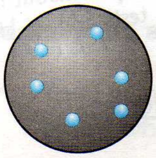
The Scientific Process

You need to know a few things about how the world of science works. First up is the scientific process — how a scientist's mad idea turns into a widely accepted theory.

Scientists Come Up with Hypotheses — Then Test Them



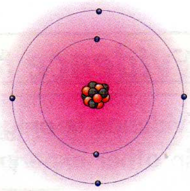
About 100 years ago, scientists hypothesised that atoms looked like this.

1) Scientists try to explain things. Everything.
2) They start by observing something they don't understand — it could be anything, e.g. planets in the sky, a person suffering from an illness, what matter is made of... anything.
3) Then, they come up with a hypothesis — a possible explanation for what they've observed.
4) The next step is to test whether the hypothesis might be right or not — this involves gathering evidence (i.e. data from investigations).
5) The scientist uses the hypothesis to make a prediction — a statement based on the hypothesis that can be tested. They then carry out an investigation.
6) If data from experiments or studies backs up the prediction, you're one step closer to figuring out if the hypothesis is true.

Investigations include lab experiments and studies.

Other Scientists Will Test the Hypothesis Too

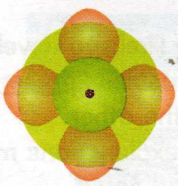
1) Other scientists will use the hypothesis to make their own predictions, and carry out their own experiments or studies.
2) They'll also try to reproduce the original investigations to check the results.
3) And if all the experiments in the world back up the hypothesis, then scientists start to think it's true.
4) However, if a scientist somewhere in the world does an experiment that doesn't fit with the hypothesis (and other scientists can reproduce these results), then the hypothesis is in trouble.
5) When this happens, scientists have to come up with a new hypothesis (maybe a modification of the old hypothesis, or maybe a completely new one).



After more evidence was gathered, scientists changed their hypothesis to this.

If Evidence Supports a Hypothesis, It's Accepted — for Now

1) If pretty much every scientist in the world believes a hypothesis to be true because experiments back it up, then it usually goes in the textbooks for students to learn.
2) Accepted hypotheses are often referred to as theories.



Now we think it's more like this.

3) Our currently accepted theories are the ones that have survived this 'trial by evidence' — they've been tested many, many times over the years and survived (while the less good ones have been ditched).
4) However... they never, never become hard and fast, totally indisputable fact. You can never know... it'd only take one odd, totally inexplicable result, and the hypothesising and testing would start all over again.

You expect me to believe that — then show me the evidence...

If scientists think something is true, they need to produce evidence to convince others — it's all part of testing a hypothesis. One hypothesis might survive these tests, while others won't — it's how things progress. And along the way some hypotheses will be disproved — i.e. shown not to be true.

Your Data's Got To be Good

Evidence is the key to science — but not all evidence is equally good.
The way evidence is gathered can have a big effect on how trustworthy it is...

Lab Experiments and Studies Are Better Than Rumour

See page 5 for more about fair tests and variables.

1) Results from experiments in laboratories are great. A lab is the easiest place to control variables so that they're all kept constant (except for the one you're investigating). This makes it easier to carry out a FAIR TEST.
2) For things that you can't investigate in the lab (e.g. climate) you conduct scientific studies. As many of the variables as possible are controlled, to make it a fair test.
3) Old wives' tales, rumours, hearsay, "what someone said", and so on, should be taken with a pinch of salt. Without any evidence they're NOT scientific — they're just opinions.

The Bigger the Sample Size the Better

1) Data based on small samples isn't as good as data based on large samples. A sample should be representative of the whole population (i.e. it should share as many of the various characteristics in the population as possible) — a small sample can't do that as well.
2) The bigger the sample size the better, but scientists have to be realistic when choosing how big. For example, if you were studying how lifestyle affects people's weight it'd be great to study everyone in the UK (a huge sample), but it'd take ages and cost a bomb. Studying a thousand people is more realistic.

Evidence Needs to be Reliable (Repeatable and Reproducible)

Evidence is only reliable if it can be repeated (during an experiment) AND other scientists can reproduce it too (in other experiments). If it's not reliable, you can't believe it.

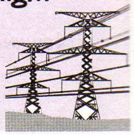
RELIABLE means that the data can be repeated, and reproduced by others.

EXAMPLE: In 1989, two scientists claimed that they'd produced 'cold fusion' (the energy source of the Sun — but without the big temperatures). It was huge news — if true, it would have meant free energy for the world... forever. However, other scientists just couldn't reproduce the results — so the results weren't reliable. And until they are, 'cold fusion' isn't going to be accepted as fact.

Evidence Also Needs to Be Valid

VALID means that the data is reliable AND answers the original question.

EXAMPLE: DO POWER LINES CAUSE CANCER?
Some studies have found that children who live near overhead power lines are more likely to develop cancer. What they'd actually found was a correlation (relationship) between the variables "presence of power lines" and "incidence of cancer" — they found that as one changed, so did the other.
But this evidence is not enough to say that the power lines cause cancer, as other explanations might be possible. For example, power lines are often near busy roads, so the areas tested could contain different levels of pollution from traffic. So these studies don't show a definite link and so don't answer the original question.



RRRR — Remember, Reliable means Repeatable and Reproducible...

By now you should have realised how important trustworthy evidence is (even more important than a good supply of spot cream). Unfortunately, you need to know loads more about fair tests and experiments — see p. 5-10.

Bias and Issues Created by Science

It isn't all hunky-dory in the world of science — there are some problems...

Scientific Evidence can be Presented in a Biased Way

1) People who want to make a point can sometimes present data in a biased way, e.g. they overemphasise a relationship in the data. (Sometimes without knowing they're doing it.)
2) And there are all sorts of reasons why people might want to do this — for example...

- They want to keep the organisation or company that's funding the research happy. (If the results aren't what they'd like they might not give them any more money to fund further research.)
- Governments might want to persuade voters, other governments, journalists, etc.
- Companies might want to 'big up' their products. Or make impressive safety claims.
- Environmental campaigners might want to persuade people to behave differently.

Things can Affect How Seriously Evidence is Taken

1) If an investigation is done by a team of highly-regarded scientists it's sometimes taken more seriously than evidence from less well known scientists.
2) But having experience, authority or a fancy qualification doesn't necessarily mean the evidence is good — the only way to tell is to look at the evidence scientifically (e.g. is it reliable, valid, etc.).
3) Also, some evidence might be ignored if it could create political problems, or emphasised if it helps a particular cause.

EXAMPLE: Some governments were pretty slow to accept the fact that human activities are causing global warming, despite all the evidence. This is because accepting it means they've got to do something about it, which costs money and could hurt their economy. This could lose them a lot of votes.

Scientific Developments are Great, but they can Raise Issues

Scientific knowledge is increased by doing experiments. And this knowledge leads to scientific developments, e.g. new technologies or new advice. These developments can create issues though. For example:

Economic issues: Society can't always afford to do things scientists recommend (e.g. investing heavily in alternative energy sources) without cutting back elsewhere.

Social issues: Decisions based on scientific evidence affect people — e.g. should fossil fuels be taxed more highly (to invest in alternative energy)? Should alcohol be banned (to prevent health problems)? Would the effect on people's lifestyles be acceptable...

Environmental issues: Chemical fertilisers may help us produce more food — but they also cause environmental problems.

Ethical issues: There are a lot of things that scientific developments have made possible, but should we do them? E.g. clone humans, develop better nuclear weapons.

Trust me — I've got a BSc, PhD, PC, TV and a DVD...

We all tend to swoon at people in authority, but you have to ignore that fact and look at the evidence (just because someone has got a whacking great list of letters after their name doesn't mean the evidence is good). Spotting biased evidence isn't the easiest thing in the world — ask yourself 'Does the scientist (or the person writing about it) stand to gain something (or lose something)?' If they do, it's possible that it could be biased.

Science Has Limits

Science can give us amazing things — cures for diseases, space travel, heated toilet seats... But science has its limitations — there are questions that it just can't answer.

Some Questions Are Unanswered by Science — So Far

1) We don't understand everything. And we never will. We'll find out more, for sure — as more hypotheses are suggested, and more experiments are done. But there'll always be stuff we don't know.

EXAMPLES:

- Today we don't know as much as we'd like about the impacts of global warming. How much will sea level rise? And to what extent will weather patterns change?
- We also don't know anywhere near as much as we'd like about the Universe. Are there other life forms out there? And what is the Universe made of?

2) These are complicated questions. At the moment scientists don't all agree on the answers because there isn't enough reliable and valid evidence.
3) But eventually, we probably will be able to answer these questions once and for all... All we need is more evidence.
4) But by then there'll be loads of new questions to answer.

Other Questions Are Unanswerable by Science

1) Then there's the other type... questions that all the experiments in the world won't help us answer — the "Should we be doing this at all?" type questions. There are always two sides...
2) Think about new drugs which can be taken to boost your 'brain power'.
3) Different people have different opinions on them:

Some people think they're good... Or at least no worse than taking vitamins or eating oily fish. They could let you keep thinking for longer, or improve your memory. It's thought that new drugs could allow people to think in ways that are beyond the powers of normal brains — in effect, to become geniuses...

Other people say they're bad... taking them would give you an unfair advantage in exams, say. And perhaps people would be pressured into taking them so that they could work more effectively, and for longer hours.

4) The question of whether something is morally or ethically right or wrong can't be answered by more experiments — there is no "right" or "wrong" answer.
5) The best we can do is get a consensus from society — a judgement that most people are more or less happy to live by. Science can provide more information to help people make this judgement, and the judgement might change over time. But in the end it's up to people and their conscience.

Chips or rice? — totally unanswerable by science...

Right — get this straight in your head — science can't tell you whether you should or shouldn't do something. That kind of thing is up to you and society to decide. There are tons of questions that science might be able to answer in the future — like how much sea level might rise due to global warming, what the Universe is made of and whatever happened to those pink stripy socks with Santa on that I used to have.