**Name:**

Objectives

|  |  |
| --- | --- |
| * 1. **The Scientific Method** | **Objectives** |
| 1.1.1 Biology | 1. Define the term: Biology. 2. Name three areas of study incorporated in Biology. |
| 1.1.2 Scientific Method | 1. State the process of the Scientific Method Including Observation, Hypothesis, Design experiment, Collect & Interpret Data, Conclusions, 2. Compare to Existing Knowledge Reporting, Developing Theory & Principle 3. State the limitations of value of the Scientific Method including extent of basic knowledge, basis of investigation, application to the natural world in a state of change, accidental discovery. 4. State some possible sources of errors |
| 1.1.3 Experimentation | 1. State the principles of experimentation – which include:   Planning & Design, Safety Procedures and Experimental Control,   1. And explain why:   Sample Size, Random Selection, Replicates and Double-Blind Testing are important |

**Science** is the study of the physical, material and living world.

**Biology** is the study of living things.

|  |  |
| --- | --- |
| **Areas of biological study** | **Study of:** |
| Botany | Plants |
| Zoology | Animals |
| Microbiology | Small organisms – mycology, bacteriology, virology |
| Anatomy | Overall structure |
| Physiology | Overall function |
| Ecology | Organisms and their environment |
| Genetics | Inheritance |
| Biochemistry | Chemical reactions |
| Taxonomy | Classification |
| Cytology | Cells |

**Scientific method** is the way to solve a problem.

The scientific method involves:

**Observation** – an unbiased, accurate report of an event.

Observations may be made directly using our senses (seeing, hearing etc), or indirectly using equipment e.g. microscopes or thermometers.

**Hypothesis** – an ‘educated guess’ based on observations.

**Experiment** –an experiment is designed to test a hypothesis.

**Data** – results (measurements, observations or information gathered during an experiment. Graphs, tables and statistical analysis are used to present the data in the most logical manner possible.

**Conclusions** – data is interpreted to show if hypothesis is true or false.

**Relating the conclusion to existing knowledge** You accept, reject or change the hypothesis. If hypothesis confirmed – test further with new experiments or observations (need consistent and accurate results). If hypothesis unconfirmed change hypothesis and test.

**Publish** – write a report so that experiments can be repeated. Results scan be analysed, ideas made available to all scientists which adds to the growth of scientific understanding. Can be published in journals, magazines, newspapers, www and tv.

**Theory** – an explanation based on repeated hypotheses and experimentation.

**Principle or Law**: a theory that is valid against long-term testing.

Experiments are based on:

1. **Careful planning and design**

Example 1:

Observation – seedlings bend as they grow.

Hypothesis – seedling are growing towards light coming from one side.

Design – shoebox with interior compartments – one with a hole on top and the other with a hole to the side.

One variable here – light. A variable (difference) is a factor that may change in an experiment. Others variables may be wind (draught) or temperature – but these are kept constant here (draught –free room at constant temperature.

1. **Safe procedures**

Wear lab coat and safety glasses.

Be aware of the safety information for chemicals.

Tie back long hair.

Never place fingers in eyes/mouth unless washed.

Report all accidents to teacher

Avoid contact between electrical equipment and water.

1. **Control experiment** – a comparison

* used to provide a standard against which the actual experiment can be judged. The control or copy experiment differs in one variable from the real expt.
* Example 1 - In seedlings experiment have a third compartment with no hole.
* Example 2 – testing the effect of an arthritic drug. A number of patients are x-rayed and deformities noted. The drug is administered for 6 months and they are x-rayed again and found to have improved.

1. **Fair procedures**

* **Large sample size** – Produces more reliable results. In seedling experiment use a large number of seedlings. Reduces the risk that results are individual differences. In arthritic drug test if one person treated and recovered it may have been due to person recovering of their own accord whereas if hundreds of people treated and improve then the result is more likely to be due to the drug given.

**Random selection** – prevents bias/unfairness. It would not be fair to test seeds of one type in above experiment. Want to prove that results apply to all seeds. In arthritic drug test it would not be fair to test only females or those above 50 years of age – the results may be influenced by the factor selected.

**Others must be able to replicate experiment.** Reporting experiments publicly so that they can be replicated/repeated.

**Double blind testing.** Neither the person being tested or the tester should know who is receiving the real treatment or who is receiving the placebo.

**Limitations of the scientific method**

* **Is limited by the extent of our knowledge** – Forming an hypothesis and designing an experiment is based on what we know. Until viruses were discovered many diseases e.g. smallpox could not be explained.

# Design of experiment is limited to observation method and instrument e.g. discovery of viruses depended on the discovery of the electron microscope.

* **Human error e.g. mistakes in recording** the observations or inaccurate use of measuring instrument.
* **Deliberate falsifications of results** i.e. scientific fraud
* **Bias** – confidence in the hypothesis can affect accuracy of observation and interpretation of results
* **Is limited by our ability to interpret the results**

– Wrong interpretations can lead to wrong conclusions e.g. thalidomide was used to treat morning sickness in human pregnancy in 1950s. It was safely tested on many animals and then wrongly interpreted as safe for humans. Problem was that the drug was not tested on embryo in womb – caused limb deformities in babies. Drug was withdrawn in 1961.

* **Is limited to the present** – what is true now may not have been true in the past or in the future e.g. penicillin used to be effective against many bacteria but now strains have evolved that are resistant to penicillin. As changes occur, scientific theories may need to be updated or revised.
* **Ethical and legal responsibilities** - Ethics refers to whether issues are right or wrong e.g. use of captive animals in experiments, origin of life, whether or not evolution took place, the way in which evolution may have taken place, contraception, abortion, assisted fertilisation, GMOs, cloning animals, freezing human sperm and embryos, the use of stem cells from embryos to form new tissues/organs, organ transplants e.g. from animals to humans.
* **Accidental discoveries** have contributed enormously to the development of scientific thinking e.g. the discovery of antibiotic penicillin by Alexander Fleming in 1928. Fleming carelessly left a dish of bacteria uncovered and it became contaminated by a fungus. He noticed that the bacteria were killed in areas around the fungus. The fungus produced penicillin which killed the bacteria.

**Steps in scientific method**

|  |  |
| --- | --- |
| Observation | Edward Jenner observed that milkmaids working with cows never got smallpox but they did get the milder disease, cowpox. |
| Hypothesis |  |
| Prediction |  |
| Experiment |  |
| Result |  |
| Conclusion |  |

**1.1 The Scientific Method**

## Section A

**SEC Sample Paper HL**

**4.** Answer the following in relation to the scientific method.

What is an hypothesis?

………...……………………………………………………..……………………………………

...………………………………………………………..…………………………………………

What might an hypothesis develop into? ............................................................................

Why is a control important in an experiment? ..................................................................

……………………………………………………………..………………………………………

Give an example of a control in a **named** experiment …………...…………………...….

………………………………………………………..…………………………….………

State **two** ways in which the results of an experiment may be presented.

**1**……………....…………………………………………………...……………………

**2** …………………………………………………………………………………………

**2005 HL**

**2.** Explain each of the following terms in relation to the scientific method

(a) Hypothesis ……………...……………………………...………………….…..…………

……………………………………………………..…………………………………………...…

(b) Control ………………….………………………………………………..………………

……………………………………………………..………………………………………………

(c) Data ……………………..…………………………………………………………..……

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(d) Replicate …………………………………………………..……………………………..

…………………………………………………..………………………………………………...

(e) Theory …………………………………………………………..…..……………………

…………………………………………………..………………………………………………...

**2008 HL**

**3.** Answer the following, which relate to the scientific method, by completing the blank spaces.

(a) As a result of her observations a scientist may formulate a ………………………………………

She will then progress her investigation by devising a series of ……………………………..…

and then carefully analysing the resulting ……………………………………………………….

(b) Why is a control especially important in biological investigations? ……………………………

……………………………………………………………………………………………………

(c) If a scientist wished to determine the effect of a certain herbicide on weed growth she would include a control in the investigation. Suggest a suitable control in this case.

………………………………...………………………………………………………………….

(d) The use of replicates is an important aspect of scientific research. What, in this context, are replicates? …………………….…………………………………………………………………..

……………………………………………………………………………………………………

(e) Suggest where a scientist may publish the results of her investigations …………………………

……………………………………………………………………………………………………

**2013 OL**

**3.** Indicate whether the following statements are true (**T**) or false (**F**) by drawing a circle around **T** or **F** in

each case.

(e) In science, a hypothesis is an educated guess based on observations. T F

(f) In experiments the factor that is changed is called the variable. T F

## Section B

**2010 HL**

**8.** (a) Answer parts (i) and (ii) in relation to the scientific method.

(i) What is a hypothesis? …………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(ii) Why is a control normally used when carrying out an experiment?

…………………………………………………………………………………………………

………………………………………………………………………………………………

**2011 HL**

**7.** (a) In relation to the scientific method, explain each of the following.

(i) Experiment. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii) Theory. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(b) Scientists investigated the effect of a certain mineral on the growth of wheat.

Use your knowledge of biology and laboratory procedures to answer the following questions.

(i) Suggest a reason why the seeds used were all taken from one parent plant.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii) The compost in which the wheat plants were grown was sterilised at the start of the

investigation.

1. Suggest a way in which the scientists may have sterilised the compost.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. State **one** reason why it was important to sterilise the compost.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(iii) Why did the scientists divide the young wheat plants into two equal groups?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(iv) During the investigation the scientists kept the two groups of plants under identical

conditions. Why was this?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(v) Name **two** conditions you think the scientists would have kept constant during the

investigation.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(vi) Why did the scientists repeat the investigation several times before publishing their results in

a scientific journal?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**2012 HL**

7.(a) In relation to the scientific method, explain each of the following:

(i) Data. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii) Replicates. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**2013 HL**

**9.** (a) (i) Explain the importance of *double-blind* testing in scientific experimentation.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii) How does a *hypothesis* differ from a *theory*?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**2011 OL**

**8.** (a) (i) The scientific method involves making a hypothesis, carrying out experiments,

recording results, and forming conclusions.

Why is it a good idea to repeat an experiment many times?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii) Why is a control used when carrying out experiments?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**2013 OL**

**8.** (b) Answer the following in relation to an activity you carried out to demonstrate osmosis.

(v) What is the purpose of a control in scientific experiments?

………………………………………………………………………………………………...………

……………………………………………………………………………………………...…………

**Answers**

**Section A**

## 2004 HL Sample Q4

|  |  |  |  |
| --- | --- | --- | --- |
| **4.** |  | | **6(3)+2** |
|  |  | An educated guess to explain an observation |  |
|  |  | A theory |  |
|  |  | **Control** acts as a standard against which the experiment can be compared/ acts as a comparison |  |
|  |  | **Name**: e.g. Enzyme factor experiments  **Control**: Use boiled enzyme instead of active enzyme **OR**  **Name**: in starch test:  **Control**: use water instead of test solution |  |
|  |  | In a report/ graph/ table (spreadsheet)/ list/ diagram ***Any two*** |  |

## 2005 HL Q2

|  |  |  |  |
| --- | --- | --- | --- |
| **2.** |  | | **3(2)+2(7)** |
|  | **(a)** | A (possible) explanation (for an observation) or explained e.g. assumption |  |
|  | **(b)** | (Set up for) comparison or explained |  |
|  | **(c)** | Measurements or observations or information gathered |  |
|  | **(d)** | A repeat of an experiment or procedure or explained |  |
|  | **(e)** | A supported hypothesis or explained |  |

## 2008 HL Q3

|  |  |  |  |
| --- | --- | --- | --- |
| 3. |  | **3(1) + 3(4) + 5** |  |
|  | (a) | Hypothesis |  |
|  |  | Experiments |  |
|  |  | data **or** information **or** findings **or** outcomes |  |
|  | (b) | for comparison **or** reference to (biological) variability |  |
|  | (c) | no herbicide **or** implied |  |
|  | (d) | repeat of experiment |  |
|  | (e) | (scientific) journal **or** named journal [*accept* Internet] |  |

## 2013 OL Q3

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **3.** |  |  |  | **6(3) + 2** |
|  | (e) |  | **T** |  |
|  | (f) |  | **T/F** |  |

## Section B

## 2010 HL Q8

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **8.** | (a) | (i) | Educated guess **or** (possible) explanation | **3** |
|  |  | (ii) | Comparison (with experiment) | **3** |

## 2011 HL Q7

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **7.** | (a) | (i) | Test of hypothesis **or** test of prediction | **3** |
|  |  | (ii) | Hypothesis (or explained) supported (by experiment) | **3** |
|  | (b) | (i) | To minimise (genetic) variation | **3** |
|  |  | (ii) | 1. Heat (or method of heating) **or** named chemical **or** irradiation (or named) 2. To kill organisms **or** to prevent contamination **or** to eliminate competition **or** to eliminate disease **or** described | **3**  **3** |
|  |  | (iii) | As control (or described) | **3** |
|  |  | (iv) | To have only one variable (or explained) | **3** |
|  |  | (v) | Temperature / Light **/** pH / CO2 / humidity / other minerals / H2O  ***Any 2*** | **2(3)** |
|  |  | (vi) | To ensure (statistical) reliability | **3** |

## 2012 HL Q7

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **7.** | (a) | (i) | Observations **or** results **or** other | **3** |
|  |  | (ii) | Repeats (or copies) of experiment | **3** |

## 2013 HL Q9

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **9.** | (a) | (i) | Avoidance of bias | **3** |
|  |  | (ii) | Hypothesis can develop into a theory **or** explained | **3** |

## 2011 OL Q8

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **8.** | (a) | (i) | To verify results /(statistical) reliability/ minimise error | **5+1** |
|  |  | (ii) | To compare (with experiment) |  |

## 2013 OL Q8

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **8** | (b) | (v) | To compare (with the experiment) | (1 pt) |