What is Science?

By Dr Rob Morrison (Board Member of the AusSMC)
July 2005

What is Science?

Science has rules. Break them, and you fall outside the realm of what can properly be called scientific. Science is, above all, a process by which we can decide what is true and what is not – in the natural world at least.

Boiled down to its essentials, science involves:-

- making an observation that two or more phenomena may be causally linked;
- formulating a hypothesis that a particular cause leads to a particular effect;
- devising an experiment or collecting data to test the hypothesis;
- interpreting the experimental findings, perhaps using statistics;
- drawing a conclusion which supports or does not support the hypothesis;
- reporting that conclusion is a way that allows others to repeat the experiment.

It all looks simple enough, but there are some subtle and important points involved.

- Science is not simply a collection of unarguable facts, inviolable dogma and infallible laws or theories. While science has established millions of facts, laws, and theories, none of them are ultimately much good if they are not supported by experimental findings. If they are not they must be re-examined and, if necessary, changed.

- In science, if experimental data and findings don't support the hypothesis, the hypothesis must be accepted as incorrect. This distinguishes science from pseudoscience, in which a position is taken that can never be abandoned. In pseudoscience, only the evidence that fits is accepted as valid; other evidence is discounted or experimental results are manipulated or wrongly interpreted to arrive at a desired outcome.

- While hypotheses are interesting, and can be exciting (possible cancer cures, likely asteroid impacts, miracle diets etc) it is arguable that they are not really 'science news' until they have been tested experimentally, supported by the results of the experiment and preferably published in a reputable journal.

- Ultimately, the test of a scientific finding often rests on the quality of the published report or publication. This is often assessed for publication by peer review (in other words, other well qualified scientists believe the work was done well), and should then be so clearly written up that others can repeat the experiment in exactly the same way to see whether they can obtain the same result. If they can't, questions then arise about whether the findings and conclusions are truly accurate, and perhaps whether the hypothesis is correct.

What is not Science?

A fact or belief is not science because lots of people believe it is, because a famous person declares it to be true or simply because a particular group calls it science.

Something that cannot be tested experimentally or in some other scientific way is not science, however true it appears or however strongly people may believe in it. Similarly, something which is not potentially refutable is not science; in other words, those involved must accept that if a belief or assumption is not supported by experiment, it needs to be changed or abandoned.

Some advertising uses a pseudoscience approach. ***"Beautiful filmstars use X soap, so X soap makes you beautiful" - "9 out of 10 dentists recommend Y toothpaste" – "Science proves that Z diet will make you lose weight"*** - but analysis of claims like these shows that they are misinterpretations of the scientific process.

Coincidences or correlations are sometimes incorrectly regarded as providing scientific evidence of cause and effect. In the middle ages, people often noticed that events came together, and they assumed one caused the other (thunder makes the milk go sour; red sunsets cause rain etc). More recently, the great tsunami of 2004 was linked incorrectly in the media to global warming. In fact events that are correlated are often unrelated or may both result independently from the same cause instead of one causing the other.

Some faiths, practices and professions also use 'science' in their titles, but that does not necessarily make them scientific. On the contrary, if they refuse to modify fundamental beliefs in the light of conflicting evidence, they are unscientific.

Can Science answer everything?

No. Science has proved to be our most effective way of investigating the natural world to determine what is true and what is not, but it cannot investigate many things that are matters of faith, religion, philosophy or subjective experience. These things may or may not be true, but cannot be tested by science.

Can Science prove things are true?

Again, largely 'No,' but that doesn't mean that these things are **not** true. To understand that, one has to understand what is meant by proof. To a lawyer, mathematician and scientist, the word 'proof' means different things.

Science works largely by trying to disprove things. If hypotheses cannot be disproved by the most rigorous tests, they are accepted as being true (at least until a test comes along that can disprove them). Scientists often talk about supporting a hypothesis rather than proving it.

If that sounds a little pedantic, consider this. Can you 'prove' gravity exists by dropping a pencil? No. Every time you have dropped a pencil in the past, gravity made it fall, but there is nothing that says it has to fall the next time you drop it. Of course it is extremely unlikely that it will not drop, but philosophically that is not proof.

Many scientific discoveries are not as clear cut as dropping a pencil, so statistics are often used to show just how reliable they are. Scientists sometimes talk about their results in terms of probability, which gives a measure of just how likely they are to be true.

Of course, if an experiment is repeated often by different people, and they all get similar results, that greatly increases the probability that the findings are correct; but that is still not proof.

Hypothesis, Theory and Law

'But it's only a theory….' That is sometimes said as if it somehow weakens a scientific claim, but it shows a misunderstanding of what a scientific theory is. We should also look at hypothesis and law here.

A hypothesis is really a hunch: "I think that (a) causes (b)." It may be true or it may not. We have to test the hypothesis by experimentation before we can say whether our hypothesis is supported by the findings or not. Until then, it is just an interesting idea.

A law is a statement. "This happens." Laws such as the Gas Laws, the Law of Reflection, the Laws of Thermodynamics and so on are tremendously powerful because they tell us how the natural world actually works. A law is a statement of what will always occur under certain described conditions. For less general statements, the term principle may sometimes be used (eg principle of the lever, Archimedes' principle).

A law is as close to dogma as science gets, but even laws may have to be changed. Newton's First Law of Thermodynamics once said that 'Matter can neither be created nor destroyed….' and it served us well until the atom was split, destroying matter to create energy. Now the law says something like "Under normal circumstances, matter can neither…."

A theory is not a simple statement like a law, but has an explanatory quality to it, such as the Theory of Natural Selection, the Theory of Relativity etc. Like other scientific conclusions, a theory is an explanation or model which is based on experimental findings, has been tested and confirmed and provides a general principle to explain natural phenomena. Essentially a scientific theory must:

1. explain what has been observed;
2. be able to predict what has not yet been observed;
3. be testable by further experimentation;
4. be modified as required in the light of new data.

Science and Technology

Sometimes science is seen as a body of facts, and technology as a collection of things that work, but there is more to it. While science is a systematized body of knowledge based on observation and experiment, technology is the application of scientific discoveries and inventions for industrial purposes. It is sometimes called applied science. Science and technology are closely related, but there is also a fundamental philosophical difference between them.

Science involves looking at many different events or objects and, by induction, discovering a general principle that is true of all of them (***Animals with feathers and beaks are all birds; Molecules are all composed of different combinations of atoms; Action and reaction are equal and opposite*** **etc**.)

Discovering the general principles that unite many separate observations may give scientists sudden insights into how Nature works; what they sometimes call the 'AHA!' experience.

A technologist, on the other hand, starts with the known law, principle or theory and, by deduction, uses it to make or build a particular object that will work.

Science and technology can be seen as opposite sides of the same logical circuit: