THEORY OF SCIENCE

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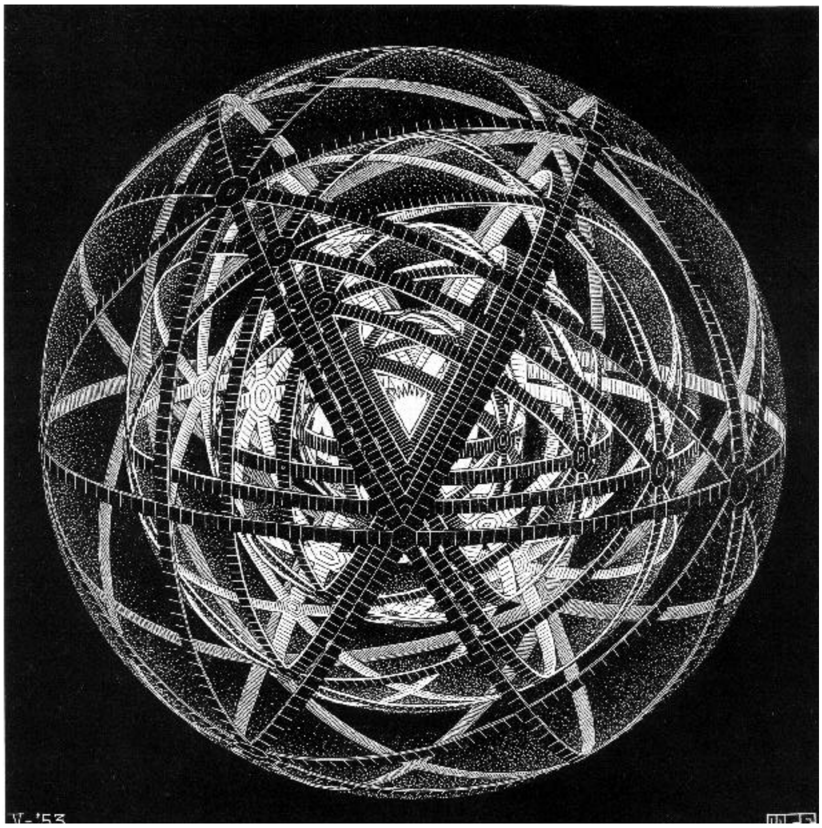

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INTRODUCTION

In the 21th century we live in a world that is more scientific then ever in history of humanity. The number of active scientists today exceeds considerably the total number of all scientists in the past. Our civilization is permeated by science. Science has become in one way or another a part of every humans life, deeply integrated in our culture.

What is then this thing called science?

We hear that something is scientifically proved. It sounds like its true. What does true mean? What is scientific truth? How is science made? How is it formulated? How is it communicated? What is communication? How do we use different languages?

There is a red thread in this course, or rather an Ariadne's thread[1], and that is *critical thinking*. We are going to use critical thinking as method when approaching science, and we are going to think (critically!) about critical thinking.

Last but not least we take a look at science and scientists from the ethical point of view. Just not to forget that science is made by humans, and indeed *for* humans.

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[1] Greek mythology tells the story of Ariadne, the daughter of the King of Crete who solved the puzzle of the labyrinth with a simple spool of thread. *Ariadne's Thread is about finding and following the line that can lead the way out of a complex and virtually unsolvable problem.*

Ariadne's father, King Minos, forced the king of Athens to send men each year as sacrifices to the minotaur (half bull, half human) who lived at the center of a labyrinth. Theseus was one of these Athenians. When Ariadne saw Theseus, she fell in love with him and she gave him a spool of thread to help him return from the labyrinth. Theseus used the sword to slay the minotaur and the thread to guide him back.
See: http://www.hsa.brown.edu/~maicar//Ariadne.html

1 WHAT IS SCIENCE?

"Scientists are people of very dissimilar temperaments doing different things in very different ways. Among scientists are collectors, classifiers and compulsive tidiers-up; many are detectives by temperament and many are explorers; some are artists and others artisans. There are poet-scientists and philosopher-scientists and even a few mystics."

Peter Medawar. Pluto's Republic, Oxford University Press, NY, 1982, p. 116.

Science is an extremely complex phenomenon, and difficult if not entirely impossible to define in a simple way. Here is an attempt to determine science by goal and process as well as by contrast (i.e. by defining what is *not* science).

Definitions by Goal and Process

Science (*Lat. scientia, from scire, "to know"*) is wonder about nature. Like philosophy, science poses questions - but also has the means to answer them, as long as they concern the state and behavior of the physical world.

Science is the systematic study of the properties of the physical world, by means of repeatable experiments and measurements, and the development of universal theories that are capable of describing and predicting observations. Statements in science must be precise and meaningful, such that other people can test them (in order to establish "universality").

Science is

1. the systematic observation of natural events and conditions in order to discover facts about them and to formulate laws and principles based on these facts.
2. the organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation.
3. any specific branch of this general body of knowledge, such as biology, physics, geology, or astronomy.

Academic Press Dictionary of Science & Technology

Science involves more than the gaining of knowledge. It is the systematic and organized inquiry into the natural world and its phenomena. Science is about gaining a deeper and often useful understanding of the world.

Multicultural History of Science page at Vanderbilt University

Science alone of all the subjects contains within itself the lesson of the danger of belief in the infallibility of the greatest teachers in the preceding generation…As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts.

Richard Feynman, Nobel-prize-winning physicist, in The Pleasure of Finding Things Out

Definitions by Contrast

To do *science* is to search for repeated *patterns*, not simply to accumulate facts.

Robert H. MacArthur, Geographical Ecology

Religion is a culture of faith; *science* is a culture of *doubt*.

Richard Feynman

I think that we shall have to get accustomed to the idea that we must not look upon science as a "body of knowledge", but rather as a system of hypotheses, or as a system of guesses or anticipations that in principle cannot be justified, but with which we work as long as they stand up to tests, and of which we are never justified in saying that we know they are "true".

Karl R. Popper, The Logic of Scientific Discovery

2 WHAT IS "THE SCIENTIFIC METHOD"?

The scientific method is the logical scheme used by scientists searching for answers to the questions posed within science, as well to formulate theories as to assure the means for producing them (instruments, tools, algorithms). The simple version looks something like this (see Figure 1):

1. Pose the question in the context of existing knowledge (theory & observations).
   (It can be a new question that old theories are capable of answering (usually the case), or the question that calls for formulation of a new preliminary theory).

2. Formulate a hypothesis as a tentative answer.

3. Deduce consequences and make predictions.

4. Test the hypothesis in a specific new experiment/theory field. The new hypothesis must prove to fit in the existing world-view (1, ´normal science´, according to Kuhn).
   In case the hypothesis leads to contradictions and demands a radical change in the existing theoretical background, it has to be tested particularly carefully. *The new hypothesis has to prove fruitful and offer considerable advantages, in order to replace the existing scientific paradigm*. This is called "*scientific revolution*" (Kuhn) and it happens very rarely.
   As a rule, the loop 2-3-4 is repeated with modifications of the hypothesis until the agreement is obtained, which leads to 5. If major discrepancies are found the process must start from the beginning, 1.

5. When consistency is obtained the hypothesis becomes a theory and provides a coherent set of propositions that define a new class of phenomena or a new theoretical concept. Theory at that stage is subject of process of natural selection among competing theories (6). A theory is then becoming a framework within which observations/theoretical facts are explained and predictions are made. The process can start from the beginning, but the state 1 has changed to include the new theory/improved old theory.

THE SCIENTIFIC METHOD

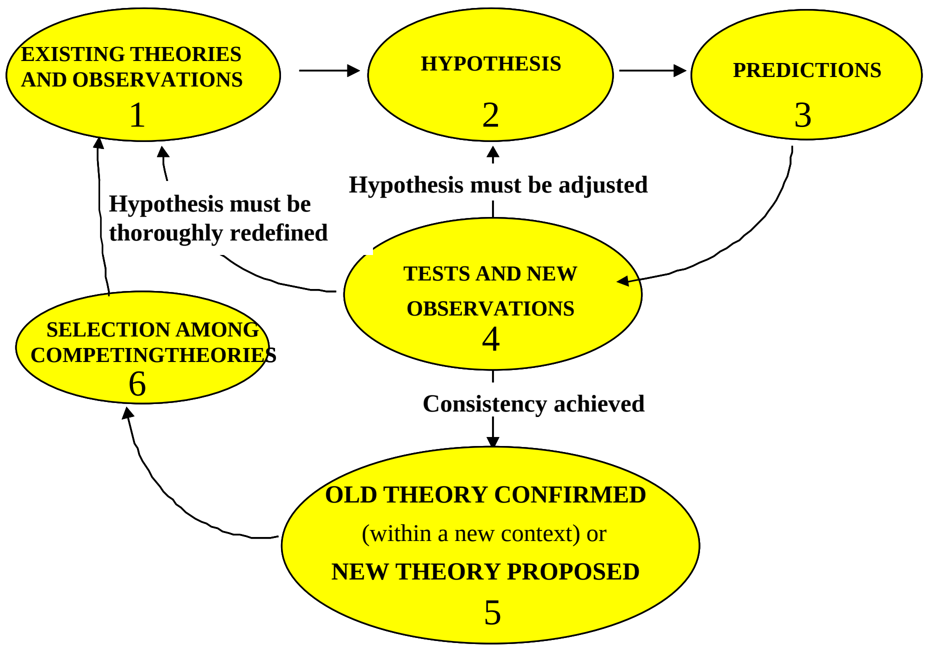

Figure 1 Diagram describing iterative nature of the scientific method (hypothetico-deductive)

Figure 1 describes the *logical structure of scientific method* in a very general scheme. As the flow diagram suggests, science is in a state of permanent change and development. The one of the most important qualities of science is its *provisional character:* it is subject to continuous re-examination and self-correction.

For an individual scientist it is of course possible to enter any phase of a scientific project. One can for example start by analyzing some experimental/observational results (4). However, it is crucial to understand that the *logic of science is recursive*: prior to every observation/experiment/theoretical test it is a hypothesis (2) that has its origins in the pre-existing body of knowledge (1). Every experimental/observational result has a certain world-view built-in. Or, to say it by Feyerabend, every experimental data is “theory-contaminated”.

Here it is also interesting to mention that designing new experimental equipment or procedure match the same scheme. So we proceed as follows: (1) Start from existing theoretical/experimental facts; (2) Formulate the problem; (3) Infer consequences; (4) Test if it works as expected; (5-6) Accept. As soon as a piece of equipment or method is designed and used as a tool for testing new hypotheses it is supposed that it works according to the design specification. The detailed information about its internal structure is therefore hidden.

The scheme of the scientific method in Figure 1 is without a doubt an abstraction and simplification. Critics of the hypothetico-deductive method would argue that there is in fact no such thing as “the scientific method”. *By the term “the scientific method” they actually mean the set of rules defining how to proceed in posing new relevant questions and formulating successful hypotheses (1)®(2).*

Indeed, the formulation of hypothesis (1)→(2) is a part of scientific work where we can accept Feyerabends formulation “anything goes”. (Educated) guess, chance, intuition, metaphysical concepts…anything can lead to formulating new hypothesis.

Essential however is that *the new result/concept/hypothesis have to withstand tests and observations/experiments and moreover it has to survive the “natural selection” among competing theories/concepts/results.* The reaction of the scientific community is decisive in this context. New results have to endure cross-examinations and show their correctness, usefulness, power and beauty.

Figure 1 leaves out many significant aspects of scientific work as for example its *social nature*. Modern science is an activity that often includes big groups of scientists that are communicating all over the world across national borders, sharing scientific results and ideas. *The co-operation between scientists* is indeed a crucial part of the scientific way of work.

Let us mention only the very evident fact that it is impossible for every scientist to independently do every experiment or derive every theorem to confirm every theory. *Because time at our disposal is limited, scientists have to rely on other scientists.* That is, the scientific community provides the support for individual scientists. One can also say that the body of scientific knowledge and thought belongs to *scientific community* and that individual scientists can contribute to the development of their scientific field only through the process of *communication* with the scientific community.

It is a tradition that scientific methods, results and ideas, within fundamental science at least, are the common heritage of humanity and they are *shared without profit*. They are general *(universal*) and unrestrained. In that respect, science belongs to very few fields of human activity where information is free. It is the *open information exchange* that constitutes the very backbone of modern science.

In the process of development of science, experiments/theories usually do get repeated as part of other experiments/theories. Most scientific papers contain suggestions for other scientists to follow up. *Usually the first step in doing new research is to repeat earlier work.* So there is a principle that a new theory has to reproduce results of old theory within the domain where the old theory has been demonstrated to work. This is basically the demand for the consistency between the old and the new theories. For example Einstein’s special theory of relativity gives the Newtonian theory in the limit $v/c \rightarrow 0$ (i.e. where velocities are neglectable compared to speed of light).

The important advantage of the scientific method is that it is *impartial*:[2] one does not have to believe a given researcher, one can (in principle) repeat the experiment and determine whether certain results are valid or not. The conclusions will hold irrespective of the state of mind, or the religious persuasion, or the state of consciousness of the investigator. The question of *impartiality* is closely related to *openness* and *universality* of science, which are its fundamental qualities.

A theory is accepted based in the first place on the results obtained through *logical reasoning, observations* and/or *experiments*. The results obtained using the scientific method have to be *reproducible*. If the original claims are not verified, the causes of such discrepancies are exhaustively studied.

It is not always possible to repeat the studied event many times under controlled forms. There are for example only few large laboratories in the world running experiments in particle physics. Very complicated and sophisticated experiments are not so seldom unique. Also, when studying certain astronomical objects like distant stars we cannot perform experiments; all information is thus obtained from observations and measurements. Theories are then devised by extracting some regularity in the observations and formulating this into physical laws (theories).

There is an important characteristic of a scientific theory or hypothesis that differentiates it from, for example, a religious belief: a scientific theory must be *"falsifiable"*. This means that there must be some observation/experiment or another well-approved theory that could disprove the theory in question. For example, Einstein's theory of relativity made predictions about the results of experiments. These experiments could have produced results that contradicted Einstein, so the theory was (and still is) falsifiable.

Observe yet an important distinction (Feyerabend):
"No theory ever agree with all facts in its domain, yet it is not always theory that is to blame. Facts are constituted by older ideologies, and a clash between facts and theories may be a proof of progress."

So it would be naïve to believe that single experimental discrepancy would be able to falsify any of well-established theories. As Kuhn describes the process, it is the act of revolution, and it calls for very dramatic changes in science, which means fundamental (and very expensive) re-building that is done only if there is no other solution to the problems but to abandon the established world-view ("paradigm").

A frequent criticism made of the scientific method is that *it cannot accommodate anything that has not been proved*. The argument then points out that many things thought to be impossible in the past are now everyday realities. This criticism is based on a misinterpretation of the scientific method.

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[2] *Impartial* is used here as synonymous for *objective, unbiased, unprejudiced, dispassionate***.**
Note, however that this is the statement about *science, not about individual scientists* whose attitude to their pursuit is as a rule passionate**.** The fact that science is shared by the whole scientific community results in theories that are in a great extent *free from individual bias***.** On the other hand the whole of scientific community use to share *common paradigms***,** which are the very broad concepts deeply rooted in the *culture. Paradigm shift is a process that occurs in a very dramatic way, partly because of cultural (not strictly rational) nature of paradigm, (Kuhn).*

All scientific truths are *provisional*. But for a hypothesis to get the status of a theory it is necessary to win the confidence of the scientific community. In the fields where there are no commonly accepted theories (as e.g. explanation of the process of creation of the universe- where the "big bang" hypothesis is the most popular one) the number of alternative hypotheses can constitute the body of scientific knowledge.

Socratic Method vs. Scientific Method

As we already pointed out, science is developing during history. It is therefore instructive to compare the classic Socratic method (based as a rule on "thought experiments") and the modern scientific method. We find a very similar structure comparing those two!

Table 1 Socratic Method vs. Scientific Method

Socratic Method	Scientific Method
1. Wonder. Pose a question (of the "What is *X ?*" form).	*1. Wonder*. Pose a question. (Formulate a problem).
2. *Hypothesis*. Suggest a plausible answer (a definition or *definiens*) from which some conceptually testable hypothetical propositions can be deduced.	2. *Hypothesis*. Suggest a plausible answer (a theory) from which some empirically testable hypothetical propositions can be deduced.
3. *Elenchus* ; "testing," "refutation," or "cross-examination." Perform a thought experiment by imagining a case which conforms to the *definiens* but clearly fails to exemplify the *definiendum*, or vice versa. Such cases, if successful, are called *counterexamples*. If a counterexample is generated, return to step 2, otherwise go to step 4.	3. *Testing*[3]. Construct and perform an experiment, which makes it possible to observe whether the consequences specified in one or more of those hypothetical propositions actually follow when the conditions specified in the same proposition(s) pertain. If the test fails, return to step 2, otherwise go to step 4.
4. Accept the hypothesis as *provisionally true*. Return to step 3 if you can conceive any other case which may show the answer to be defective.	4. Accept the hypothesis as *provisionally true*. Return to step 3 if there are predictable consequences of the theory which have not been experimentally confirmed.
5. Act accordingly.	5. Act accordingly.

[3] In the field of logic and mathematics, a proof must be found that demonstrates its validity. In other theoretical fields the hypothesis should relate to existing theories and prove its consistency and advantages.

In order to pose the question and formulate hypothesis (Figure 1, (1)→(2)), we use different approaches:

1. Intuition
2. Analogy[4]
3. Paradigm
4. Metaphor

Last but not least: a very important factor leading to many scientific discoveries is *chance*!

Criteria to Evaluate Theories

When there are several rivaling hypotheses number of criteria can be used for *choosing the top candidate for a best theory* (Figure 1, (6)). Following can be evaluated:

- Theoretical scope
- Appropriateness
- Heuristic value
- Validity
- Parsimony (Simplicity, see Ockham's razor in Dictionary)

The theory must necessarily fulfill the following criteria

- Logically consistent
- Consistent with accepted facts [5]
- Testable
- Parsimonious
- Consistent with related theories
- Interpretable: explain and predict
- Pleasing to the mind (Esthetic, Beautiful)
- Useful (Applicable)

[4] the "resonant similarity", Timothy Budd
[5] Of course not always all those criteria can be met. In the case of paradigm shift, a new theory is contradicting the old ones. Neither a full consistency between different theories is always found (quantum physics, relativity), nor ideal beauty is possible to achieve (nuclear physics!).

We can conclude that the process of asking a relevant question and formulating a successful hypothesis/theory is essentially not different from any other creative process like writing music, or poetry or performing art. That specific part of the working process within science has lead Feyerabend and other critics to claim the non-existence of a scientific method.

What is crucial for science however is that the hypothesis (theory), must be thoroughly investigated and either fit into the existing framework (normal science) or lead to thorough reformulation of the existing scientific paradigm (scientific revolution).

Let us have a look on the following table illustrating how the general context influences our focus, including the type of questions we ask as well as type of answers we search for.

Table 2 Focus of Classical Antiquity Science vs. Contemporary Science, Dominant Characteristics

Science of Classical Antiquity	Contemporary Science
why?	how?
eternal	present
explain	predict/use
holism	reductionism
individual	groups/institutions
local	global
knowledge *for its own sake*	knowledge *for application*
reasoning	experiment

3 WHAT IS KNOWLEDGE?

Knowledge is justified, true belief.
Plato in dialogue Meno

The objective of the analysis of knowledge is to state the conditions that are necessary and sufficient for *propositional knowledge*: *knowledge that such-and-such is the case*. Propositional knowledge must be distinguished from *non-propositional knowledge (tacit knowledge)* that is the *knowing how to do something*.

Abstraction

Our knowledge is built out of *concepts* or *notions*, i.e. theoretical representations that are the abstract "image" of the objective world. The first step of abstraction is the immediate processing of sensory impression (visual, auditory, tactile…). The consciousness is a dynamic interplay of these two types of abstractions. Instant sensory representation is also *mediated*: that is, it is with human, cultured sense organs that we view nature. *There is nothing like "direct" (unmediated) observation*.

Concepts are *abstractions*. They are extracted from the concrete world and interconnection with everything else, *idealized*, *concentrated* and *simplified*.
No abstraction exists in nature, outside of human consciousness, because everything outside of consciousness moves, changes, is immensely complex, interconnected, and in perpetual transition and movement.

It is however *not* to say that we cannot *know* matter. It simply means that *our knowledge is not the same thing as matter*. Indeed, there is nothing *to know* of matter *in itself*.

Our knowledge is given in the form of immediate, essential or theoretical perception, and it is indeed knowledge of the world *beyond sensation*.

If the conceptual abstractions by means of which we are able to grasp the immediate abstractions of sense perception are not to be found in the material world, but only in our heads, how do we understand the relation between these abstractions and the materiality of the world?

How do we explain the fact that we can build bridges which don't fall down even after thousands of trucks have been driven over them? When we conjecture things about what we can't actually see, is there any basis for doing so? And if you and I see different things, is it sensible to talk about something that exists independently of you *or* I seeing it?

The key idea is *information hiding*. In order to build a bridge we do not need to have an exact understanding of how the basic physical laws act in a bridge. It is sufficient to start with previous experience in building bridges.

The Origins of Knowledge

Conceptual knowledge dates back to the time when human beings emerged as a species. Pre-humans developed certain practices, ways of living, in which they took from nature what they needed and changed it to meet their needs, initially just by carrying it elsewhere, later by breaking it up and then putting pieces together in new ways. At this point humans are much like any other animal.

The Role of Science in Knowledge Creation

The major purpose of science is to develop laws and theories to understand, explain, predict, and control phenomena.

Science must have a distinct subject matter, a set of phenomena which serves as a focal point for investigation. The discovery of the underlying regularities among these phenomena yields empirical generalizations, laws, principles, and theories. Through this process, science produces knowledge of the world by establishing generalizations governing the behavior of the world. How does this process relate to the "scientific method"?

Knowledge and Objectivity

Knowledge can be stable and it can be in a state of transition. It may be available in the form of public beliefs shared by all, and it may reside in special individuals.

As Kuhn, Popper, and others have noted, *observations are always interpreted in the context of an a priori knowledge*. The history of science provides numerous examples of the fact that *"what a man sees depends both upon what he looks at and also upon what his previous visual-conceptual experience has taught him to see"*.

All observation is potentially ”contaminated”, whether by our theories, our worldview or our past experiences. Nevertheless, it does not mean that science cannot ”objectively”[6] choose from among rival theories on the basis of empirical testing. Obviously, if *objectivity* requires *certainty* (no possibility of error), then science is not objective. In science, all knowledge claims are *tentative*, subject to revision on the basis of new evidence. Although science cannot provide one with hundred percent certainty, yet it is the most, if not the only, objective mode of pursuing knowledge.

[6] What is here meant by ”objectively” does not refer to ”object” i.e. things *as they are*, but instead points out *non-subjective* nature that is the fact that it must be agreed upon (within scientific group or community).

Perception and "Direct Observation"

A common idea about the scientific method is that one makes observations, and then systematizes facts about the objects under investigation (see also Appendix 5). Here are some comments on "direct observations" and why it is impossible to perform experiments independent of theory (Mach, often cited by A Einstain at that point).

Conceptually and logically we always start from existing ideas (1) in Figure 1, when making experiments/observations.

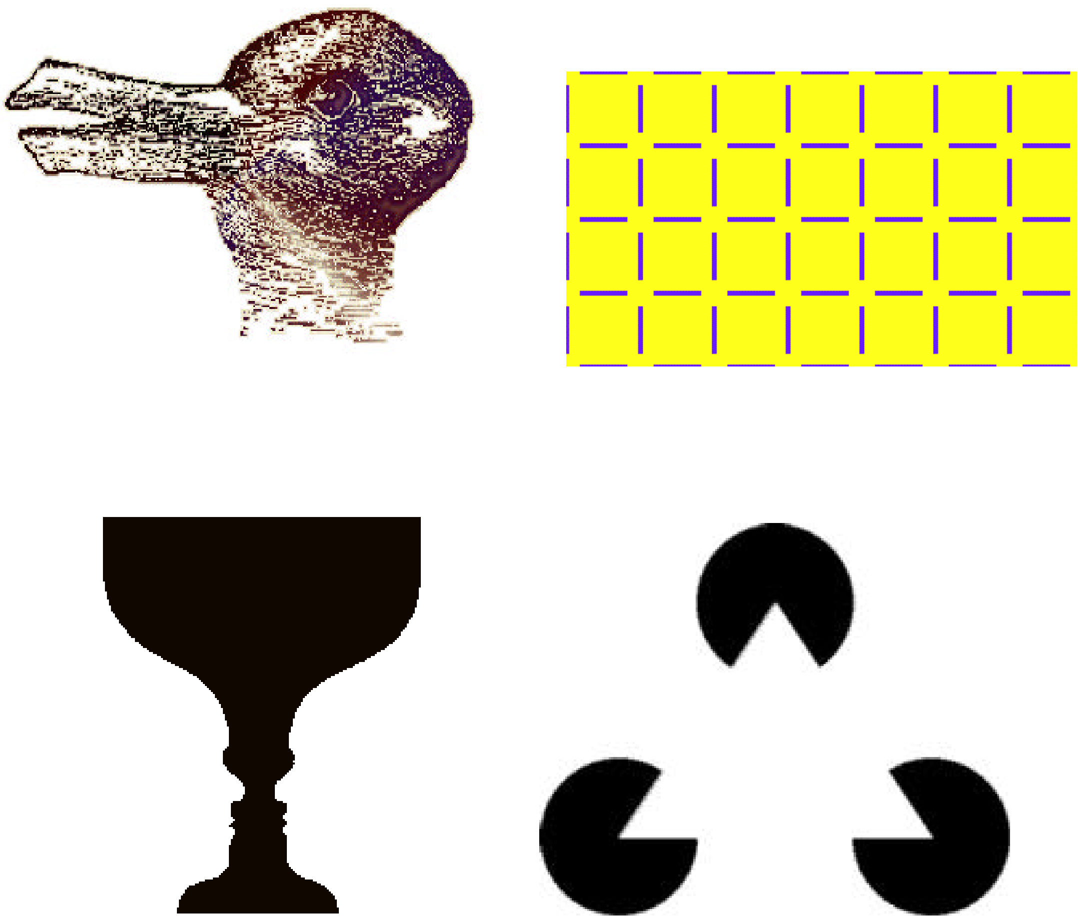

Figure 2 What do you see here?

(A rabbit or a duck? Circles? A black vase or white profiles? Triangle?)

Observing implies a variety of choices and characterizations. The description and the explanation depend on what aspect of a phenomenon we are focused on.

Take another (non-visual) example. Onomatopeic words used in different languages to describe the sounds made by familiar animals. What french, english, german or japanese hear that cat says is very different (Miaow? Mjau? …). What is actually the true thing cat says?

Some more "I see!" examples…

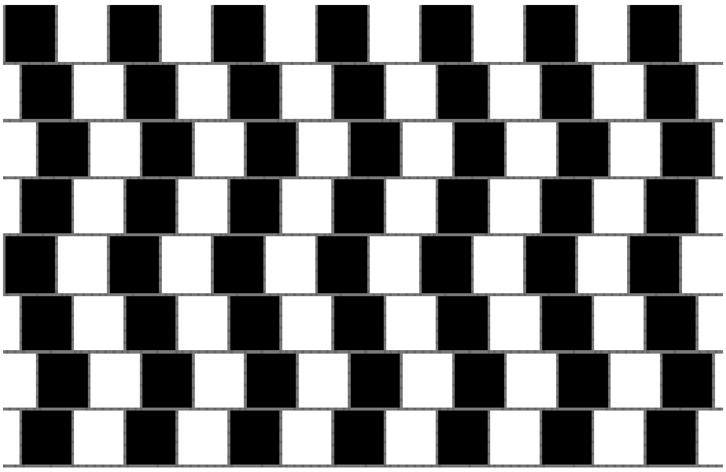

Figure 3 Parallel lines!

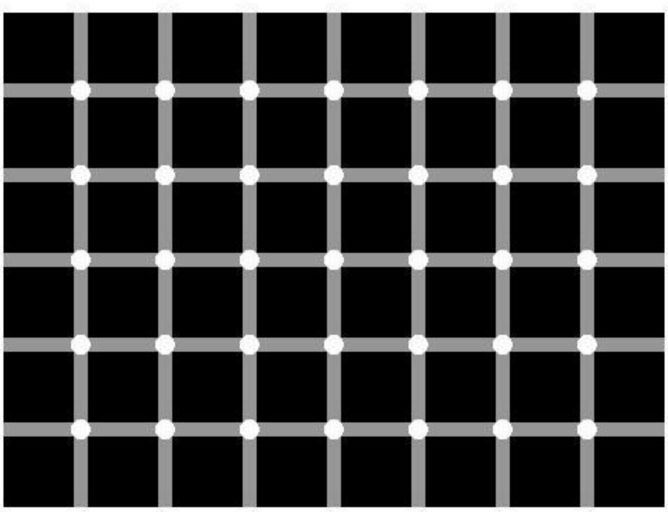

Figure 4 Count black dots. Look sharp!

It is not obvious that our observations, not even the most direct ones (like the counting in the above figure) are reliable…

Not to mention problems coupled with the complexity of experimental apparatus (do we really measure what we intend to?), measurement uncertainties (how good/reliable/precise are our results?), and alike. There is a specific scientific discipline called theory of measurement…so it is not an entirely trivial problem.

4 SCIENCE AND TRUTH

There are two conceptions of science that embody two different views of scientific life and of the purpose of scientific inquiry.

Science as Consensus

According to this approach, scientific knowledge is the product of a collective human enterprise to which scientists make individual contributions that are purified and extended by mutual criticism and intellectual cooperation. According to this theory the goal of science is a consensus of rational opinion over the widest possible field.

Scientific knowledge is distinguished from other intellectual artifacts of human society by the fact that its contents are consensible. This implies that scientific communication should be so transparent and unambiguous that the recipient is able either to give it approval or to offer well-founded objections. The goal of science, moreover, is to achieve the maximum consensus. Ideally the general body of scientific knowledge should consist of facts and principles that are firmly established and accepted without serious doubt, by a majority of competent, well-informed scientists.

The origin of the consensus in science may be found in the scientist's adherence to the logic of scientific inference. Sociologists argued that science exhibited so high a degree of agreement because scientists shared a set of norms or standards, which governed the professional life of the scientific community. Based upon the consensual view of science, science was thought to be strictly *cumulative and converging*.

Science as Controversy

Kuhn has, however, noted that in the consensual approach the emergence of new scientific ideas "requires a decision process which permits rational men to disagree, and such disagreement would generally be barred by the shared algorithm which philosophers have generally sought. If it were at hand, all conforming scientists would make the same decision at the same time." Kuhn maintains that it is only the existence of different preferences and values among scientists that results in new theories. What makes the broad degree of agreement in science even more perplexing is the fact that the theories around which consensus forms do themselves rapidly come and go.

The rival theories are often radically incommensurable. The impossibility of full translation between rival paradigms is further enhanced by the fact that the advocates of different paradigms often subscribe to different methodological standards and have non-identical sets of *cognitive values*.

Feyerabend has argued that many highly successful scientists have repeatedly violated the norms or canons usually called scientific. Specifically, Feyerabend believed that it is undesirable for scientists to ever reach consensus about anything. *His ideal of science is the sort of endless questioning of fundamentals which one associates with pre-Socratic natural philosophy: nothing is taken as given, everything can reasonably be denied or affirmed.*
For the supporters of this doctrine, scientific debate and disagreement is far more likely the "natural" state of science than consensus is. In this view, science is *diverging*.

5 CRITICAL THINKING: LOGICAL ARGUMENT

Reserve your right to think, for even to think wrongly is better than not to think at all.
Hypatia[7], natural philosopher and matematician

What is an argument? An argument is a statement logically infered from premises. Neither an opinion nor a belief can qualify as an argument.

How do we analyse the soundness of an argument? It is a good practice to begin a critical analysis of an argument by isolating the conclusion. By examining the conclusion we find the *point* of the argument. The next step is examining of premises that the argument rests on.

It is important to note that some premises can be implied and not stated explicitly within the argument. We might call these premises assumed premises or *underlying assumptions*. Here is yet another reason to reflect critically upon ideas. Many arguments would never be made if the arguer were forced to make explicit her assumptions; i.e. *the underlying assumptions can be extremely erratic*!

Not all the discussions contain arguments consisting of a supporting premises and a conclusion. Discussions often contain statements that are not part of the argument. Such statements can be included in order to give necessary background information in support of an argument.

Typically, arguments are understood as either being *deductive* or *inductive*.
As long as the structure corresponds to the given forms, the argument will attain validity. Let us define *validity* as follows:

A *valid* argument is an argument that is built according to the demonstrated rules of construction.

Note that *validity* does not guarantee *truth* of an argument. For instance, even with false premises we can still have a *valid* argument.

What does it mean now that the conclusion *necessarily* follows from the premises? In the given examples, the premises, if true, force us to accept the conclusion. In a deductive argument the conclusion is irrefutable.
If an argument is valid but the conclusion is wrong, we may describe the argument as possessing *validity* but not possessing *soundness*.

A *sound* argument is an argument that is *valid* in its construction and whose conclusion is *true*.
A *cogent* argument is an argument that possesses *validity, soundness*, and is *convincing*.

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[7] Hypatia of Alexandria (355 - 415) was the most prominent woman scholar in the ancient world. Her father, Theon, gave her an education in the style of Plato in every aspect of the learning of the time. Hypatia studied Diophantine equations and taught at the Mouseion in Alexandria. She was brutally murdered by a Christian lynch mob in 415.

6 DEDUCTION

Typically, a deductive argument is defined as:

- constructed according to valid rules of inference
- the conclusion necessarily follows from the premises.

First, what is meant by “constructed according to valid rules of inference”? There are valid ways for constructing arguments. A well-constructed argument will support its conclusions and endure against criticism. What follows below are four of the more common models for constructing arguments:

MODUS PONENS

$$\begin{array}{l} P \supset Q \\ \underline{P} \\ \therefore Q \end{array}$$

Let P represent “All humans” and let Q represent “are mortal.”
The horseshoe symbol can be read as “then.”
The three dots symbol can be read as “thus.”
A Modus Ponens argument would be formulated as follows:

All humans are mortal. (premise)
<u>Kevin is human. (premise)</u>
Thus, Kevin is mortal. (conclusion)

MODUS TOLLENS

$$\begin{array}{l} P \supset Q \\ \underline{\sim Q} \\ \therefore \sim P \end{array}$$

Let P represent "All birds" and let Q represent "have wings."
A *Modus Tollens* argument would be formulated as follows:

All birds have wings. (premise)
<u>Kevin has no wings. (premise)</u>
Kevin is not a bird. (conclusion)

DISJUNCTIVE SYLLOGISM

$$\begin{array}{l} P \vee Q \\ \underline{\sim Q} \\ \therefore P \end{array}$$

Let P represent "The baby is a boy" and Q "The baby is a girl."
A *Disjunctive Syllogism* argument would be formulated as follows:

The baby can either be a boy or a girl. (premise)
<u>The baby is not a girl. (premise)</u>
The baby is a boy. (conclusion)

HYPOTHETICAL SYLLOGISM

$$\begin{array}{l} P \supset Q \\ \underline{Q \supset R} \\ \therefore P \supset R \end{array}$$

Let P represent " If Karro is a terrier, Karro is a dog "
and let Q represent “ If Karro is a dog, Karro is a mammal."
A *Hypothetical Syllogism* argument would be formulated as follows:

If Karro is a terrier, Karro is a dog. (premise)
<u>If Karro is a dog, Karro is a mammal. (premise)</u>
If Karro is a terrier, Karro is a mammal. (conclusion)

In order to build a valid deductive argument, we must follow the above patterns. There are of course many more rules, but we have listed only the most common ones.

7 EMPIRICAL INDUCTION

In a simplified scheme, deductive inferences can be said to move from general statements to particular conclusions. Inductive inferences move from particular assertions to general conclusions.

Here is the generic form of an inductive argument:

- *Every A we have observed is a B.*
- *Therefore, every A is a B.*

Many of scientific hypotheses are formulated via induction. Consider the following:

- Every instance of water (at sea level)[8] we have observed has boiled at 100° Celsius.
- Therefore, all water (at sea level) boils at 100° Celsius.

It is important to note that even the best inductive argument will never offer 100% probability in support of its position. An inductive argument poses general statement in a way that it assumes a general domain for phenomena that are tested in some part of that domain.

The classical example is that by induction we know that sun rises every morning in the east. Our conclusion is based on experience that so was the case at least as long as people inhabit earth. But we are not aware of any law that would imply *the necessity*[9] of being so.

In other words, an inductive argument have no way to logically (with certainty) prove that:

- the phenomenon studied do exist in general domain, and
- that it continues to behave according to the same pattern.

Therefore we can say that the induction hypothesis is a *tentative conclusion*.
Hypothesis supports working theories or models that are based on the collected evidence. These models, which are induction-based, are not described as certainty as they will no longer be accepted as soon as one certain relevant *counter-instance* is found.

Counter-example 1

Perhaps the most well known counter-example was the discovery of black swans in Australia. Prior to the point, it was assumed that all swans were white. With the discovery of the counter-example, the induction concerning the color of swans had to be re-modeled.

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[8] Note the text ”at sea level”.

A typical problem with inductive *argument is that it is formulated generally, while the observations are made under specific conditions*. We could add here ”in an open vessel” as well.

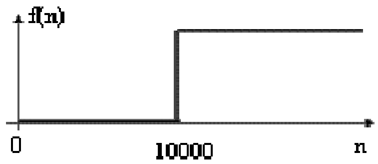
[9] Law of gravitation tells us how the celestial bodies (sun, earth) are placed and how they move, but nothing says that gravitation constant for example, can’t change!

Counter-example 2

Suppose the following are the results of measurements (observations):
f(0) = 0, f(1) = 0, f(2) = 0, …f(10) = 0,…f(100)= 0, ….f(1000) = 0….f(5000) = 0…

Here we maybe conclude that the result is zero for every n!
It is however possible that the law that f follows is of the form:

f(n) = n/10000 (integer division)



which agrees with our measurements, but contradicts our conclusion! (f(10000) = 1).

The question is: how much problem this can cause? For the most practical purposes this discrepancy is of no importance whatsoever as the parameter range of interest is far below, i.e. *we focus on investigating parameters in the relevant range*.

Talking about scientific method we pointed out the importance of thorough examination of *the whole range of parameters of interest*. It is clear that we never can examine all parameters in *all possible ranges*.
But as far as we are sure that (in this case) range of n ≥ 10000 is of no interest for us, we can accept the inductive conclusion, with no severe consequences.

In short, although induction cannot guarantee certainty, it can be a very useful method for constructing working models and theories. As long as we understand the limits of induction we may use induction productively.

Actually the induction is the only method we have to explore enlarged domains for phenomena under investigation.

8 MATHEMATICAL INDUCTION

It is important to make a clear distinction between *empirical* induction and *mathematical* induction. In the empirical induction we try to establish the law.
In the mathematical induction we have the law already formulated.
We are trying to prove that it holds generally.
The basis for mathematical induction is the property of the *well-ordering principle* for the natural numbers.

The Principle of Mathematical Induction

Suppose P(n) is a statement involving an integer n.
Than to prove that P(n) is true for every $n \geq n_0$ it is sufficient to show these two things:

1. $P(n_0)$ is true.
2. For any $k \geq n_0$, if P(k) is true, then P(k+1) is true.

A *proof by induction* is an application of this principle.
The two parts of inductive proof are called *the basis step* and *the induction step.*
In the induction step, we assume that statement is true in the case n = k, and we call this assumption *the induction hypothesis*.

The Strong Principle of Mathematical Induction

Suppose P(n) is a statement involving an integer n. In order to prove that P(n) is true for every $n \geq n_0$ it is sufficient to show these two things:

1. $P(n_0)$ is true.
2. For any $k \geq n_0$, if P(n) is true for every n satisfying $n_0 \leq n \leq k$, then P(k+1) is true.

A proof by induction using this strong principle follows the same steps as the one using the common induction principle. The only difference is in the form of induction hypothesis.
Here the induction hypothesis is that k is some integer $k \geq n_0$ and that *all* the statements $P(n_0)$, $P(n_0 +1)$, …, P(k) are true.

Example 1. Proof by strong induction

P(n): n is either prime or product of two or more primes, for $n \geq 2$.
Basic step. P(2) is true because 2 is prime.
Induction hypothesis. $k \geq 2$, and for every n satisfying $2 \leq n \leq k$, n is either prime or a product of two or more primes.

*Statement to be shown in induction step***.** If k+1 is prime, the statement P(k+1) is true.
Otherwise, by definition of prime, k+1 = r*s, for some positive integers r and s, neither of which is 1 or k+1. It follows that $2 \leq r \leq k$ and $2 \leq s \leq k$.
By the induction hypothesis, both r and s are either prime or product of two or more primes.
Therefore, k+1 is the product of two or more primes, and P(k+1) is true.

The *strong principle of induction* is also referred to as the *principle of complete induction,* or *course-of-values induction.* It is as intuitively plausible as the ordinary induction principle; in fact, the two are equivalent.

As to whether they are *true*, the answer may seem a little surprising. Neither can be proved using standard properties of natural numbers. Neither can be disproved either!

This means essentially that to be able to use the induction principle, we must adopt it as *an axiom*.
A well-known set of axioms for the natural numbers, the Peano axioms, includes one similar to the induction principle.

Peano's Axioms

1. N is a set and 1 is an element of N.
2. Each element x of N has a unique successor in N denoted x'.
3. 1 is not the successor of any element of N.
4. If x' = y' then x = y.
5. *(Axiom of Induction)* If M is a subset of N satisfying both:
   1 is in M
   x in M implies x' in M
   then M = N.

The assertion that every nonempty subset on N (set of natural numbers) has a smallest element is usually referred to as the *well-ordering principle* for the natural numbers.
It probably seems so obvious that no proof is necessary. It turns out that it is also equivalent to the two versions of the induction principle. In other words, it is also impossible to prove without using induction or something comparable.

Example 2 An *inductive definition* of natural numbers**.**

The natural numbers can be pulled, more or less, from the thin air, by the operation of *collection* (Kimber, Smith).

We start with no numbers, and collect what we have.
This collection of nothing we write as { }. Call this representation *zero*.
Now we have something, so we can collect our *zero*: {{ }}. Call this *one*. Now we have two things to collect:{{ }, {{ }}}. This last collection, call it *two*, is the collection of two items:

- The collection of nothing { }, and
- The collection of collection of nothing {{ }}.

Now we have three objects to collect, and the process continues, defining operations on all natural numbers in terms of operations on collection. It means that we have specified the base object (in this case the empty object) and an operation to produce new objects from previously defined ones (in this case, collection).

9 INDUCTION VS DEDUCTION, HYPOTHETICO-DEDUCTIVE METHOD

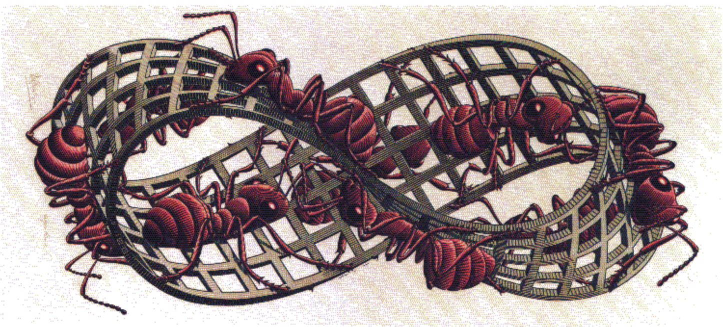
Talking about the *deduction* and *induction* as being a separate methods, we have not yet pointed out the fact that they actually occur as a part of the common hypothetico-deductive method, which can be simplified in the following scheme:

- Ask a question and formulate a hypothesis/educated guess (*induction).*
- Make predictions about the hypothesis (*deduction*).
- Test the hypothesis (*induction*).

Deduction, if applied correctly, leads to true conclusions. But deduction itself is based on the fact that we know something for sure. For example we know the general law which can be used to deduce some particular case, such as "All humans are mortal. Socrates is human. Therefore is Socrates mortal."
How do we know that all humans are mortal? How have we arrived to the general rule governing our deduction? Again, there is no other method at hand but (empirical) induction.

In fact, the truth is that even *induction* implies steps following *deductive* rules. On our way from specific (particular) up to universal (general) we use deductive reasoning. We collect the observations or experimental results and extract the common patterns or rules or regularities by deduction. For example, in order to infer by induction the fact that all planets orbit the Sun, we have to analyse astronomical data using deductive reasoning.

In short: deduction and induction are - like two sides of a piece of paper - the *inseparable parts of our thinking process.*



Möbius strip, Maurits Cornelis Escher

10 REPETITIONS, PATTERNS, IDENTITY

"The choice is always the same. You can make your model more complex and more faithful to reality, or you can make it simpler and easier to handle. Only the most naïve scientist believes that the perfect model is the one that perfectly represents reality. Such a model would have the same drawbacks as a map depicting every park, every street, every building, every three, every pothole, every inhabitant, and every map[10]."

James Gleick, Chaos

Repetitions and patterns

Empirical method relies on observations and experiments, which lead to a collection of data describing phenomena.

In order to establish a pattern or regularity of behavior, we have to analyze (compare) the results (data) searching for similarities (repetitions) and differences.

All repetitions are approximate: the repetition B of an event A is not *identical* with A, or *indistinguishable* from A, but only *similar* to A.

As repetition is based upon similarity, it must be *relative*. Two things that are similar are always *similar in certain respects*.

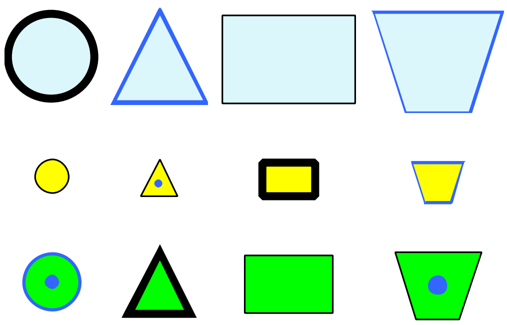


Figure 5 What do we call similar here?

We find that some of the figures above are similar with respect to shading, other are similar with respect to shape and some are similar with respect to edge or size.

Above diagrams illustrate the point that things may be similar in different respects, and that any two things which are from one point of view similar may be dissimilar from another point of view.

Generally, similarity, and consequently repetition, always *presuppose the adoption of a point of view:* some similarities or repetitions will strike us if we are interested in one problem, and others if we are interested in another problem.This shows how naïve it is to look upon repetition (pattern) as something ultimate, absolute or given by "direct observation".

[10] The idea of 1:1 map can be found in L Carroll's Sylvie and Bruno Concluded, Chapter 11

Searching for similarity and differences leads to *classifications* i.e. the division of objects or events in different groups/classes. The simplest tool by for classification is the *binary opposition or dichotomy (dualism)*. When we use dichotomy, we only decide if an object is of kind A or of kind ~A. Examples of frequent dichotomies are yes/no, true/false, before/after, more/less, above/below, etc. See also Appendix 4.

Dualism seems to be deeply rooted in the development of human categorization. Jakobson and Halle observe that 'the binary opposition is a child's first logical operation'. Whilst there are no opposites in 'nature', the binary oppositions we employ in our cultural practices have developed historically as they *help to generate order out of the dynamic complexity of experience*. At the most basic level of individual survival humans share with other animals the need to distinguish between own species and other, safe and dangerous, edible and inedible, dominance and submission, etc.

Identity

The basic feature of experimental method is its *reproducibility*: It must be possible to establish essentially the same experimental situation in order to obtain the same results. This means that the experimental arrangement can be made with *essentially equivalent* parts.

What we call “essentially equivalent” (or we can call it “essentially the same”) depends on situation. Even here the principle of information hiding helps us to get a practical “level of resolution” which means information hiding for all objects below that level.

For most purposes, one can, for example, assume that atoms (of certain kind, under well-defined conditions) are in practice identical, as well as their constituent parts. In fact, it is true as long as we are not interested in the structure of certan type of atom (or any other particle). If our focus is on the specific features of an atom, we will find that each atom of a certain type is a complex system of particles (protons, neutrons, electrons, etc) that can be in different energy states, in different spatial organizations etc.

So declaring two systems/particles/states as *identical* is entirely the matter of focus. For example if we focus on question of how many people in this country are vegetarians, we just treat all people as equal units. If we want to know how many women in this country are vegetarian, we discriminate between men and women in our analysis of people.

We can e.g. also assume that bacteria of particular sort are interchangeable (indistinguishable) in certain context. That enables us to make repeated experiments with different agents and treat all bacteria of the same type as equal. It does not mean that they are *identical in the absolute sense*. It only means that for our purpose the existing difference does not have any significance.

Let us take ancient atomic theory as another example. The problem of showing that one single physical body- say piece of iron is composed of atoms is at least as difficult as of showing that *all* swans are white. Our assertions go in both cases beyond all observational experience. The difficulty with these structural theories is not only to establish the universality of the law from repeated instances as *to establish that the law holds even for one single instance*.

A singular statement like “This swan here is white” may be said to be based on observation. Yet it goes beyond experience- not only because of the word “white”, but because of the word “swan”. For by calling something a “swan”, we attribute to it properties which go far beyond mere observation. So *even the most ordinary singular statements are always the interpretations of the facts in the light of theories*!

An illustration of identity: Snow myth (http://whyfiles.org/123snow/2.html)
Is there any truth to the myth that every one of the countless trillions of snowflakes has a unique shape? Pao-Kuan Wang, an atmospheric physicist who studies flakes and ice in clouds at the University of Wisconsin-Madison, says it depends on how hard you look. "With a microscope, going down to the molecular level, of course they're all different, But without a microscope, at the superficial level, they may look alike."

Frege’s Puzzle about Identity Statements

Here are some examples of identity statements:

117 + 136=253.

The morning star is identical to the evening star.

Mark Twain is Samuel Clemens.

Bill is Debbie’s father.

Frege believed that these statements all have the form "*a=b*", where ‘*a* ’ and ‘*b* ’ are either names or descriptions that *denote* individuals. He naturally assumed that a sentence of the form "*a*=*b*" is true if and only if the object denoted by ‘*a* ’ is the same as the object denoted by ‘*b* ’. For example, "117 + 136=253" is true if and only if ‘117 + 136’ and ‘253’ denote the same number. And "Mark Twain is Samuel Clemens" is true if and only if ‘Mark Twain’ and ‘Samuel Clemens’ denote the same person. So the truth of "*a=b*" requires that the expressions flanking the identity sign denote the same object.

But Frege noticed that on this account of truth, the truth conditions for "*a=b*" are no different from the truth conditions for "*a=a*". For example, the truth conditions for "Mark Twain=Mark Twain" are the same as those for "Mark Twain=Samuel Clemens"; not only do the names flanking the identity sign denote the same object in each case, but the object is the same between the two cases. The problem is that the cognitive significance (or meaning) of the two sentences differ. We can learn that "Mark Twain=Mark Twain" is true simply by inspecting it; but we can’t learn the truth of "Mark Twain=Samuel Clemens" simply by inspecting it. Similarly, whereas you can learn that "117 + 136=117 + 136" and "the morning star is identical to the morning star" are true simply by inspection, you can’t learn the truth of "117 + 136=253" and "the morning star is identical to the evening star" simply by inspection. In the latter cases, you have to do some arithmetical work or astronomical investigation to learn the truth of these identity claims.

So the puzzle Frege discovered is: if we cannot appeal to a difference in denotation of the terms flanking the identity sign, how do we explain the difference in cognitive significance between "*a=b*" and "*a=a*"?

11 CAUSALITY AND DETERMINISM

Causality

Causality refers to the way of knowing that *one thing causes another*.

Early philosophers, as we mentioned before, concentrated on conceptual issues and questions (why?). Later philosophers concentrated on more concrete issues and questions (how?). The change in emphasis from conceptual to concrete coincides with the rise of empiricism.

Hume is probably the first philosopher to postulate a wholly empirical definition of causality. Of course, both the definition of "cause" and the "way of knowing" whether X and Y are causally linked have changed significantly over time. Some philosophers deny the existence of "cause" and some philosophers who accept its existence, argue that it can never be known by empirical methods. Modern scientists, on the other hand, define *causality in limited contexts* (e.g., in a controlled experiment).

Aristotle's Causality[11]: Any discussion of causality begins with Aristotle's Metaphysics. There Aristotle defined four distinct types of cause (four answers to the question of why):

- the *material cause* is the stuff from which the thing is made;
- the *formal cause* is the pattern or structure it has;
- the *efficient cause* is the agent that imposed this form on that matter; and
- the *final cause* is the purpose for the thing.

To illustrate these definitions, think of a vase, made (originally) from clay by a potter, as the "effect" of some "cause," Aristotle would say that clay is *the material cause* of the vase. The vase's form is its *formal cause*. The energy invested by the potter is its *efficient cause*. And finally, the potter's intent is the *final cause* of the vase. Aristotle's final cause involves a teleological explanation and virtually all modern scientists reject teleology. Nevertheless, for Aristotle, all "effects" are *purposeful*; every thing comes into existence for some purpose (telos).

Modern scientists may also find Aristotle's material and formal causes curious. Can fuel "cause" a fire? Can a mold "cause" an ingot? On the other hand, Aristotle's efficient cause is quite close to what physicists mean by the phrase "X causes Y."

Indeed, this causal type well suited to modern science. An efficient cause ordinarily has an empirical correlate, for example; X is an event (a motion) producing another event, Y (for example another motion). Lacking any similar empirical correlates, material, formal, and (especially) final causes resist all attempts at empirical testing.

Galileo's Causality: Galileo was one of many Enlightenment scientists who wrote explicitly about causality. Galileo viewed cause as the set of necessary and sufficient conditions for an effect. If X and Y are causes of Z, in other words, then Z will occur whenever both X and Y occur; on the other hand, if only X or only Y occurs, then Z will not occur. We can state this more succinctly as "If and only if both X and Y occur, then Z occurs."

There is one problem with Galileo's definition. First, the list of causes for any Z would have to include every factor that made even the slightest difference in Z. This list could be so long

[11] Aristoteles cause can be described as a set of necessary conditions needed to produce a certain effect.

that it would be impossible to find something that was not a cause of Z. This makes it virtually impossible to test many causal hypotheses and, so, it makes Galileo's definition not practically useful to scientists.

Hume's Causality: David Hume's major philosophical work, A Treatise of Human Nature, lays the foundation for the modern view of causality. Hume rejected the existing rationalist concept of cause, arguing that causality was not a real relationship between two things but, rather, a perception. Accordingly, Hume's definition of causality emphasizes three elements that can be verified through observation. According to Hume, "X causes Y" if Precedence: X precedes Y in time. Contiguity: X and Y are contiguous in space and time. Constant Conjunction: X and Y always co-occur (or not occur).

At first glance, Hume's definition seems foolproof. But consider the causal proposition that "day causes night." This proposition satisfies all of Hume's three criteria but, yet, fails to satisfy our common expectation of causality. Day does not cause night and this highlights a potential flaw in Hume's definition. Indeed, each of Hume's three criteria poses special problems for the modern scientific method.

Contiguity (proximity): Spatial contiguity makes good common sense. If a cause occurs in one place, we should seek its effect in its vicinity. In historical context, however, Hume's criterion of spatial contiguity seemed to reject Newton's gravitational model. The orbits of planets, tides, and a range of other mechanical phenomena required *action at a distance*. In fact, contiguity is not amenable to empirical verification.

Precedence: Precedence also makes good common sense. If a cause occurs today, we should seek its effect tomorrow (or perhaps next week) but would not expect to see the effect yesterday (or perhaps last week). Causes should precede effects, not vice versa, and this implies further that there is a finite delay (maybe no longer than a nanosecond but a delay nevertheless) between cause and effect.

Kant offered the example of a lead ball resting on a cushion and causing an impression (dent) on the cushion. Did the lead ball (X) cause the impression (Y)? If so, X and Y occurred simultaneously.

(In fact there are nevertheless changes in quantum systems that appear instantaneously as a consequence of conservation laws, as e.g. in famous Einstein-Rosen-Podolsky paradox).

Constant Conjunction: The most controversial of Hume's three criteria is constant conjunction. The crux of this controversy can be illustrated by the hypothetical results of a simple experiment. We first culture 1000 bacterial colonies. We then treat 500 of the colonies (selected at random) with an anti-bacterial agent. The remaining 500 colonies are treated with a placebo agent. The controversy can be illustrated by the hypothetical result:

		Yes	No
X Occurs?	Yes	500	
	No		500

is consistent with "X causes Y".

		Yes	No
X Occurs?	Yes	495	5
	No	5	495

is consistent with "X does not cause Y"

Though oversimplified, this hypothetical result demonstrates the problematic nature of the constant conjunction criterion. By Hume's criteria, there would be few causal relationships in the biological and social sciences.

Comparing the causality of Galileo and Hume gives an insight into the evolution of causal thought. Although Galileo was clearly a scientist, his definition of causality was not entirely empirical. Hume, on the other hand, is an empiricist.

Hume's causality is based on experiential or sensory relationships. To be sure, Hume argued that "X causes Y" could not be empirically verified but that a hypothetical causal relationship could be tested nevertheless. This sets the stage for an operationalized causality; i.e., a definition explicitly in terms of causality testing.

Mill's Causality: John Stuart Mill concentrated on the problems of operationalizing causality. Mill argued that causality could not be demonstrated without experimentation. His four general methods for establishing causation are

- *the method of concurrent variation*
  ["Whatever phenomenon varies in any manner, whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation."];
- *the method of difference*
  ["If an instance in which the phenomenon under investigation occurs and an instance in which it does not occur, have every circumstance in common except for one, that one occurring in the former; the circumstances in which alone the two instances differ, is the effect, or the cause, or an indispensable part of the cause of the phenomena."];
- *the method of residues*
  ["Subduct from any phenomena such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomena is the effect of the remaining antecedents."]; and
- *the method of agreement*
  ["If two or more instances of a phenomena under investigation have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or effect) of the given phenomenon."].
  All modern experimental designs are based on one or more of these methods.

Probabilistic Causality: One approach to the practical problem posed by Hume's constant conjunction criterion is to make the criterion probabilistic. If we let P(Y | X) denote the probability that Y will occur given that X has occurred, then constant conjunction requires that

$$P(Y \mid X)=1 \text{ and } P(Y \mid {\sim}X)=0$$

where ~X indicates that X has not occurred. The problem, of course, is that biological and social phenomena virtually never satisfy this criterion. Probabilistic causalities address this problem by requiring only that the occurrence of X make the occurrence of Y more probable. In the same notation, if

$$P(Y \mid X) > P(Y \mid {\sim}X)$$

then "X causes Y." While this makes the constant conjunction criterion more practical, however, it raises other problems. To illustrate, suppose that X has two effects, Y1 and Y2, and that Y1 precedes Y2. A widely used example is the atmospheric electrical event that causes lightening and thunder. Since we always see lightening (Y1) before we hear thunder (Y2), it appears that "lightening causes thunder. Indeed, Y1 and Y2 satisfy the probabilistic criterion

$P(Y2 \mid Y1) > P(Y2)$ that we require of $Y1 \Rightarrow Y2$.

But in fact, lightening does not cause thunder. The foremost proponent of probabilistic causality, Patrick Suppes, solves this problem by requiring further that Y1 and Y2 have no common cause. As we discover at a later point, research designs constitute a method for ruling out common causes.

Design as Operational Causality: The history of causality can be broken into two eras. The first era begins with Aristotle and ends with Hume. The second era begins with John Stuart Mill and continues today. The difference between Hume and Mill may be unclear; after all, both were orthodox empiricists. But while Hume and Mill had much in common, Hume's causality was largely conceptual. Little attention was paid to the practical problem of implementing the concepts. Mill, on the other hand, described exactly how working scientists could implement (or operationalize) his causality.
The most influential modern philosophers have followed Mill's example. Although the field of (experimental) design often deals with causality only implicitly, we can think of design as operationalized causality.

Rubin Causality: Many proposed causalities work well in one context but not in another. To solve this problem, some modern philosophers have tried to limit their causalities to specific contexts, circumstances, or conditions. Accordingly, Rubin causality (named for Donald B. Rubin) is defined in the limited context of an experimental milieu. Under Rubin causality, only the relationship demonstrated in an experiment is a valid causal relationship.

To illustrate, suppose that we want to measure the effectiveness of an anti-bacterial soap. We apply the soap to a single bacterium. If the bacterium dies, the soap works. But if the bacterium dies, we still have this problem: sooner or later, all bacteria die; maybe this one died of natural causes. We eliminate this (and every other alternative hypothesis) by showing that a placebo treatment does not kill the bacterium. But since the bacterium is already dead, how is this possible?

The fundamental dilemma of causality, according to Rubin, is that, if we use an experimental unit (a bacterium, e.g.) to show that "X causes Y," we cannot use that same unit to show that some "non-X does not cause Y." We solve this dilemma by assuming that all units are more or less the same. This allows us to treat one bacterium with the anti-bacterial soap and another with a placebo. *To make sure that the two bacteria are virtually indistinguishable, however, we randomly assign* the bacteria to the soap and placebo. Since random assignment is unfeasible in some situations, Rubin causality holds that some variables (e.g., "race") cannot be causes.

*Suppes Causality***:** Probabilistic causality, as proposed by Suppes, is another causality defined for a limited milieu. Where X and ~X denote the occurrence and nonoccurrence of X respectively, Suppes infers that X=>Y if two conditions are satisfied

$$P(Y \mid X) > P(Y \mid \sim X)$$

$$P(Y \mid X \text{ and } Z) \sim= P(Y \mid \sim X \text{ and } Z)$$

The first criterion ensures that the probability that Y will occur given that X has occurred is greater than the complementary probability that Y will occur given that X has not occurred. The second criterion ensures that X and Y are not asynchronous co-effects of Z.

Determinism

Determinism is the philosophical doctrine *which regards everything that happens as determined by what preceded it*. From the information given by a complete description of the world at time t, a determinist believes that the state of the world at time t + 1 can be deduced; or, alternatively, a determinist believes that every event is an instance of the operation of the laws of Nature.

The wide acceptance of this view, at least in the Western world, was a result of the work of mathematical physics in the 18th and 19th centuries. At this point, it looked as if Newton and his successors had reduced the universe to systems of equations, through which *the position of any particle in the universe could be predicted forever, provided that sufficient information was known about the factors affecting its motion (in other words, providing that the position of all other particles in the universe was known).*

Determinism is not a position of which Newton himself would have approved, since it denies any need for the existence of God, and seems to reduce human beings to the status of predictable machines. It was, however, regarded by others (for example the 18th-century mathematicians Laplace and Lagrange) as the triumph of science, showing that, through the laws of cause and effect, the future was as fixed as the past.

In science, determinism as a serious philosophy could not survive without the Newtonian (mechanicistic) view of the universe.

The quantum theory brought chance (probability) into physical theory at the beginning of the 20th century, as the uncertainty principle of Werner Heisenberg showed that some events were *inherently unpredictable*.

Einstein found indeterminacy of quantum theory deeply disturbing: 'God does not play dice', he insisted. Believing that apparent indeterminacy masks a deeper causality, Einstein found himself in a minority among physicists.
Many philosophers however (for example Russell) began to feel that the concept of cause and effect was itself just an illusion. [12]

The new non-determinism which resulted from all this has led to the view, held by many scientists and others throughout the 20th century, that the universe is inherently chaotic, that actions do not lead to consequences. This view was a major influence on *existentialism.*

A third point of view is *'compatibilism'*, which holds that it is possible to give an account of human freedom without invoking non-determinist explanations of human action. As applied to political and historical thought determinism describes the views of those who think that individual 'choice' is
(a) determined by conditions beyond the individual's control, and/or
(b) that it is the result of free will.

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[12] In modern physics, instead of causal relations one is searching for “correlations” between phenomena, which is a symmetric relation, contrary to causation.
Feedback processes are yet another example where it is not self-evident which is to be called the cause and which is the effect (as e.g. women’s emancipation and education for women).

Historical determinism emphasizes the limits imposed by long-term economic, political and social conditions. Economic determinism is the theory which attributes all major social and political interests and actions and their organization to the economic causes.

Economic determinism assumes that individuals are always seeking to maximize their utility, and are always engaged in 'rent-seeking'. In Marxist thought, economic determinism is supported by the doctrine of historical materialism which attempts to explain history as the product of changes in material conditions rather than as the product of changes in ideas, values and culture.

12 LIMITATIONS IN FORMAL LOGICAL SYSTEMS GÖDEL'S THEOREM

Axiomatic system of Euclid: Shaking up Geometry

Euclid showed that geometry can be built on a set of few axioms (ideas which are considered so elementary and manifestly obvious that they do not need to be proven as any proof would introduce more complex ideas).

When a system requires increasing number of axioms (as e.g. number theory does), doubts begin to arise. How many axioms are needed? How do we know that the axioms aren't mutually contradictory?

Until the 19th century no one was too worried about this. Geometry seemed rock solid. It had stood as conceived by Euclid for 2100 years. If Euclid's work had a weak point, it was his fifth axiom, the axiom about parallel lines. Euclid said that for a given straight line, one could draw only one other straight line parallel to it through a point somewhere outside it.

Around the mid-1800s mathematicians began to experiment with different definitions for parallel lines. Lobachevsky, Bolyai, Riemann and others created new geometries by assuming that there could be several parallel lines through the outside point or there could be no parallel lines. These geometries weren't mere intellectual constructs. In fact, it turns out that Riemann's geometry is better at describing the curvature of space than Euclid's. Consequently Einstein incorporated Riemann's ideas into relativity theory.

These new geometries became known as *non-Euclidean*, and they worried mathematicians a lot. The view of Kant that mathematics (and in particular Euclidean geometry) was *a priori truth* had been shattered in its ground. Scientists got far more inclined to accept that mathematical equations were not necessarily the arbiters of what goes on in the universe.

Euclids axioms had been unchanged for centuries. Since arithmetic is more complex than geometry, how could they be sure its axioms were trustworthy?

In a bit of brilliant work, German mathematician, David Hilbert, converted geometry to algebra, showing that if algebra was consistent, so was geometry. This served as a useful cross check but wasn't proof positive of either system.

Axiomatic system of Principia: Paradox in Set Theory

Uneasy mathematicians hoped that Hilbert's plan would fulfil its promise because axioms and definitions are based on commonsense intuition, but intuition was proving to be an unreliable guide. Not only had Riemann created a system of geometry which put commonsense notions on its head, but the philosopher-mathematician Bertrand Russell had found a serious paradox for set theory.

A set is one of the basic ideas of mathematics and logic. It is any collection of items chosen for some characteristic common for all its elements. Handling sets seemed fairly simple.

Russell's paradox was the following: There are two kinds of sets

- normal sets, which do not contain themselves, and
- non-normal sets, which are sets that do contain themselves.

The set of all apples is not an apple. Therefore it is a normal set. The set of all thinkable things is itself thinkable, so it is a non-normal set.

Let 'N' stand for the set of all normal sets. Is N a normal set? If it is a normal set, then by the definition of a normal set it cannot be a member of itself. That means that N is a non-normal set, one of those few sets which actually are members of themselves. But on the other hand…N is the set of all normal sets; if we describe it as a non-normal set, it cannot be a member of itself, because its members are, by definition, normal.

Russell did not feel that this paradox was insurmountable. By redefining the meaning of 'set' to exclude awkward sets, such as "the set of all normal sets," he felt that he could create a single self-consistent, self-contained mathematical system. Using improved symbolic logic, he and Alfred North Whitehead set out to do just that. The result was their masterful three volume Principia Mathematica. However, even before it was complete, Russell's expectations were dashed.

The man who showed once and for all that Russell's aim was impossible was Kurt Gödel. His revolutionary paper was titled "On Formally Undecidable Propositions of Principia Mathematica and Related Systems."

Gödel: Truth and Provability

Kurt Gödel actually proved two extraordinary theorems. They have revolutionized mathema tics, showing that mathematical truth is more than logic and computation. Gödel has been called the most important logician since Aristotle. His two theorems changed logic and mathematics as well as the way we look at *truth* and *proof*.

Gödels first theorem proved that any formal system strong enough to support number theory has at least one undecidable statement. Even if we know that the statement is true, the system cannot prove it. This means the system is incomplete. For this reason, Gödel's first proof is called "*the incompleteness theorem*".

Gödel's second theorem is closely related to the first. It says that no one can prove, from inside any complex formal system, that it is self-consistent.

Hofstadter says, "Gödel showed that provability is a weaker notion than truth, no matter what axiomatic system is involved." In other words, *we simply cannot prove some things* in mathematics (from a given set of premises) *which we nonetheless can know are true*.

Implications of Gödel's Theorem

What do Gödel's theorems mean? First, Gödel shattered expectations that human thinking could be reduced to algorithms (a step by step, usually repetitive, procedures). Computers use algorithms. What it means is that our thought cannot be a strictly algorithmic process. [13]

In 1959 a disillusioned Russell lamented: "I wanted certainty in the kind of way in which people want religious faith. I thought that certainty is more likely to be found in mathematics than anywhere...But after some twenty years of arduous toil, I came to the conclusion that there was nothing more that I could do in the way of making mathematical knowledge indubitable. "

Gödel showed that "*it is impossible to establish the internal logical consistency of a very large class of deductive systems - elementary arithmetic, for example - unless one adopts principles of reasoning so complex that their internal consistency is as open to doubt as that of the sytems themselves.*"

[13] Roger Penrose makes much of this, arguing in Shadows of the Mind that computers will never be able to emulate the full depth of human thought. However, modern AI refute this sort of argument pointing out that computers can be made to switch between different formal systems as well as their logic can be made

inconsistent (or not completely consistent).

Observe however, that he did not prove a contradictory statement, that A = ~A, (the kind of thinking that occurs in many Eastern religions). Instead, he showed that no system can decide between a certain A and ~A, even where A is known to be true. Any finite system with sufficient power to support a full number theory cannot be self-contained.

Hence there are provable truths, unprovable truths, unprovable untruths and provable untruths. Alan Turing has shown that there are as many unprovable truths as there are provable truths.

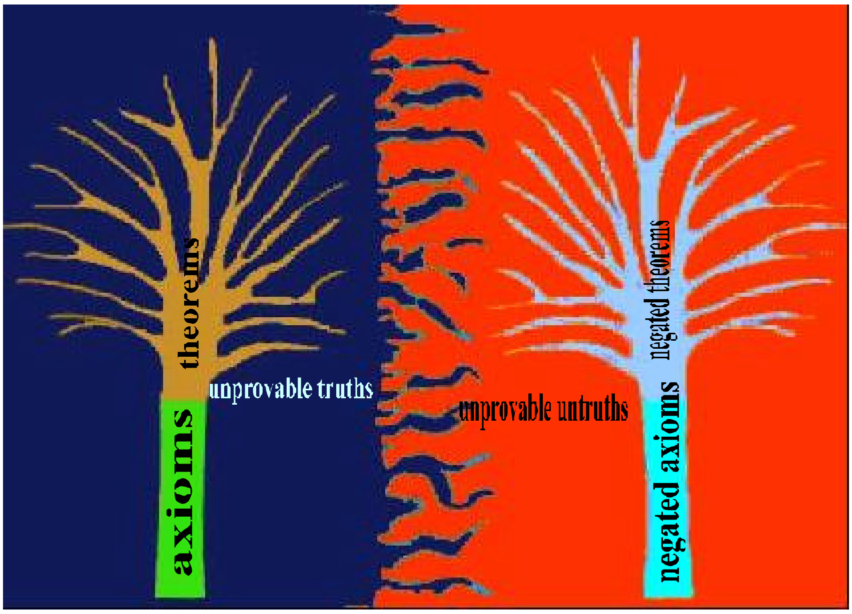

Figure 6 Truth vs. provability according to Gödel

The fact that a particular sentence is neither provable nor disprovable within a system means that it is logically independent of the axioms. Possible adding new axioms (or rules of inference) does not help in Gödel's case. Even if Gödel's sentence is added as an axiom, the new system would contain another unprovable sentence, saying of itself that it is not provable. Gödel's theorems uncover a *fundamental limitation of formalization*, and they say that this limitation could be overcome only at the price of consistency.

The theorems show that the supposed ideal of formalization - proving all and only all true sentences - is self-contradictory and actually undesirable:

- what good is a formalization that can prove a sentence which says that it is not provable (first theorem)?
- what good is a formalization that can prove its consistency when it would imply that it is not consistent (second theorem)?

Gödel's theorems show that the notions of truth and provability cannot coincide completely, which at first appears disturbing, since, as Quine says, *we used to think that mathematical truth consisted in provability*.

However, the notion of truth has a problem of its own, namely the classical *liar paradox*, of which Gödel's sentence is a paraphrase in proof-theoretic terms. Thus, Gödel's theorems do not actually establish any new discrepancy between provability and truth. Assuming consistency, Gödel's sentence is not simply true, because it is not always true i.e. not in all interpretations. If it were, it would be provable: provability is truth in all interpretations (according to the completeness theorem).

Gödel's theorem thus shows that there must always exist such unusual, unintended interpretations of the system; as Henkin says:

" We tend to reinterpret Gödel's incompleteness result as asserting not primarily a limitation on our ability to prove but rather on our ability to specify what we mean ... when we use a symbolic system *in accordance with recursive rules* [Gödel & the synthetic a priori]. "

Similarly, Polanyi says, though only in connection with the second theorem: " we never know altogether what our axioms mean. "

This characterization of formal language sounds more like something that might be said about ordinary, natural language. Thus, if we take as a characteristic of ordinary language its peculiar inexhaustibility and the frequent discrepancy between intended and expressed meaning, Gödel's theorems would show that, in this respect, formal languages are in fact not so far from natural ones.

Certain similarities between the self-reference in natural language and in Gödel's sentence and theorems have also been noticed at the lexical and pragmatic level [Hofstadter, p. 709]).

FUZZY LOGIC

The precision, clarity and beauty of mathematics are the consequence of the fact that the logical basis of classical mathematics possesses the features of parsimony and transparency.

Classical logic owes its success in large part to the efforts of Aristotle and the philosophers who preceded him. In their endeavour to devise a concise theory of logic, and later mathematics, they formulated so-called "Laws of Thought".

One of these, the "Law of the Excluded Middle," states that *every proposition must either be True or False*.

Even when Parminedes proposed the first version of this law (around 400 B.C.) there were strong and immediate objections. For example, Heraclitus proposed that things could be simultaneously True and not True.

It was Plato who laid the foundation for what would become fuzzy logic, indicating that there was a third region (beyond True and False) where these opposites "tumbled about." Some among more modern philosophers follow the same path, particularly Hegel. But it was Lukasiewicz who first proposed a systematic alternative to the bi-valued logic of Aristotle.

In the early 1900's, Lukasiewicz described a three-valued logic, along with the corresponding mathematics. The third value he proposed can best be translated as the term "possible," and he assigned it a numeric value between True and False. Eventually, he proposed an entire notation and axiomatic system from which he hoped to derive modern mathematics.

Later, he declared that in principle there was nothing to prevent the derivation of an infinite-valued logic. Lukasiewicz felt that three- and infinite-valued logics were the most intriguing, but he ultimately settled on a four-valued logic because it seemed to be the most easily adaptable to Aristotelian logic.

Knuth proposed a three-valued logic similar to Lukasiewicz's, from which he speculated that mathematics would become even more elegant than in traditional bi-valued logic.

It was not until relatively recently that the notion of an infinite-valued logic took hold.

In 1965 Lotfi A. Zadeh published his seminal work "Fuzzy Sets" which described the mathematics of fuzzy set theory, and by extension fuzzy logic. This theory proposed making the membership function (or the values False and True) operate over the range of real numbers [0.0, 1.0].

New operations for the calculus of logic were proposed, and showed to be in principle a generalization of classic logic.

An example of fuzzy logic application is given in Appendix 7.

13 FALLACIES

What about not properly built arguments? Let us make the following distinction:

- A *formal fallacy* is a wrong formal construction of an argument.
- An *informal fallacy* is a wrong inference or reasoning.

Formal Fallacies

Let's analyze following argument: "All fish swim. Kevin swims. Therefore Kevin is a fish", which *appears* to be a valid argument. It *appears* to be a *modus ponens*. But actually the argument does not follow the form of a modus ponens. The argument is a fallacious and invalid. If we were to use the symbols from the argument forms above, we could write:

If H is true, then so is I.
(As the evidence shows), I is true.
H is true

This form of reasoning, known as the fallacy of "*affirming the consequent*" is deductively invalid: its conclusion may be false even if premises are true. It is beyond the scope of this text to explore in more detail formal fallacies. We take just another typical example.

An auxiliary hypothesis is an assumption that is used in order to deduce the implications from the hypothesis.

First an example incorrect deduction when using auxiliary hypotheses:

If H and A_1, A_2, …., A_n is true, then so is I.
But (As the evidence shows), I is not true.
H and A_1, A_2, …., A_n are all false

(Comment: One can be certain that H is false, only if one is certain that all of A_1, A_2, …., A_n are all true.)

And now again the fallacy of affirming the consequent:

If H is true, then so are A_1, A_2, …., A_n.
(As the evidence shows), A_1, A_2, …., A_n are all true.
H is true

(Comment: A_1, A_2, …., A_n can be a consequence of some other premise, and not H.)

We shall leave our discussion of formal fallacies by concluding that if an argument is not built correctly, then the argument contains a formal fallacy.

Informal Fallacies

Usually we examine *content* rather than *structure* when we analyze an argument.
An informal fallacy is a mistake in reasoning related to the *content* of an argument.

What follows is a brief listing of some of the more common *informal fallacies*.

Appeal to Authority
Arises when the appeal is made to an authority but the claim is outside of that authority's expertise. Professional athletes that appear in TV commercials have expertise in their specific sports but not in food, fashion, or banking - unless, of course, they gain that expertise.

Ad Hominem
Arises when the character of your opponent is called into question instead of the validity of their position. A person's character has nothing to do with the validity of their position!

False Cause
Arises when one event is said to cause another simply because the one event follows the other in time.

Leading Question
Arises when the conclusion is assumed in the premises. Leading question is sort of a circular argument.

Appeal to Emotion
Arises when the persuasive point of the argument is not found within the truth of the argument but in how the argument "tugs at our heart strings." Appealing to pity is a very common fallacy. Appealing to fear is another "tried-and-true" fallacious method for winning hearts and minds.

Straw Man
Arises when the arguer attacks a position that is represented as the opponent's position which is really not the case. The common technique is to reinterpret the opponent's position usually in a way that is easy to dismiss, and defeat it, then credit yourself with victory. This type of argument is very common in political debate.

Equivocation
Arises when the meaning of a term becomes confused. When we equivocate we are employing a genuine meaning of a term but we are not employing the most appropriate meaning.

Composition
Arises when the attributes of the parts are applied to the whole. One example might be to assume that if all the parts of a watch are in perfect order then the watch itself must be in perfect order.

Division
Arises when the attributes of the whole are applied to the parts. For instance, one might argue that since a person was from a well-to-do family that the person in question was wealthy.

It is of course important to avoid both formal and informal fallacies within arguments. Every time a fallacy is invoked, the argument fails! Special attention should be paid to informal fallacies that can be difficult to detect. We should in the least examine the content of what we are saying before we embed our premises within our arguments.
Isolating, identifying, and eliminating fallacies will help us understand certain position better and will help us defend that position more effectively.

Some not Entirely Uncommon "Proof Techniques"

Proof by vigorous handwaving
Works well in a classroom or seminar setting.

Proof by cumbersome notation
Best done with access to at least four alphabets and special symbols.

Proof by exhaustion
Proof around until nobody knows if the proof is over or not.

Proof by omission
'The reader may easily supply the details. "The other 253 cases are analogous.'

Proof by obfuscation
A long plotless sequence of true and/or meaningless syntactically related statements.

Proof by example
The author gives only the case n = 2 and suggests that it contains most of the ideas of the general proof.

Proof by funding
How could three different government agencies be wrong?

Proof by eminent authority
'I saw Karp in the elevator and he said it was probably NP-complete.'

Proof by personal communication
'Eight-dimensional colored cycle stripping is NP-complete [Karp, personal communication].'

Proof by reduction to the wrong problem
'To see that infinite-dimensional colored cycle stripping is decidable, we reduce it to the halting problem.'

Proof by reference to inaccessible literature
The author cites a simple corollary of a theorem to be found in a privately circulated memoir of the Slovenian Philological Society, 1883.

Proof by importance
A large body of useful consequences all follow from the proposition in question.

Proof by accumulated evidence
Long and diligent search has not revealed a counterexample.

Proof by cosmology
The negation of the proposition is unimaginable or meaningless. Popular for proofs of the existence of God.

Proof by mutual reference
In reference A, Theorem 5 is said to follow from Theorem 3 in reference B, which is shown from Corollary 6.2 in reference C, which is an easy consequence of Theorem 5 in reference A.

Proof by metaproof
A method is given to construct the desired proof. The correctness of the method is proved by any of these techniques.

Proof by picture
A more convincing form of proof by example. Combines well with proof by omission.

Proof by vehement assertion
It is useful to have some kind of authority in relation to the audience.

Proof by ghost reference
Nothing even remotely resembling the cited theorem appears in the reference given.

Proof by forward reference
Reference is usually to a forthcoming paper of the author, which is often not as forthcoming as at first.

Proof by semantic shift
Some standard but inconvenient definitions are changed for the statement of the result.

Proof by appeal to intuition
Cloud-shaped drawings frequently help here.

Proof by intimidation
'Trivial.'

Proof by exact naming:
'Let be p a point q and let's call it r.'

Proof by pacifism
'Before you battle about it, rather believe it.'

Proof by communication
Perhaps someone among you knows this?'

Proof by anti-question:
'Who really wants to know the proof?'

14 LANGUAGE AND COMMUNICATION

Communication

- *Communication* is imparting of information, interaction through signs/messages.
- *Information* is the meaning that a human gives to signs by applying the known conventions used in their representation.
- *Sign* is any physical event used in communication.
- *Language* is a vocabulary and way of using it.

Semiotics, the science of signs, looks at how humans search for and construct meaning.

Three Levels of Semiotics (Theory of Signs)

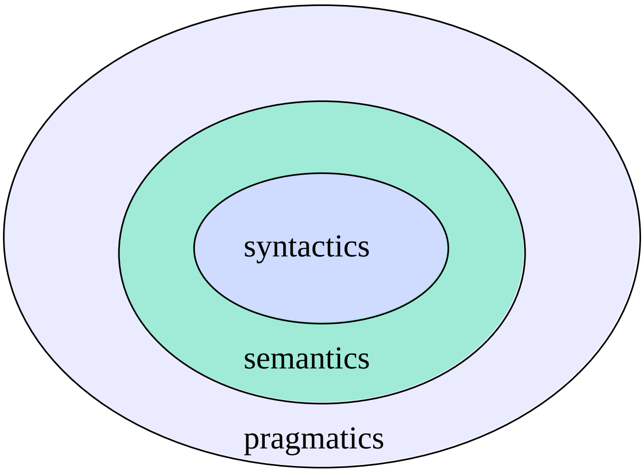

Figure 7 Semiotics Levels

Semiotics is important because it can help us not to take 'reality' for granted as something having a *purely objective existence* independent of human interpretation. *It teaches us that reality is a system of signs.*

Studying semiotics can assist us to become more aware of *reality as a construction* and of the roles played by ourselves and others in constructing it. It can help us to realize that information or meaning is not 'contained' in the world or in books, computers or audio-visual media. Meaning is not 'transmitted' to us - *we actively create it* according to a complex interplay of *codes or conventions* of which we are usually unaware.

The study of signs is the study of the *construction and maintenance of reality*.

'A sign... is something which stands to somebody for something in some respect or capacity' (Peirce). Sign takes a form of words, symbols, images, sounds, gestures, objects, etc.

Anything can be a sign as long as someone interprets it as 'signifying' something - referring to or *standing for* something.

A common 'dyadic' or two-part model of the sign defines (Saussure) a sign as composed of:

- a 'signifier' - the *form* which the sign takes and
- the 'signified' - the *concept* it represents.

The *sign* is the whole that results from the association of the signifier (a pointer) with the signified (that what pointer points to).

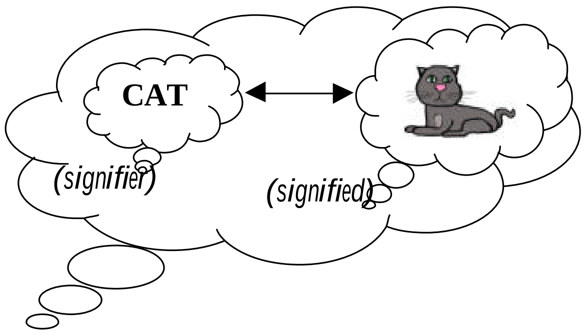

Figure 8 Sign

Although the signifier is treated by its users as 'standing for' the signified, semioticians emphasize that there is no necessary, intrinsic, direct or inevitable relationship between the signifier and the signified. 'That which we call a rose by any other name would smell as sweet', Shakespeare says.

Figure 9 “This is not a Magritte’s pipe”

Reality is divided up into arbitrary categories by every language and the conceptual world with which each of us is familiar could have been divided up very differently. Indeed, no two languages categorize reality in the same way. 'Languages differ by differentiating differently' (Passmore). Linguistic categories are not simply a consequence of some predefined structure in the world. There are no 'natural' concepts or categories which are simply 'reflected' in language. Language plays a crucial role in 'constructing reality'.

The idea that signs (e.g. words) are symbols for things, actions, qualities, relationships, etc, is naïve, gross simplification. The full meaning of a sign does not appear until it is placed in its context, and the context may serve an extremely subtle function- as with puns, or double entendre. And even then the ”meaning” will depend upon the listener, upon the speaker, upon their entire experience of the language, upon their knowledge of one another, and upon the whole situation.

'The whole depends on the parts, and the parts depend on the whole' (Saussure).

It should be noted however that whilst the relationships between signifiers and their signifieds are *ontologically* arbitrary (philosophically, it would not make any difference to the status of these entities in 'the order of things' if what we call 'black' had always been called 'white' and *vice versa*), this is not to suggest that signifying systems are *socially* or *historically* arbitrary. Natural languages are not, of course, arbitrarily established

As part of its social use within a code, every sign acquires a history and connotations of its own which are familiar to members of the sign-users' culture.

Although the signifier may seem to be freely chosen, from the point of view of the linguistic community it is imposed rather than freely chosen because a language is always an inheritance from the past which its users have no choice but to accept.

Structuralists seek to describe the overall organization of sign systems as 'languages' - as with Lévi-Strauss and myth, kinship rules and totemism.

Language and Thought

Different media and genres provide different frameworks for representing experience, facilitating some forms of expression and inhibiting others. The differences between media lead Emile Benveniste to argue that the *'first principle' of semiotic systems is that they are not 'synonymous'*: 'we are not able to say "the same thing" in systems based on different units in contrast to Hjelmslev, who asserted that *'in practice, language is a semiotic into which all other semiotics may be translated'*.

We find corresponding two opposite discourses (Timothy Budd):

1. Translation is possible (*linguistic realism*).
   Applying Chomsky’s hypothesis that the basis of language is inborn capability of every human being, we can conclude that at least some parts of language must be common, and possible to map between different languages.
   We can also reason as follows. If there is a mapping from one language to the common world that we live in, as well as mapping from any other language to the (essentially the same) world, then we can say that there is a mapping from the first language to the second language.[14]
   As a special case, ”Fortran programs can be written in any language. (Timothy Budd)
   Church’s conjecture: “Any computation for which there exists an effective procedure can be realized by an Turing machine.”

2. Translation is essentially impossible.
   The Sapir-Whorf hypothesis (named after the linguists E Sapir and B L Whorf) can be described as relating two associated principles: *linguistic determinism* and *linguistic relativism.* Applying these two principles, the thesis is that people who speak

[14] Of course “common world” is not exactly the same in Africa and Antarctic. It is neither the same for the blind or deaf people. So parts of our language are not directly coupled to our actual experiences of the “common world”. They are “translated” in terms of words for phenomena we have direct experience of.

languages with very different phonological, grammatical and semantic distinctions perceive and think about the world quite differently, their worldviews being shaped or determined by their language.

The Sapir-Whorf Hypothesis

"It may be possible for any individual working in one language to imagine thoughts or to utter ideas that cannot in any way be translated, cannot even be understood, by individuals operating in a different linguistic framework. (…when the language have no equivalent words and lacks even concepts or categories for the ideas involved in thoughts…)."

Sapir argued in a classic passage that:

"The fact of the matter is that the 'real world' is to a large extent unconsciously built upon the language habits of the group. No two languages are ever sufficiently similar to be considered as representing the same social reality. The worlds in which different societies live are distinct worlds, not merely the same world with different labels attached... We see and hear and otherwise experience very largely as we do because the language habits of our community predispose certain choices of interpretation."

A very important question in semiotics and even in anthropology is whether the Sapir-Whorf hypothesis is true. While easy to formulate, it has proved hard to establish or disprove. The reason is that such research needs unusual circumstances - ideally two culturally identical groups using language that differs in one respect that affects a testable way of thinking.

A natural experiment however that fulfills the criteria for showing the existence of the Sapir-Whorf effect has recently been discovered, in the case of deaf infants raised by hearing/deaf parents in their understanding of mental state terms. This research shows that parents´ language has a strong impact upon infants´ cognition. Thus we can conclude that differences between languages can affect cognition as claimed by Sapir and Whorf.

Here it is important to point out that the lack of certain words or ideas is nothing permanent or definitive. Our understanding of the world is dynamic and ever adapting to new circumstances. Let alone mention new products on the market that force us all the time to accept new words and new concepts. Or take for example an African who has no experience of snow, coming to north and getting in contact with it; (s)he forms a new idea connected to that new experience. Even without any practical familiarity with some unknown phenomenon we can get an idea about it via analogy with well-known phenomena. For example we can describe chimerical visual effects of a fata morgana (mirage) in terms of some known optical phenomena.

Sapir-Whorf hypothesis has a tendency to underestimate non-verbal concepts i.e. the tacit knowledge. The language has certainly a strong inpact on our cognition, but the opposite is true as well: our cognition influences forming of our language, and thinking process can be very creative and lead to new concepts, that have not been present in language before.

”Language is called the garment[15] of thought; however, it should rather be, language is flesh-garment, the body of thought.”

Carlyle, Past and Present

To conclude with, we can re-state (translate!) our original question about (im)possibility of translation to the following form: what is (an adequate) translation after all?

Reality and Communication

If a tree falls and the media aren’t there, has it really fallen?

Hierarchical Structure of Language

Object-language ←→ Meta-language

In dictionaries on SCIENCE no definition of science!

The definition of SCIENCE can be found in PHILOSOPHY dictionaries.

Ambiguities of Language

To formulate and to communicate our thoughts, we use language. However, language is used not only to express thoughts, but also feelings, statements and like. So its function is complex and not strictly logical.

Building blocks of every language are words, structured in sentences according to some set of syntactic rules.
The meaning of the word is affected by its context, and it is by no means unambiguous.

Some of the most important types of language ambiguity are:

1. *Lexical* ambiguity, where a word have more than one meaning.

Let us compare different meanings of the word “meaning” in English and Swedish. We only take into account synonyms of the word “meaning” and synonyms of synonyms. There are two groups of synonyms, the first one centered on “sense”, and the other one centered on “significance”.

meaning (sense, connotation, denotation, import, gist;
significance, importance, implication, value, consequence, worth)

sense (intelligence, brains, intellect, wisdom, sagacity, logic, good judgment; feeling)
connotation (nuance, suggestion, implication, undertone, association, subtext, overtone)
denotation (sense, connotation, import, gist)
import (bring in, introduce, trade in, introduction, significance)
gist (general idea, substance, idea, general picture, essence)

[15] (clothes)

significance (meaning, implication, import, consequence, worth, connotation, importance)
importance (significance, meaning, weight, consequence, magnitude, import, substance, value, worth)
implication (*insinuation, inference, suggestion, allegation, allegation, allusion, allusion, proposition, connotation, inference)*
value (worth, price, cost, charge, rate, assessment, importance, worth, denomination)
consequence (result, effect, outcome, end result, upshot, corollary, importance, significance)
worth (value, merit, appeal, significance, attraction, importance, meaning, worth, worth)

Here is the Swedish translation.

meaning (mening, uppfattning betydelse, innebörd; tanke, avsikt)

mening (view, idea, intention, purpose, object, aim, sense, context, sentence)

uppfattning (opinion, convictions)

betydelse (meaning, signification, import, sense, significance, importance)

innebörd (meaning, signification, import, content, purport)

tanke (thought, idea, opinion)

avsikt (intention, purpose, aim, object, end, design, motive, intent)

We see that there is a considerable difference between English and Swedish meaning of “meaning”. The alternative centered on “significance” is missing. It would be of course even more pronounced if we continued to search for synonyms of synonyms.

Some more ambiguities…

2. *Syntactic* ambiguity like in “small dogs and cats” (are cats small?).
3. *Semantic* ambiguity comes often as a consequence of syntactic ambiguity. “Coast road” can be a road that follows the coast, or a road that leads to the coast.
4. *Referential* ambiguity is a sort of semantic ambiguity (“it” can refer to anything).
5. *Pragmatic* ambiguity (If the speaker says “I’ll meet you next Friday”, thinking that they are talking about 17th, and the hearer think that they are talking about 24th, then there is miscommunication.)
6. *Local* ambiguity occurs when sub-string can be parsed in several ways, but only one of those ways fits into a larger context. (“In English, the radio broadcasts” is a noun phrase in “the radio broadcasts inform”, and a noun phrase followed by a verb in “the radio broadcasts information”. It is possible for a phrase to be syntactically ambiguous but semantically unambiguous, as “S_1 and S_2 and S_3”.
7. *Vagueness* is an important feature of natural languages. “It is warm outside” says something about temperature, but what does it mean? A warm winter day in Sweden is not the same thing as warm summer day in Kenya.

A Quest for an Ideal Language

The question is: is it possible, even in principle, to construct a non-ambiguous language? The language Leibniz envisioned, the one that could be used for perfectly correct formulation of logical reasoning?

Wittgenstein, Whitehead, Russell – have made an attempt to formulate a non-contradictory formal logical/philosophical system using well-defined elements. As the main problem in exact codifying and communicating of thoughts (logic) they identified ambiguities in natural languages. The ambition was to build up a perfect formal systems using purified and formalized unambiguous language. Bases of mathematics (as a generalization of ordinary logic) In Principia Mathematica by Russell and Whitehead was written almost entirely by mathematical symbols, without words.

However, Gödel theorem have shown that it was an utopia as within any sufficiently powerful logical system statements can be formulated which can neither be proved nor disproved within the system, unless the system itself is inconsistent.

The Evolution of Language

The question of origins and evolution of language is very interesting and disputed one.
In 1866, The Société de Linguistique de Paris passed a by-law banning of all debate on the origin of language. However, outside the halls of that body, the discussion goes on. One theory is (Chomsky) that there is language module in the human brain, i.e. that language is something we have hard-coded as humans.

There is now considerable evidence that language use is made possible by a number of different skills that developed together with general cognitive capabilities, and that many traces of predecessors of human language can be found in other primates and even in the fossil record.

It is worthy of note that best trained and talented monkey have learned to use about thousand words, which indeed is a remarkable achievement, but no animal have ever been trained to communication capability comparable to four-years old human.

15 EVOLUTION OF SCIENTIFIC THEORY

Table 1 may suggest that not much has happened since Socrates. Appearances are however deceptive! Let us mention only the recent developments of scientific theory.

Logical Positivism

During much of this century, “positivism” has dominated discussions of the scientific method. Positivism *recognizes as valid only the knowledge based on experience*.

During the 1920s positivism emerged as a philosophy of science in the form of *logical positivism.* Developed by the Vienna Circle, a group of scientists and philosophers, logical positivism accepted as its central doctrine Wittgenstein’s verification theory of meaning. The verification theory holds that *statements or propositions are meaningful only if they can be empirically verified*. This criterion was adopted in an attempt to differentiate scientific (meaningful) statements from purely metaphysical (meaningless) statements.

According to logical positivists, universal scientific propositions are true according to whether they have been verified by empirical tests. (Yet no finite number of empirical tests can ever guarantee the truth of universal statements!). In short*, empirical inductive inference can never be justified on purely logical grounds.*

As a result of these difficulties, Carnap developed a more moderate version of positivism, which has come to be known as *logical empiricism* that became the “received view” in the philosophy of science for approximately next twenty years.

Logical Empiricism

Essentially, Carnap replaced the concept of verification with the idea of *“gradually increasing confirmation”*. He argued that if verification is taken to mean the “complete and definitive establishment of truth,” then universal statements could never be verified. However, they may be *“confirmed”* by the accumulation of successful empirical tests. Thus, science progresses through the accumulation of multiple confirming instances obtained under a wide variety of circumstances and conditions.

Logical empiricists believe that *all knowledge begins with observation*. This leads to empirical generalizations among observable entities. As our ideas progress, theories are formulated deductively to explain the generalizations, and new evidence is required to confirm or disconfirm the theories. Throughout the process, data are given precedence. Indeed, the entire process is viewed as essentially an inductive one.

Science in general and knowledge in particular are believed to emerge in an upward fashion: from data to theory as *“an ‘upward flow’ of meaning from the observational terms to the theoretical concepts,”* and it is construed in a similar way by Hempel, Carnap and others logical empiricists.

Logical empiricism is characterized by the inductive statistical method. In this view, science begins with observation, and its theories are ultimately justified by the accumulation of further observations, *which provide probabilistic support for its conclusion*.

Of course, the logical empiricist's use of a probabilistic interpretation does not avoid the problem of induction. It remains to be shown how a finite number of observations can lead to the logical conclusion that a universal statement is "probably true".

Moreover, attempts to justify induction on the basis of experience are necessary circular.

The argument that induction has worked successfully in the past is itself an inductive argument and cannot be used to support the principle of induction (Chalmers).

In addition to the problem of (empirical) induction, logical empiricism encounters further difficulties because of its insistence that science rests on a secure observational base. There are at least two problems. The first is that *observations are always subject to measurement error*. The second, and even more significant, problem concerns *the theory dependence of observation*.

The fact that observation is theory impregnated does not, by itself, refute the logical empiricist position. It does, however, call into question the claim that science is securely anchored by the objective observation of "reality".

In his development of falsificationism, Popper has offered an alternative method of theory justification that is designed to overcome some of the difficulties inherent in logical empiricism.

Popper and Falsificationism

Unlike positivists, Popper accepted the fact that *"observation always presupposes the existence of some system of expectations"*. For Popper, the scientific process begins when observations clash with existing theories or preconceptions. To solve this scientific problem, a theory is proposed and the logical consequences of the theory (hypotheses) are subjected to rigorous empirical tests.

The objective of testing is the refutation of the hypothesis. When a theory's predictions are falsified, it has to be ruthlessly rejected. Those theories that survive falsification are said to be *corroborated (= confirmed) and tentatively accepted*.

In contrast to the gradually increasing confirmation of induction, falsificationism substitutes the logical necessity of deduction. Popper exploits the fact that a universal hypothesis can be falsified by a single negative instance. In Popper's approach, if the deductively derived hypotheses are shown to be false, the theory itself is taken to be false.

Thus the problem of induction is seemingly avoided by denying that science rests on inductive inference. Note nevertheless that Popper's notion of corroboration itself depends on an inductive inference. According to falsificationism, then, science progresses by a process of "conjectures and refutations" (Popper).

Despite the apparent conformity of much scientific practice with the falsificationist account, serious problems remain with Popper's version of the scientific method. *The most severe* *problem is that it is impossible to conclusively refute a theory because realistic test situations depend on much more than just the theory under investigation*.

Take for example all of the background assumptions that might be wrong - flaws in the equipment, the effects of unknown or wrongly disregarded physical processes, and the like. Any outcome can be rationally distrusted and explained away by ad hoc hypotheses that alter the background assumptions. Falsification can thus be regarded as particularly ambiguous.

The recognition that established theories often resist refutation by anomalies and some new theories frequently progress despite their empirical failures led a number of writers to challenge the positivistic views of Popper and the logical empiricists.

The scientific practice is often governed by a conceptual framework highly resistant to change.

In particular, *Kuhn pointed out that the established framework is rarely, if ever, overturned by a single anomaly*. Kuhn's model helped to initiate a new approach in the philosophy of science in which emphasis is placed on the *conceptual frameworks* that guide research activities.

Kuhn's Scientific Revolutions

Central to Kuhn's argument is the concept of a *"paradigm"*, *the world-view of a scientific community*. The paradigm will include a number of specific theories that depend, in part, on the shared metaphysical beliefs of the community.

In Kuhn's view, the individual scientist's decision to pursue a new paradigm must be made on faith in its "future promise". Furthermore, in his view, science progresses through *"paradigm shifts"*, but there is no guarantee that it progresses toward anything - least of all toward "the truth" (Kuhn).

Given its (seeming) advocacy of relativism, Kuhn's Structure of Scientific Revolutions became one of the most carefully analyzed and evaluated works in the philosophy of science.

In criticism of Kuhn, some writers have suggested alternative worldview models as for example "research tradition" concept, which attempts to restore rationality to theory selection by expanding the concept of rationality.

16 WHAT IS AFTER ALL THIS THING CALLED SCIENCE?

The whole is more than the sum of its parts.
Aristotle, Metaphysica

Up to now we have made an attempt to define science. We have given the definitions by goal and process and the definitions by contrast (i.e. we have tried to say what is *not science*). We have described the scientific method and we have compared to ancient Greek Socratic method for searching the truth by pure logical reasoning. We have also problematized the ideas of *knowledge*, *truth*, and *objectivity*. In a short historic part we have studied the evolution of scientific thought.

Let us now apply that given theoretical framework and try to describe sciences as specific branches of this general knowledge, and look for some regularities and patterns that can help us to get a general view of relationships between them.

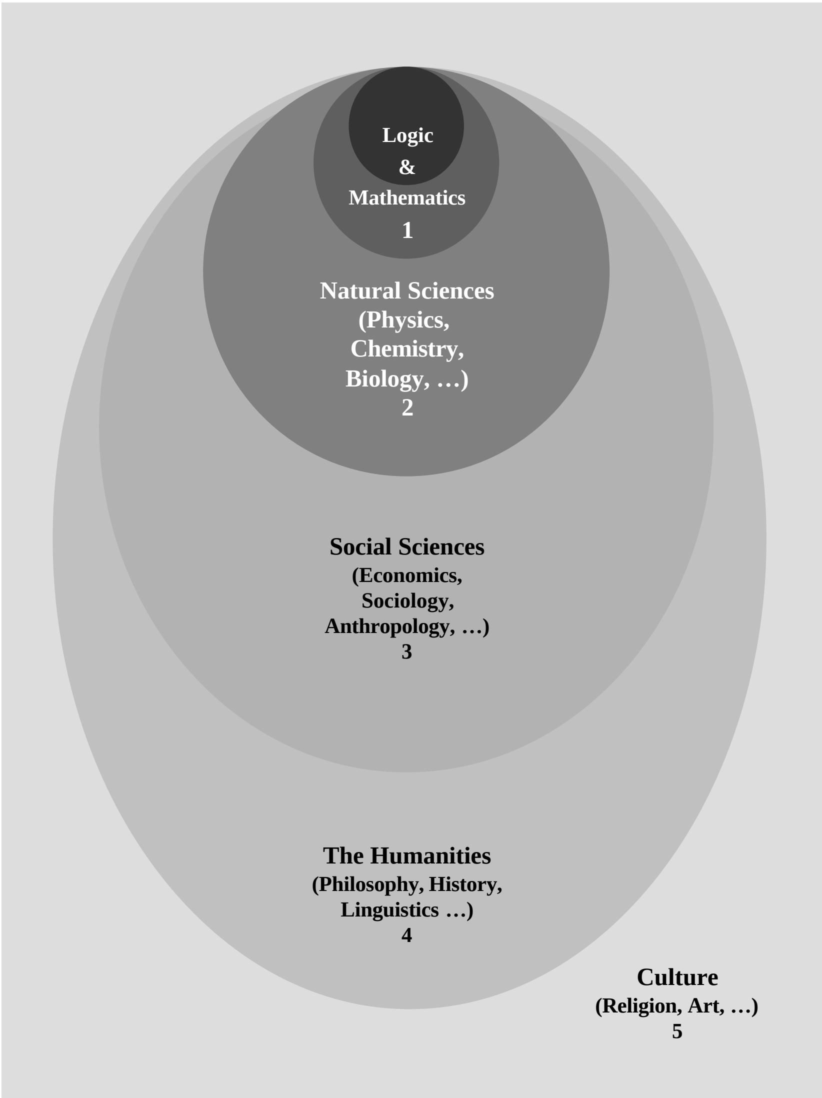

Figure 10 What is science?

Table 3 Sciences, Objects and Methods

SCIENCE	OBJECTS	DOMINATING METHOD
	Simple	Reductionism (analysis)
Logic & Mathematics	Abstract objects: propositions, numbers, ...	Deduction
Natural Sciences	Natural objects: physical bodies, fields and interactions, living organisms ...	Hypothetico-deductive method
Social Sciences	Social objects: human individuals, groups, society, ..	Hypothetico-deductive method + Hermeneutics
Humanities	Cultural objects: human ideas, actions and relationships, language, artefacts…	Hermeneutics
	Complex	*Holism (synthesis)*

One more time we have to point out that the definition of science is not simple and unambiguous. See also APPENDIX 1 and APPENDIX 2 for several different classifications. For example, history and linguistics are often but not always catalogued as sciences.

The next thing we can realize from the scheme of Figure 10 is that sciences have *specific areas of validity*. The logic and mathematics (the most abstract and at the same time the most exact sciences) are more or less important part of every other science. They are very essential for physics, less important for chemistry and even less for biology, and their significance continues to decrease towards the outer regions. The logical reasoning as a basis of all human reasoning is of course present in every kind of science as well as in philosophy.

We can imagine this as analogy of looking into a microscope. With the highest resolution we can reach the innermost regions. Inside those regions logic is not only the tool used to make conclusions. It is at the same time (together with mathematics) the *object of investigation*. Even though big parts of mathematics can be reduced to logical reasoning (Frege, Rusell and Whitehead) it is impossible to reduce the whole of mathematics to pure logic. *On every next level of lower magnification the inner regions are given as prerequisites for the outer ones*. Physics is using mathematics and logic as tools, without questioning their internal structure. In that way information about the deeper structure of mathematics and logic is hidden looking from the outside. In much the same way, physics is a prerequisite for chemistry, that is a hidden level inside biology etc.

The basic idea of Figure 10 is to show in a schematic way the relation between the three main groups of sciences (Logic & Mathematics, Natural Sciences and Social Sciences) as well as the connections to thought systems represented by the Humanities. Finally the whole body of human knowledge, scientific and speculative is immersed in and impregnated by the cultural environment.

The transition between Social science and Humanities is not a sharp one. Moreover there are many connections between inner and outer regions of Figure 10, and the most important fact is that our cultural framework constitutes the basis that everything is built upon. For example metaphysics that is a philosophical discipline has a very strong coupling to physics.

In our scheme, the innermost sciences, *Logic and Mathematics* are the most fundamental ones and the ones with the highest degree of certainty. They have the most abstract and the simplest objects of investigation. Their language is the most formal one. They relay predominantly on the deductive method. From the existing axioms one is deducing theorems. It is however important to notice that *the basic elements in both logic and mathematics have been extracted from our real-life language and purified into set of well defined formulae/symbolic expressions via an essentially inductive process*. For instance, in order to define a triangle, one have to idealize (generalize, abstract) geometric shapes that can be found in nature, which is made by observing big enough number of such objects. Natural numbers have been defined similarly. The first step on the way to Peano axioms was to count concrete physical objects, as our fingers (probably the first thing used for counting), people, animals, etc.

The next region, *Natural Sciences*, is not an axiomatized theory as the previous one. Physics, which is the ideal of science for many philosophers of science (Popper, Carnap, Kuhn, Chalmers) contains both theoretical parts with pure mathematical formulations derived from “first principles” and parts that are empirical i.e. shortcut expressions for observed facts that are built-in into system as they proved useful. Far away from all theoretical physics can be axiomatized. Even less so is the case for experimental physics, for quite obvious reasons.

Natural sciences are dominated by an empirical method which Popper calls *hypotetico-deductive method* that we have already studied in the chapter about scientific method. Physics is a basis for chemistry, which is the basis for biology. It means that through *information hiding* mechanism physical levels are taken for granted in chemistry, while chemical levels (including physical levels (including mathematical (logical levels))) are taken for granted in biology. It is however instructive to notice that neither the whole of physics nor chemistry or biology can be derived from “first principles”. So in biology for example we do not start from atoms to build up living organisms, but instead go in the opposite direction. Biologist starts from the macroscopic facts and proceeds towards more and more detailed microscopic levels.

Social Sciences include sociology, pedagogic, anthropology, economics etc. The objects studied are humans as social beings, alone or in a group. Social sciences relay primarily on the qualitative methods. The aim is to *understand (hermeneutics)* and *describe* phenomena. The quantitative aspects of their methodology are related to statistical methods.

The Humanities (The Liberal Arts) include philosophy, history, linguistics and similar. The difference between Humanities and Social Science is not a very sharp one, but we can say that

Humanities predominantly have a qualitative approach, and very rarely depend on any statistical methods.

It is worth to point out that moving from the central towards the outer regions implies more complex objects as well as more holistic (synthetic) concepts. *Language* used in wider regions is more and more free, with all the ambiguities it implies.

Figure 10 represents a dynamic scheme seen in a specific moment. For example a corresponding scheme for the medieval age (compare to Table 4) would be very different. We can also remark that the *culture* is like a flow that all sciences follow. Albeit very slow, that flow steadily changes the framework for all the sciences.[16]

Sciences belonging to several different regions

Our scheme represents the classical groups of sciences. It says nothing about a modern type of science such as psychology. It gives us no clue whether to categorize psychoanalysis as "cultural heritage", some sort of fine art or a science. The answer is not unambiguous!

The development of human thought parallel to the development of human society has led to a emergence of sciences that do not belong to any of the classic types we have described earlier, but rather share common parts with several of these.

Computer science for example includes the field of artificial intelligence that has its roots in mathematical logic and mathematics but uses physics, chemistry and biology and even has parts where medicine and psychology are very important.

Moreover, we seem to be witnessing an exciting paradigm shift:

"We should, by the way, be prepared for some radical, and perhaps surprising, transformations of the disciplinary structure of science (technology included) as information processing pervades it. In particular, as we become more aware of the detailed information processes that go on in doing science, the sciences will find themselves increasingly taking a metaposition, in which doing science (observing, experimenting, theorizing, testing, archiving,) will involve understanding these information processes, and building systems that do the object-level science. Then the boundaries between the enterprise of science as a whole (the acquisition and organization of knowledge of the world) and AI (the understanding of how knowledge is acquired and organized) will become increasingly fuzzy. "

Allen Newell
"Artificial Intelligence - Where Are We?" Artif. Intell. 25 (1985) 3.

Many of the modern sciences are of interdisciplinary, "eclectic" type. It is a trend for new sciences to search their methods and even questions in very broad areas. It can be seen as a result of the fact that the communications across the borders of different scientific fields is nowadays much easier and more intense than before. Here we can find a potential of the new synthetic (holistic) worldview that is about to emerge in the future.

[16] The opposite is of course also true: there is a two-way communication between culture and science.

17 SCIENCE, RESEARCH, TECHNOLOGY

Aristotle's Distinctions between Science and Technology

In his famous reflections on science and technology, Aristotle has identified four key distinctions that are frequently quoted until today, giving them a kind of common sense status. It is therefore instructive to try to analyze modern science and technology in the light of the original formulations of Aristotle.

Objects: Unchangeable vs. Changeable

According to Aristotle's first distinction, science (episteme) is about the *unchangeable*, while technology (techne) is about the *changeable*.

In order to illustrate one possible interpretation, we take chemistry as an example. The change of chemical substances by chemical reaction is the very essence of chemistry. So, chemistry would be a kind of technology according to this criterion. But the same would be for high-energy physics, cosmology, biology, geology, and so on. Nearly all of modern sciences are about changeable things.

In fact, the same is true for Aristotle's own science of nature (episteme) that is also about changeable things, in contrast to mathematics and his 'theology', which are about the unchangeable.

This apparent contradiction may be solved only by distinguishing between two types of objects, the concrete empirical objects changeable by nature, and their abstractions including *principles and patterns of change* that remain constant.

We can also say that science is studying the behavior of substances that are unchangeable, in our time-perspective[17] at least, such as elements, atoms, elementary particles, living species, etc. Objects of technology are steadily changing like computers (including their constituent hardware and software) in computer technology.

Principles of Change: Inherent vs. Imposed

Aristotle made a distinction between *theoretical science* (theoretike) and *practical science* (poietike) with regard to the different principles of motion of their objects'. The objects of Aristotle's physics (as a theoretical science) bear their own principle of motion, i.e., they are moved or generated by their own inherent forces.

The objects of techne or practical science, on the other hand, have their principle of motion outside of the object, i.e., they are moved or generated by the technician's activity, according to the aims that may change from day to day.

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[17] An objection can be made here that even elementary forces of nature are (very slowly, but anyway) changing according to modern physical theory.

Experimental chemistry has accordingly the status of a practical science, since most of its objects motions are generated by chemists. Chemists lose their status as scientists of nature by the intended intervention, by disturbing the inherent principle of motion of their objects.

However, the metaphysical distinction based on the concept of *principle of motion* has been dropped since the dawn of mechanistic philosophy. Physicists do not care, whether their objects are of artificial or natural origin as long as these are describable in terms of physical laws.

While motions may be explained in terms of causes, Aristotle's principle of motion has lost any meaning in science. Secondly, and more important, generating phenomena in artificial contexts is the very essence of the experimental method.

Aristotle's concept of theoretical science is the *'spectator notion of knowledge'* (Dewey). This has been discarded in most sciences for centuries - in chemistry/alchemy, for millennia.

Hence, since according to this Aristotle's criterion all experimental science would be technology, we should better abandon it today.

Ends: General vs. Specific

Starting from sensations of concrete things, *science finally aims at general knowledge, whereas technology applies general knowledge back to concrete things*.

The latter seems to be again a distinguished characteristic of preparative chemistry. Chemists apply general chemical knowledge to change concrete material samples. But our modern concept of science is methodologically different to Aristotle's concept.

Since Bacon Aristotelian inductivism has lost its prestige. *General knowledge always remains preliminary knowledge,* subject to empirical falsification. As soon as a general law is born, we try to apply it to new experimental arrangements, i.e., to concrete things, in order to test or to exhaust the law.

Moreover, once a general law has been established, it is used for new instrumental skills. It is actually hard to imagine modern science simply stopping at a certain general law, without trying to apply it.

Goals: End in Itself vs. End in Something Else

Scientists look for theoretical knowledge (theoria), that is an activity having an end in itself (and as such being a candidate for the highest form of happiness!). Technicians, on the other hand, produce new things, and such an activity has always an end in something else.

In other words: the purpose of scientific activity is just that activity itself, whereas technical activity is always good for something else.

Producing new chemical substances is a typical technical activity. Moreover, the production of new substances is usually intended to be good for something else. Consequently, preparative chemistry would be a technology par excellance. However, the aim of producing new substances is, for the most part, to improve the abilities of the field. Hence, though the individual practical activity has not an end in itself, it has an end in its own field: supporting the scientific community. *Modern ('big') science is a complex network of cooperative research based on the division of labor* that was quite unknown to Aristotle. If we do not consider that, substantial parts of modern science would again be characterized as technology.

It should be emphasized, that ordinary distinctions between different 'qualities' of aims, say, between *'practical use'* and *'understanding the world'*, do not lead back to Aristotle's point. As soon as a certain activity is instrumentalized, which is necessarily the case in cooperative research of 'big science', it definitely loses its character of having an end in itself (and misses Aristotle's ideal of happiness).

In the light of modern “big science”, we might be willing to reformulate Aristotle's distinction: *if the activity aims to contribute to its own field, it is science; if the end is outside of the field, it is technology*. But even that can run into trouble, since, first, we have interdisciplinary research undermining the field distinction. And, secondly, scientific fields are usually heterogeneous and intricate with regard to ends; some, for sure, always get outside of the field.

So we may conclude that Aristotle's four distinctions between science and technology, though frequently repeated in various combinations until today, fail, because the structure of science has basically changed since the ancient Greek. Today's science is:
(1) about changeable things (revealing general, unchangeable laws, however)
(2) very often experimental science, or based on experimental science
(3) following different methodology, and
(4) 'big science' in the sense of complex research cooperation based on the division of labor.

Recent Methodological Distinctions

More recent philosophers have claimed some further methodological differences between science and technology.

Abstracting vs. Modeling Complex Systems

Scientists, it is said, use *abstracting methods* to discover general laws. Engineers, on the other hand, apply *multi-factorial models* to approach concrete and complex systems.

Yet, that sounds rather like a distinction between physics and chemistry! In fact, chemists are concerned with developing multi-factorial models to approach the concrete and complex systems of chemical substances. Every substance is different, and it is just the difference that chemists are interested in. But the same kind of approach can be found in biology, mineralogy, geology, meteorology, and the rest.

What is wrong with this distinction is that it mixes up characteristic of theoretical physics with science in general.

Conceptualizing vs. Optimizing Processes

It is sometimes stated that scientist try to *understand a process in principle*, while engineers try to *optimize the process for certain aims*.

Even that distinction runs into trouble when applied to chemistry. In fact, chemists are very busy to optimize the yield of their preparation according to theoretical standards. The higher the yield, the better the scientific result. The reason behind that is quite simple: *Modern science has a cooperative structure.* The outcome of a certain research serves as a means for later research and is, consequently, subject to optimizing.

Optimizing strategies are not restricted to chemistry. You can find the same even in physics, especially in solid-state physics. For instance in the field of superconductivity the physics Nobel Prize was awarded for *materials exhibiting the superconductivity at until then highest temperature*.

So again this distinction fails because of a one-sided conception of science.

Meta-methodological Distinction

Discovery vs. Invention

An old dispute among philosophers is whether scientific innovations should be named '*discovery*' or '*invention*'. According to the discovery-paradigm, chemists discover new *changeability*, e.g., that substance A changes to B under certain conditions. According to the invention paradigm, chemists invent new *procedure,* e.g., producing substance B from A under those conditions.

Similar approach is used to distinguish between science and technology: *science discovers, technology invents*.

Accordingly, there are two different types of results: science produces law-like statements, while technology produces rule-like statements.

Even this criterion applied in practice works poorly. It is related to two opposite philosophical assumptions:

- empiricists prefer the discovery paradigm, so they reconstruct any activity as science
- constructivist prefer the invention paradigm, so they see the same activity as technology.

Searching for empirical evidence, we can analyze the linguistic form of scientific reports. There are indeed some perceptive linguistic studies on chemistry papers and textbooks giving the impression that the use of rule-like or law-like statements is just a temporarily fashion.

Rule-like and law-like statements seem to be pragmatically (though not syntactical) equivalent, in the sense that every rule-like statement is easily translated into a law-like statement, and vice versa, without losing information.

Standard sharp binary distinctions between science and technology seem to fail, because the underlying concepts of science are out-dated, one-sided or arbitrary. Today's science is much more complex and heterogeneous than science of the Aristotle’s time, the fact that even many modern philosophers have difficulty to admit.

Philosophers of science have nearly neglected what Kuhn called the 'Baconian Sciences' covering more than 90% of today's science, i.e. experimental solid state physics and the whole of material sciences, molecular biology, genetics and genetical engineering, pharmacy and biomedical sciences, mineralogy, petrology and the major part of earth sciences, and so on. All these fields are more closely related to chemistry than to (the idealized philosophical image of) physics.

That is why philosophy of science is in vital need of a deeper, more realistic understanding of contemporary sciences. The time is ripe for paradigm change in philosophy of science!

Table 4 Standard Distinctions between Science and Technology

	Science	Technology
Object	unchangeable	changeable
Principle of motion	inside	outside
End	knowing the general	knowing the concrete
Activity	theoria: end in itself	poiesis: end in something else
Method	abstraction	modeling concrete (complex)
Process	conceptualizing	optimizing
Innovation form	discovery	invention
Type of result	law-like statements	rule-like statements
Time perspective	long-term	short-term

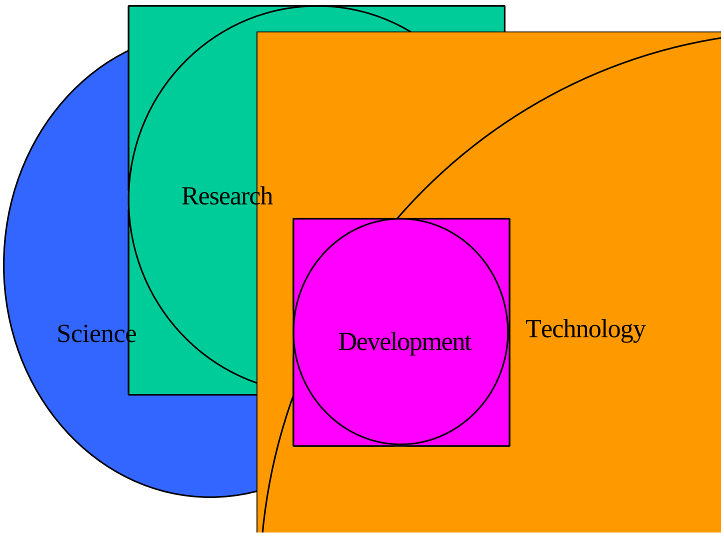

Figure 11 Mutual relations between science, research, development and technology

18 PSEUDOSCIENCE

A pseudoscience is a set of theories presented as scientific, while they are not. A theory about empirical facts is scientific if and only if it explains a range of observed phenomena and can be empirically tested in some meaningful way. Scientific testing involves deducing empirical predictions from the theory. To be meaningful, such predictions must, at least in theory, be falsifiable (Popper). A pseudoscientific theory claims to be scientific, but either the theory is not really falsifiable, or it has been falsified but its adherents refuse to accept that fact.

Pseudoscientists claim to base their theories on empirical evidence, and they may even use some elements of the scientific method, though often their understanding of a controlled experiment is inadequate. For example, "the truth of the hypothesis that plague is due to evil spirits is not established by the correctness of the deduction that you can avoid the disease by keeping out of the reach of the evil spirits."

There are several characteristics of pseudoscience that help us to identify them:

1. The tendency to propose theories that are put forth as scientific, but which cannot be empirically tested in any meaningful way. That is, the theory is consistent with every conceivable empirical event and no deduced prediction from it could ever falsify it.
2. The dogmatic refusal to give up an idea in the face of overwhelming evidence that the idea is false, and the use of ad hoc hypotheses to try to explain away contrary evidence.
3. The selective use of data: the tendency to take into account only confirming instances and to ignore disconfirming instances.
4. The use of personal anecdotes as evidence.
5. The lack of concern over the absence of evidence in support of one's theory.
6. The use of myths or ancient mysteries to support theories which are then used to explain the myths or mysteries.
7. Naivety, especially about paranormal, supernatural or extraterrestrial claims.

19 SCIENCE AND ETHICS

The Conventionally Accepted Ethical Norms

R.K. Merton first suggested in 1942 that the behavior of scientists could be exemplified by a coherent set of norms.

Communalism requires that scientific knowledge should be public knowledge; that the results of research should be published; that there should be freedom of exchange of scientific information between scientists everywhere, and that scientist should be responsible to the scientific community for the trustworthiness of their published work.

Universalism requires that science be independent of race, color, or creed and that it should be essentially international.

Disinterestedness requires that the results of bona fide scientific research should not be manipulated to serve considerations such as personal profit, ideology, or expediency, in other words they should be honest and objective; it does not mean that research should not be competitive.

Organized skepticism requires that statements should not be accepted on the word of authority, but that scientists should be free to question them and that the truth of any statement should finally rest on a comparison with observed fact.".

C – communalism U – universalism D – disinterestedness O – originality OS - organized skepticism

Precautionary Principle

An ethical principle for guiding human activities, to prevent harm to the environment and to human health, has been emerging during the past ten years. It is called the "principle of precautionary action" or the "precautionary principle" for short.

An international group of scientists, government officials, lawyers, and grass-roots environmentalist met 1998 at Wingspread, Wisconsin to define and discuss the precautionary principle. The group issued the following consensus Wingspread Statement on the Precautionary Principle:

"The release and use of toxic substances, the exploitation of resources, and physical alterations of the environment have had substantial unintended consequences affecting human health and the environment. Some of these concerns are high rates of learning deficiencies, asthma, cancer, birth defects and species extinctions, along with global climate change, stratospheric ozone depletion and worldwide contamination with toxic substances and nuclear materials.

We believe existing environmental regulations and other decisions, particularly those based on risk assessment, have failed to protect adequately human health and the environment - the larger system of which humans are but a part.

We believe there is compelling evidence that damage to humans and the worldwide environment is of such magnitude and seriousness that new principles for conducting human activities are necessary.

While we realize that human activities may involve hazards, people must proceed more carefully than has been the case in recent history. Corporations, government entities, organizations, communities, scientists and other individuals must adopt a precautionary approach to all human endeavors. Therefore, it is necessary to implement the Precautionary Principle:

"When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof. "

The process of applying the Precautionary Principle must be open, informed and democratic and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action."

Thus, as formulated here, the principle of precautionary action has four parts:

1. People have a duty to take anticipatory action to prevent harm.
2. The burden of proof of harmlessness of a new technology, process, activity, or chemical lies with the proponents, not with the general public.
3. Before using a new technology, process, or chemical, or starting a new activity, people have an obligation to examine "a full range of alternatives" including the alternative of doing nothing.
4. Decisions applying the precautionary principle must be open, informed, and democratic and must include affected parties.

The precautionary principle is not really new. The essence of the principle is captured in common-sense aphorisms such as "An ounce of prevention is worth a pound of cure," "Better safe than sorry," and "Look before you leap."

However, environmental policy in the U.S. and Europe for the past 70 years has been guided by entirely different principles perhaps best reflected in the aphorisms, "Nothing ventured, nothing gained". The ethics comes into the picture when we understand that risks are as a rule taken (decided upon) by one group, and hazards are taken by some other group of people.

Etisk kodex för forskare (Uppsala 1984-01-24)

Forskningen är en omistlig verksamhet som har stor betydelse för människan -för hennes världsbild, för hennes materiella förhållanden, för hennes sociala liv, för hennes välbefinnande.
Forskningen kan bidraga till lösningen av de stora problem mänskligheten står inför såsom hotet om kärnvapenkrig, förstöringen av livsmiljön och den ojämna fördelningen av Jordens tillgångar. Dessutom är forskningen berättigad och värdefull som ett rent kunskapssökande, och den bör bedrivas med ett fritt och öppet utbyte av metoder och resultat. Men forskningen kan också, direkt eller indirekt, förvärra mänsklighetens problem.

Denna etiska kodex för forskare har tillkommit på grund av oro över forskningsresultatens tillämpningar och konsekvenser. Särskilt tycks riskerna för mänskligheten vid krigföring i dag vara så stora, att det är tveksamt om något stöd till vapenutveckling från forskare är etiskt försvarbart.

Kodexen är avsedd att användas av forskaren själv - han eller hon har att bedöma sin egen verksamhet. En sådan bedömning är alltid svår och kanske inte så sällan omöjlig att göra. Forskaren råder som regel inte över sina resultat och deras användning, ofta inte ens över sin egen verksamhet. Men detta hindrar inte att varje forskare ärligt bör försöka att fortlöpande bedöma tänkbara konsekvenser av sin forskning, att informera om dessa och att avstå från sådan forskning som han eller hon anser oetisk.

Härvid skall särskilt beaktas att:

1. Forskningen skall ges en sådan inriktning att dess tillämpningar och andra konsekvenser inte orsakar väsentliga ekologiska skador,

2. Forskningen skall ges en sådan inriktning att dess konsekvenser inte försvårar för dagens människor och kommande generationer att få en trygg tillvaro. Vetenskapliga insatser skall därför inte syfta till tillämpningar och färdigheter att användas för krig eller förtryck. Forskningen skall heller inte ges en sådan inriktning att dess konsekvenser står i strid med grundläggande mänskliga rättigheter som de uttrycks i internationella överenskommelser om medborgerliga, politiska, ekonomiska, sociala och kulturella rättigheter ,

3. Forskaren har ett ansvar att omsorgsfullt bedöma forskningens konsekvenser och att informera om dessa,

4. En forskare som bedömer att den forskning han eller hon utför eller deltar i står i strid med denna kodex skall avbryta denna forskningsverksamhet och informera om sin bedömning. Vid en sådan bedömning skall hänsyn tagas både till hur sannolika och hur allvarliga de negativa effekter är som kan följa av forskningsinsatsen. Det är mycket angeläget att forskarsamhället stöder forskare som anser sig behöva avbryta sin forskning av skäl som anförs i denna kodex.

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22 APPENDIXES

APPENDIX 1 What Sciences Are There?

Table 1 Example from Library Catalogue

General
Agricultural Sciences
Anthropology
Archaeology
Astronomy
Behavioral Sciences
Biology
Chemistry
Computer Science & Electronics
Communications
Cosmology
Earth Sciences
Education
Engineering
Evolution
Experiments, Instruments &
History & Philosophy
Mathematics
Medicine
Nature & Ecology
Paleontology
Psychology
Physics
Sociology

Table 2 New Scientist categorization

5. Earth Science

Geography
Geology
Measurement & Units
Oceanography
Paleontology
Polar Science
Weather

6. Physical Sciences & Mathematics

Astronomy
Chemistry
Energy
Mathematics
Physics
Space Exploration

7. Technology
8. AI, A-Life & Robotics

Computer Science
Engineering
Internet
Inventions & Patents
Nanotechnology
Technology
Transportation

9. Life Sciences

Agriculture & Gardening
Anatomy &
Physiology
Biology
Botany
Conservation

10. Environment & Ecology

Evolution
Food Science
Genetics
Health & Medicine

11. Zoology

Animals
Birds
Insects & Spiders
Marine Life
Zoos & Aquaria

12. Social Science

Anthropology
Archaeology
Biography
History of Science
Philosophy & Ethics
Psychology
Science Education

Table 3 Looking more closely…Physics and Mathematics

13. Physics	14. Mathematics
Accelerator Physics	Algebra
Acoustics	Analysis of PDEs
Astrophysics	Calculus
Atmospheric and Oceanic Physics;	Category Theory
Atomic Physics	Chaos
Atomic and Molecular Clusters	Classical Analysis
Biophysics;	Combinatorics
Chaos	Complex Variables
Chemical Physics	Computability
Condensed Matter	Cryptography
Classical Physics	Differential Equations
Computational Physics	Differential Geometry
Crystallography	Dynamical Systems
Electromagnetism	Education
Fluid Dynamics;	Fractals
General Physics;	Functional Analysis
Geophysics	General Mathematics
High Energy Physics	General Topology
History of Physics	Geometry
Mathematical Physics	Geometric Topology
Medical Physics	Graph Theory
Nuclear Physics	Group Theory
Optics	History of Mathematics
Particle Physics	Information Theory
Physics Education	K-Theory and Homology;
Physics and Society	Linear Algebra
Plasma Physics	Logic
Popular Physics	Mathematical Physics
Space Physics	Metric Geometry
Relativity	Number Theory
Quantum Physics	Numerical Analysis
Vacuum Physics	Operator Algebra
	Optimization and Control
	Probability Theory
	Quantum Algebra
	Representation Theory
	Rings and Algebras
	Scientific Computation
	Set Theory
	Spectral Theory
	Symplectic Geometry

Table 4 The Medieval Science

Alchemy
Astrology
Zoology
Astronomy
Botany
Calendars
Cartography
Mathematics
Medicine
Physics
Time

Medieval Metaphor of Moon

APPENDIX 2 What Liberal Arts Are There?

The College of Liberal Arts
University of South Carolina Departments

- Aerospace Studies
- Anthropology
- Art
- Geography
- Germanic, Slavic and East
- Asian Languages
- Government and International Studies
- History
- Modern Languages
- Military Science (Army)
- Philosophy
- Psychology
- Religious Studies
- Sociology
- Theatre, Speech & Dance

Massacussets College of Liberal Arts
Academic Department

- Biology
- Business Administration & Economics
- Center for Academic Advancement
- Chemistry
- Computer Science & Information Systems
- Education
- English/Communications
- Fine & Performing Arts
- History, Political Science & Geography
- Interdisciplinary Studies
- Library & Media Services
- Mathematics
- Modern Languages
- Philosophy
- Physical Education
- Psychology
- Physics
- Sociology, Anthropology & Social Work

The University of New England
Subjects in the Faculty of Arts

- Ancient History
- Archaeology
- Asian Societies
- Classical Languages (Greek or Latin)
- Classical Studies
- Communication Studies
- European Cultures
- Geography
- History
- International Relations
  Modern Languages
- Linguistics
- Music
- Palaeoanthroplogy
- Philosophy
- Planning
- Political Science
- Psychology
- Public Policy
- Sociology
- Studies in Religion
- Theatre Studies
- Women's and Gender Studies

APPENDIX 3 Usual Naïve Image of Scientific Method

(The narrow inductivist conception of scientific inquiry)

”If we try to imagine how a mind of superhuman power and reach[18], but normal so far as logical processes of its thought are concerned, … would use the scientific method, the process would be as follows:
First, all facts would be observed and recorded, *without selection* or *a priori guess* as to their relative importance. Secondly, the observed and recorded facts would be analyzed, compared, and classified, without hypothesis or postulates other than those necessarily involved in the logic of thought. Third, from this analysis of the facts generalizations would be inductively drawn as to the relations, classificatory or causal, between them. Fourth, further research would be deductive as well as inductive, employing inferences from previously established generalizations."[19]

This narrow idea of scientific inquiry is *groundless*, for several reasons (see Hempel):

1. A scientific investigation as described above could never get off the ground. Its first phase could never be carried out, for a collection of *all facts* would take infinite time, as there are infinite number of facts. Of course the only possible way to do data collection is to take only relevant facts. But in order to decide what is relevant and what is not, we have to have a theory or at least a hypothesis about what is it we are observing.
   Empirical facts or findings can be qualified as logically relevant or irrelevant only in reference to a given *hypothesis*, and not in reference to a given *problem.*
   A hypothesis is needed to give *the direction* to a scientific investigation.
2. A set of empirical “facts” can be analyzed and classified in many different ways. Without hypothesis, analysis and classification are blind.
3. Induction is sometimes imagined as a method that leads, *by mechanical application of rules*, from observed facts to corresponding general principles. Unfortunately, such rules do not exist!
   We can mention one simple reason why it is not possible to derive hypothesis (theory) directly from the data. For example, theories about atoms contain terms like “atom”, “electron”, “proton”, “psi-function”, etc; yet what one actually measures are spectra (wave lengths, traces in bubble chambers, calorimetric data, etc. So the theory is formulated on a completely different (and more abstract) level than the observable data.
   The transition from data to theory requests creative imagination. Scientific hypothesis is formulated based on “educated guesses” at the connections between the phenomena under study, at regularities and patterns that might underlie their occurrence. Scientific guesses are completely different from any process of systematic inference.
   The discovery of important mathematical theorems, like the discovery of important theories in empirical science, requires inventive ingenuity. It calls for imaginative, insightful guessing.

[18] Here: grasp, range, influence, extent
[19] A. B. Wolfe, “Functional Economics” in The Trend of Economics, ed. R. G. Tugwell (New York: Alfred Knopf, Inc., 1924), p. 450 (italics are quoted).

The interests of *scientific objectivity* are assured by the demand for an *objective validation* of such conjectures (hypotheses). And when e.g. a mathematical proposition has been proposed as a conjecture, its proof or disproof still requires inventiveness and ingenuity. For not even the rules of deductive inference provide a general mechanical procedure for constructing proofs. Their systematic role is rather the modest one of criteria of soundness of arguments offered as proofs. An argument will constitute a valid mathematical proof if it proceeds from axioms to the proposed theorem by a chain of steps each of which is valid according to one of the rules of deductive inference.

Scientific knowledge is not a result of applying some inductive inference procedure to the collected data, but rather by what is called *hypotetico-deductive* method, i. e. by inventing hypothesis as trial answer to a problem under study, and then subjecting hypothesis to empirical/logical test.

APPENDIX 4 Scientific Method Case Study: The Copernican Revolution [20]

Greek philosopher Aristotle (the fourth century BC) had formulated the astronomy with the earth as the center of the universe, and sun, planets and stars orbiting it. The universe was divided into two regions: sub-lunar and super-lunar. All celestial objects in super-lunar region were made of incorruptible element called *ether*. Ether had a natural property to move around the center of the universe *in perfect circles*. Planets moved in circles, called epicycles, whose center moved, in circle around the Earth.

All substances in sub-lunar region were mixtures of four elements:

- Air
- Earth
- Fire and
- Water

Each element had a natural place in the universe.
The natural place for the Earth was in the center of the universe; for Water on the surface of the Earth, for Air in the region above the surface of the Earth, and for the Fire above the atmosphere.

Consequently, each earthly object would have a natural place in the sub-lunar region depending on the proportion of four elements. *All objects on Earth were thought to have natural property to move in strait lines upwards or downwards, towards their natural place.* Thus stones have the natural motion straight downwards, towards the center of the earth, and flames have a natural motion straight upwards, striving towards the top of the atmosphere.

All motion other than natural motion requires a force.
For instance, arrow needs to be propelled by a bow, and a wagon has to be drawn by horses.

20

Before Copernicus, it was the Pythagoreans who had first said that the "Sun is in the middle and the earth is one of the stars (planets) revolving round the Sun having day and night".

In the second century AD Ptolemy developed within the Aristotelian physics a geocentric astronomical system that specified the orbits of the moon, the sun and all the planets. Ptolemy's system was held as definite truth during the Antique and Middle Ages.

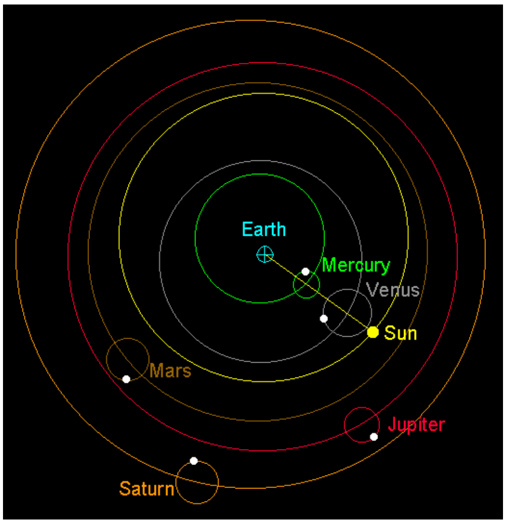


Figure 1 Ptolemy's system

In 1543 Copernicus published his new astronomy with sun in the center[21], and planets, including earth, orbiting the sun. The Copernican view was a radical negation of Aristotelian and Ptolemy's physics and astronomy.

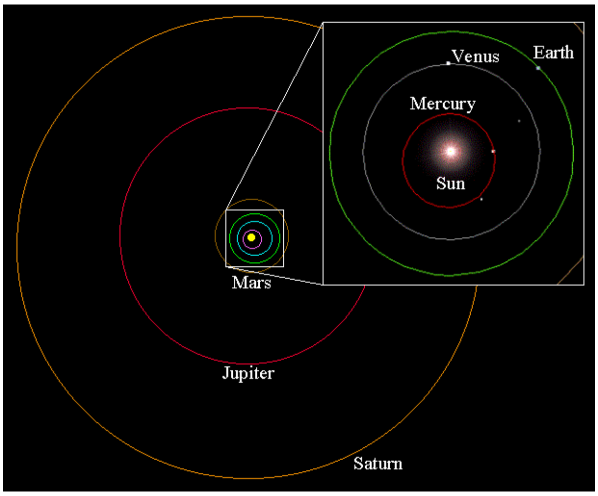


Figure 2 Copernican system

[21] The idea of Copernicus was not really new! A sun-centered system had been proposed as early as about 200 B.C. by Aristarchus of Samos. However, it did not survive long under the weight of Aristotle's influence and "common sense".

Aristarchus postulated that the planets orbited the sun – not the Earth – over a thousand years before Copernicus and Galileo made similar arguments.
Aristarchus used deductive logic to estimate the size of the earth, the size and distance to the moon, the size and distance to the sun, then he even deduced that the points of light we see at night are not dots painted on some celestial sphere but stars like our sun at enormous distances. Aristarchus' discoveries remained truly unbelievable to the people of his time but stand today as *pillars of deductive reasoning*.

At first, the problem was that Copernicus had no alternative for Aristotelian physics, and hence had no strong enough arguments to defend his heliocentric system.

- Copernicus model was against *Aristotelian ideas of earth as natural center of the universe*.

Moreover, there were number of other arguments against it, such as:

- *Tower argument* (the stone dropped from the top of a tower strikes the ground at the base of the tower, contrary to the hypothesis that the earth is spinning around its axes).
- Loose objects on the surface of the earth would be expected to flung from the earth surface in much the same ways stones would be flung from the rotating wheel.
- Absence of parallax in the observed positions of the stars
- Mars and Venus, as viewed by the naked eye, do not change size appreciably during the course of the year
- If the earth were moving through the universe one would expect wind blowing all the time…
- How to explain that the moon follows the earth on its journey through the universe?

Unfortunately, Copernicus had no adequate answers to those questions. He was himself deeply influenced by Aristotle's physics!

Even worse: the results obtained with *circular, heliocentric orbits contradict observations*, so Copernicus, like Ptolemy was forced to add epicycles (ad-hoc hypothesis)! Not even with this "improvement" could Copernicus show the results better than the old Ptolemy's.

From the point of view of theory of science, the interesting question is: *Why should anyone leave the old well-established theory giving satisfactory predictions*[22]*, theory in agreement with physical laws (of its own time) for a new one turning the whole worldview of physics and astronomy upside-down and promising no better agreement with observations?*

[22] Certain refinements have been made in Ptolemy's scheme and epicycles inside epicycles introduced in order to get better agreement with observations.

Nevertheless, a number of natural philosophers were attracted by Copernicus system. They have become more and more successful in defending it over the next hundred years or so.

The most prominent among those scientists was Galileo Galilei.

Galileo devised new mechanic to replace Aristotelian and so remove arguments against Copernicus.

He distinguished between the ideas of *velocity* and *acceleration* (change of velocity), and asserted that *freely falling objects move with a constant acceleration that is independent of their weight.*

He denied the Aristotelian claim that all motion requires a force and instead proposed *circular law of inertia*, according to which a moving body subject to no force will move indefinitely in a circle around the sun *at uniform speed*. (This law of inertia is later on replaced by Newton's *linear law of inertia*)

Galileo introduced the idea of *relative motion and argued that the uniform motion could not be detected by mechanical means, without access to some reference point outside the system.* He based his argument mainly on *thought experiments*, but *he actually did perform a number of experiments* as for example the famous ones with rolling spheres down inclined planes.

The new Galileo's mechanics helped to defend Copernican system.

An object held at the top of a tower and sharing its circular motion around the center of the earth will continue that motion (because of inertia) along with tower, after it is dropped and will strike the ground at the foot of the tower.

Galileo proposed the following experiment to show the correctness of the law of inertia. If we drop a stone from the mast of a uniformly moving ship on the sea, the stone will strike the deck at the foot of the mast!

Galileo also used telescope to observe celestial bodies. The discovery of the phases of Venus was another Galileo's contribution to a success of Copernican theory.

The next major support for Copernicus heliocentric scheme was from Kepler, Galileo's contemporary, who had at his disposal Tycho Brache's recordings of planetary positions, that were more accurate than those available to Copernicus.

Kepler discovered the following three (Kepler!) laws of planetary motion:

- LAW 1: The orbit of a planet/comet about the sun is an ellipse with the sun's center of mass at one focus. (That eliminated ad-hoc epicycles from Copernican model).

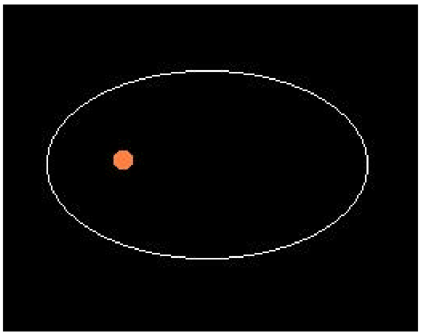


Figure 3 Keplers's first law

- LAW 2: A line joining a planet/comet and the Sun sweeps out equal areas in equal intervals of time

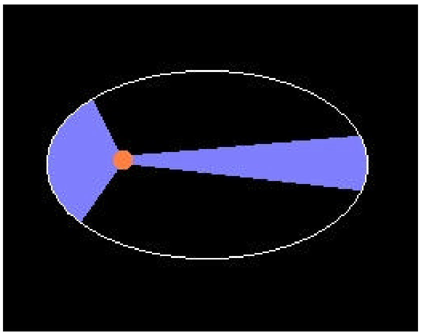


Figure 4 Keplers's second law

- LAW 3: The squares of the periods of the planets are proportional to the cubes of their semimajor axes:

$$Ta^2 / Tb^2 = Ra^3 / Rb^3$$

In 1687 Newton published his Principia. He defined *force as the cause of acceleration rather than motion.* He replaced Galileo's law of circular inertia with *a law of linear inertia*, according to which *bodies continue to move in strait lines at uniform speed unless acted on by force.*

In Principa Newton defines *mass, velocity,* and *acceleration* and his three laws of motion. From this and Kepler's Laws he attacked the problem of the planets devising the law of gravitation. He knew that the moon should fly away from the earth but somehow was held in orbit around the earth. But there was nothing connecting the moon to the earth. He showed that the force that causes Kepler's elliptical orbits is a central force, directed to the center of motion.

He also demonstrated that planets under the influence of this central force follow Kepler's second law. The gravitational law means that all masses attract all other masses. There is no repulsion in case of gravitation, contrary to magnetism.

Newton used the following thought experiment (gedanken experiment). Suppose we fire a cannon horizontally from a high mountain. The projectile will eventually fall to earth, because of the gravitational force directed toward the center of the earth. But as we increase the velocity, the projectile will travel further and further before returning to earth.

Finally, Newton reasoned that if the cannon projected the cannon ball with exactly the right velocity, the projectile would travel completely around the earth, always falling in the gravitational field but never reaching the earth, which is curving away at the same rate that the projectile falls. That is, the cannon ball would have been put into orbit around the earth.

Newton concluded that the orbit of the moon was of exactly the same nature: the moon continuously "fell" in its path around the earth because of the acceleration due to gravity, thus producing its orbit.

Utilizing Kepler's third law, Newton derived the law of gravitation.

Newton further realized that the mass of the sun must also be a factor, so he adjusted constants so to describe mass of the sun.

$$F = G \frac{M_S M_P}{R^2}$$

Gravitational force is directly proportional to masses (M_S and M_P) and inversely proportional to the square of their distance R. Constant G is called gravitational constant.

Newton further generalized his theory to apply to any two masses, not only planets and sun.

Newton's three laws of motion constitute the basis for classical mechanics:

1. *A body continues in a state of rest, or motion with a constant velocity, unless compelled to change by a force.*
2. *The acceleration of an object is directly proportional to the net force acting upon it and inversely proportional to its mass. F = ma, where F = net force, m = mass of the object, and a = the acceleration of the object = the time rate of change of the velocity. The direction of the acceleration is in the direction of the net force.*
3. *For every action force, there is an equal and opposite reaction force.*

Newton's greatest contribution to support Copernicus was the *law of gravitation.* It enabled him to explain both Kepler's laws of planetary motion and Galileo's law of free fall.

In Newton's physics, the same universal laws govern both celestial bodies and earthly bodies.

That was the major scientific advancement compared to Aristotelian physics!

What can we learn from this historical example?

We can conclude that neither inductivists nor falsificationists can give a satisfactory explanation of Copernican revolution.

- The Copernican revolution did not take a place as a result of a new theory supported by experimental confirmation.

- New physical concepts of force, inertia and action on distance did not come in the first place as a result of observation and experiment.

- Early formulations of the new theory, involving vaguely formulated novel conceptions, were preserved *in spite of apparent falsifications*!
  It was only due to the intellectual effort of number of scientists developing a new physics during several centuries, that the new theory could be satisfactory justified.

APPENDIX 5 Hilbert's Program

Deciding which outstanding problems in mathematics are the most important is to decide the course of mathematics' future development. Perhaps the mathematician who had the greatest impact on the direction of 20th century mathematics – through naming problems that most wanted attention – was David Hilbert. At the second International Congress of Mathematicians, which met at Paris in 1900, Hilbert gave one of the leading addresses, in which he reviewed the basic trends of mathematical research at the end of the 19th century, and then formulated 23 problems, extending over all fields of mathematics, which he believed should occupy the attention of mathematicians in the following century.

Because of Hilbert's prestige, these problems were in focus of mathematicians, and many of them were solved. Some, however, have been solved only very recently, and still others continue to challenge matematicians. Each of these famous problems, with commentary where appropriate, is listed below.

1. The Continuum Hypothesis. Kurt Godel proved in 1938 that the generalized continuum hypothesis (GCH) is consistent relative to Zermelo Fraenkel set theory. In 1963, Paul Cohen showed that its negation is also consistent. Consequently, the axioms of mathematics as currently understood are unable to decide the GCH.
2. Whether the axioms of arithmetic are consistent. Kurt Gödel proved in 1933 that no theory (such as a arithmetic) is strong enough to prove its own consistency. However, Zermelo Fraenkel set theory can prove the consistency of (the Peano axioms) of arithmetic.
3. Whether two tetrahedra of equal base and altitude necessarily have the same volume. This was proved false by Max Dehn in 1900.
4. To construct all the metrics in which straight lines are geodesics.
5. How far Lie's conception of continuous groups of transformations is approachable without assuming that the transformations are differentiable. It was shown in the 1950's that every locally Euclidean group is a Lie group.
6. To axiomatize mathematical physics. Partially solved. In particular, John Von Neumann and others axiomatized quantum mechanics.
7. Whether a^b is transcendental, where a is algebraic and b is irrational. This stubborn problem remains unsolved.
8. The Riemann (zeta) Hypothesis. Unsolved.
9. To find the most general law of reciprocity in an algebraic number field. Solved by Artin in 1927 for abelian extensions of the rational numbers, but the non-abelian case remains open.
10. To find a method to determine whether a given Diophantine Equation is soluble. This "decidability" problem is kin to the larger problem pursued by the logicist program of decidability of theories in general. The particular case of Diophantine equations was finally dealt with in a direct way by Matijasevich in 1970, who showed that no such method exists.

11. The study of quadratic forms with algebraic coefficients.
12. The study of any algebraic number field extensions.
13. To show that the general equation of the seventh degree cannot be solved by means of functions of only two arguments.
14. Whether the ring *K intersect* $k[x_1, \ldots, x_n]$ is finitely generated over *K*, where *K* is a field, $k[x_1, \ldots, x_n]$ is a polynomial ring, and *k* is a subset of *K*, which is in turn a subset of $k(x_1, \ldots, x_n)$. Proved false by Nagata in 1959.
15. The rigorous foundation of Schubert's Enumerative Calculus.
16. The investigation of the topology of algebraic surfaces.
17. The expression of a definite rational function as a quotient of sums of squares. Artin showed in 1927 that a positive definite rational function is a sum of squares.
18. Whether there exist non-regular space-filling polyhedra.
19. Whether the solutions of Lagrangians are always analytic.
20. Whether every variational problem has a solution, provided suitable assumptions are made about boundary conditions.
21. To show that there always exists a linear differential equation of the Fuchsian class, with given singular points and monodromic groups. Solved by Deligne in 1970.
22. Development of the calculus of variations.

APPENDIX 6 A Proof of Gödels Theorem

The proof of the incompleteness theorem is beyond the scope of this text, occupying, as it does at least 30 pages, but we can give a hint here.

We begin with logical theory of numbers. In this theory, there is a single constant, 0 (zero) and a single function S (the successor function). In the intended model, S(0) denotes 1, S(S(0)) denotes 2, and so on. The language has names for all the natural numbers.

The vocabulary also includes the function symbols +, $\times$ and Expt (exponentiation), and the usual set of logical connectives and quantifiers ($\wedge$, $\vee$, $\neg$, $\exists$, $\forall$).

The first step is to notice that the set of sentences that can be written in this language can be enumerated. (Imagine defining an alphabetical order on the symbols and then arranging in alphabetical order each of the sets of sentences of length 1, 2, and so on.)
We can then number each sentence α with $\#\alpha$ (the Gödel number). This is important: *number theory contains a name for each of its own sentences*. Similarly, we can number each possible proof P with a Gödel number G(P), because a proof is simply a finite sequence of sentences.

Now suppose that we have a set A of sequences that are true statements about the natural numbers. Recalling that A can be named by a given set of integers, we can imagine writing in our language a sentence α(j,A) of the following sort:

$\forall$i, i is not the Gödel number of a proof of the sentence whose Gödel number is j, where proof uses only premises in A.

Then let σ be the sentence $\alpha(\#\sigma, A)$, that is, a sentence that states its own unprovability from A. (That this sentence always exists is true, but not entirely obvious.)

Now suppose that σ is provable from A. Then σ is false (because σ says it cannot be proved). But then we have a false sentence that is provable from A, so A cannot consist of only true sentences – a violation of our premise. Therefore σ is *not* provable from A. But this is exactly what σ itself claims. Hence σ is a true sentence.

So, we have shown that for any set of true sentences of number theory, and in particular for any set of basic axioms, there exist true sentences that cannot be proved from those axioms.

This establishes, among other things, that we can never prove all the theorems of mathematics within any given system of axioms. Clearly, it was an important discovery for mathematics. It can be summarized as follows:

For any non-trivial formal system F (a formal language, and a set of axioms and inference rules), it is possible to construct so-called “Gödel sentence” G(F) with the following properties:

- G(F) is a sentence of F, but cannot be proved within F.
- If F is consistent, then G(F) is true.

APPENDIX 7 Fuzzy Logic Application

Fuzzy logic is a superset (generalization) of conventional (Boolean) logic that has been extended to handle the concept of partial truth - truth values between "completely true" and "completely false". It was introduced by Lotfi Zadeh of UC/Berkeley in the 1960's as a means to model the uncertainty of natural language.

Zadeh says that rather than regarding fuzzy theory as a single theory, we should regard the process of ``fuzzification" as a methodology to generalize ANY specific theory from a crisp (discrete) to a continuous (fuzzy) form.

Thus recently researchers have also introduced "fuzzy calculus", "fuzzy differential equations", and so on.

Fuzzy Subsets

Just as there is a strong relationship between Boolean logic and the concept of a subset, there is a similar strong relationship between fuzzy logic and fuzzy subset theory.

In classical set theory, a subset U of a set S can be defined as a mapping from the elements of S to the elements of the set {0, 1},

U: S ?   {0, 1}

This mapping may be represented as a set of ordered pairs, with exactly one ordered pair present for each element of S. The first element of the ordered pair is an element of the set S, and the second element is an element of the set {0, 1}. The value zero is used to represent non-membership, and the value one is used to represent membership. The truth or falsity of the statement

x is in U

is determined by finding the ordered pair whose first element is x. The statement is true if the second element of the ordered pair is 1, and the statement is false if it is 0.

Similarly, a fuzzy subset F of a set S can be defined as a set of ordered pairs, each with the first element from S, and the second element from the interval [0,1], with exactly one ordered pair present for each element of S. This defines a mapping between elements of the set S and values in the interval [0,1]. The value zero is used to represent complete non-membership, the value one is used to represent complete membership, and values in between are used to represent intermediate DEGREES OF MEMBERSHIP. The set S is referred to as the universe of discourse for the fuzzy subset F. Frequently, the mapping is described as a function, the membership function of F. The degree to which the statement

x is in F

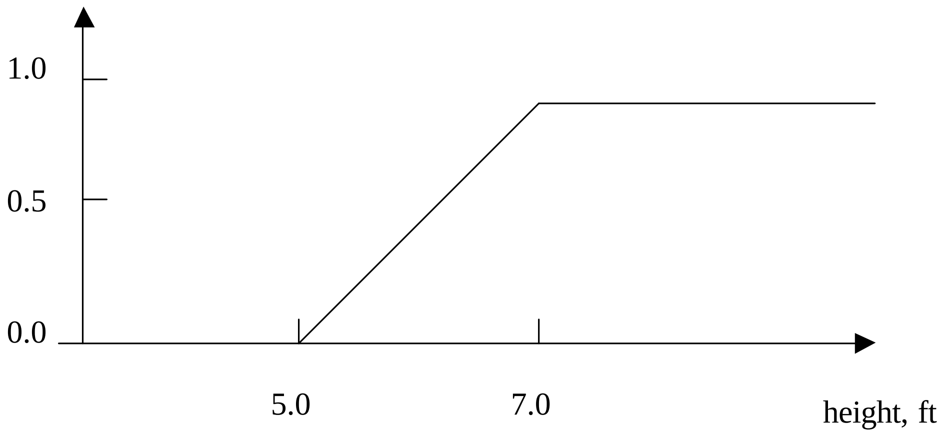
is true is determined by finding the ordered pair whose first element is x. The DEGREE OF TRUTH of the statement is the second element of the ordered pair.

In practice, the terms "membership function" and fuzzy subset get used interchangeably.

Here is an example. Let's talk about people and "tallness". In this case the set S (the universe of discourse) is the set of people. Let's define a fuzzy subset TALL, which will answer the question "to what degree is person x tall?" Zadeh describes TALL as a linguistic variable, which represents our category of "tallness". To each person in the universe of discourse, we have to assign a degree of membership in the fuzzy subset TALL. The easiest way to do this is with a membership function based on the person's height.

tall(x) = { 0,	if height(x) < 5 ft.,
(height(x)-5ft.)/2ft.,	if 5 ft. <= height (x) <= 7 ft.,
1,	if height(x) > 7 ft. }

A graph of this looks like:



Given this definition, here are some example values:

Person	Height	degree of tallness	
Billy	3' 2"	0.00	[I think, ☺]
Fred	5' 5"	0.21	
Drew	5' 9"	0.38	
Erik	5' 10"	0.42	
Mark	6' 1"	0.54	
Kareem	7' 2"	1.00	[depends on who you ask]

Expressions like "A is X" can be interpreted as degrees of truth, e.g., "Drew is TALL" = 0.38.

Note: Membership functions used in most applications almost never have as simple a shape as tall(x). At minimum, they tend to be triangles pointing up, and they can be much more complex than that. Also, the discussion characterizes membership functions as if they always are based on a single criterion, but this isn't always the case, although it is quite common. One could, for example, want to have the membership function for TALL depend on both a person's height and their age (he's tall for his age).

This is perfectly legitimate, and occasionally used in practice. It's referred to as a two-dimensional membership function, or a "fuzzy relation". It's also possible to have even more criteria, or to have the membership function depend on elements from two completely different universes of discourse.

Logic Operations:

Now that we know what a statement like "X is LOW" means in fuzzy logic, how do we interpret a statement like

(X is LOW) and (Y is HIGH) or (not Z is MEDIUM)

The standard definitions in fuzzy logic are:

truth (not x)	=	1.0 - truth (x)
truth (x and y)	=	minimum (truth(x), truth(y))
truth (x or y)	=	maximum (truth(x), truth(y))

Some researchers in fuzzy logic have explored the use of other interpretations of the AND and OR operations, but the definition for the NOT operation seems to be safe.

Note that if you plug just the values zero and one into these definitions, you get the same truth tables as you would expect from conventional Boolean logic. This is known as the EXTENSION PRINCIPLE, which states that the classical results of Boolean logic are recovered from fuzzy logic operations when all fuzzy membership grades are restricted to the traditional set {0, 1}. This effectively establishes fuzzy subsets and logic as a true generalization of classical set theory and logic. In fact, by this reasoning all crisp (traditional) subsets ARE fuzzy subsets of this very special type; and there is no conflict between fuzzy and crisp methods.

Some examples -- assume the same definition of TALL as above, and in addition, assume that we have a fuzzy subset OLD defined by the membership function:

old (x) = { 0,	if age(x) < 18 yr.
(age(x)-18 yr.)/42 yr.,	if 18 yr. <= age(x) <= 60 yr.
1,	if age(x) > 60 yr. }

And for compactness, let

a = X is TALL and X is OLD
b = X is TALL or X is OLD
c = not (X is TALL)

Then we can compute the following values.

Height	age	X is TALL	X is OLD	a	b	c
3' 2"	65	0.00	1.00	0.00	1.00	1.00
5' 5"	30	0.21	0.29	0.21	0.29	0.79
5' 9"	27	0.38	0.21	0.21	0.38	0.62
5' 10"	32	0.42	0.33	0.33	0.42	0.58
6' 1"	31	0.54	0.31	0.31	0.54	0.46
7' 2"	45	1.00	0.64	0.64	1.00	0.00
3' 4"	4	0.00	0.00	0.00	0.00	1.00

Here is a little conversion table to the metric system:

Feet+Inches = Meters	
3' 2"	0.9652
3' 4"	1.0160
5' 5"	1.6510
5' 9"	1.7526
5' 10"	1.7780
6' 1"	1.8542
7' 2"	2.1844

Fuzzy logic is supposed to be used for reasoning about inherently vague concepts. But it turns out that the useful applications are not in high-level artificial intelligence but rather in lower-level machine control, especially in consumer products.

Usually, fuzzy controllers are implemented as software running on standard microprocessors. A few special-purpose microprocessors have been built that do fuzzy operations directly in hardware, but even these use digital binary (0 or 1) signals at the lowest hardware level. There are some research prototypes of computer chips that use analog signals at the lowest level, but these chips simulate the operation of neurons rather than fuzzy logic.

Conclusion

Fuzzy systems, including fuzzy logic and fuzzy set theory, provide a rich and meaningful addition to standard logic. The mathematics generated by these theories is consistent, and fuzzy logic may be a generalization of classic logic. The applications which may be generated from or adapted to fuzzy logic are wide-ranging, and provide the opportunity for modeling of conditions which are inherently imprecisely defined, despite the concerns of classical logicians. Many systems may be modeled, simulated, and even replicated with the help of fuzzy systems, not the least of which is human reasoning itself.

APPENDIX 8 Common Dichotomies

yes/no	simple/complex	win/lose	adult/child
before/after	straight/curved	mind/body	urban/rural
right/wrong	text/context	question/answer	product/process
true/false	central/ peripheral	positive/negative	physical/mental
open/closed	stability/change	art/science	hard/soft
in/out	quantity/quality	active/passive	similarity/difference
up/down	knowledge/ignorance	theory/practice	temporary/permanent
major/minor	fact/fantasy	product/system	nature/culture
top/bottom	part/whole	sex/gender	poetry/prose
left/right	gay/straight	liberal/conservative	married/single
near/far	more/less	wet/dry	strong/weak
on/off	above/below	teacher/learner	subjective/objective
high/low	inner/outer	war/peace	dead/alive
fast/slow	thought/feeling	body/soul	shallow/deep
static/dynamic	north/south	fact/fiction	unity/discord
cause/effect	subject/object	form/content	live/recorded
front/back	producer/consumer	form/function	head/heart
prmary/secondary	work/play	original/copy	formal/casual
birth/death	good/evil	means/ends	structure/agency
presence/absence	masculine/feminine	appearance/reality	message/medium
problem/solution	health/illness	strange/familiar	form/meaning
male/female	comedy/tragedy	speech/writing	words/deeds
light/dark	insider/outsider	order/chaos	fact/theory
inclusion/exclusion	happy/sad	signifier/signified	words/things
success/failure	superior/inferior	foreign/domestic	base/superstructure
good/bad	present/absent	wild/domestic	concrete/abstract
black/white	clean/dirty	maker/user	love/hate
hot/cold	natural/artificial	realism/idealism	new/old
horizontal/ vertical	speaker/listener	them/us	large/small
one/many	classical/romantic	system/process	local/global
self/other	type/token	young/old	structure/process
figure/ground	nature/technology	majority/minority	words/actions
	rights/obligations	accept/reject	beautiful/ugly
fact/opinion	reason/emotion	rich/poor	individual/society
life/death	sacred/profane	fact/value	literal/metaphorical

APPENDIX 9 Eskimo Terms for Snow

Snow Particles

(1) Snowflake

qanuk 'snowflake'

qanir- 'to snow'

qanunge- 'to snow' [NUN]

qanugglir- 'to snow' [NUN]

(2) Frost

kaneq 'frost'

kaner- 'be frosty/frost sth.'

(3) Fine snow/rain particles

kanevvluk 'fine snow/rain particles

kanevcir- to get fine snow/rain particles

(4) Drifting particles

natquik 'drifting snow/etc'

natqu(v)igte- 'for snow/etc. to drift along ground'

(5) Clinging particles

nevluk 'clinging debris/

nevlugte- 'have clinging debris/...'lint/snow/dirt...'

Fallen Snow

(6) Fallen snow on the ground

aniu [NS] 'snow on ground'

aniu- [NS] 'get snow on ground'

apun [NS] 'snow on ground'

qanikcaq 'snow on ground'

qanikcir- 'get snow on ground'

(7) Soft, deep fallen snow on the ground

muruaneq 'soft deep snow'

(8) Crust on fallen snow

qetrar- [NSU] 'for snow to crust'

qerretrar- [NSU] 'for snow to crust'

(9) Fresh fallen snow on the ground

nutaryuk 'fresh snow' [HBC]

(10) Fallen snow floating on water

qanisqineq 'snow floating on water'

Snow Formations

(11) Snow bank

qengaruk 'snow bank' [Y, HBC]

(12) Snow block

utvak 'snow carved in block'

(13) Snow cornice

navcaq [NSU] 'snow cornice, snow (formation) about to collapse'

navcite- 'get caught in an avalanche'

Meteorological Events

(14) Blizzard, snowstorm

pirta 'blizzard, snowstorm'

pircir- 'to blizzard'

pirtuk 'blizzard, snowstorm'

(15) Severe blizzard

cellallir-, cellarrlir- 'to snow heavily'

pir(e)t(e)pag- 'to blizzard severely'

pirrelvag- 'to blizzard severely'

APPENDIX 10 Large-Scale Science (CERN-example)

What is CERN?

CERN is the European Organization for Nuclear Research, the world's largest particle physics center. Founded in 1954, the laboratory was one of Europe's first joint ventures, and has become an excellent example of international collaboration. From the original 12 signatories of the CERN convention, membership has grown to the present 20 Member States.

CERN explores what matter is made of, and what forces hold it together.

The Laboratory provides state-of-the-art scientific facilities for researchers. These are accelerators which accelerate tiny particles to a fraction under the speed of light, and detectors to make the particles visible.

Ever since the dawn of civilization, people have endeavoured to learn more about their Universe. The goal is simply to learn but practical benefits often come later. In the 19th Century, Michael Faraday was asked by a sceptical member of the British government what was the use of his work on electricity. His reply showed great foresight: "One day, Sir," he said, "you may tax it."

Just as Faraday was driven by the desire to know, the quest for pure knowledge at CERN drives technology forward. CERN has given the world advances as varied as medical imaging and the World-Wide Web. But the scientists responsible for these developments were not interested in medicine or computers. *Their motivation was simply to find out*.

CERN also plays an important role in advanced *technical education*. A comprehensive range of training schemes and fellowships attracts many talented young scientists and engineers to the Laboratory. Most go on to find careers in industry, where their experience of working in a high-tech multi-national environment is highly valued.
To design and build CERN's intricate machinery and ensure its smooth operation, to help prepare, run, analyze and interpret the complex scientific experiments, and to carry out the myriad of tasks in such a large and special organization, *CERN employs just under 3000 people*, encompassing a wide range of skills and trades - engineers, technicians, craftsmen, administrators, secretaries, workmen, ...

CERN's research program, based on its unique range of big machines, attracts scientists from the Member States and from further afield - the United States, Japan, Canada, the Russian Federation, the People's Republic of China, Israel, India, ... *Some 6500 scientists, half of the world particle physicists, use CERN's facilities.* They represent 500 universities and over 80 nationalities. CERN's primary function is to provide research facilities and basic support to this vast community of users. CERN gives also a particular attention to integrate itself as harmoniously as possible in its environment.

Why do we need CERN?

This is easy to see. Even if some of the larger European countries could afford to construct and run a laboratory as big as CERN, the human resources to run it could not be found within a single nation. For smaller countries especially, the problem in science is to sustain research activities in as many fields as possible. This is not a luxury. They need to provide high-level teaching in all areas of science, hold the door to any field of research open for specially gifted and interested candidates, and keep the public informed about progress in research.

For economic reasons, countries have to maintain the level of insight needed to understand and exploit new ideas and discoveries leading to new applications. Smaller countries spend usually a smaller fraction of their gross national product on fundamental research than larger countries, and the only solution to maintaining a high level of research in many fields is by international collaboration. Particle physics is relatively expensive but, thanks to CERN, most European countries have the chance to take an active part in the world's most advanced experiments, without consuming an unacceptable fraction of the national science budget.

The Research Sector

The Research sector provides direct support to the physics experiments and acts as the interface to the other sectors, seen from the point of view of the users. It consists of four divisions:

- *The Information Technology Division (IT)* provides computing support for experiments and operates both centralized and distributed computing services.
- *The Experimental Physics Division (EP)* executes and supports the experimental program at CERN. The majority of the external users are integrated into the division, which provides a Users Office as their main link to the CERN administration.
- *The Theoretical Physics Division (TH)* gives physics research support both in phenomenology and in theory models.
- *The Education and Technology Transfer Division (ETT)* is responsible for communicating the scientific results, their cultural and educational implications to social groups and society at large, as well as handling the technology transfer issues.

More than 800 CERN staff members are working in the Research sector, representing about 30% of the total CERN staff strength.

The Accelerator Sector

The Accelerator sector is responsible for operating the accelerator and experimental areas infrastructure at CERN. Comprising an injector chain of four major machines (LIL, PS and Booster, SPS, LEP), the Accelerator sector provides the beams for the physics experiments.

- The PS Division operates the PS machine complex, including also LIL and the Booster.
- The SL Division operates the SPS and LEP machines.
- The LHC Division manages the next major project of CERN, the LHC. It works in close contact with the other Divisions in the Accelerator sector and in particular with AC on which it relies heavily.
- The small AC Division provides dedicated managerial resources for the LHC.

The total staff strength of the Accelerator sector is close to 1 100 persons which is some 35% of the total CERN staff strength.

The Technical Sector

The Technical sector provides technical services for the entire CERN site. These services range from water distribution to video conferencing.

- The Engineering Support and Technologies Division (EST) is responsible for technical design and engineering services, mechanical workshops and special materials technologies.
- The (ST) Division has the mandate to provide technical support for accelerators and related experimental areas, including the LHC project, in the fields of civil engineering, cooling with air and demineralised water, heavy handling, access control and video systems and monitoring of the technical infrastructure. ST Division is responsible for the management of general services related to buildings and building facilities, such as heating, air conditioning and low voltage electrical systems, including cleaning and green area maintenance.
- The Technical Inspection & Safety Commission (TIS) is responsible for safety on the CERN site. It operates the CERN fire brigade and the medical unit, monitors and reports on the protection of the environment and on work safety matters.

More than 650 CERN staff are involved in providing these services, amounting to some 20% of the total CERN staff strength.

The Administration Sector

The main task of the Administration sector is to run the administrative operations of the Laboratory and to assist the CERN Management in related issues.

- The Administrative Support Division (AS) is responsible for providing informatics tools and services to the Divisions in relation with all administrative procedures. In close collaboration with other Divisions, it operates large data bases for human resources, procurement and financial purposes.
- The Directorate Services Unit (DSU) assists the Directorate in legal matters, member state issues, internal auditing, strategic planning and other administrative tasks.
- The Finance Division (FI) authorizes and records all payments and prepares the annual budget, financial accounts and other financial documents for the Council and Finance Committee.
- The Supplies, Procurement & Logistics Division (SPL) manages the purchasing and logistics functions which are related to both external procurement as well as to the on-site stores where standard items are made readily available for the CERN users.
- The Human Resources Division (HR) manages the recruitment process and related interfacing both internally and externally. It also provides personnel statistics and other data
- for manpower planning purposes.

The Administration sector includes more than 350 staff members which represents less than 15% of the total CERN staff.

Accelerators

By accelerating particles to very high energies and smashing them into targets, or into each other physicists can unravel the forces acting between them. CERN's accelerators are amongst the world's largest and most complex scientific instruments. Built at the leading edge of technology, these are some of the finest achievements of 20th century science.

There are two types of accelerators, linear and circular, and CERN has both. Accelerators use powerful electric fields to push energy into a beam of particles. Magnetic fields are used to keep the beam tightly focused, and in circular machines to steer the particles around the ring. Linear machines push energy into the beam all along the accelerator's length. The longer the machine, the higher the final energy.

In circular machines the particles go round and round again, collecting energy with each lap. But the faster the particles are going, the more they try to 'skid' off the ring, just like cars going round a tight curve in the road. CERN's biggest accelerator, the Large Electron Positron collider LEP, is 27 kilometres round.

With the largest interlinked accelerator complex in the world CERN is unrivalled in providing beams of high energy particles. CERN's accelerators juggle with all kinds of different particles, for all kinds of different experiments.

CERN's accelerator complex is the most versatile in the world and represents a considerable investment. It includes particle accelerators and colliders, can handle beams of electrons, positrons, protons, antiprotons, and "heavy ions" (the nuclei of atoms, such as oxygen, sulphur, and lead). Each type of particle is produced in a different way, but then passes through a similar succession of acceleration stages, moving from one machine to another. The first steps are usually provided by linear accelerators, followed by larger circular machines. CERN has 10 accelerators altogether, the biggest being the Large Electron Positron collider (LEP) and the Super Proton Synchrotron (SPS).

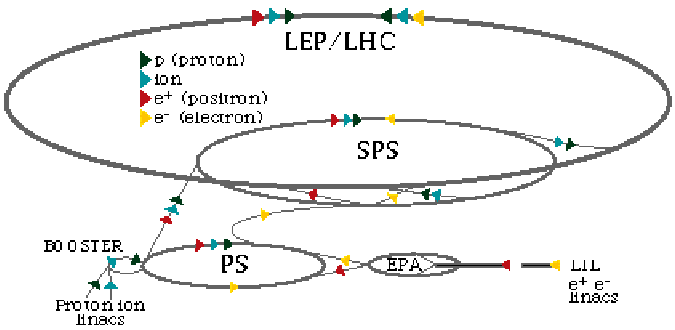


Figure 4 CERN accelerators

CERN's first operating accelerator, the Synchro-Cyclotron, was built in 1954, in parallel with the Proton Synchrotron (PS). The PS is today the backbone of CERN's particle beam factory, feeding other accelerators with different types of particles. The 1970s saw the construction of the SPS, at which Nobel-prize winning work was done in the 1980s. The SPS continues to provide beams for experiments and is also the final link in the chain of accelerators providing beams for the 27 kilometre LEP machine. CERN's next big machine, due to start operating in 2005, is the Large Hadron Collider (LHC). For all these large projects, CERN took a series of measures to preserve the environment .

CERN-Affiliated Nobel Prize Winners in Physics

1976

The prize was awarded jointly to:

- **Richter, Burton,** U.S.A., b. 1931,
  Stanford Linear Accelerator Center, Stanford University, Stanford, CA

and

- **Ting, Samuel C. C.,** U.S.A., b. 1936,
  Massachusetts Institute of Technology, Cambridge, MA, and
  CERN, Geneva, Switzerland,
  "for their pioneering work in the discovery of a heavy elementary particle of a new kind".

1984

The prize was awarded jointly to:

- **Rubbia, Carlo** , Italy, b. 1934,
  CERN, Geneva, Switzerland,

and

Van Der Meer, Simon, the Netherlands, b. 1925,
CERN, Geneva, Switzerland,
"for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction".

1988

The prize was awarded to:

- **Lederman, Leon M.** , U.S.A., b. 1922,
  Fermi National Accelerator Laboratory, Batavia, IL,
  (Bottom quark within the Standard Model)

and

- **Schwartz, Melvin** , U.S.A., b. 1932,
  AssureNet Pathways (formerly Digital Pathways), Inc., Mountain View, CA,
  Stanford University, Stanford, CA,
  Stanford Linear Accelerator Center, Stanford University, Stanford, CA

and

- **Steinberger, Jack** , U.S.A., b. 1921,
  CERN, Geneva, Switzerland,
  "for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon-neutrino".

1992

The prize was awarded to:

- **Charpak, Georges** , France, b. 1924, (in Poland),
  Ecole Superieure de Physique et Chimie, Paris and
  CERN, Geneva, Switzerland,
  "for his invention and development of particle detectors, in particular the multiwire proportional chamber".

APPENDIX 11 Some Examples of Pseudoscience

(see also http://www.physto.se/~vetfolk/Folkvett/index.html, http://www.skepdic.com/pseudosc.html)

Afrocentrism
Alchemy
Anthropometry
Aromatherapy
Astrology
Astrotherapy
Biorhythms
Cellular memory
Codependency
Craniometry
Creationism
Dianetics
Enneagram
Facilitated communication
Graphology
Homeopathy
Synchronicity and the Collective Unconscious
Lunar myths (the full moon)
Lysenkoism
Manifesting
Mesmerism
Metoposcopy
Multi-frequency Detectors (MFDs)
Multiple personality disorder
Naturopathy
New Age Therapies
Orgone energy
Phrenology
Physiognomy
Repressed memory therapy
Reverse speech
Scientology
Zecharia Sitchin's Earth Chronicles
Subliminal advertising
Velikovsky's Worlds in Collision
von Däniken's Chariots of the Gods

APPENDIX 12 Interesting Links

http://web.clas.ufl.edu/users/rhatch/pages/ (History of Science)
http://liinwww.ira.uka.de/bibliography/index.html (Computer Science Bibliographies)
http://www.physlink.com (Physics and Astronomy on-line)
http://www.earlham.edu/~peters/philinks.htm (Guide to Philosophy on the Internet)
http://www.bib.mh.se/osd/nyfosd/omars00.htm (Mitthögskolans bibliotek, Östersund)
http://galileo.imss.firenze.it/vr/index.html (Galileo Museum Florenze)
http://philosophy.wisc.edu/forster/PhilSci/default.htm (Philosophy of Science Wisconsin)
http://www.utm.edu/research/iep/ (The Internet Encyclopedia of Philosophy)
http://www.nature.com/nature/ (Nature)
http://www.infidels.org/library/historical/charles_darwin/origin_of_species/ (Darwin)
http://www.kb.nl/dutchess/08/00/info-3551.html (Directory of On-Line Philosophy Papers)
http://www.kb.nl/dutchess/index.html (Search Engine)
http://www.intrepidsoftware.com/fallacy/toc.htm (Logical Fallacies)
http://www.intrepidsoftware.com/fallacy/syllog.htm (Syllogistic Fallacies)
http://www.websyte.com/alan/metamul.htm (Metaphysics)
http://www.bcc.ctc.edu/philosophy/jokes.htm (Philosophy Jokes)
http://www.netfunny.com/rhf/jokes/computer.html (Computer & Science Jokes)
http://www.u.arizona.edu/~chalmers/phil-humor.html (Philosophical humor)
http://www.newscientist.com/nsplus/insight/quantum/genious.html (New Scientist Quantum World)
http://www.blackwellpublishers.co.uk/philos/#stars (Philosophy Resources)
http://digital.library.upenn.edu/webbin/book/subjectstart?QA (Online books: Math and Comp. Sci.)
http://digital.library.upenn.edu/books/ (Books On-Line)
http://www.student.nada.kth.se/~d90-mst/geb/ (Mårten's GEB Page)
http://cns.pds.pvt.k12.ny.us/~jonathan/geb.html (Godel, Escher, Bach)
http://members.aol.com/McNelis/medsci_index.html (The Medieval Science Page)
http://encyclozine.com/Science/ (Worlds of Science)
http://encyclozine.com/Science/Method/ (What is Science?)
http://encyclozine.com/Science/Philosophy/ (The Philosophy of Science)
http://www.rhodes.edu/Philhtmls/philnet.html (Search of Philosophy)
http://www.earlham.edu/~peters/philinks.htm (Guide to Philosophy on the Internet)
http://www.geocities.com/SoHo/Museum/3828/escher.html (Esher)
http://antioch-college.edu/~andrewc/pedagogy.html (Course Materials in Philosophy)
http://www.exploratorium.edu/origins/cern/place/index.html (CERN)
http://cern.web.cern.ch/CERN/ (CERN)
http://www.pbs.org/wnet/hawking/html/home.html (Stephen Hawking's Universe)
http://www.exploratorium.edu/origins/cern/ideas/bang2.html (CERN, Standard Model)
http://www.sciam.com/2000/0400issue/0400scicit1.html (Scientific American: Fireballs of Free Quarks)
http://www.ai.sri.com/~luong/research/proof.html (Dictionary of useful proof methods - humor)
http://www.princeton.edu/~missouri/humor12.html (How to prove it - humor)
http://www.informatik.htw-dresden.de/~logic/conclusions/rule3.html (Logic)
http://www.sjsu.edu/depts/itl/graphics/induc/ind-ded.html (Induction and Deduction)
http://classroomextension.com/primers/criticalthinking/ (Critical Thinking)
http://mrrc.bio.uci.edu/se10/causality.html (Causality)
http://bayes.cs.ucla.edu/IJCAI99/mainframes.html (Reasoning with Cause and Effect)
http://dir.yahoo.com/Science/Research/Scientific_Method__The/

http://elib.cs.sfu.ca/Collections/CMPT/cs-journals/ (Computing Science Journals)
http://citeseer.nj.nec.com/ (Research Index)
http://www.cv.nrao.edu/fits/www/yp_comp_sci.html (Computer Science-related resources)
http://www.cs.ucla.edu/csd/cs_catalog.html#scope (Computer Science Program and Courses)
http://cdsweb.u-strasbg.fr/astroweb/comp_sci.html (AstroWeb: Computer Science Resources)
http://www.cs.unb.ca/~alopez-o/comp-faq/faq.html (Comp.Theory FAQ)
http://www.brooklyn.liunet.edu/cwis/bklyn/library/resources/social/computer/compnotes.htm (Computer Web)
http://users.ox.ac.uk/~jrlucas/implic.html (The Implications of Gödel's Theorem)
http://www.thymos.com/tat/machine.html (Thinking About Thought)
http://nl.ijs.si/~damjan/g-m-c.html (Gödel)
http://www.geometry.net/goedel.html (K Gödel)
http://www.astr.ua.edu/4000WS/4000WS.html (Women in Science)
http://liinwww.ira.uka.de/bibliography/ (Computer Science Bibliographies**)**
http://www.cvc.org/science/kepler.htm (Kepler laws)
http://www.literature.org/authors/carroll-lewis/alices-adventures-in-wonderland/ (Alice's Adventures in Wonderland, Lewis Carroll)
http://www.xrefer.com/entry/551556 (Causality)
http://www.exploratorium.edu/origins/cern/ (CERN)
http://www.monitor.net/rachel/r586.html (Precautionary Principle)
http://www.perseus.tufts.edu/GreekScience/Students/Kristen/Aristarchus.html#three (Astronomy. Aristarchus)
http://members.aol.com/gca7sky/planets.htm Our Solar System
http://www.scottlan.edu/lriddle/women/women.html (Women Mathematicians)
http://www-history.mcs.st-andrews.ac.uk/history/Mathematicians/ (Biographies of Mathematicians)
http://plato.stanford.edu/entries/search.html (Stanford Encyclopedia of Philosophy)
http://es.rice.edu/ES/humsoc/Galileo/Catalog/catalog.html (Catalog of the Scientific Community in the 16th and 17th Centuries)
http://www.hsa.brown.edu/~maicar/SearchGML.html (Greek Mythology Link)
http://hypatia.dcs.qmw.ac.uk/ (Hypatia Electronic Library in Computer Science and Pure Mathematics)
http://ucsu.colorado.edu/~brindell/soc-epistemology/Bibliographies/Feminist_Soc_Epis/phil-science.htm Bibliography: Feminist Epistemology
http://www.geocities.com/RainForest/3621/PHILINKS.HTM Links on the Philosophy of Technology

APPENDIX 13 Dictionary

Absolute- Modern science has abandoned the following myths of absolute:

- Absolute truth
- Absolute space (geometry)
- Absolute time
- Absolute motion/rest
- Absolute form of matter (mass/energy)
- Absolute determinism
- Absolute causality

Empiricism (*Lat. empirismus, the standpoint based on experience*).
Primarily, the term signifies the theory that the phenomena of consciousness are simply the product of sensuous (physical) experience.
Secondarily, in its logical (epistemological) usage, it designates the theory that all human knowledge is derived exclusively from experience, which means, either explicitly or implicitly, external sense-percepts and internal representations and inferences. In this connection it is opposed to *Intellectualism, Rationalism and Apriorism.*
Empiricism appears in the history of philosophy in three principal forms: Materialism, Sensism, and Positivism.

Evidence - the observations and measurements made to understand phenomena.

Epistemology – theory of knowledge.

Experiment [*Lat. experimentum*]
A trial or special observation, made to confirm or disprove something; under conditions determined by the experimenter; an act or operation undertaken in order to discover some unknown principle or effect, or to test, establish, or illustrate some suggest or known truth; practical test; poof.

Feminist philosophy of science-Feminist philosophers have focused very much on scientific methodology. They have developed a number of new methodologies, including an adapted historical materialism (Nancy Hartsock), phenomenology (Dorothy E. Smith), and interactive observation processes (Evelyn Fox Keller). A principled rejection of a model of objectivity which relies on detachment is common theme.

Feminist philosophers bring a new perspective into study of scientific method. It is however worth to remind that the key quality of science is its generality and universality. Feminist contributions are to be evaluated in that perspective.

Hermeneutics Derived from a Greek word connected with the name of the god Hermes, the reputed messenger and interpreter of the gods.

Hermeneutics studies the *principles of interpretation of the meaning of written texts*. It includes the whole question of how a particular text is 'received,' especially considerations such as discerning the authors intentions as well as understanding the social context and the thought-forms of the period.

Grounded Theory is a strategy for handling research data within Social Sciences, providing modes of conceptualization for describing and explaining. It emphasizes the *inductive process*. Most research today is designed to verify existing theories, not to generate new ones.

Researchers seek out small gains of knowledge from existing "grand theories" rather than explore new areas. The existing research culture emphasizes good scientific, *quantitative* verification studies and downplays more *qualitative* studies whose objective is theory generation. Most of theory is thus generated through logical deduction from past studies and knowledge and not from the data itself. Grounded theory is an attempt to improve present situation *towards more innovative theories.*

One comment we can make here is that there is no observation or data collection without some (however simple but still) theoretical idea about what the goal is, what it might be we are observing and what we are looking for. The focus on data collection and systematization (which relies heavily on deduction of course) can be explained by the fact that the existing theories within Social Sciences have not been satisfactory. There is a trend (cultural phenomenon) to force these sciences to go towards more and more pronounced quantitative methods. So it is understandable that focus is set to data acquisition and systematization. There is nevertheless a question if this field of human research can ever be expressed quantitatively in the same way as natural sciences with their considerably simpler research objects.

The "exactness" of science is closely related to the language that is used to formulate scientific laws. Social sciences use sort of language that is almost as free and unrestricted as our everyday language. And it is not a mere coincidence. Social Sciences operate on our everyday life level. And that means they have to concentrate the whole of our everyday complexity in preferably the same form as geometry does with its abstract and simple idealized objects.

Hypothesis - a proposition explaining the occurrence of a phenomenon or phenomena, often asserted as a conjecture to guide further investigation.

Inference, deductive - a conclusion based on reasoning from accepted premises.

Inference, inductive (empirical induction)- a conclusion based on repeated observation.

Materialism in its basic shape was taught by the ancient atomists (Democritus, Leucippus, Epicurus, Lucretius), who, reducing all reality to atoms and motion, taught that experience is generated by images reflected from material objects through the sensory organs into the soul. The soul, a mere complex of the finest atoms, perceives not the objects but their effluent images. With modern materialists (Helvetius, Diderot, Feuerbach, etc.), knowledge is accounted for either by cerebral secretion or by motion. Avenarius, Mach, etc. subtilize this process so far as to reduce all experience to internal (empirio-criticism).

Metaphor – a form of expression where signs (words, pictures, etc) are not used in their ordinary meaning, but are referring to something else which has the qualities one wants to express. A crane[23] may be used as a metaphor of eternal life.

Multiple working hypotheses - a method of research where one considers not just a single hypothesis but instead several hypotheses that might explain the phenomenon under study. Many of these hypotheses will be contradictory, so that some, if not all, will prove to be false.

Myth In common jargon, a myth is a fiction - something which is untrue. Scholars of mythology define myth differently: a myth is a special kind of story which tries to interpret some aspect of the world around us. Robert W. Brockway, in his book Myth from the Ice Age to Mickey Mouse concisely summarizes a number of different scholarly ideas about the meaning of myth as follows:

“Myths are stories, usually, about gods and other supernatural beings (Frye). They are often stories of origins, how the world and everything in it came to be in illo tempore (Eliade). They are usually strongly structured and and their meaning is only discerned by linguistic analysis (Lévi-Strauss). Sometimes they are public dreams which, like private dreams, emerge from the unconscious mind (Freud). Indeed, they often reveal the archetypes of the collective unconscious (Jung). They are symbolic and metaphorical (Cassirer). They orient people to the metaphysical dimension, explain the origins and nature of the cosmos, validate social issues, and, on the psychological plane, address themselves to the innermost depths of the psyche (Campbell).

Some of myths are explanatory, pre-scientific attempts to interpret the natural world (Frazer). As such, they are usually functional and are the science of primitive peoples (Malinowski). Often, they are enacted in rituals (Hooke).

Natural law - a term rarely used today. Nineteenth-century science presumed that it could arrive at unchangeable, absolutely true, universal statements about nature, and these were to be “natural laws”. Newton’s ideas about gravitation, for example, were considered the “laws of gravity”.

NP (nondeterministic polynomial time) <*complexity*> A set or property of computational decision problems solvable by a nondeterministic Turing Machine in a number of steps that is a polynomial function of the size of the input. The word "nondeterministic" suggests a method of generating potential solutions using some form of nondeterminism or "trial and error". This may take exponential time as long as a potential solution can be verified in polynomial time.

[23] a large bird with very long neck and long legs that eats fish, frequent in Japanese woodcuts.

NP-complete- (NPC, Nondeterministic Polynomial time complete) A set or property of computational decision problems which is a subset of NP (i.e. can be solved by a nondeterministic Turing Machine in polynomial time), with the additional property that it is also NP-hard. Thus a solution for one NP-complete problem would solve all problems in NP.

Positivism Positivists, following Comte, do not deny the supersensible[24]; they declare it unknowable. The only source of cognition, they claim, is sense-experience, experiment, and induction from phenomena. John Stuart Mill, following Hume, reduces all knowledge to series of conscious states linked by empirical associations and enlarged by inductive processes. The mind has no certainty of an external world, but only of “a permanent possibility of sensations”. Spencer makes all knowledge relative. The actual existence of things is their persistence in our consciousness. Consciousness contains only subjective feelings. The relative supposes the absolute, but the latter is unknowable to us. Absolute is the object of faith and religion (Agnosticism[25]). All things, mind included, have resulted from a cosmic process of mechanical evolution in which they are still involved; hence all concepts and principles are in a continuous change.

Sensism By denying any essential difference between sensations and ideas (intellectual states), sensism logically involves materialism.

Sensism, which is found with Empedocles and Protagoras amongst the ancients, was given its first systematic form by Locke, Bacon and Hobbes. Locke derives all simple ideas from external experience (sensations), and all complex ideas from internal experience (reflection). Substance and cause are simply associations of subjective phenomena. *Universal ideas are mere mental fabrication*. Locke admits the existence, though he *denies the demonstrability* of the soul which is an immaterial and immortal principle.

Berkeley, accepting the teaching of Locke that ideas are only transformed sensations, subjectivizes not only the sensible or secondary qualities of matter (e.g. colour and sound), but also the primary qualities (extension, space, etc.), which Locke held to be objective. Berkeley denies the objective basis of universal ideas and indeed of the whole material universe. The reality of things he places in their being perceived, and this “perceivedness” is achieved in the mind by God, not by the object or subject. He still retains the substance-reality of the human soul and of spirits generally, God included.

Hume agrees with his two empiricist predecessors in teaching that the mind knows only its own subjective organic impressions, whereof ideas are but the images. The supersensible is therefore unknowable; the principle of causality is resolved into a mere feeling of successiveness of phenomena; its necessity is reduced to a subjective feeling resulting from uniform association experienced in consciousness, and the spiritual essence or substantial being of the soul is dissipated into a series of conscious states.

[24] what is beyond our senses, reality that is unobservable
[25] skepticism

Theory - a coherent set of propositions that explain a class of phenomena that are supported by extensive factual evidence and that may be used for prediction of future observations.
(John A. Cagle's definition)
A theory is a scientific account of phenomena. At a minimum theory is a strategy for handling data in research, providing a conceptual system for describing and explaining.
(Darnell's definition)
A theory is a set of statements, including some law-like generalizations, systematically and logically related such that the set implies something about reality. It is an argument that purports to provide a necessary and sufficient explanation for a range of phenomena.
It must be capable of corrigibility - that is, it must be possible to disconfirm or jeopardize it by making observations.
A theory is valuable to the extent that it reduces the uncertainty about the outcome of a specific set of conditions.

Example of familiar theories:

15. Copernicus's theory of the heliocentric solar system,
16. Newton's theory of gravity,
17. Einstein's theory of relativity, and
18. Darwin's theory of natural selection
19. Each of these theories draws on huge numbers of facts:
20. observations of the passage of the sun and planets for the heliocentric theory;
21. the behavior of the planets, of projectiles, and rather famously of apples for the theory of gravity, and
22. the existence and location of fossils, as well as the modern distribution and reproduction of organisms, for the theory of natural selection.

Ockham's Razor (*also spelled* Occam's Razor *even called law of economy***,** *or law of parsimony*) **-** a philosophical statement developed by William of Ockham, (1285–1347/49), a scholastic, that *Pluralitas non est ponenda sine necessitate;* "Plurality should not be assumed without necessity." The principle gives precedence to simplicity; of two competing theories, the simplest explanation of an entity is to be preferred. The principle is also expressed "Entities are not to be multiplied beyond necessity."

As a consequence of Ockham's Razor , theory should minimize unsupported assumptions.

Paradigm - a way of thinking, a conceptual world view.

Thomas Kuhn in The Structure of Scientific Revolution, defined the concept of "paradigm shift". Kuhn argues that scientific progress is not evolutionary, but rather is a "series of peaceful interludes punctuated by intellectually violent revolutions", and in those revolutions "one conceptual world view is replaced by another".

In science, a major example of a change in paradigms was the change from Scholasticism to Scientific Empiricism, roughly around AD 1600.
Scholasticism, which assumed that answers to questions about nature could be deduced from ancient texts and philosophical principals, gave way to the modern view of science where induction from accumulated evidence is (or should be) the underpinning of theories.
When Galileo was threatened by church authorities with torture for his claim that the earth orbits the sun, Galileo and his accusers were not only at odds about an astronomical theory.

They were also arguing, if unwittingly, because they were using two very different paradigms: the churchmen were using scholasticism, and Galileo “scientific empiricism ”.

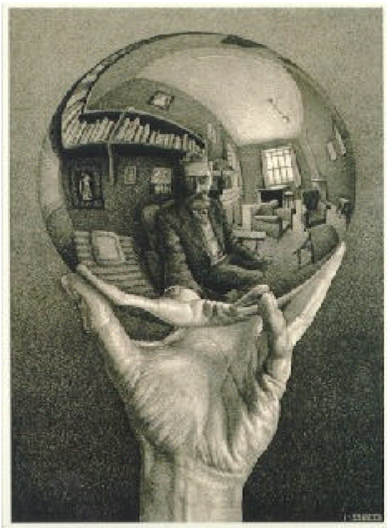
Parable – a short story told in order to make moral, religious or philosophical point.

Paradox –statement or condition that is strange because it involves two opposite facts or qualities, which appear impossible to be true at the same time (like rectangular circle or a barber who shaves all those who do not shave themselves).

Philosophy of Language In the end of the previous century, both Edmond Husserl and Gottlob Frege searched for such foundations of mathematics, which would allow understanding its subject matter without taking resort to psychology. Their ways of doing it parted; and each of them laid the foundation of an important philosophical school, Husserl of *phenomenology* and Frege of *analytic philosophy*.

Nowadays, however, the boundary between analytical philosophy and phenomenology seems to slowly fade away.

At the end…a little reflection on reflection…



Hand with Reflecting Sphere
Maurits Cornelis Escher