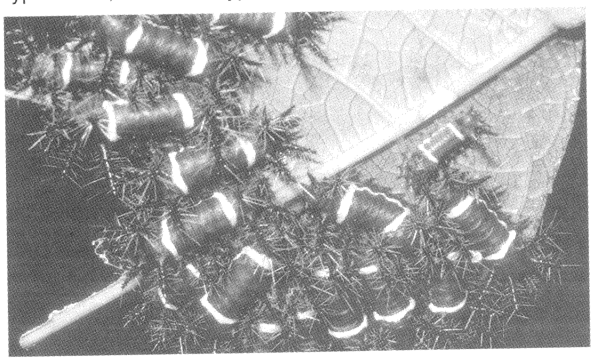
Hypotheses and Predictions

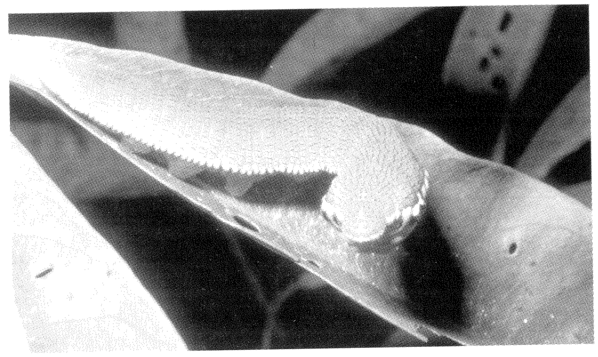
A hypothesis offers a tentative explanation to questions generated by observations and leads to one or more **predictions** about the way a biological system will behave. Experiments are constructed to test these predictions. For every hypothesis, there is a corresponding **null hypothesis**; a hypothesis of no difference or no effect. Creating a null hypothesis enables a hypothesis to be tested in a meaningful way using statistical tests. If the results of an experiment are statistically significant, the null hypothesis can be rejected. If a hypothesis is accepted, anyone should be able to test the predictions with the same methods and get a similar result each time. Scientific hypotheses may be modified as more information becomes available.

Observations, Hypotheses, and Predictions

Observation is the basis for formulating hypotheses and making predictions. An observation may generate a number of plausible hypotheses, and each hypothesis will lead to one or more predictions, which can be tested by further investigation.

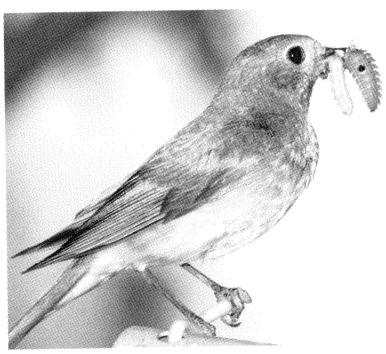


Observation 1: Some caterpillar species are brightly colored and appear to be conspicuous to predators such as insectivorous birds. Predators appear to avoid these species. These caterpillars are often found in groups, rather than as solitary animals.



Observation 2: Some caterpillar species are cryptic in their appearance or behavior. Their camouflage is so convincing that, when alerted to danger, they are difficult to see against their background. Such caterpillars are usually found alone.

Assumptions



Any biological investigation requires you to make **assumptions** about the biological system you are working with. Assumptions are features of the system (and your investigation) that you assume to be true but do not (or cannot) test. Possible assumptions about the biological system described above include:

- Insectivorous birds have color vision.
- Caterpillars that look bright or cryptic to us, also appear that way to insectivorous birds.
- Insectivorous birds can learn about the palatability of prey by tasting them.

1. Study the example above illustrating the features of cryptic and conspicuous caterpillars, then answer the following:

   (a) Generate a hypothesis to explain the observation that some caterpillars are brightly colored and conspicuous while others are cryptic and blend into their surroundings:

   Hypothesis:

   (b) State the null form of this hypothesis:

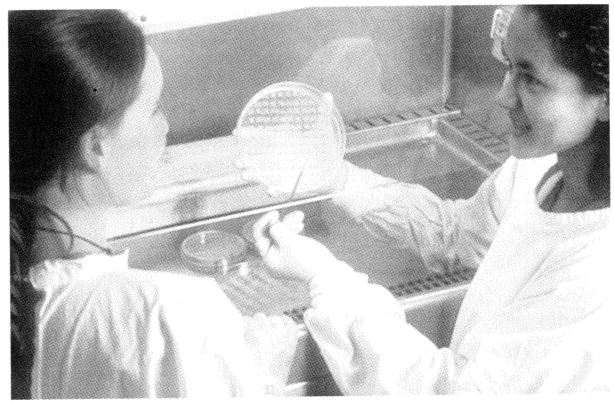
   (c) Describe one of the **assumptions** being made in your hypothesis:

   (d) Based on your hypothesis, generate a **prediction** about the behavior of insectivorous birds towards caterpillars:

2. During the course of any investigation, new information may arise as a result of observations unrelated to the original hypothesis. This can lead to the generation of further hypotheses about the system. For each of the incidental observations described below, formulate a prediction, and an outline of an investigation to test it. *The observation described in each case was not related to the hypothesis the experiment was designed to test:*

(a) **Bacterial cultures**

Prediction:



Observation: During an experiment on bacterial growth, these girls noticed that the cultures grew at different rates when the dishes were left overnight in different parts of the laboratory.

Outline of the investigation:

(b) **Plant cloning**

Prediction:

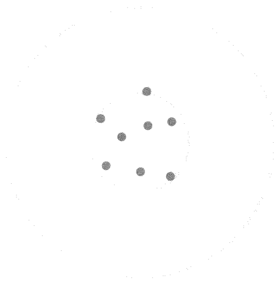
Observation: During an experiment on plant cloning, a scientist noticed that the root length of plant clones varied depending on the concentration of a hormone added to the agar.

Outline of the investigation:

Accuracy and Precision

The terms accuracy and precision are often confused, or used interchangeably, but their meanings are different. In any study, **accuracy** refers to how close a measured or derived value is to its true value. Simply put, it is the correctness of the measurement. It can sometimes be a feature of the sampling equipment or its calibration. **Precision** refers to the closeness of repeated measurements to each other, i.e. the ability to be exact. A balance with a fault in it could give very precise (i.e. repeatable) but inaccurate (untrue) results. Using the analogy of a target, repeated measurements are compared to arrows being shot at a target. This analogy can be useful when thinking about the difference between accuracy and precision.

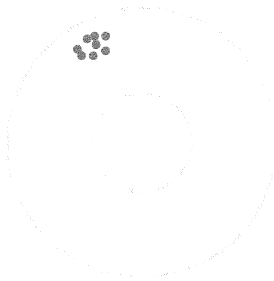
Accurate but imprecise



The measurements are all close to the true value but quite spread apart.

Analogy: The arrows are all close to the bullseye.

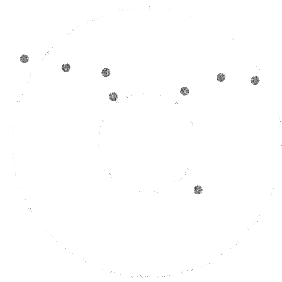
Precise but inaccurate



The measurements are all clustered close together but not close to the true value.

Analogy: The arrows are all clustered close together but not near the bullseye.

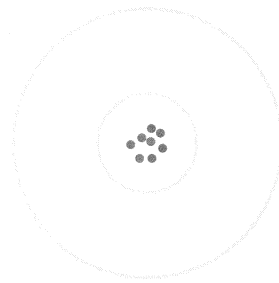
Inaccurate and imprecise



The measurements are all far apart and not close to the true value.

Analogy: The arrows are spread around the target.

Accurate and precise

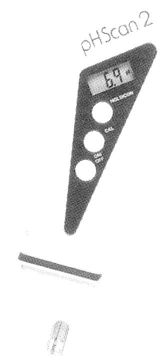


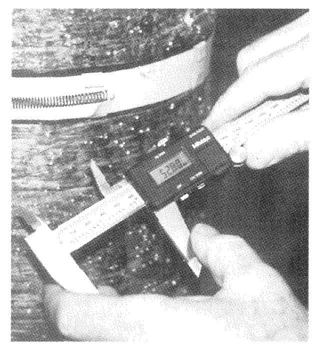
The measurements are all close to the true value and also clustered close together.

Analogy: The arrows are clustered close together near the bullseye.

The accuracy of a measurement refers to how close the measured (or derived) value is to the true value. The precision of a measurement relates to its repeatability. In most laboratory work, we usually have no reason to suspect a piece of equipment is giving inaccurate measurements (is biased), so making precise measures is usually the most important consideration. We can test the precision of our measurements by taking repeated measurements from individual samples.

Population studies present us with an additional problem. When a researcher makes measurements of some variable in a study (e.g. fish length), they are usually trying to obtain an estimate of the true value for a parameter of interest (e.g. the mean size, therefore age, of fish). Populations are variable, so we can more accurately estimate a population parameter if we take a large number of random samples from the population.





RA

A digital device such as this pH meter (above left) will deliver precise measurements, but its accuracy will depend on correct calibration. The precision of measurements taken with instruments such as callipers (above) will depend on the skill of the operator.

1. Distinguish between accuracy and precision: ____________________

____

____

2. Describe why it is important to take measurements that are both accurate and precise: ____________________

____

____

3. A researcher is trying to determine at what temperature enzyme A becomes denatured. Their temperature probe is incorrectly calibrated. Discuss how this might affect the accuracy and precision of the data collected:

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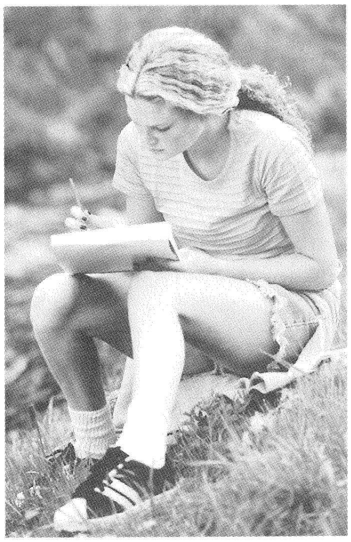
Variables and Data

When planning any kind of biological investigation, it is important to consider the type of data that will be collected. It is best, whenever possible, to collect quantitative or numerical data, as these data lend themselves well to analysis and statistical testing. Recording data in a systematic way as you collect it, e.g. using a table or spreadsheet, is important, especially if data manipulation and transformation are required. It is also useful to calculate summary, descriptive statistics (e.g. mean, median) as you proceed. These will help you to recognize important trends and features in your data as they become apparent.



The values for monitored or measured variables, collected during the course of the investigation, are called data. Like their corresponding variables, data may be quantitative, qualitative, or ranked.

Types of Variables

Qualitative

Non-numerical and descriptive, e.g. sex, color, presence or absence of a feature, viability (dead/alive).

e.g. Sex of children in a family (male, female)

Ranked

These provide data which can be ranked on a scale that represents an order, e.g. abundance (very abundant, common, rare); color (dark, medium, pale).

e.g. Birth order in a family (1, 2, 3)

Quantitative

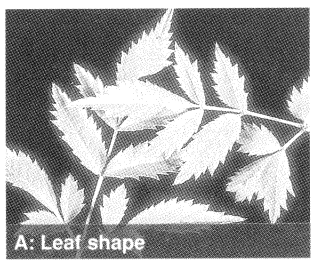
Characteristics for which measurements or counts can be made, e.g. height, weight, number.

Discontinuous

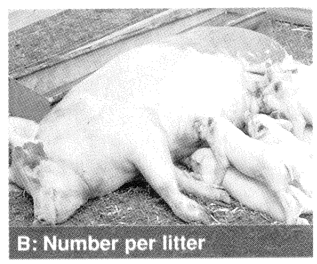
e.g. Number of children in a family (3, 0, 4)

Continuous

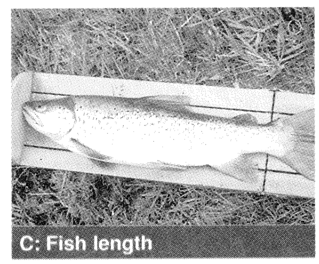
e.g. Height of children in a family (1.5 m, 1.3 m, 0.8 m)



A: Leaf shape



B: Number per litter



C: Fish length

BH

1. For each of the photographic examples (A – C above), classify the variables as quantitative, ranked, or qualitative:

   (a) Leaf shape: __________

   (b) Number per litter: __________

   (c) Fish length: __________

2. Why it is desirable to collect quantitative data where possible in biological studies?

3. How you might measure the color of light (red, blue, green) quantitatively?

4. (a) Give an example of data that could not be collected in a quantitative manner, explaining your answer:

   (b) Sometimes, ranked data are given numerical values, e.g. rare = 1, occasional = 2, frequent = 3, common = 4, abundant = 5. Suggest why these data are sometimes called **semi-quantitative:**

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