



## Accuracy, Reliability and Validity

Year after year Chief Examiner's Reports point out that many students don't understand the meanings of and the differences between terms such as accuracy, validity and reliability. Some even think that they are all the same thing!

This Factsheet explains what these terms mean and surveys the very wide range of exam questions that can test your understanding of them.

### Key terms

**Accuracy** relates to how close your observed or measured value is to the correct/real value.

**Accuracy** can be improved by changing the experimental technique e.g. by ensuring that you use the most appropriate size of quadrat in transect measurements.

**Reliability** relates to the consistency in (or your confidence with) a set of measurements. Reliability is improved by repetition - if repeated results lie close together then the results have high reliability. Taking repeat measurement also helps you identify and omit anomalous results - those that are clearly out of line with the other data.

### Extract from Chief Examiner's Report

Candidates must comment on the reliability of their evidence. This can be done by:

- considering the spread of their results
- considering the closeness of replicates to the mean
- calculating variance, standard deviation, standard error or 95% confidence intervals
- considering the size of range bars or error bars on their graphs

Candidates must state what their error bars are telling them about their results. Error bars do not show accuracy of results, rather they are an indicator of reliability.

**Validity** is whether a test actually measures what it sets out to measure. If you are asked to comment on the validity of an investigation or to suggest ways in which the validity could be improved you should try to identify factors that are not or cannot be controlled and which may therefore be limiting the validity of the investigation.

### Ecological investigations

Polychlorinated biphenyls (PCBs) are a group of 209 man-made organic chemicals which differ only in the number and position of chlorine atoms around the outside of the molecule. Because of their useful properties they were widely used for over 50 years in transformers, electromagnets, paints and plastics for example. However, PCBs were found to be carcinogenic i.e. capable of causing cancer and production of PCBs is now banned in many countries.

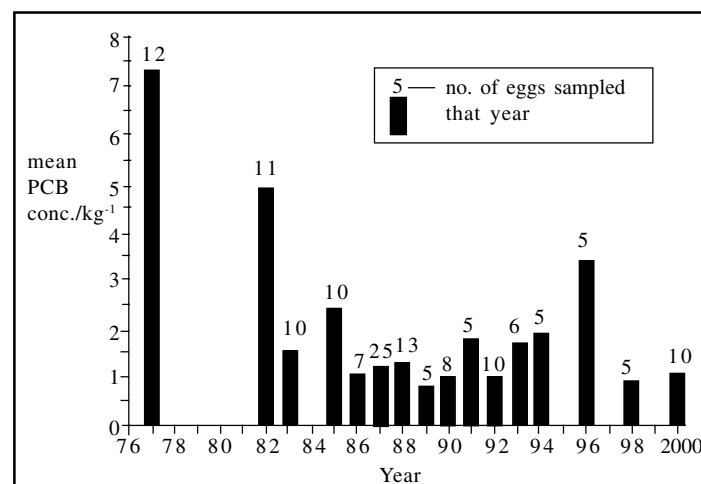
Scientists at the University of British Columbia monitored the concentration of PCBs in the eggs of great blue herons (*Ardea herodias*) from 1977 to 2000. The great blue heron feeds in wetlands and on coasts across the United States and southern Canada.

It is a top predator with a varied diet of small fish, crawfish, frogs, salamanders, snakes, lizards, rodents, small birds and insects.



The scientists were interested in whether the herons were suffering from the biomagnification of the PCBs up their food chains. Fig 1. shows the mean concentration of PCBs in sampled heron eggs.

Fig 1. Mean PCB concentrations in heron eggs



### Typical Exam Question

How could the reliability of this data have been improved? (3)

- Sample greater number of eggs each year;
- Sample equal number of eggs each year;
- Sample eggs each year;
- Ref to calculate standard deviations etc;

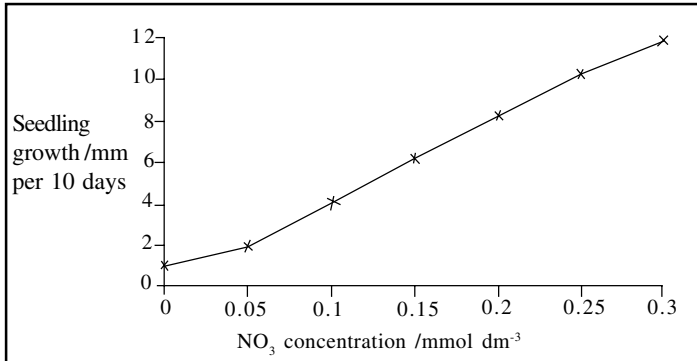
### Laboratory investigations

A student investigated the effect of nitrate ion concentration on the growth of cress seedlings.

She measured the length from shoot tip to root tip of 7 seedlings. Each seedling was suspended in a test tube so that its roots were immersed in a solution of mineral ions. Each tube contained a different concentration of nitrate ions.

The seedlings were left in a sunny position for ten days. The student then re-measured the length from shoot tip to root tip of each seedling and calculated the difference between the final length and initial length. Fig.2 shows her results.

**Fig 2. Nitrate concentration and seedling growth**



- (a) Suggest why:
- (i) measuring difference in length rather than just final length increases the validity of the investigation (1)
  - (ii) calculating the difference between final mass and initial mass of each cress seedling may have been a better indicator of growth (1)
- (b) Suggest **four** variables that the student would need to keep constant to ensure the reliability of her data (4)

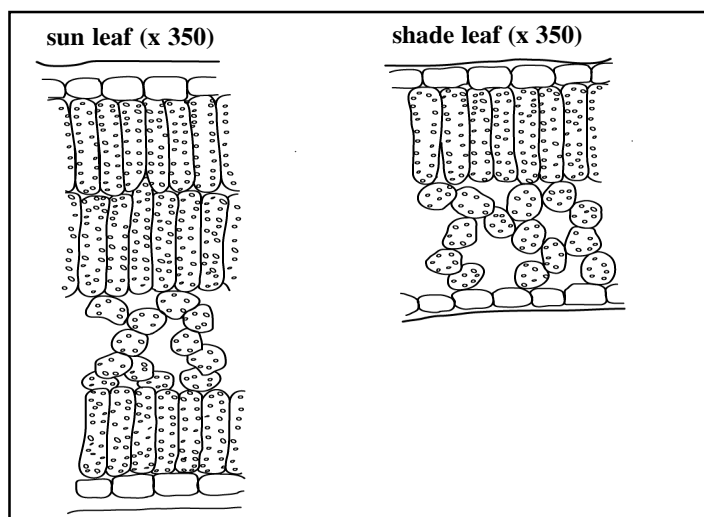
(a) (i) seedlings different lengths at start/final length is not a measure of growth / growth equals change in length;  
 (ii) plants grow in other dimensions / measuring length may be more difficult than measuring mass;  
 (b) volume of solution; concentration of other minerals; temperature; light intensity; measuring technique; seedling age/ stage of development; seedlings of same genotype;

**Markscheme**

**Planning your own investigations: Sun and shade leaves**  
 Beech trees (*Fagus sylvatica*) have both “sun” and “shade” leaves. “Sun” leaves are usually found high in the canopy where they are exposed to lots of sunlight. “Shade” leaves are usually found lower in the canopy, where they receive less sunlight due to shading.

Sun leaves are usually thicker and contain more chlorophyll than shade leaves and so should absorb more CO<sub>2</sub> and photosynthesise faster (Fig.3).

**Fig 3. Sun leaf and shade leaf**



The rate of CO<sub>2</sub> uptake can be measured by recording how long it takes for hydrogen carbonate-indicator solution to turn from orange to red.

**Your task:** Devise a plan to test the hypothesis that “sun” leaves absorb carbon dioxide faster than “shade” leaves.

You are supplied with:

- “sun” leaves and “shade” leaves of beech
- hydrogen carbonate-indicator solution
- any general school laboratory apparatus that you need

- (a) Identify the:
- (i) independent variable (1)
  - (ii) dependent variable (1)
- (b) Identify **one** other major variable which must be controlled and state how this might be achieved (2)
- (c) Outline a suitable method that you could use to test this hypothesis (4)
- (d) Identify the problem with this method of measuring CO<sub>2</sub> uptake that would affect the **accuracy** of the results (1)
- (e) Distinguish between the accuracy and the reliability of results (2)

(a) Independent variable: “sun” or “shade” leaf;  
 Dependent variable: uptake of CO<sub>2</sub>/time for hydrogen carbonate-indicator solution to turn red;

(b) **Light intensity** must be high enough not to be a limiting factor; lamp placed close to the leaves;

**Temperature** must be equal for each type of leaf; Ensure lamps are equal distances from leaves;

(c) leaf enclosed in a test tube/conical flask etc;  
 sun leaf and shade leaf in separate test tubes/conical flasks;  
 hydrogen carbonate-indicator solution in bottom of vessel;  
 lamp placed same distance from the glass vessel for each experiment;  
 measure the time taken for hydrogen carbonate-indicator solution to turn from orange to red;

(d) Subjective nature of colour measurement/ Difficulty of determining when the indicator solution has turned equally red in both experiments;

(e) Accuracy relates to the measurement technique/how close the observed value lies to the correct/real value;  
 Reliability relates to the variability of biological material/ consistency in or confidence with a set of measurements/is determined by repetition/repeated results lie close together then the results have high reliability;

**Extract from Chief Examiner’s Report:**  
 The planning question was highly discriminating. (This means that lots of candidates didn’t do well on it and the range of marks was great). Many candidates were unable to distinguish between the independent and dependent variables but even more discriminating was the question asking candidates to distinguish between the accuracy and the reliability of the results. Only the most able were able to gain both marks.

**Practice Questions**

A student earned money at the weekend by cutting grass lawns. One of his customers always complained that her lawn had too many buttercups, whilst other neighbours liked the buttercups. The lawn mowers were supplied by the customers and were of two types; those that had a box to collect grass cuttings and those that didn't.

The student wondered whether leaving the cuttings on the lawn influenced the number of buttercups. He selected four lawns randomly on which cuttings were collected and four that were cut without a grass box. He used a quadrat to randomly sample the number of buttercups on each lawn. The table shows his results.

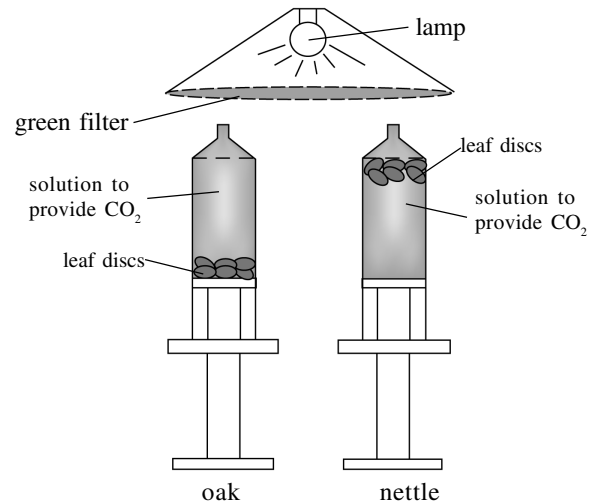
Type of mowing	Lawn no.	Mean no. of buttercups/m <sup>2</sup>	Overall mean
Grass cuttings collected and removed	1	24	11
	2	5	
	3	11	
	4	4	
Grass cuttings left on lawn	5	24	
	6	26	
	7	22	
	8	24	

- (a) Calculate the mean number of buttercups on lawns where the grass cuttings were left on the lawn (1)  
 (b) Comment on the reliability of this investigation given the variability in the data (2)
- Wardens and 12 volunteers surveyed woodland birds over a five-year period at a nature reserve in Shropshire. They recorded all birds seen in the woodland areas of the reserve over a five-month period from March to July each year. Recordings were taken on three, four or five days per month, depending on the weather.

Suggest limitations of their method to collect the data that might reduce the reliability of the results (4).

- An investigation was carried out to compare photosynthesis in oak and nettle leaves. Six discs were cut from each type of leaf and placed in syringes containing a solution that provided carbon dioxide. A procedure was used to remove air from the leaf discs to make them sink. The apparatus was placed in a darkened room. The discs were then illuminated with a lamp covered with a green filter. Leaf discs which carried out photosynthesis floated.

The positions of the discs one hour later are shown in the diagram below.



- Suggest a reason why the investigation was carried out in a darkened room. (1)
- Explain why it was good experimental procedure to use six discs from each plant.(1)
- In setting up the investigation, precautions were taken to ensure that the results obtained would be valid. Give **one** precaution relating to the:
  - preparation of the leaf discs (1)
  - solution that provided carbon dioxide. (1)
- Suggest a reason why the leaf discs which carried out photosynthesis floated. (1)
- Nettles are shade plants which grow beneath sun plants such as oak trees. Explain how the results show that nettles are well adapted as shade plants. (1)

**Answers**

- (a) To prevent entry of other light/so discs only receive green light/light from lamp;  
 (b) Increase reliability/Minimise error due to chance/Reduce the effect of an atypical result;  
 (c) (i) same size/diameter/mass/weight/leaf used/thickness/surface area;  
 (ii) same concentration/temperature/volume;  
 (d) Nettles can use green light for photosynthesis;  
 Gas/Oxygen made so discs are more buoyant/less dense/lighter;  
 (e) Shade plants/forest floor receives green light/light not absorbed by sun plants/Light transmitted by canopy

- Problems of accurate identification;  
 No ref to birds that were heard but not seen being recorded;  
 Number of recording days per month varied;  
 No recording when weather poor;  
 Birds may have been double counted/missed;  
 No winter surveys;  
 Nocturnal species not recorded;  
 Observation may cause disturbance/altered behaviour;
- This reduces the reliability of the investigation;  
 and removed is high;  
 (b) Mean number of buttercups on lawns where grass collected