

# SCIENTIFIC KNOWLEDGE

Key questions here are:

- What do we mean by “scientific knowledge”?
- What other kinds of knowledge are there?
- How are they different from scientific knowledge
- Science involves theory with “LAWS” or “PRINCIPLES”. What are they?
- Do other forms of knowledge involve these? How are they different?
- Science involves experiment/observation. What are these?
- Why are experiments/observations important? In what way?
- Science involves theory – what is this? Is it more than hypothesis?
- How do theory & observation/experiment work together?
- What limitations are there to scientific enquiry & scientific knowledge?
- How trustworthy is scientific knowledge?
- Where do errors and uncertainty come from in science?
- Why is science always changing? Does this make it unreliable?
- What is the relation between scientific knowledge & the REAL WORLD?
- Which parts of science are the most reliable/well established? Why?
- Which parts are the least well established? Why?
- What is the importance of consensus in establishing scientific “truth”?
- Is there a “scientific method? What is it?

Also – how has our understanding of all of this changed as science has changed?

SOME USEFUL

HISTORY

(up to Modern Era)

# PLATO: the THEORY of “FORMS”

Plato (428-348 BC)



Plato’s “Theory of Forms” postulated a supra-sensible realm of “ideas” or “**Forms**”, beyond the world of appearances. These were abstractions from particular imperfect instances of things in the sensible world (eg., objects that were approximately circular), to the ‘real’ things, the universal ‘Forms’, like ‘**Circle**’, which could only be defined in the higher world of Forms.

From ideas about simple Forms like “Circle”, Plato went on to discuss higher forms, culminating in the highest of all: the “**Good**”.

Plato’s Cave allegory likens sense perceptions to the shadows of real objects cast upon the wall of a cave. The real objects, in this allegory, are the higher “Forms” of which we have no direct perception. True knowledge is knowledge of the archetypal forms themselves, which are real, eternal, & unchanging. Sense perception does not give us access to reality, but only to the impermanent world of perception.

In modern physics, the ultimate constituents of matter resemble Platonic Forms: one deals with Fields & Quantum Probability amplitudes. Ironically, these very abstract entities have been discovered by us, not by philosophical speculation or ratiocination, but instead by mathematical theory and experiment:

A theme underlying almost all of Greek philosophy is that beneath the disorganized, subjective, ever-changing world of experience must be something more fundamental; & that rational thinking enabled us to discover features of this underlying world.

# Aristotle: the Real World

Aristotle (384-322 BC)

**Aristotle classified and organized all of thought in a way so detailed, & perceptive, that modern education (school & university) is still designed along the lines he laid out.**

**Aristotle denied Plato's supra-sensible world- arguing for a single physical world. The fundamental "stuff" of this he called "substance". Any object in the world was described in terms of 4 'Causes':**

**Material Cause:** the matter from which it is made

**Formal Cause:** the form the matter takes

**Efficient Cause:** the influences/agencies acting to change the object

**Final Cause:** the purpose or goal of the object and of the changes

**Only one of these (the efficient cause) conforms to the modern use of the term 'cause'. For Aristotle, it was impossible to separate any of these causes from the others – it was meaningless to talk about 'form' or 'Forms" separately from the rest. The fundamental nature, including the very existence of an object, resulted from its 4 Causes.**

**Aristotle strongly emphasized empirical observation in biology. However his theories became rigid orthodoxy, and this blocked further progress. The influence of Aristotle reigned supreme in the West & Islamic worlds for 1800 yrs**

**GREEK SCIENCE:** This involved

- hugely sophisticated mathematics & logic
- sophisticated ideas about cosmology & astronomy
- no experiments (they were considered to be "not Natural")
- very advanced observational astronomy, with accurate measurements
- theories of astronomical observations that were very wrong-headed

# EMPIRICISM & 'EMPIRICAL PHILOSOPHY'

**Francis Bacon** was a politician of in the courts of Elisabeth I and James I. He felt strongly that to obtain knowledge of the world, one had to proceed by first organizing empirical facts/data, then formulating a theory, and then testing it by means of experiment, in an "**EMPIRICAL PHILOSOPHY**". He was very strongly influenced by **Galileo's** work.

He saw that this was an "**inductive**" process, i.e., that repeated tests of a theory gave inductive evidence for its truth. His ideas were very influential, first on the founders of the Royal Society in 1662 (particularly on **Newton**), and later on writers from **Voltaire** and **Kant** to **Charles Darwin**.

Bacon talked of "**Immaculate Perception**": 'All depends on keeping the eye steadily fixed upon the facts of nature & so receiving their images simply as they are.'

However....

Human understanding is "like a false mirror, which, receiving rays irregularly, distorts & discolours the nature of things by mingling its own nature with it".

And so....

**"The bee takes a middle course: it gathers its material from the flowers of the garden and of the field, but transforms and digests it by a power of its own.... Philosophy neither relies solely or chiefly on the powers of the mind, nor does it take the matter which it gathers from natural history & mechanical experiments & lay it up in the memory whole, as it finds it, but lays it up in the understanding altered and digested. Therefore from a closer and purer league between these two faculties, the experimental & the rational (such as has never yet been made), much may be hoped."**



Francis Bacon (1561-1626)

## HOW EMPIRICIST IDEAS EVOLVED

Empirical ideas found favour in the UK and the Netherlands, where they went hand in hand with very rapid scientific advances, eg.,

**Physics** (Newton, Huyghens, Halley, etc, ...)

**Biology** (Leeuwenhoek, Hooke, etc...)

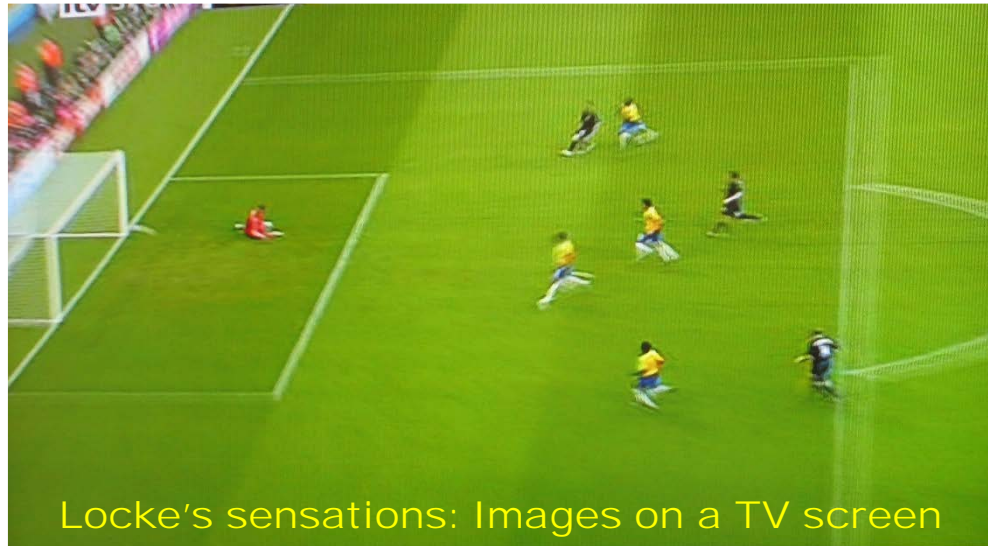
However in France & Germany a different attitude flourished, based on a "Rationalistic philosophy". The main proponents of this were **Descartes** & **Leibniz**. In philosophies such as these, the idea was to "derive" the most fundamental properties of the world using purely rational arguments.

---

John LOCKE (1632-1704): For Locke, all human knowledge comes from experience.

The mind is filled with "ideas" derived entirely from experience; ideas of 'sensation', coming via our senses, and of 'reflection', where the mind observes itself & its contents. Our knowledge of ideas is CERTAIN – it is direct.

Locke's 'mind' was like a TV screen, on which 'ideas' play. Locke assumed things existed in the real world (the 'primary qualities', independent of us) but we can't ever know these 'real things', only 'secondary qualities' from our senses. In Locke's theory one can say nothing about the relation between the 'ideas' & the things they represent. It makes, eg., hallucinations just as certain as any other experience.



Locke's sensations: Images on a TV screen

George BERKELEY (1685-1753): For Berkeley the only reality was what was conceived of by the mind – there was no “external world”:

*"No object exists apart from the mind; mind is therefore the deepest reality"*

Thus nothing exists apart from what is on the “TV screen”. In this view there is nothing except the sensations & ideas of the mind. To the argument that there must be some independent ‘reality’ which ‘supports’ or causes the qualities or sensations, Berkeley responds that this supporting reality is just the percipient mind. As Berkeley remarked: *“esse es percipi”* (to be is to be perceived). To those asking whether, eg., unperceived trees existed, he answered that they were being perceived by God.

David HUME (1711-1776): The far more profound work of Hume pointed out that one could make no logical or empirical distinction between “inner” & “outer” experience – just as we have no experience of any external world, we have none of the “self”, or even of the “mind”. All we have is a disconnected set of “impressions”; objects like the mind, soul, God, space & time, or features of these impressions like “causality”, are simply invented, & are “associations of impressions”. Thus, eg., we believe that A is caused by B because we frequently (or perhaps always) see them together.

The arguments of Hume were in the end very influential (and continue to be so – they strongly influenced later writers as diverse as **Einstein** and **Kant**). Hume made no attempt to answer the paradoxes created by his arguments – they were simply left by him as inevitable consequences of a purely empirical philosophy.

Thus undiluted empiricism leads initially to solipsism (Berkeley) but eventually to the result that no structural features of our experience can be taken for granted – none of them are *a priori* guaranteed (Hume).

These kinds of questions preoccupied many thinkers in other parts of the world as well. Thus, eg., the Chinese writer Zhuangzi (sometimes Zhuang Tzu) (c. 369-286 BC), from the same time as Aristotle, described the problem in the form of the "butterfly parable" (where he wakes from a dream in which he is a butterfly, to find he is a person – but then wonders which is dream and which is reality). This appears in the "Zhuangzi" text, which is part of the Tao Te Ching". However it was only in Europe and the Islamic world that there was a fusion between philosophy and science, in which these philosophical questions played a major role in the genesis of modern science.

## FURTHER DEVELOPMENTS in the WEST

Immanuel KANT (1724-1804): Kant tried to resolve the situation left by Hume by some very novel arguments. His ideas are complex – two key points are:

- (i) Kant argued again that experience was an amalgam of sensory input & a structure or pattern imposed on this input by mental faculties. However he further argued that there were certain key features of this pattern, without which experience as we know it would be in principle impossible. In particular
- we presuppose the ideas of space & time to give spatiotemporal structure
  - we presuppose ideas like "cause" and "substance"

These were for Kant "*categories of understanding*"; note that for philosophers ranging from Bacon to Kant, the term "understanding" meant what was in the mind before intellect and reasoning operated on it. The separation between "inner" and "outer" experience also arises as a necessary condition of all experience.

- (ii) Kant gave the name "phenomena" to the objects and processes which we discern in the world of experience. Thus, eg., space & time are such phenomena. He insisted however that not only could we not know the relationship between the phenomena of our experience & the "Noumenon", which was the "Thing in itself" (ie., the reality underlying the phenomena), but that we could NEVER know it.

All this set the stage for the modern view