# Accuracy and precision

When planning and evaluating an experiment, you need to think about the accuracy and precision of your measurements. The words accurate and precise have specific meanings in science.

## Key facts

- ✓ **Accurate measurements are ones that are close to the true value being measured.**
- ✓ **Precise measurements are those that give the same (or similar) values when the measurement is repeated.**
- ✓ **Errors in measurements can be random or systematic.**

### Accurate or precise?

A measurement is considered more accurate if it is closer than other measurements to the true value being measured. It is precise if repeating the measurement several times produces values that are the same or very close to each other. To understand the difference, it helps to think of measurements as trying to hit a target.

The center of the target represents the true value being measured.

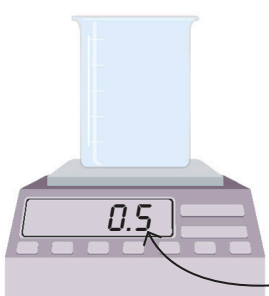
**Inaccurate and imprecise**
The measurements are inaccurate, as they are not near the center of the target, and imprecise, as they are not close to each other.

**Precise but inaccurate**
These measurements are precise because they are all nearly the same value, but they are inaccurate because they aren't close to the center.

**Accurate but imprecise**
These are close to the center but not to each other, so they are accurate but imprecise.

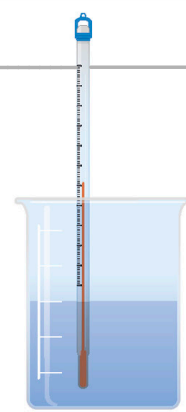
**Accurate and precise**
These measurements are both accurate and precise.

## Types of error




This should be zero when the beaker is empty.

**Systematic errors**
The accuracy of some instruments depends on how they're used. Balances should be set to zero with a container on them so you only measure the mass of the contents. If a balance is not zeroed properly, all the measurements will be incorrect by the same amount. This is a systematic error and reduces the accuracy of the measurements.



**Random errors**
Random errors are different for every reading. For example, if you take the temperature of water in a beaker, the thermometer might return a slightly different reading each time it dips into a different part of the water. This reduces the precision of your measurements.

# Evaluations

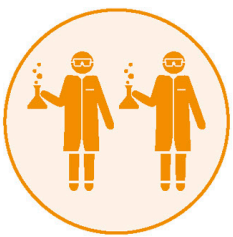
We often evaluate our experiments to decide how much we can trust the results. An experiment has to be valid and fair, and the conclusions must be based on high-quality data. An evaluation may also suggest how the method could be improved.

**Is the experiment valid?**
An experiment is valid if you can answer "yes" to all of these questions.

**Was it a fair test?**
Did you control all the variables apart from the independent variable you were testing?

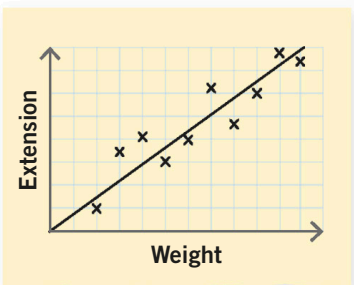
**Is it reproducible?**
If a different person carries out the experiment using different equipment, do they get the same results?

**Is it repeatable?**
If you repeat the experiment using the same equipment, do you get the same results?

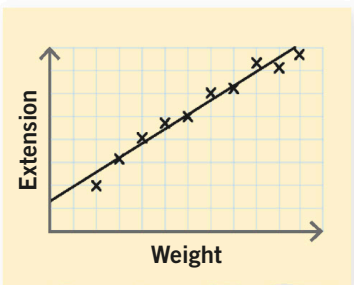


**Did it test the hypothesis?**
Did you make a prediction from your hypothesis? Was the experiment a good test of the hypothesis?

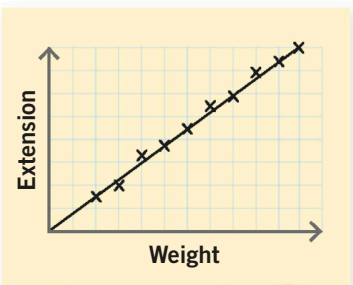
**Data quality**
Good data is accurate and precise. You can assess the quality of your data by repeating an experiment, but sometimes you can also tell by looking carefully at the results. The graphs below are from an experiment measuring the extension of a spring holding different weights.




The data points are scattered around the line of best fit. The data is imprecise.




The points are closer to the line, so the data is precise. However, extension should be zero for zero weight, so it's odd that the line does not pass through the origin. There may be a systematic error (see page 26) causing inaccurate data.




This data is very close to the line of best fit, and the line goes through the origin, as we expect. This data is both accurate and precise.