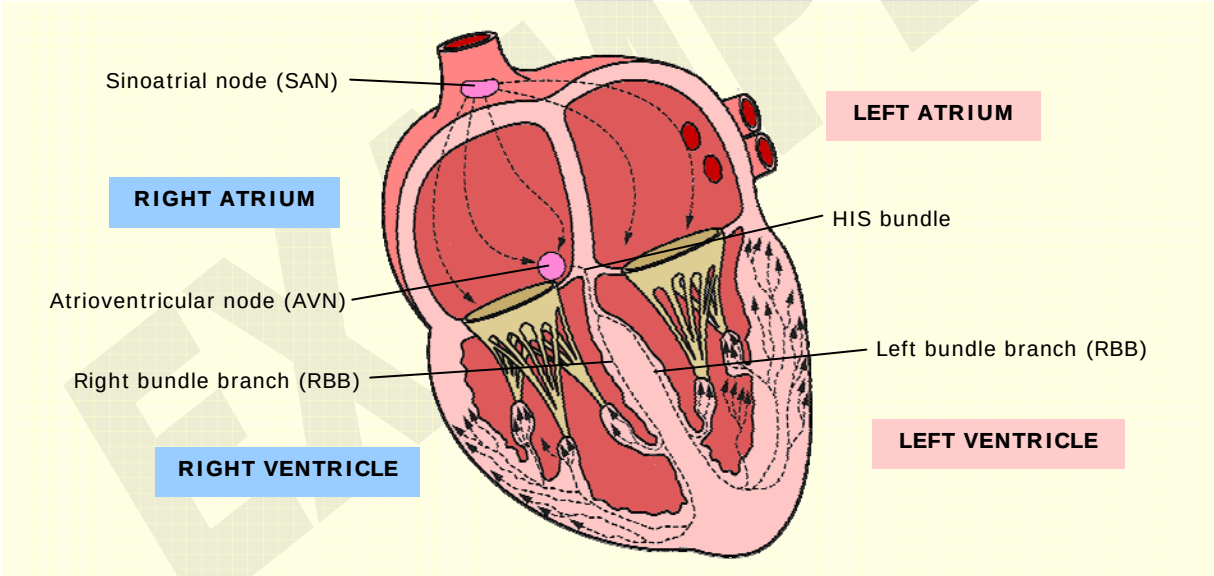
**Is the recovery rate of human hearts influenced by gender?**

Skill A

Introduction

I am doing this experiment because I have been involved in sports and I am interested in learning about some of the finer points of the recovery system. I am interested in finding out if their are any differences in the recovery rates of the different genders; this is because it is a controversial argument that men are fitter then women.

The measurement of how fast the heart recovers is said to be the Heart Recovery Rate.
The structure of the heat makes it very efficient, it never stops pumping, and this means that it is very important that the heart is strong. The average heart contracts and relaxes 70-80- times per minute (cardiac output) 70 ml of blood is pumped out the heart in one beat at rest and fluctuates as the intensity levels change.




(3)

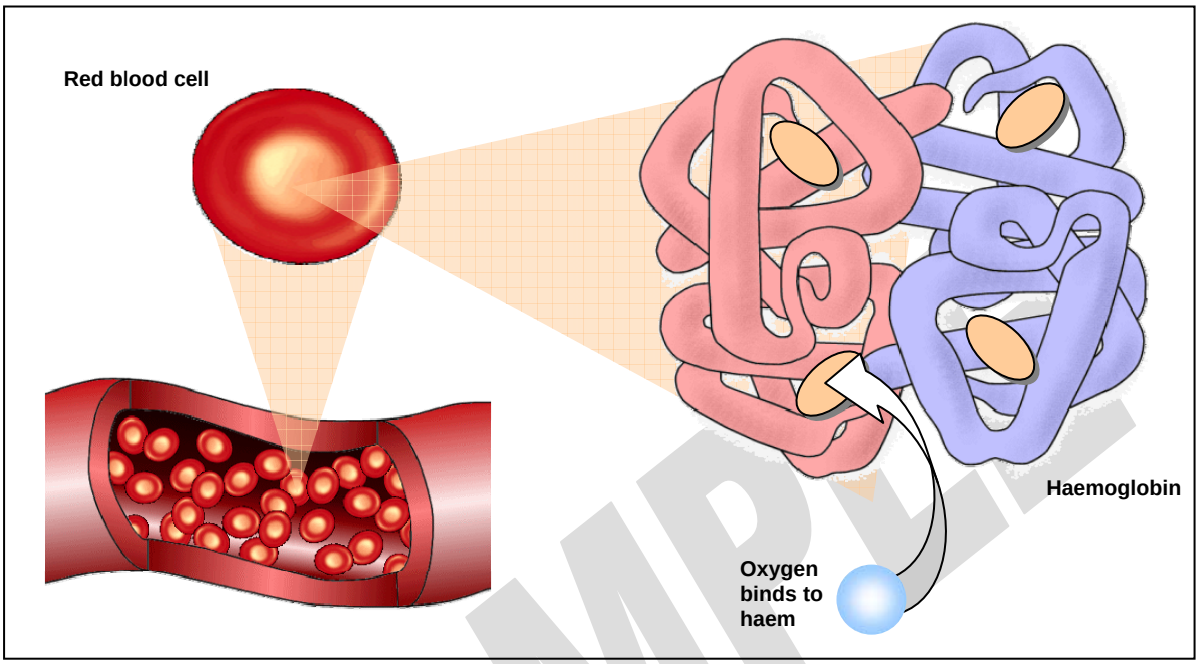
The heart is locacted just to the left behind the breastbone and is the size of an adult fist. The heart has 4 main chambers which the blood passes through. The blood enters the heart deoxygenated and when it leaves is oxygenated. Each chamber holds 70 ml of blood.

The job of the heart is to pump enough blood around the body to the working muscles as efficiently as possible so that they don't fatigue. In terms of recovery the heart is able to get back to it's resting heart rate after exercise and this varies in the male and female body due to the fact that males have a higher maximum heart rate for adults in particular.

WOMEN: 220-age=maximum heart rate.
MEN: 226-age= maximum heart rate.

The system that is being used for recovery is the autonomic nervous system. This is the part of the nervous system that can regulate the heart and blood supply system (1).

Athlete's heart is a common term for the enlargement of the heart due to extra stress and exercise on the body this is why elite athletes are able to have a more efficient respiratory system and therefore they will be able to recover a lot quicker than the average heart.




(5)

The size of the heart makes a difference in the recovery rates and therefore a bigger heart will recover quicker. Males have a bigger respiratory system so there fore it will be expected that males will have a quicker recovery rate than women due to oxygen debt being the main cause that the body has to recover after exercise. This size difference is due to the fact that males are bigger physically any way. Women also have a lower hemeoglobin level in the cells which carry the oxygen in the blood to the working muscles this oxygen will be used in the recovery rate and therefore males will again recover quicker than the women. There is a 10- 1 5% gap in the efficiency and working of the female body in terms of exercise and this will also have effects on the recovey rates. It is expected that the heart rate of any person should fall by at least 20 beats per minute in the first minute after exercise after this it is expected that the rate will slow down gradually.

Null hypothesis

There will be no difference in the recovery rate of males and females after exercise.

Hypothesis

The recovery rates of the females will be slower then the recovery rates of the males due to differences in anatomy and physical fitness.

Aim

To determine if their is a significant difference between the recovery rates of males and females I will be taking the resting rate and then exercising the participant's and then recording how long it takes for them to reach their resting heart rate.

Prediction

I predict that the mean male recovery rate will be faster by at least one minute compared to the mean female recovery rate.

Preliminary test

Method:

1. Ask participants if they have any medical reason why they can't take part.
2. Tell the participants exactly what you are doing.
3. Take the participants heart rate before they do any exercise.
4. Participants run for 7 minutes.
5. Take heart rate immediately afterwards.
6. Take heart rate for 6 minutes at 1-minute intervals.

Safety

| **Hazard** | **Problems** | **Corrections** |
|---|---|---|
| Footwear | The correct footwear must be worn to make sure that none of the participant's fall over and injures themselves. | Check all participant's footwear before they begin the exercise. Make sure that they are wearing trainers that have a grip on the bottom. |
| Fitness | Some people may find it hard to take part in the experiment if they are not fit or have an injury that will affect their performance or cause them to be in pain. | Ask the participant's if they have got any injuries or are not fit to participate in the experiment. |
| Environment | It could be unsuitable for the experiment to take place on the ground The surface may be unsuitable and could be dangerous | Check the area around where you are going to carry out the experiment. Make sure that the ground is not dangerous |

For my preliminary test I did a 7minute run rather than a step test, however it did not have the same effect on the heart rate of the participants also it was difficult to keep them running at a steady pace as some were quiet obviously fitter and able to run at a faster pace than some of the other participants. The proposed method will have to be changed to a step test. This will allow me to control a set pace of stepping. This means I should get reliable results.

Equipment

- Stop watch.
- Bench (for step test).
- Pens.
- Paper.
- Participant's.

Fair test

I have made my experiment a fair test by making sure that all the participants are the same age, testing them all at the same time so as to have them in virtually the same position in terms of their heart rate. I made sure that they were exercising at the same rate for the same amounts of time.

Variables

Dependant Variable:
Male or female subjects

Independant Variable:
Recovery time after exercise

Variables that need to be controlled:

- Age of subjects. This is because recovery times will change as humans age as they slowly lose their physical fitness.
- Intensity of the exercise is being kept the same. This will make sure the same amount of stress is put on all the subject's hearts.
- The pulse rate will be measured in exactly the same way each time.
- The environmental conditions in the test room should be the same.

Final Method

1. Tell the participant's exactly what you are doing.
2. Take the participant's heart rate before they do any exercise.
3. Participant's step for 3 minutes.
4. Take heart rate immediately afterwards.
5. Take heart rate for 6 minutes at 1 minute intervals.

Table to show the time taken to recover resting pulse rate after exercise:

| **student** | **Resting pulse** | **Pulse immediately after exercise** | **60 s** | **120 s** | **180 s** | **240 s** | **300 s** | **360 s** |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
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| | | | | | | | | |
| Mean | | | | | | | | |

Enough result's will be collected to carry out a statistical analysis using the student t test (9).

A graph should be plotted of mean time (s) from completion of exercise on the x axis against pulse rate (bpm) on the y axis for males and females. Range bars may be included to show variability of the results.

Bibliography

1 http://www.skyaid.org/Skyaid%200rg/Medical/stress_test_recovery_rate.htm

2 www.mamashealth.com/HEART

3 http://www.biologybits.co.uk/images/heart.jpg

4 http://home.hia.no/-stephens/gender.htm

5 http://www.heart-beats.com/hemoglobin.jpg

6 www.tiscalli.co.uk/reference/encyclopedia/hutchinson/mOO06818.html

7 www.sin.fi.edu/bioscilstructure/structure.html

8 www.abc.net.au/rn/talks/8.30/helthript/stories/563595.htm

9 Statistics in Advanced Biology. Coxon, S.R. and Coxon, B. Cambridge University Press.

Skill B

Results

Table to show the time taken to recover resting pulse rate after exercise (girls):

| Student | Resting pulse | Pulse immediately after exercise | 60 s | 120 s | 180 s | 240 s | 300 s | 360 s |
|---|---|---|---|---|---|---|---|---|
| A | 72 | 168 | 104 | 96 | 88 | 76 | 76 | 72 |
| B | 80 | 172 | 156 | 136 | 120 | 104 | 80 | 78 |
| C | 88 | 188 | 128 | 116 | 136 | 116 | 88 | 85 |
| D | 70 | 144 | 140 | 120 | 112 | 96 | 68 | 70 |
| E | 80 | 120 | 92 | 88 | 88 | 88 | 84 | 80 |
| F | 116 | 170 | 120 | 108 | 80 | 68 | 60 | 68 |
| G | 100 | 120 | 112 | 128 | 108 | 92 | 88 | 88 |
| H | 68 | 160 | 104 | 68 | 64 | 64 | 56 | 59 |
| I | 84 | 168 | 124 | 88 | 72 | 68 | 64 | 64 |
| | | | | | | | | |
| mean | 74.9 | 156.6 | 119.5 | 105.3 | 96.4 | 85.7 | 73.7 | 73.7 |

These girls showed a range of recovery from 120 to 360 seconds. Mean recovery time for these girls was 4.1minutes.

Table to show the time taken to recover resting pulse rate after exercise (boys):

| Student | Resting pulse | Pulse immediately after exercise | 60 sin | 120 s | 180 s | 240 s | 300 s |
|---|---|---|---|---|---|---|---|
| J | 70 | 136 | 120 | 112 | 108 | 108 | 96 |
| K | 80 | 128 | 116 | 96 | 72 | 68 | 68 |
| L | 76 | 112 | 64 | 64 | 60 | 60 | 56 |
| M | 80 | 160 | 116 | 80 | 68 | 64 | 64 |
| N | 92 | 156 | 80 | 72 | 72 | 72 | 68 |
| O | 68 | 104 | 100 | 76 | 64 | 64 | 60 |
| P | 40 | 120 | 68 | 60 | 40 | 40 | 40 |
| Q | 88 | 104 | 88 | 88 | 88 | 76 | 68 |
| R | 68 | 108 | 96 | 84 | 80 | 68 | 68 |
| | | | | | | | |
| mean | 74.0 | 124.0 | 91.0 | 77.0 | 68.0 | 64.0 | 61.5 |

These boys showed a range of recovery from 60 to 240 seconds. Mean recovery time for these girls was 2.3minutes.

I am not using Js' results due to the fact that I cannot determine when he will recover as all the others have recovered by 5 minutes.

Statistical test

Boys:

| | **Recovery in minutes** | $-x$ | $(X-x)^2$ |
|---|---|---|---|
| K | 3 | 0.7 | 0.49 |
| L | 1 | 1.3 | 1.69 |
| M | 2 | 0.3 | 0.09 |
| N | 1 | 1.3 | 1.69 |
| O | 3 | 0.7 | 0.49 |
| P | 3 | 0.7 | 0.49 |
| Q | 1 | 1.3 | 1.69 |
| R | 4 | 1.7 | 1.7 |
| | | | $\sum$= 9.52 |

Standard deviation= $\sqrt{\frac{\sum(X-x)^2}{n-1}}$

Standard deviation= $\sqrt{\frac{9.52}{7}}$

standard deviation= 1.17

Girls:

| | **Recovery in minutes** | $-x$ | $(X-x)^2$ |
|---|---|---|---|
| A | 6 | 1.9 | 3.61 |
| B | 5 | 0.9 | 0.81 |
| C | 5 | 0.9 | 0.81 |
| D | 5 | 0.9 | 0.81 |
| E | 6 | 1.9 | 3.61 |
| F | 2 | 2.1 | 4.41 |
| G | 3 | 1.1 | 1.21 |
| H | 2 | 2.1 | 4.41 |
| I | 3 | 1.1 | 1.21 |
| | | | $\sum$= 20.89 |

Standard deviation= $\sqrt{\frac{\sum(X-x)^2}{n-1}}$

Standard deviation= $\sqrt{\frac{20.89}{8}}$

Standard deviation= 1.62

The T-test:

Girls = 1.17 Boys = 1.62
A B

$$T = \frac{X_A - X_B}{\sqrt{\frac{(S_A)_2}{n} + \frac{(S_B)_2}{n}}}$$

$$T = \frac{4.1 - 2.3}{\sqrt{\frac{(1.62)_2}{9} + \frac{(1.17)_2}{8}}}$$

$$T = \frac{1.8}{\sqrt{0.2916 + 0.1711}}$$

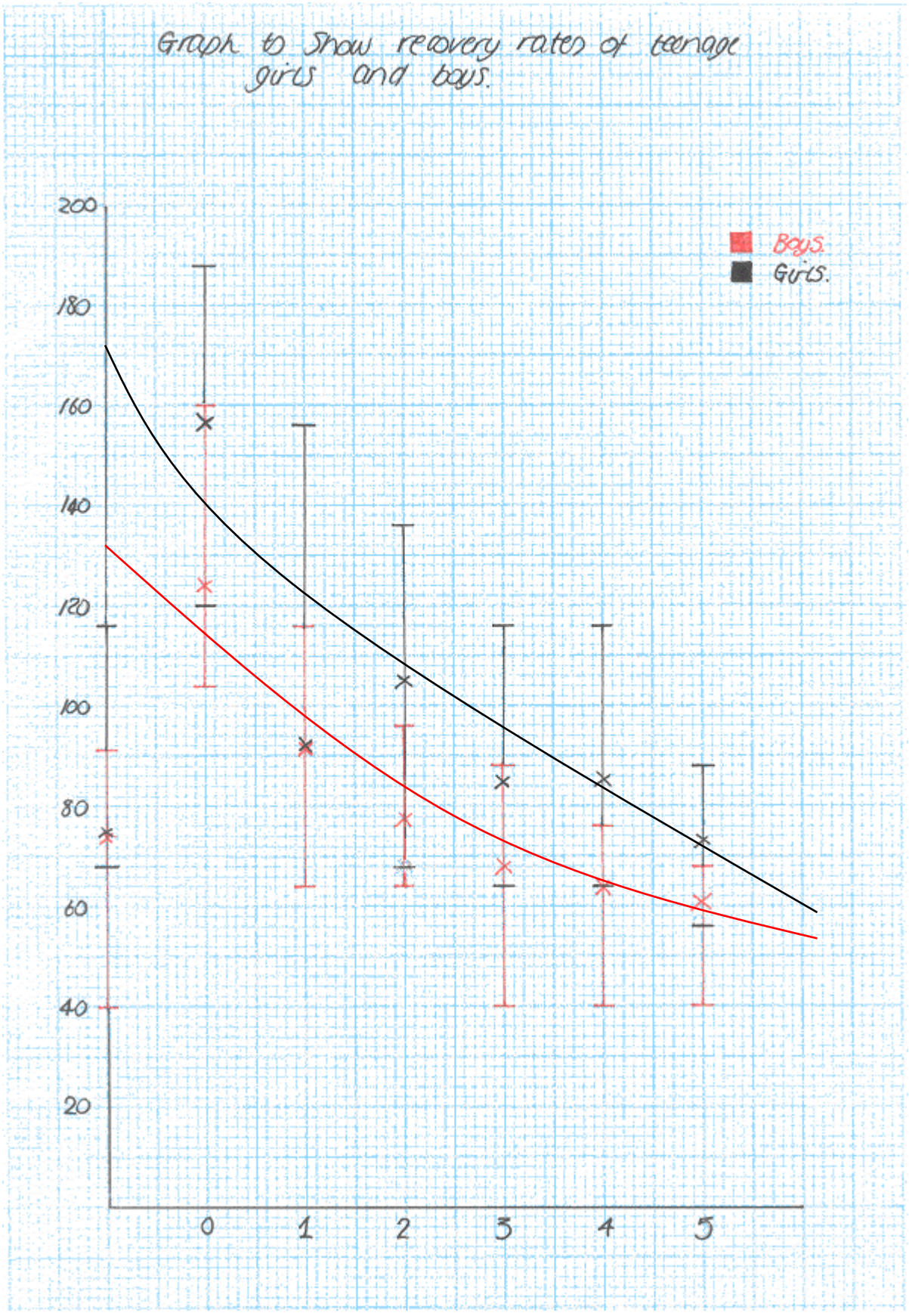
$$T = \frac{1.8}{0.6802}$$

T= 2.6462

Degrees of freedom = (n-1) + (n-1)
= 8 + 7
= 15

Critical value = 2.131

This means I reject my Null Hypothesis.


Graph to Show recovery rates of teenage girls and boys.
Boys
Girls.
200
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5

Skill C

Analysis, Evaluation And Conclusion

From the graph it is obvious that both males and females recover form exercise but the recovery rate of a male is on average quicker than that of a female. This is mainly because their is a 10-15% gap in the efficiency of the heart and the respiretory system. It may also be because of the difference in physical size of the male and female body, the heart will adapt to the size of the body for example in males their body is bigger so they will have a bigger and therefore more efficient heart. This is important, as the whole reason for the body needing to recover is the oxygen debt that occurs after exercise. Their is also evidence to suggest that women have a lower hemeoglobin level, which will also lead to males recovering faster because this will supply more oxygen to get rid of the oxygen debt a little faster in males.

My statistical tests show that in my results there is a significent difference and therefore I am able to reject my Null hypothesis. This accepts that my prediction was correct and that males do in fact recover faster than females. I have used the T test because for my results it will be the most accurate test to carry out. I was able to use my degrees of freedom to decide wether I could accept or reject my null hypothesis at 5% . Although my results show that their was a difference this may not be as big as first thought due to the fact that there are overlaps on my graphs showing that at some stages of the graph the rate of recovery was virtually the same. This could be due to not having enough data and therefore my results not being as reliable as they should be.

However, if I were to do my experiment again I would make some changes to make it more reliable. I do not have a lot of confidance in my results due to the fact that their aren't many of them and this will not show a perfect result of how much of a difference their actually is. The more results that I have the more precise my results will be. I would also be a lot more random in my selection of subjects.

Limitations

The main limitations were;

1 differences in physical ability.
2 differences in the amount of body fat/BMI
3 smokers or non smokers
4 varied diet before the experiment was undertaken

The fact that some subjects would have had more physical training by taking part in sports than others would have meant that they were likely to recover more quickly males (L, P) and females (E, F) might have been the most physically fit and from my data this can make a lot of differance in the recovery rate of the heart and so my results are quite varied for both sexes. Had I used fifteen males and fifteen females my results would have been more accurate. I have to admit that my planned data collection did not turn out to be very reliable.

Some subjects were overweight so the body mass index of some subjects would have been much higher than others. This would have meant their hearts ‘at rest’ would have been under more strain so their resting pulse rate would probably have been higher and their recovery slower. In my small sample this factor could have been the cause of the slower recovery time for females.

Improvements

1 A larger sample of subjects, a minimum of 15 males and 15females. This would have made my data collection more reliable.

2 Only allow subjects with a BMI of between 20-24 to take part. This would have meant the experiment started with 'low stress' hearts.

3 Only allow non smokers to take part

4 Use a complete medical questionnaire before entering subjects into the experiment.

Smoking has a large affect on the cardiovascular system, up to 20% less oxygen is carried to the muscles so the pulse rate would be higher than average and the oxygen debt larger than average so it would take longer than average to recover, perhaps male J is a smoker

Medical screening would also help to make the data more accurate as some short or long term medications can alter the cardiovascular system, this could lead to longer recovery time or a subject being unable to complete the experiment. I now realize that subjects on medication should not be allowed to take part in this experiment

Overall my experiment was carried out successfully and my results confirmed my prediction. I did not have to modify my experiment throughout as my results were what I had expected.
But now I have carried out the experiment I realize how many variables I did not properly control so it might be pure chance that my results agreed with my prediction. My experiment is not really valid due to the mistakes I made, however if the improvments were carried out for a second experiment the results would be more valid.

I had to exclude one of the boys results based on the time of his recovery, the rest of the boys had recovered by the 5minute mark and he was still recovering to his normal resting heart rate at 7 minutes, so I cannot be sure of when he did actually recover.

**Candidate 2 – Skill A marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| A1 | Question set out in "Aim" section (i.e. "determine if there is a significant difference between the recovery rates of males and females"). | 1 |
| A2 | Prediction clearly stated in its own section, and is quantitative. | 1 |
| A3 | Much irrelevant material, not used to justify question or prediction; some links to learning outcome 1.2.1 in Unit F221 but stroke volume not explained in the context of this experiment; the descriptor can not be awarded. | 0 |
| A4 | No links to A2 theory made. | 0 |
| A5 | Some control variables identified; independent variable and dependent variable clearly stated but the **wrong way around**. | 0 |
| A6 | The candidate has **not** stated clearly anywhere in the report for Skill A how many participants will be in each category, therefore the descriptor cannot be awarded (it only becomes apparent from the Skill B report how many males and females are participating). | 0 |
| A7 | Reference 9 has been used to inform the data collection strategy (to define how many results to collect), and has been referenced in the text and in a bibliography. | 1 |
| A8 | "Preliminary test" used to develop a potentially more reliable data collection strategy (though ideally the data from the preliminary study should have been presented). | 1 |
| A9 | Risk assessment present in a table in the "Safety" section. | 1 |
| A10 | Data collection strategy **not** described in sufficient detail (e.g. How high is the step? / How is the heart rate measured? How are the start and stop times administered, and how is accuracy ensured? How are variables controlled?) | 0 |
| A11 | The **sequence** is clear, even though the method lacks details. | 1 |
| A12 | There is a discussion of some of the control variables (though a number of significant factors, e.g. BMI etc., not considered); however, the lack of detail in the data collection strategy and lack of justification of the apparatus and techniques chosen means that there is insufficient evidence that the candidate has fully considered how the planned strategy will maximise the validity of the data collected. | 0 |
| A13 | Incorrect table format – the independent variable (gender) should be in the first column with sufficient rows to record results for 10 males and 10 females; dependent variable columns lack informative heading. | 0 |
| A14 | Appropriate processing suggested (T-test). | 1 |
| A15 | It is not clear from the description of the proposed graph what type of graph will be plotted (bar? line?) and it is not clear what data will be plotted on the x-axis. | 0 |

**MARK FOR SKILL A: 7/15**

**Candidate 2 – Skill B marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| B1 | Validated by teacher. | 1 |
| B2 | Results recorded for only nine males and nine females, which does not meet the minimum requirement of 10 in each category for a gender based investigation, nor the minimum requirement for 20 results for the t-test. | 0 |
| B3 | No report of how effect of uncontrolled variables was minimised. | 0 |
| B4 | All raw data recorded to the nearest second – an appropriate level of precision for a stopwatch, due to impact of human reaction time. | 1 |
| B5 | Innapropriate table format, as described in A13. | 0 |
| B6 | Mean pulse rate calculated at each time point (though this is irrelevant, and there are a number of calculation and rounding errors); candidate has not shown how they calculated the mean recovery time, and it is incorrect.. | 0 |
| B7 | Standard deviation and t-test calculated correctly. | 1 |
| B8 | The switch from seconds to decimal minutes is not appropriate. | 0 |
| B9 | An anomalous set of data has been identified but the reasoning is inappropriate. | 0 |
| B10 | A graph has been plotted by hand but there are no labels or units on the axes; it is not clear which data have been plotted; x-axis scale is not correct; etc. | 0 |

**MARK FOR SKILL B: 3/10**

**Candidate 2 – Skill C marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| C1 | A basic trend is described but has not been supported by quotes from the processed data. | 0 |
| C2 | Uses outcome of t-test to reject null hypothesis, and relates this to the prediction. | 1 |
| C3 | There is just enough significant scientific knowledge and understanding (SKU) from the AS units. | 1 |
| C4 | No significant SKU from the A2 units. | 0 |
| C5 | Third paragraph comments on reliability of the raw data. | 1 |
| C6 | No clear discussion of the accuracy of the raw data; the descriptor can not be awarded if there is not **clear** evidence in support of it. | 0 |
| C7 | This descriptor could have been awarded due to comments relating to the reliability of the existing data collection strategy in the "Improvements" section, but these do not relate to **errors**. | 0 |
| C8 | Lists (more than) three significant limitations, but these would not impact the **accuracy** and/or **precision** of the **raw** data (they would impact the reliability of the data and the validity of any conclusions drawn). | 0 |
| C9 | Explains in the "Improvements" section the effect of smoking on blood oxygen concentration, but does not describe how this would have any effect on the **accuracy** and/or **precision** of the raw data. | 0 |
| C10 | Notes in the "Improvements" section that some medications can "alter" the cardiovascular system, but does not describe how this would have any effect on the **accuracy** and/or **precision** of the raw data. | 0 |
| C11 | Lists (more than) three possible improvements, but these would not impact the **accuracy** and/or **precision** of the raw data. | 0 |
| C12 | It is not made clear how the suggested improvements would impact the **accuracy** and/or **precision** of the raw data. | 0 |
| C13 | | 0 |
| C14 | Comments on significance levels following the t-test, and on the range bars, and links these to a lack of confidence in the results of the investigation. | 1 |
| C15 | Spelling, punctuation and grammar errors throughout mean this descriptor can not be awarded. | 0 |

**MARK FOR SKILL C: 4/15**

**TOTAL MARK FOR EXTENDED INVESTIGATION: 14/40**

## Extended Investigation F226

## Does human memory decline with increasing age?

### SKILL A - Designing a data collection strategy

*Introduction*

Memory is located in a section of the fore brain called the hippocampus, a part of the limbic system. The hippocampus is thought to be responsible for short term memory whilst the long term memory is located in the frontal and temporal lobes of the cerebral cortex. Short term memory is a temporary store of information required to carry out complex tasks such as learning, reasoning, and comprehension. It is involved in encoding information to long term memory as well as retrieving information from long term memory (2).

Long term memory can be in the form of facts, sound or smell. Memory is thought to be possible as synapses between brain cells are either newly made or reinforced by recalling existing memories. The biological mechanism of memory is not fully understood but it seems to result from changes in connections (synapses). One possible mechanism is long-term potentiation (LTP), this refers to a process whereby if two neurones are usually active together the connection between them will be strengthened, this means that activity in one neurone will tend to produce activity in another neurone (3).The multi store model of memory was proposed in 1968. It suggests that short term memory (STM) and long term memory (LTM) are permanent structural features of the brain with control processes to transfer memories from STM to LTM (1). People suffering from stroke in their left brain lose STM and this type of test could be used to find out how damaged STM is and possibly by repetition of this type of test some LTP can be built up again to improve the quality of life. (4).

*Prediction*

As the age group increases the mean number of symbols correctly remembered will decrease by one symbol for each 10 year increase in age.

*Variables*

Independent variable - The age of each subject

Dependent variable - The number of symbols correctly remembered

Controlled variables -

1 The environment used for carrying out the memory tests. The same corner of the laboratory will used.

2 Time of day- all test will be carried out.

3 colour blind subjects- the grid will be black symbols on a white background so any form of colour blindness will not interfere with the ability to memorise.

Uncontrolled variables -

It will not be possible to check for alcohol consumption before the test (I do not have access to a breathaliser) or to determine whether the participants are taking long term medication.

*Proposed method*

1 Select seven subjects for each of five age groups (16-20, 21-25, 31-35, 41-45 and 51-55 years).

2 Give a brief outline of the test they will undertake in writing.

3 Ask the subject to sign a consent form to ensure that they have given informed consent to participate in the experiment.

4 Present a randomised grid of numbers and letters for the subject to attempt to memorise (into their short term memory).

5 After 5 seconds remove the grid. Ask the subject to fill in a blank grid.

6 Record the number of correct responses in a raw data table.

7 Thank subject for taking part in the experiment.

I shall use this grid for my preliminary test -

| | | |
|---|---|---|
| 6 | 8 | 3 |
| R | X | A |
| 2 | 9 | 1 |
| J | Y | S |

*Preliminary study*

I gained the following results from seven members of my class:

| Subject | Correct number of responses (maximum 12) |
|---|---|
| 1 | 7 |
| 2 | 6 |
| 3 | 8 |
| 4 | 7 |
| 5 | 4 |
| 6 | 6 |
| 7 | 7 |

The mean number of correct responses was 6.4. This was lower than expected for subjects under 20 years of age. Several subjects complained afterwards that they did not have long enough to look at the grid. As this might lead to older subjects getting very low scores I will double the exposure time to 10 seconds in my final method. I will also make sure that only one subject at a time is in the room and that the subject's score remains confidential. They also complained that the grid was too small (36font)

So I will change it to 72 font.

*Risk assessment*

1 I will make sure the corner of the laboratory has no hazards such a chemicals (ask the technician to clean the bench )

2 Also that there are no trip hazards (such as bags, trailing wires)

3 Make sure the subject is at ease before conducting the test.

*Justification of final proposed method*

I have chosen a low number of subjects as this is all that is necessary for the Mann Whitney U test. It can determine significance with only seven pieces of data. (5)

I will change the exposure time to 10 seconds to reduce stress on the subjects and ensure the possibility of a wider range of results. Changing the font size to 72 will also be less stressful for those subjects with poor eyesight.
I originally planned to use 11- 15 year olds as my first age group but I would need written consent from their parents and this going to be too difficult to do. As I am interested in aging the 16-20 yrs group will be acting as a base line that I would expect to give similar results to 11-15 year olds.

*Data recording*

Correct recall of symbols by human subject

| Age (years) | Number of symbols correctly recalled by each subject | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Subject 1 | Subject 2 | Subject 3 | Subject 4 | Subject 5 | Subject 6 | Subject 7 | Mean |
| 16-20 | | | | | | | | |
| 21-25 | | | | | | | | |
| 31-35 | | | | | | | | |
| 41-45 | | | | | | | | |
| 51-55 | | | | | | | | |

I will use the Mann Whitney U test to test for significant differences between each age group tested. (5)

A bar chart will be plotted to show the mean number of correctly recalled symbols (on the y-axis) against human age in years (on the x-axis). Range bars will be added to indicate the variability of the results.

*Bibliography*

1 Psychology of the science of the mind and behaviour. Gross R. Hodder and Stoughton 2001 ISBN 0 340 796061 x

2 www. Medterms.com/script/main/art?articlekey=7142

3 www.memorylossonline.com/glossary/memory

4 Human Biology OCR Greatrell B. Lowie P. Tilley A. Editor Fuller F. Heinemann 2008 ISBN978-0-435-69210-0 page 231

5 www.theseashore.ork.uk/stats/for /twits

**SKILL B - Collecting and processing raw data**

*Record of raw data*

Correct recall of symbol by Human subject

| Age Class (years) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean correct Recall of symbols |
|---|---|---|---|---|---|---|---|---|
| 16-20 | 12 | 12 | 11 | 10 | 9 | 11 | 12 | 11.0 |
| 21-25 | 11 | 11 | 11 | 10 | 12 | 10 | 10 | 10.7 |
| 31-35 | 10 | 10 | 9 | 10 | 9 | 8 | 11 | 9.6 |
| 41-45 | 7 | 9 | 8 | 12 | 8 | 9 | 10 | 9.0 |
| 51-55 | 10 | 7 | 9 | 8 | 9 | 8 | 7 | 8.3 |

The Mann Whitney u test was carried out comparing each age group against the 51-55 year age group. The method used followed the formula given on the FSC website (5)

*The Null hypothesis*

There is no significant difference between the memory of symbols in different age groups.

*Alternative Hypothesis*

There is a significant difference between the memory of symbols of different age groups

From tables of U the critical value for a comparison of 7 samples with 7 samples is 8. If a U value is equal to or lower than this value the difference is significant at the 5% confidence level.

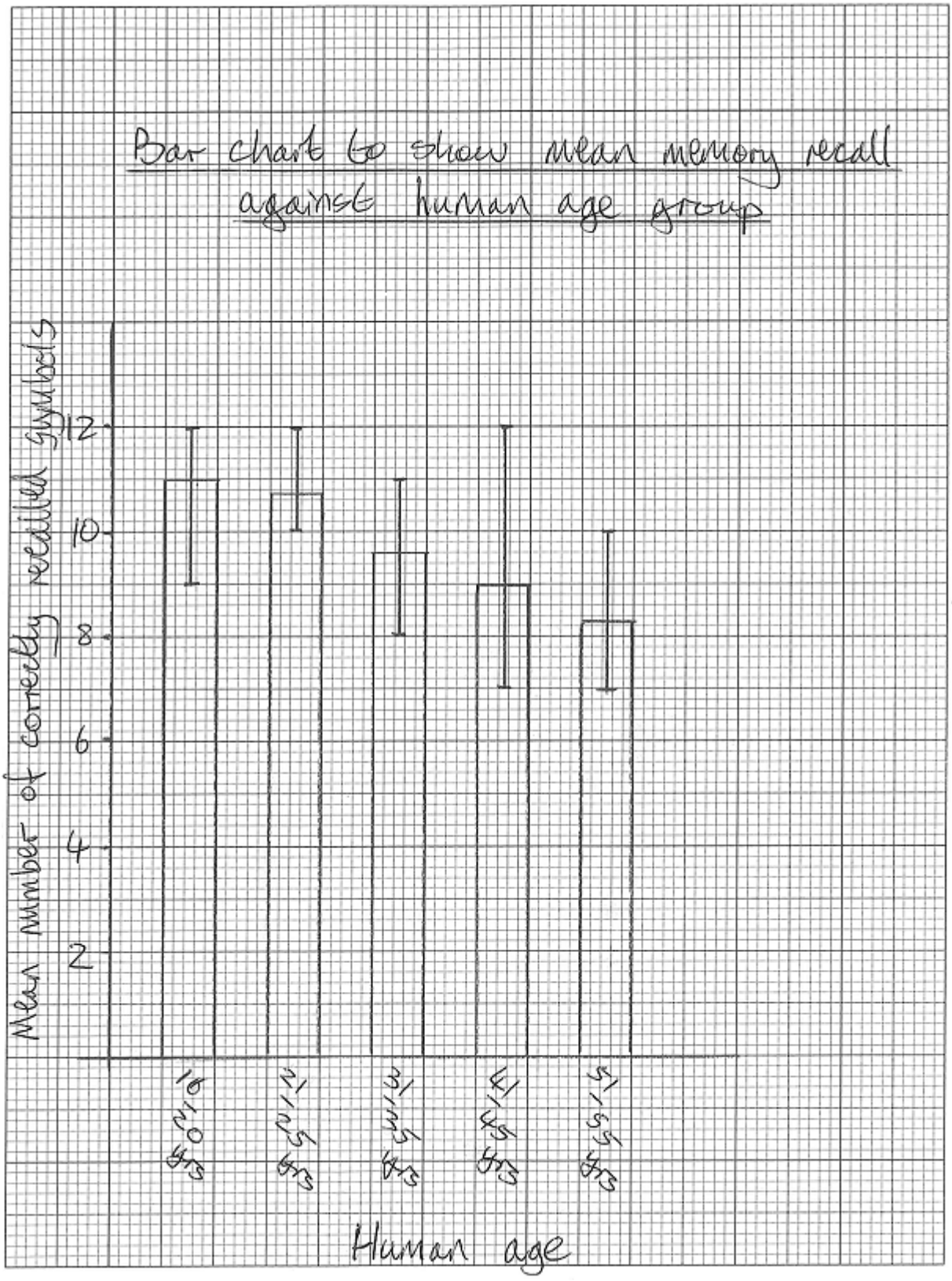
| Age group compared to 51-55yrs old | Lower U value | Accept or reject Null hypothesis |
|---|---|---|
| 16-20 | 2.5 | accept |
| 21-25 | 1.5 | accept |
| 31-35 | 9.5 | reject |
| 41-45 | 18.5 | reject |

*Effects of uncontrolled variables*

*Anomalous results*

There is one possible anomaly subject 4 in 41-45 yrs scored 12. This may be a genuine score or as only twelve symbols needed to be recalled there could have been an element of luck. I will leave the result in the table for analysis.

*Graphical presentation*



**SKILL C - Analysis and evaluation**

*Trends in the data*

There is a clear trend in the data. As age increases the short term memory deceases. The youngest age class had a mean correct recall of 11.0 symbols out of a maximum of 12 whereas the oldest age class only had a correct recall of 8.3 symbols.

The rate of decline is not constant and can be best seen on the graph. In this experiment the fastest rate of decline was between 21-25 year olds and 31-35 year olds and the smallest decline between 16-20 year olds and 21-25 year olds. However as there is not a ten year gap between these to groups as compared to the others this may not be a fair comparison.
Had I been able to test 61-65 year olds I would have expected a mean value of less than 8 if the trend continued at the same rate.

*Explanation of trends*

The trend shown by my data suggests a significant decline in memory with age. This could be due to the need for more processing time compared to younger subjects. A repeat of the experiment at different time intervals might show this to be the case. Subjects still in education might have had some pathways strengthened by regularly having to do word searches and similar puzzles. On the other hand some of the older subjects were teachers and others may do mind training puzzles so it seems to be true that putting information into STM is less efficient as you get older.

*Reliability and accuracy*

The collection of data was reliable because all the subjects could complete the task and this took place in the same environment.

*Limitations*

1 A small sample of each year group. It would have been better to test 7 males and 7 females for each year group

2 subjects not screened for
- diet
- alcohol intake
- body mass index
- weekly exercise
- family history (Alzheimer's disease)

*Improvements and modifications*

I would repeat the experiment with equal numbers of males and females to find out if there are any differences in memory ageing between the sexes. Females often have to multitask so it might be expected that their short term memory might be better than males in the older age categories.
I would screen subjects for a suitable minimum of weekly exercise as it is often suggested that exercise improves brain function.
I could not screen for the other variables in a school as rejecting subjects after filling in a simple questionnaire could be too distressing for subjects.

*Final conclusion*

This test could possibly be used to quickly reassure older people that they are not beginning to suffer from dementia as some decline in STM could easily be confused with the early symptoms of dementia. Alternatively it could be used as a therapy after left brain strokes to try to strengthen or rebuild connections in the STM centre. The results I have gathered seem to be valid as they showed significant differences between some age groups using a non parametric statistical test (a normal distribution of data is not assumed).

**Candidate 3 – Skill A marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| A1 | The candidate has not clearly stated a question, separate from the prediction, to be investigated; the descriptor can not be awarded if there is not **clear** evidence in support of it. | 0 |
| A2 | Prediction is clearly stated, and it is quantitative. | 1 |
| A3 | No SKU from the AS units has been presented. | 0 |
| A4 | Reference to F225 5.2.3, but no clear reference to 5.4.2; SKU has **not** clearly been used to inform the prediction or linked to it. | 0 |
| A5 | Some control variables identified; independent and dependent are clearly and correctly stated; however, gender is an important variable that has not been considered, so this descriptor cannot be awarded. | 0 |
| A6 | The range of five different age groups with seven participants in each group is sufficient on this occasion as the planned statistical test is the Mann Whitney U test (however, it expected that on most occasions a minimum of 10 participants should be planned for and used in a human physiology investigation). | 1 |
| A7 | Reference 5 has been used to inform the data collection strategy (to determine how many participants would be necessary), and has been referenced in the text and in a bibliography. | 1 |
| A8 | Preliminary study used to refine the data collection strategy. | 1 |
| A9 | Risk assessment not extensive but **just** adequate for the experiment, | 1 |
| A10 | Strategy lacks important details (e.g. What is the text of the briefing to participants? What does the consent form look like? What equipment is used to time the 5 seconds? Etc.), which means the method could not be repeated exactly by another student. | 0 |
| A11 | The **sequence** is clear, even though the method lacks details. | 1 |
| A12 | Some justification is present, and discussion of some of the control variables; just enough for the descriptor to be awarded. | 1 |
| A13 | Appropriate table format proposed to record data. | 1 |
| A14 | Appropriate simple processing (mean) and detailed processing (Mann Whitney U test) proposed. | 1 |
| A15 | Suitable graphical method* (although not sketched) described in sufficient detail (orientation of axes, labels and units described). | 1 |

**MARK FOR SKILL A: 10/15**

* Note: a bar chart (rather than a histogram) is appropriate here as there are 5-year gaps in between most of the sample categories.

**Candidate 3 – Skill B marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| B1 | Validated by teacher. | 1 |
| B2 | Sufficient data collected for the proposed statistical test. | 1 |
| B3 | No report of how effect of uncontrolled variables was minimised. | 0 |
| B4 | Whole number appropriate here. | 1 |
| B5 | Format appropriate.. | 1 |
| B6 | Mean values calculated correctly. | 1 |
| B7 | Mann Whitney U test carried out correctly, and significance understood. | 1 |
| B8 | Means recorded correctly and consistently to 1 decimal place (which is one decimal place more than the raw data). | 1 |
| B9 | A possible anomalous raw result is identified but the reasoning is inappropriate. | 0 |
| B10 | An appropriate graph has been plotted correctly by hand and labelled correctly. | 1 |

**MARK FOR SKILL B: 8/10**

**Candidate 3 – Skill C marking commentary**

| Descriptor | Commentary | Mark awarded |
|---|---|---|
| C1 | A basic trend is described and supported by quotes from the processed data. | 1 |
| C2 | Refers to U test statistical difference in the trend. | 1 |
| C3 | No significant SKU from the AS units. | 0 |
| C4 | Relates findings back to SKU from the A2 units, but SKU has **not** been used to explain the trend. | 0 |
| C5 | The candidate has deemed the data "reliable", but has **not** related this to a consideration of the concordancy of the raw data, the SD or SE, the range bars, etc. | 0 |
| C6 | No clear discussion of the accuracy of the raw data. | 0 |
| C7 | A more detailed consideration of the reliability of the data collection strategy is required than that given in the "Reliability and accuracy" section; discussion of error also required. | 0 |
| C8 | The limitations given would not affect the **accuracy** and/or **precision** of the raw data. | 0 |
| C9 | Explains a possible effect of gender on memory but does not describe how this or any of the limitations would have any effect on the **accuracy** and/or **precision** of the raw data. | 0 |
| C10 | | 0 |
| C11 | Three improvements are suggested, but the third statement is inappropriate and there is no discussion of how these would improve the **accuracy** and/or **precision** of the raw data. | 0 |
| C12 | | 0 |
| C13 | | 0 |
| C14 | Good use and understanding of the Mann Whitney U test. | 1 |
| C15 | Spelling, punctuation and grammar good throughout. | 1 |

**MARK FOR SKILL C: 4/15**

**TOTAL MARK FOR EXTENDED INVESTIGATION: 22/40**