

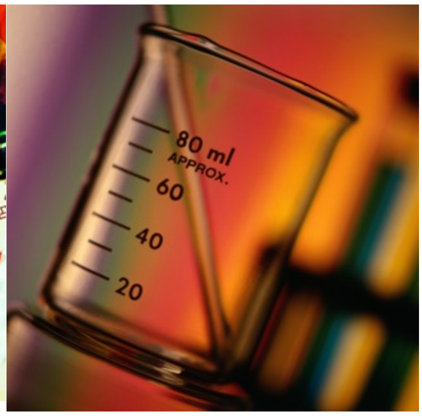

What is Science?

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First rough draft - December 2013


http://www.whatisscience.info

This document tackles the question of "What is science".

It starts with a summary and introduction to the key points.

The main pages elaborate on these points.

Appendices give more detail in selected areas.

It is written for the general reader, and those aiming to answer questions in a scientific way. It touches on areas sometimes referred to as the philosophy of science.

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Contents

What is science - summary and introduction

At first sight, the question "what is science" is an easy one - it's physics and chemistry and subjects like that. But a challenging question is where do we draw the line in applying the techniques of science - how should we use science in a courtroom, or in taxation policy, and is Japan's whaling programme "scientific" or actually "commercial". We need to understand the nature of science if we are to have a clear idea of how it should be used in policy making - how should we react if politicians ignore the science and commit public money on projects for which there is no good scientific basis. And people quite often say that something is "not very scientific", without putting their finger on why. So I think it is worth spending some time considering what science is. Read more on page 6.

Here's my short answer to "what is science":

> ***Trying to give correct answers to questions that we feel have correct answers***

I feel that this is the essence of what science is, but of course it is only a starting point to the many facets of the question.

In saying "Trying to", I am implying that science is a process, i.e. a human activity (rather than, say, "a collection of facts"). I am also implying that while we might try to give correct answers, we might not succeed initially - but the key thing is that the aim is to give correct answers. Furthermore, I am implying that there *are* questions to which we feel that there are correct answers.

So what are the fundamental elements of this process? I would say that these are:

- Open-mindedness
- Impartiality
- Reproducibility
- Collaboration
- Clarity and precision

Read more on page 7.

These are the principles, but what in practice are the methods used? I would divide them into:

- methods used for clarity and precision in discussing topics in science,
- methods used in planning investigations,
- methods used in carrying out investigations,
- methods used in analysing and interpreting results, and
- methods used in publishing results.

Some talk or write about "the scientific method", as if there is just one, but in reality there are a whole range of scientific methods that are used in different combinations in different circumstances. Read more on page 9.

In my view, the answer in the box (above) is the best short answer to the question of "what is science". I am only claiming that this is the *best answer in my opinion*, not that it is the *correct answer* to "what is science". I do not feel that it is a question with a correct answer. Instead, I would say that it is a philosophical question, one for which we can only choose what we feel to be the best answer - we don't have any agreed methods for finding an answer that we can accept as correct. Read more on page 12.

If we say that science is a human activity, then given that humans are fallible, why should we accept any scientific answer as true? The reasons I would give are

- scientific methods seem to work - they have led to the ability to predict eclipses, to the eradication of smallpox, to the technology of mobile communications, and so on.
- when science is done well, any answer comes with an assessment of how reliable that answer is.
- there is no good alternative to trying to give a correct answer to a question that we feel has a correct answer.

Read more on page 16.

Scientific methods have been developed to give correct answers to questions. They have a wide applicablility not just in the traditional locations of an observatory or a laboratory. Read more on page 18 about where scientific methods can be used. In particular they can and I believe should be used in evidence-based policy making (read more on page 20).

Why does the question matter?

At first sight, the question "what is science" is an easy one - it is physics and chemistry and subjects like that. But in several situations we need an understanding of what science is:

- People quite often say that something is "not very scientific", and we need a clear idea of the distinction between what is scientific and what is not.
- There are many examples of people trying to profit from products of dubious value. We need to be able to assess whether their claims of being, for example, "scientifically proven" are valid.
- Where do we draw the line in applying the techniques of science - how should we use science in a courtroom, or in taxation policy, and is Japan's current whaling programme "scientific" or actually "commercial".
- We need to understand the nature of science if we are to have a clear idea of how it should be used in policy making - how should we react if politicians ignore the scientific evidence and commit public money on projects for which there is no good scientific basis?
- There is the question of whether the courts should intervene in scientific disputes [1].

References

[1] US court ruling gives broad free speech protection to scientific articles (2013) *British Medical Journal* **347** doi: http://dx.doi.org/10.1136/bmj.f4259] (BMJ 2013;347:f4259)

Fundamental principles of science

If we take science to be "Trying to give correct answers to questions that we feel have correct answers", what are the fundamental principles in this process?

I would say, in summary:

- Open-mindedness
- Impartiality
- Reproducibility
- Collaboration
- Clarity and precision

Open-mindedness

There needs to be a willingness to draw whatever conclusions are indicated by the evidence, rather than starting with a particular point of view and looking only for evidence in support of it. There is no problem with having some opinion on what the outcome of research is likely to be, provided that the opinion is based on evidence; so that when new evidence is collected, opinions are adjusted appropriately, according to the new totality of evidence. Open-mindessness includes a willingness to accept unexpected discoveries (e.g. Fleming's discovery of penicillin).

Impartiality

Everything is dealt with fairly and even-handedly

- There is unbiased collection and summarising of data. This is as opposed to taking a point of view and looking only for evidence that support it.
- Conclusions are based fairly on the evidence.
- Uncertainties in data and conclusions are clearly set out.
- There is a clear distinction between "fact" and "opinion".

Reproducibility

So

- experiments are reported with enough detail of the methods to enable them to be repeated by others,
- experiments are reported with enough detail of the results and methods of analyses for the conclusions to be scrutinised,
- there is zero tolerance for dishonesty.

We might also describe this as "transparency".

Collaboration

So

- There is publication and disseminating of data and conclusions to anyone interested.
- There is integration of the conclusions from a study into other existing knowledge, with weighting based on the strength of evidence.
- Discussion is in a rational, impartial manner, as a collaborative exercise aimed at obtaining correct answers. This is as opposed to an adversarial process, with personal attacks and so on.

Clarity and precision

This is through definitions and standards (see page 9).

The above is just one way of structuring these ideas.

What is the justification for this?

I would try to justify my view of the essential element of science in two ways.

- This is the way that people behave when carrying out science that has resulted in useful answers.
- These principles seem to make sense if our aim is to give correct answers to questions that we feel have correct answers, or in current jargon, they have face validity.

Methods used in science

One implication of the answer that science is "Trying to give correct answers to questions that we feel have correct answers" is that science is a human activity i.e. the process of trying to find correct answers. This process involves a variety of methods which are used in different combinations to try to find correct answers. So, there are *scientific methods* (pleural) rather than a *scientific method* (singular), which some authors have written about.

A key part of the process is making observations and conducting experiments, and preferring conclusions based on these to mere opinions. The earliest recorded example of an experiment is in the Bible (The Book of Daniel, Chapter 1:1-16) where Daniel preferred not to eat the food and wine assigned to him, persuaded his guard to allow a ten-day trial of vegetables and water instead, and (it was said) looked healthier for it [1].

Scientific methods can be divided into

- methods used for clarity and precision in discussing topics in science
- methods used in planning investigations
- methods used in carrying out investigations
- methods used in analysing and interpreting results
- methods used in publishing results

There is a wide range of methods, depending on the field of science. The following list gives some of the main examples.

For clarity and precision in discussing science

Use of an agreed terminology

- Agreed standards such as using metre for length or kilogram for weight
- Agreed definitions e.g. using Body Mass Index (BMI) [2] when discussing normal or abnormal body weight
- Agreed rating scales such as in the definition of obesity [2]

This agreed language means that researchers can compare findings directly, without having to assess (or guess!) whether they are talking about the same things. Sometimes this agreed language comes from someone making a sensible suggestion and then everyone else taking it up, and sometimes it is from an international conference where a consensus is reached after discussing and debating alternatives, such as the internationally agreed staging for cancer [3].

Definition of any new or uncommon terminology or abbreviation

Distinguishing between facts, uncertainties and opinion

Writen and spoken text distinguishes between

- facts that do not need justification (such as that the earth is round rather than flat)
- facts where justification might be helpful - the statement is followed by reference to the research or summary text that supports it, either in brackets or referenced via

a number (generally bracketed or as a superscript) that refers to a reference list at the foot of the page or at the end of the document
- uncertainties that are denoted by appropriate text such as "this suggests that", or "a possible explanation is"
- opinions

In planning investigations

- Replication of previous experiments: in many fields, research findings are not generally accepted until successfully replicated by an independent group of researchers.
- Sufficient repetitions of a planned experiment to ensure that results are representative of what is being studied
- If there is a large variation in results, then subjects should be selected to be representative of the group to whom the results of the study will be applied.
- Specification of all procedures in advance as a *protocol*.

In carrying out investigations

- Adhering methodically to the planned protocol wherever possible
- Recording any departures from the planned protocol
- Dealing with departures from the planned procedure in a fair way
- Making use of chance findings e.g. as happened in the discovery of penicillin

In analysing and interpreting results

- Not jumping to conclusions on the basis of a small number of observations.
- Not treating an association as due to cause and effect unless there is other evidence for this.
- Construction of laws as summaries of results that seem to follow a pattern.
- Construction of models and theories i.e. provisional explanations for results, which might lead to futher studies that either support or invalidate the models and theories. There is not a clear distinction between models and theories, but generally models are taken to be smaller in scope and perhaps more mathematical than theories.

In publishing results

Publication of scientific papers in scientific journals so that
- The articles are widely disseminated around the world through subsciptions by scientific libraries and by individuals.
- The articles are available for study for years, decades or even centuries - the article never goes "out of print".
- There is "competitive publication": journals are keen to attract the best articles, and authors are keen to have articles accepted by the most prestigious journals. This maintains and improves standards.

Peer review of draft scientific manuscripts
Scientific articles when submitted for publication in a so-called *peer-reviewed* scientific journal are reviewed by two or three experts in the field of research who give their opinion (usually anonymously as far as the authors are concerned) on whether the article should be accepted for publication without alteration (which is rare), or should be accepted after some changes (more common), or should be rejected. This

- prevents poor articles from being published
- may raise standards since authors will know that their work will be assessed before publication
- improves articles via the incorporation of helpful comments from the reviewers

Reporting of all results fairly, not just those that fit some preconceptions.

Publishing the results of all completed trials, not just those that happen to fit in with a desired result.

Inclusion of a clear summary, generally at the start of the document.

Is this page fact or opinion?

What I have written on this page is my opinion of how science is generally carried out, based on personal experience and non-systematic observations, and how I feel that it should be carried out. So, each sentence could be preceded by "In my view, ...". There is a circular argument here in that if an activity does not meet my criteria, I do not consider it as part of science.

But, to varying degrees, the methods can be justified on the grounds of firstly plausibility, and secondly that we have compelling evidence that they have worked in the past (in generating predictions which have been found to be accurate).

References

[1] James Lind Library: Principles of testing (viewed 15.10.2013) http://www.jameslindlibrary.org/illustrating/records/the-book-of-daniel-chapter-11-16/key_passages

[2] NHS Wales: Glossary (viewed 20.11.13) http://www.wales.nhs.uk/sitesplus/922/page/49823: "BMI is calculated as weight (in kilograms) divided by the height squared (in metres). Adults with a BMI of 25 or more are categorised as overweight and with a BMI of 30 or more as obese."

[3] UICC TNM classification http://www.uicc.org/resources/tnm

Justification for this description of science

How can I justify my description of science as "Trying to give correct answers to questions that we feel have correct answers"?

- I can look at answers given by others to the same question and show that my answer is similar.
- I could observe scientists carrying out their work, and record what they do, and/or summarise the findings of others who have done the same thing.

This raises the question of what kind of question is "what is science" and what kind of an answer would seem to be a satisfactory one. I do not think that many people would say that the question "what is science" has a correct answer. Therefore, being consistent with my description of science, it cannot be described as a *scientific* question. Instead, I would categorise it as a *philosophical* question (see below).

Justification from the description of others

My answer is not very different from the descriptions given by some other authors. The following are some examples, but there is a wide range of views - see the examples in the Appendix: Survey of published definitions of science.

- Popper (1957) in *The aim of science* [1] said that the aim is:

  > *to find satisfactory explanations of whatever strikes us as being in need of explanation*

- A book in the Usborne series (1992) gave the descritpion [2]:

  > *Science is the process of gathering knowledge and answering questions about the world and how it works.*

Justification from the behaviour of scientists

I can point to scientists and say that, in general, the way they are acting is in accord with my answer of "trying to give correct answers to questions that we feel have correct answers". This is my belief from my experience, but I have not recorded and analysed this experience in a systematic way, and I do not know of any research that has studied this. This might be considered a circular argument in that if someone is not acting according to my description of science, then I would not judge them to be scientists, but I do not see this as a difficulty. I feel that I am making a self-consistent description of a clustering of human behaviour, which has been very successful in making predictions that have turned out to be correct.

Philosphical questions

There are some questions that I feel do not have *correct* answers, because there is no agreed way of deciding what is correct. And yet, of the answers that I have come across to any of these question, some answers are better than others, and I feel that I want to give the best answer to the question that I can. I feel that I should choose the *best* answer (in each case). I would refer to this kind of question as *philosophical* questions.

How should we answer philosophical questions?
If there is not a *correct* answer to a question, how should we choose the *best* answer? I would say

- on the basis of what seems sensible, which might also be termed "face validity" or "common sense",
- on the basis of what seems to fit with our (or my) experiences (i.e. general experiences rather than the structured categorized experiences used in science),
- to aim for consistency with other "best answers" that we want to give to related questions.

This is my best answer to this question of how should we choose best answers.

References

[1] Popper (1957) *The aim of science* presented in *Popper selections* (1985) Ed. David Miller, Princetown University Press

[2] *The Usborne Book of Scientists* (1992) Usborne, London

What is not science?

It helps to understand what science is by considering what is *not* science, including:

- Pseudoscience
- Philosophy
- Philosophy of science
- Technology
- Advertising

Pseudoscience

One published definition of pseudoscience is "a collection of beliefs or practices mistakenly regarded as being based on scientific method" [1].

Astrology is often cited as an example of a pseudoscience. The departures from scientific methods might be, for example, that evidence was collected selectively rather than in an unbiased way, or there might be an over-emphasis on case histories. The key thing is not the field of study (for example, one might carry out a proper scientific study to assess whether there is any relationship between birth date and personality), but the methods used, and the intention.

References

[1] *The New Oxford Dictionary of English* (1998), Ed. Judy Pearsall, Clarendon Press. Oxford. There is also an identical definition at http://www.oxforddictionaries.com/definition/english/pseudoscience], viewed 31 Oct. 2013.

Good science and bad science

What are the differences between good and bad science?

It comes down to following the rules or breaking the rules.

Errors have been cataloged incompletely by Andersen (1990) [1], and Ben Goldacre has also given many examples [2].

Some errors keep recurring e.g.
- not being clear about the difference between association, on the one hand, and cause and effect, on the other
- not being clear about the difference between not finding a difference, on the one hand, and domonstrating no difference, on the other.

References

[1] Andersen B (1990) *Methodological errors in medical research*, Blackwell Scientific Publications, Oxford

[2] Ben Goldacre (2008) *Bad Science* ISBN 978-0-00728487-0 www.badscience.net

How reliable is science?

According to my short answer to "what is science", we are trying to obtain correct answers, so an important question is how successful is the process.

In summary, I would say that it has been very successful on the basis that

- Scientific knowledge has been used as the basis of many human enterprises, for example
  - to predict eclipses,
  - to send rockets into space,
  - to eradicate smallpox,
  - as a basis for the technology of mobile communications.

  The success of these enterprises gives us confidence that scientific methods will be successful in these and other spheres in future studies.
- Replication of new results published in a respected journal generally gives similar results.
- Replication of systematic reviews in medicine generally gives similar or the same results [1].
- It is rare for an established body of "knowledge" to be found to be false.
- The answers in science form an interlinked whole.

Possible sources of unreliability

These include

- errors and fraud i.e. "research misconduct"
- concerns about the basis of science, e.g. the "problem of induction"

Research misconduct

Research misconduct has been defined in biomedical sciences as "behaviour by a researcher, intentional or not, that falls short of good ethical and scientific standards" [2].

The "problem of induction"

Some philosophers have raised concerns about the reliability of science. One concern is over whether the world will behave in the future in the same way as it has done in the past, which has been termed "the problem of induction". The argument is that the finding that all observations have conformed to a particular law in the past does not prove that they all will in the future. But I would say that this is not a problem for science in particular but for all decisions that we might make about the future. We cannot prove that tomorrow will be more or less like today, but it seems to be a reasonable assumption, and one that most people make without thinking about it (and perhaps without ever thinking about it). People demanding absolute proof that the future will be like the past will not get it (in my opinion). If they say that this means that science cannot be trusted, then they should never step outside of a building in case gravity suddenly fails and they float off into space, and they should never start to write anything about science because there is no certainty that the world will last long enough in its present form for anyone to read what they write.

So I feel that "the problem of induction" is a trivial problem for people who want to tackle important problems in a scientific way. We should assume in general that what we are studying scientifically will continue in the future according to the same laws of nature as it has in the past because we make the same assumption in every other aspect of our lives.

I wonder how ethical it is for people interested in the philosophy of science to propagate concerns about "the problem of induction". Suppose for example that someone wrote a book (merely for profit and personal gain) with the result of undermining confidence in scientific methods, and this book contributed to a reduction in the uptake of an immunisation programme or life-saving treatment for cancer; would this be an ethical course of action?

Expressions of concern about confidence in scientific statements

In any situation, application of the best scientific methods should give us the most accurate answer to a question together with an estimate of how much confidence we should put in that answer and/or its accuracy. Anyone with concerns that the answer or the associated degree of confidence in it could be improved should participate in the process of answering questions as well as they can be answered; those that only heckle from the sidelines should be suspected of doing so only because they have no good basis for their concerns.

References

[1] Konstantinos Siontis *et al* (2013) Overlapping meta-analyses on the same topic: survey of published studies *BMJ* 2013;347:f4501
http://www.bmj.com/content/347/bmj.f4501

[2] Aniket Tavare & Fiona Godlee (2012) Helping institutions tackle research misconduct *BMJ* 2012;345:e5402 http://www.bmj.com/content/345/bmj.e5402

Where can scientific methods be used?

The areas traditionally thought of as science are physics, chemistry, biology and related areas. But scientific methods can be and have been used in areas far removed from a laboratory, and the traditional distinction between "arts" and "science" subjects is not necessarily helpful. History is not generally considered as part of science, but many people would include archaeology in science, and historians place emphasis on good sources i.e. good evidence. Law is not generally considered as part of science, but forensic science clearly is.

As an example of scientific methods method used outside a laboratory, the possible benefits of screening women for breast cancer using mammography were explored in Scandinavia by allocating geographical areas at random to having breast screening or to not having breast screening.

Another example is the scientific studies of happiness [1].

For further examples of the use of scientific methods of study, here are two excerpts from *Counter Power* by Tim Gee [2]

> *...a recent study of 67 different revolutions found that levels of democratic rights were far higher in countries that had used nonviolent methods to achieve democracy[9] [3].*

> *Another piece of research, looking at the myriad revolutions in Africa between 1989 and 1994, concludes that democratization occurred most frequently in countries that liberalized following mass political protests, rather than through bloody revolution or coups[10]*

This suggests that some ways in which well-meaning, outside countries can support democratic revolutions may be better than others, and that scientific methods of careful observation and so on can be used wherever we want to get to a correct answer.

If we want to answer questions as accurately as possible, there seem to be no limits on where scientific methods might be used. In particular, why should we not use scientific methods in public policy making? Read more on page 20.

References

[1] Sonja Lyubomirsky (2007) *The How of Happiness* ISBN 978-0-7499-5246-4

[2] Tim Gee (2011) *Counter Power: Making Change Happen* New Internationalist Publications Ltd, Oxford, UK http://newint.org/books/politics/counterpower/

[3] Adrian Karatnycky and Peter Ackerman (2005) *How Freedom is Won: From Civic Struggle to Durable Democracy* Freedom House, Washington

http://www.freedomhouse.org/article/study-nonviolent-civic-resistance-key-factor-building-durable-democracies

Evidence-based policy making

‘There is increasing support for *evidence-based policy making* [1] [2], which is based on the use of scientific methods.

The reasons for not basing policy on the available evidence are

- lack of awareness
- unsubstantiated beliefs
- being swayed by self-interest
- succumbing to outside pressure, and
- lacking the necessary skills

or in blunt terms

- ignorance
- prejudice
- greed
- corruption, and
- incompetence

An evidence-based policy seems likely to be a better policy for the public than any of these alternatives.

In my view policies should include

- aims (together with their relative importance if more than one), and the justification for them, including reasons for non-inclusion of other potential aims,
- methods to achieve those aims, together with the reasons why it is felt that those methods will work such as evidence of their effectiveness previously,
- reference to and comparison with comparable policies.

There should be a recognition that any first version of a strategy will contain flaws, and a desire that these flaws will be removed as far as possible via a process of consultation (analogous to peer review prior to publication in scientific journals). There are Government guidelines on consultation [3].

When drawing up an evidence-based policy, if we have agreed aims, and if the evidence considered is the same, and the ways of combining evidence are the same, then two or more people or groups should come to the same conclusions. If the conclusions are different, then the aims must be different, or the evidence considered must be different, or the ways of combining the evidence must be different. These differences should be discussed, debated and resolved.

In some areas, policy documents are subjected to the test of "soundness", where to be "sound" the strategy should be [4]

- justified i.e. "founded on a robust and credible evidence base" and "the most appropriate strategy when considered against reasonable alternatives"
- effective
- consistent with national policy

It is not clear to me why all policy documents are not subjected to this or a similar test of soundness.

In my opinion, those who care about decisions being made in the best possible way should always use the methods of science, should argue for their use, and should challenge any decision-making that is not based on evidence.

How do I justify this view on policy making?
I am not aware of scientific studies on policy making, and so I am only able to say that this seems to be the best answer to how to make policies.

I am putting forward a strategy for making policies and strategies, and so I should follow my own guidelines. The key thing is that the aims are (or should be) to give the public the best policies.

References

[1] *What works: evidence centres for social policy* (2013) Cabinet Office, London https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/136227/What_Works_publication.pdf

[2] *Making Evidence Useful* (2013) Nesta
http://www.nesta.org.uk/publications/assets/documents/making_evidence_useful

[3] *Consultation principles* (2012) Cabinet Office, London
https://www.gov.uk/government/publications/consultation-principles-guidance

[4] The Planning Inspectorate (2009) *Local Development Frameworks Examining Development Plan Documents: Soundness Guidance (2nd Edition)* http://www.planningportal.gov.uk/uploads/pins/ldf_dpd_soundness_guide.pdf

Appendix 1: Survey of published definitions of science

This is a collection of published definitions of science, obtained via internet and library browsing and searches. It is not systematic, complete or necessarily representative.

- Popper (1957) in *The aim of science* [1] said that the aim is:

  to find satisfactory explanations of whatever strikes us as being in need of explanation

  although in a later work, *The growth of scientific knowledge* (1960) [2], he gave a slightly different view:

  The conscious task before the scientist is always the solution of a problem through the construction of a theory which solves the problem, for example, by explaining unexpected and unexplained observations.

- Dorland (1965) [3]:

  [L. scientia knowledge]. An accumulating body of knowledge, especially that which seeks to establish general laws connecting a number of particular facts.

- Usborne (1992) [4]:

  Science is the process of gathering knowledge and answering questions about the world and how it works.

- Larousse (1995) [5]:

  The ordered arrangement of ascertained knowledge, including the methods by which such knowledge is extended and the criteria by which its truth is tested. The older term natural philosophy implied the contemplation of natural processes per se, but modern science includes such study and control of nature as is, or might be, useful to mankind.

- The New Oxford Dictionary of English (1998) [6]

  the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment.

- The Science Council (2009) [7]:

  Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence.

- Ben Goldacre (2011) [8] This is perhaps better described as a description than a definition:

  Science isn't about authority, or white coats, it's about following a method. That method is built on core principles: precision and transparency; being clear about your methods; being honest about your results; and drawing a clear line between the results, on the one hand, and your judgement calls about how those results support a hypothesis.

- Cambridge Dictionaries Online (Cambridge University Press) (2011) [9]:

  (knowledge from) the systematic study of the structure and behaviour of the physical world, especially by watching, measuring and doing experiments, and the development of theories to describe the results of these activities

- Collins English Dictionary (2011) [10]

  1. the systematic study of the nature and behaviour of the material and physical universe, based on observation, experiment, and measurement, and the formulation of laws to describe these facts in general terms

  2. the knowledge so obtained or the practice of obtaining it

  3. any particular branch of this knowledge

  4. any body of knowledge organized in a systematic manner

  5. skill or technique

  6. archaic knowledge

- Wikipedia (2012) [11]

  Science (from Latin scientia, meaning 'knowledge') is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe

References

[1] Popper (1957) *The aim of science* presented in *Popper selections* (1985) Ed. David Miller, Princetown University Press

[2] Popper (1960) *The growth of scientific knowledge* presented in *Popper selections* (1985) Ed. David Miller, Princetown University Press

[3] *Dorland's Illustrated Medical Dictionary* 24th Ed (1965) WB Saunders Company, Philadelphia and London

[4] *The Usborne Book of Scientists* (1992) Usborne, London

[5] *Dictionary of Science and Technology* (1995) Larousse, Edinburgh

[6] *The New Oxford Dictionary of English* (1998), Ed. Judy Pearsall, Clarendon Press. Oxford. There is also an identical definition at http://oxforddictionaries.com/definition/science?q=science, viewed 9.3.2012.

[7] The Science Council (2009) www.sciencecouncil.org

[8] Ben Goldacre *The Guardian* 5 November 2011

[9] http://dictionary.cambridge.org/dictionary/british/science?q=science viewed 9.3.2012

[10] http://www.collinsdictionary.com/dictionary/english/science viewed 9.3.2012

[11] http://en.wikipedia.org/wiki/Science#cite_note-0 viewed 13.2.2012

Appendix 2: About the author

The author of this document is Ian Campbell BA, BSc, MD, FRCS, FRCR.

It has been written using experience

- as a "consumer" of science while working as a doctor in the fields of general surgery and oncology,
- as a researcher through involvement in clinical trials,
- through writing an MD thesis on *Statistical Methods in Cancer Clinical Trials*,
- as a statistical consultant helping around 70 clients with about 200 studies, mainly in the field of medical research
- in writing and analysing evidence-based documents in the field of sustainable transport.

Read more at www.iancampbell.co.uk.