



# What is Science?

A/PROF ALAN GIJSBERS

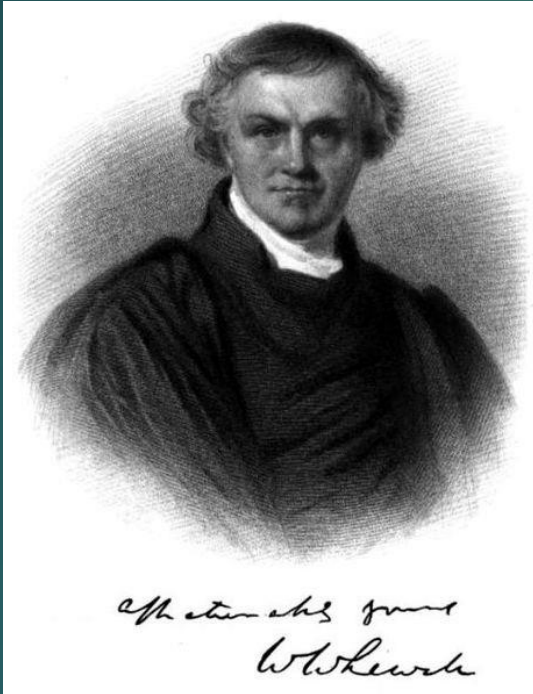
# Science

From Latin *scientia* = knowledge

1. a. The systematic study of man [sic] and his [sic] environment based on deductions and inferences which can be made and the general laws which can be formulated, from reproducible observations and measurements of events and parameters within the universe.  
  
b. The knowledge so obtained.
2. Systematic knowledge in general
3. A particular brand of knowledge.
4. Skill; proficiency

Macquarie Dictionary  
2<sup>nd</sup> Ed 1987.

# SCIENTISTS



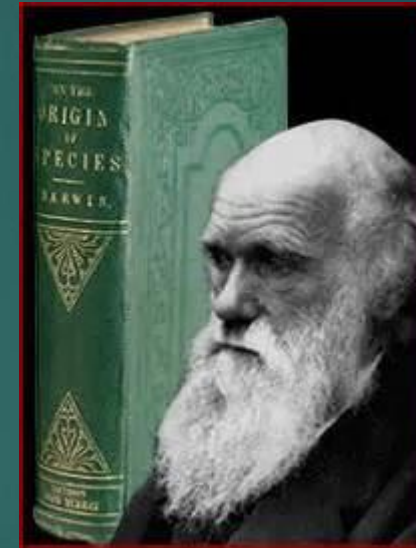
“As we cannot use physician for a cultivator of physics, I have called him a physicist. We need very much a name to describe a cultivator of science in general. I should incline to call him a Scientist. Thus we might say, that as an Artist is a Musician, Painter, or Poet, a Scientist is a Mathematician, Physicist, or Naturalist.”

Rev Dr William Whewell DD FRS FGS 1794-1866  
Master Trinity College Cambridge  
Author of a *Bridgewater Treatise*  
In *The Philosophy of the Inductive Sciences* 1840

# Inside page of Darwin's Origin of Species 1<sup>st</sup> Edition

"But with regard to the material world, we can at least go so far as this—we can perceive that events are brought about not by insulated interpositions of Divine power, exerted in each particular case, but by the establishment of general laws."

W. WHEWELL: *Bridgewater Treatise*.



Note: the mechanistic and naturalistic assumptions of this way of viewing the world.

# What is Science?

Theory under-determined by data

Ratio-empiric understanding of nature

- Francis Bacon

  - Ant


  - Spider

  - Bee

Induction towards laws

Facts and theory

Which is more powerful –  
facts or theory?



Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house.

Henri Poincaré (1854-1912). *Science and hypothesis*. 1905.

# What is Science?

“Only *art* can go some way towards making accessible, towards walking into some measure of communicability, the sheer inhuman otherness of matter...”

George Steiner *Real Presence* London Faber 1989

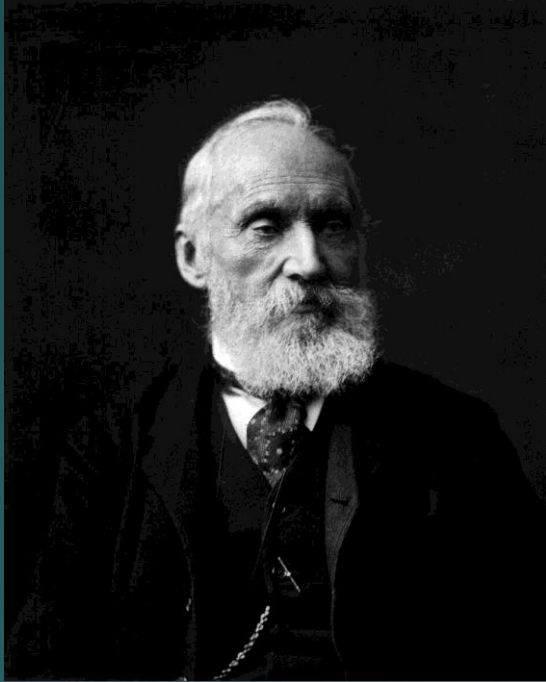
Quoted in surprise by Tom McLeish in *Faith and wisdom in science*.

OUP 2014:20.



# THE NATURE OF SCIENCE

## Measurement?



1824-1907

"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be."

Kelvin, Lord, 1883, 'Electrical Units of Measurement',  
*Popular Lectures and Addresses*, vol. 1, 1883-05-03,  
viewed 11 October 2011.

<http://zapatopi.net/kelvin/quotes/#meas>



# Understanding the sheer inhuman otherness of matter

- ▶ Reconstructions

$$E = mc^2$$

- ▶ Theories

$$F = ma$$

- ▶ Models

$$F = m_1 \times m_2 / (r^2)$$

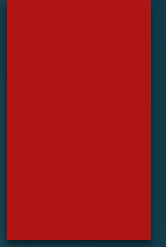
- ▶ Esp Mathematical models

- ▶ Hermeneutics – Narratives

# Standard Model of Subatomic Particles!

$$\begin{aligned}\mathcal{L} = & -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{8}\text{tr}(\mathbf{W}_{\mu\nu}\mathbf{W}^{\mu\nu}) - \frac{1}{2}\text{tr}(\mathbf{G}_{\mu\nu}\mathbf{G}^{\mu\nu}) & (\text{U(1), SU(2) and SU(3) gauge terms}) \\ & +(\bar{\nu}_L, \bar{e}_L) \tilde{\sigma}^\mu iD_\mu \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} + \bar{e}_R \sigma^\mu iD_\mu e_R + \bar{\nu}_R \sigma^\mu iD_\mu \nu_R + (\text{h.c.}) & (\text{lepton dynamical term}) \\ & -\frac{\sqrt{2}}{v} \left[ (\bar{\nu}_L, \bar{e}_L) \phi M^e e_R + \bar{e}_R \bar{M}^e \bar{\phi} \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \right] & (\text{electron, muon, tauon mass term}) \\ & -\frac{\sqrt{2}}{v} \left[ (-\bar{e}_L, \bar{\nu}_L) \phi^* M^\nu \nu_R + \bar{\nu}_R \bar{M}^\nu \phi^T \begin{pmatrix} -e_L \\ \nu_L \end{pmatrix} \right] & (\text{neutrino mass term}) \\ & +(\bar{u}_L, \bar{d}_L) \tilde{\sigma}^\mu iD_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} + \bar{u}_R \sigma^\mu iD_\mu u_R + \bar{d}_R \sigma^\mu iD_\mu d_R + (\text{h.c.}) & (\text{quark dynamical term}) \\ & -\frac{\sqrt{2}}{v} \left[ (\bar{u}_L, \bar{d}_L) \phi M^d d_R + \bar{d}_R \bar{M}^d \bar{\phi} \begin{pmatrix} u_L \\ d_L \end{pmatrix} \right] & (\text{down, strange, bottom mass term}) \\ & -\frac{\sqrt{2}}{v} \left[ (-\bar{d}_L, \bar{u}_L) \phi^* M^u u_R + \bar{u}_R \bar{M}^u \phi^T \begin{pmatrix} -d_L \\ u_L \end{pmatrix} \right] & (\text{up, charmed, top mass term}) \\ & +(\overline{D_\mu \phi}) D^\mu \phi - m_h^2 [\bar{\phi}\phi - v^2/2]^2/2v^2. & (\text{Higgs dynamical and mass term})\end{aligned}$$

# Who Understands?



# Evangelical Theology as a Science

Humanistic sciences also seek to apprehend a specific *object* and its environment in the manner *directed* by the object itself; they seek to understand it on its own terms and to speak of it along with all the implications of its *existence*. The word “theology” seems to signify a special science, a very special science, whose task is to apprehend, understand and speak of “God.”

Not just any God, but the God of the Gospel – Evangelical theology.

Barth K. Evangelical Theology: an introduction, Fontana 1965:9

# The Subject determines the methodology

Eg Evolution and geology as historic sciences

Eg Anatomy and histology as descriptive sciences

Eg Physics of complex fluids

Eg DNA double helix



# The Inductive Problem

- ▶ Once you have seen 100 white swans, another white swan....
- ▶ ....but a black swan!
- ▶ Hence the vogue for Popperian falsification

(Quickly discounted as too limited a description of the scientific process)



# THE NATURE OF SCIENCE

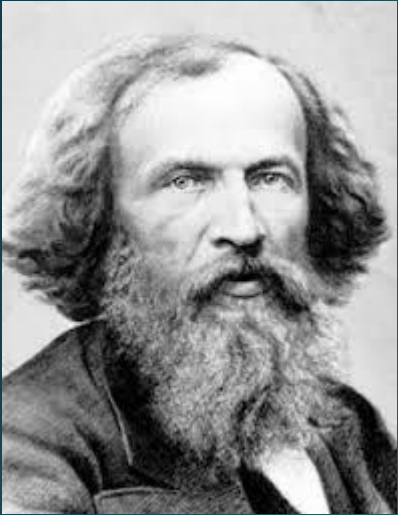


“All science is either physics  
or stamp-collecting”

Ernest Rutherford 1871-1937  
in JB Birks *Rutherford at Manchester* (1962)  
Quoted in *The Little Oxford Dictionary of Quotations* 1994p335:21



# classification



In chemistry –

"I saw in a dream a table where all elements fell into place as required. Awakening, I immediately wrote it down on a piece of paper, only in one place did a correction later seem necessary."

—Mendeleev, as quoted by Inostrantzev

<http://digitalcollections.library.cmu.edu/awweb/awarchive?type=file&item=33706>

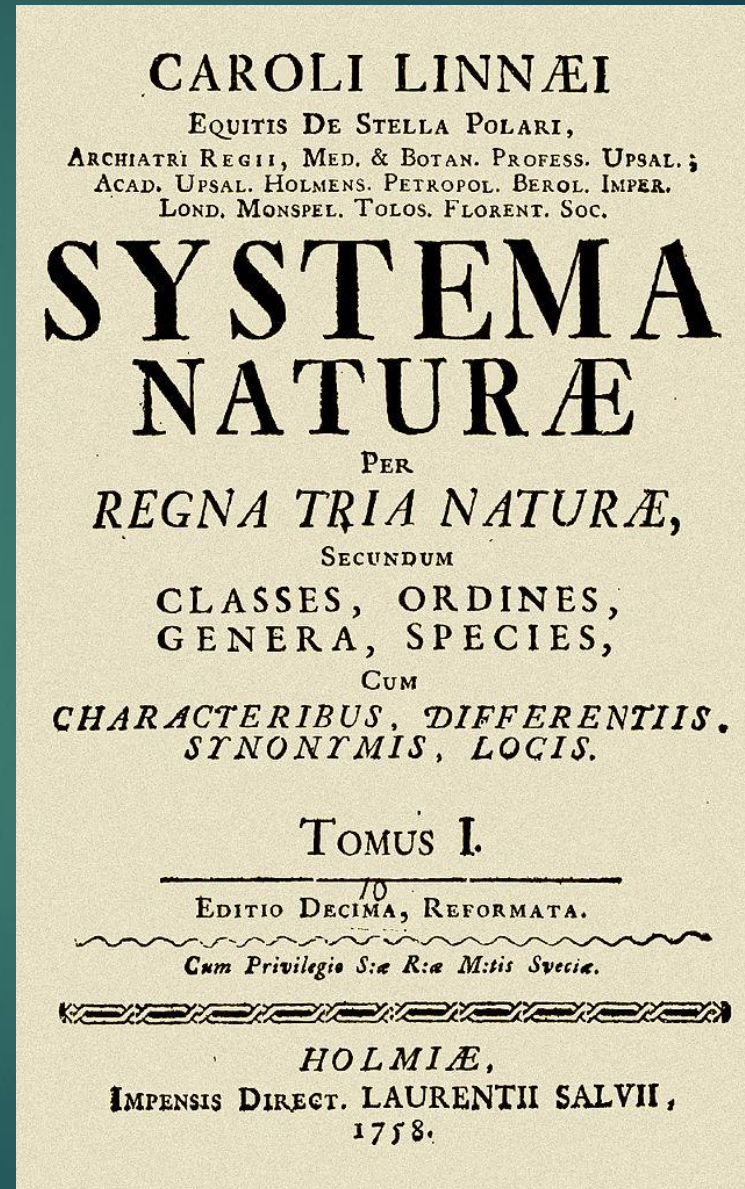
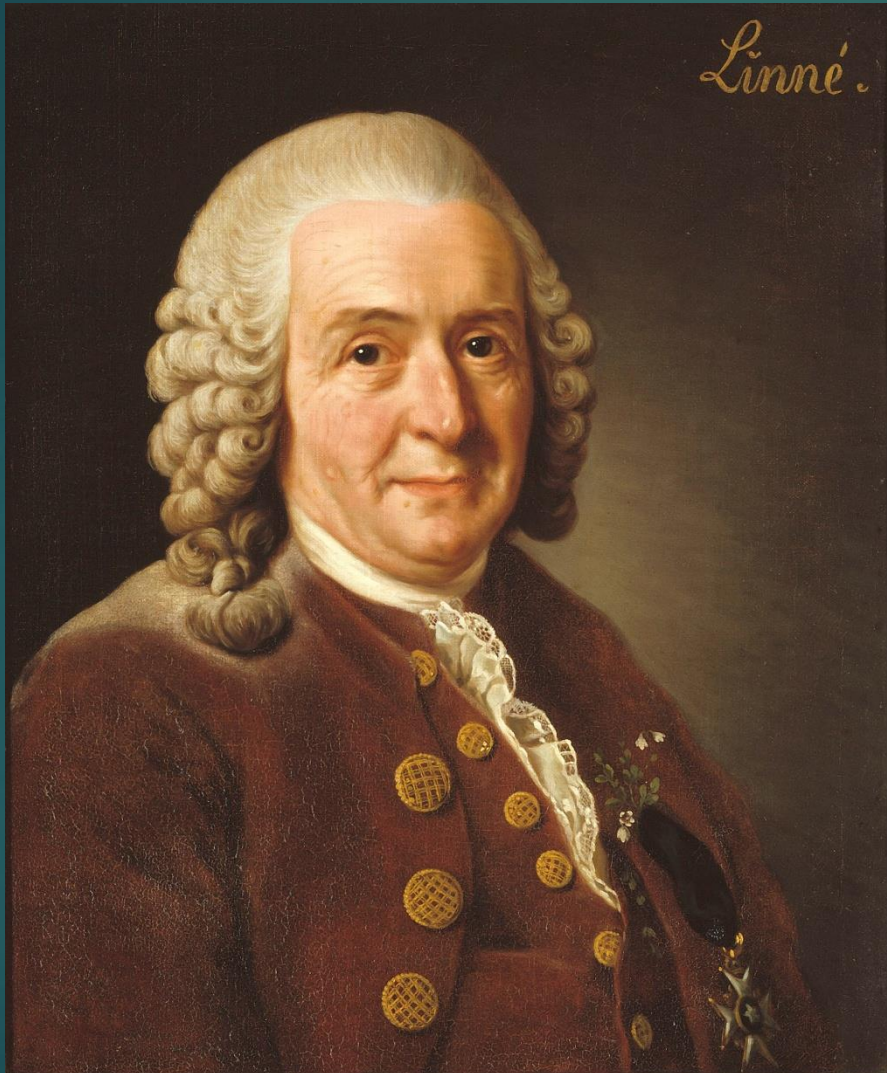
Dmitri  
Mendeleev  
1834-1907

## Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18									
1 <b>H</b> Hydrogen 1.008	Atomic # Symbol Name Atomic Mass																2 <b>He</b> Helium 4.0026									
3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.0122											5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.0064	8 <b>O</b> Oxygen 15.9994	9 <b>F</b> Fluorine 18.9984	10 <b>Ne</b> Neon 20.1797									
11 <b>Na</b> Sodium 22.98976928	12 <b>Mg</b> Magnesium 24.304											13 <b>Al</b> Aluminum 26.9815386	14 <b>Si</b> Silicon 28.0855	15 <b>P</b> Phosphorus 30.973762	16 <b>S</b> Sulfur 32.06	17 <b>Cl</b> Chlorine 35.453	18 <b>Ar</b> Argon 39.948									
<b>C</b> Solid		<b>Metals</b>										<b>Nonmetals</b>														
<b>Hg</b> Liquid		Alkali metals				Alkaline earth metals		Transition metals		Poor metals		Other nonmetals		Noble gases												
<b>He</b> Gas						Lanthanoids																				
<b>Rf</b> Unknown						Actinoids																				
19 <b>K</b> Potassium 39.0983	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.955912	22 <b>Ti</b> Titanium 47.88	23 <b>V</b> Vanadium 50.9415	24 <b>Cr</b> Chromium 51.9961	25 <b>Mn</b> Manganese 54.938045	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.933195	28 <b>Ni</b> Nickel 58.6934	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.64	33 <b>As</b> Arsenic 74.9216	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.798									
37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.90584	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.90638	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium (98.9062)	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.9055	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.8682	48 <b>Cd</b> Cadmium 112.411	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.710	51 <b>Sb</b> Antimony 121.757	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.905	54 <b>Xe</b> Xenon 131.29									
55 <b>Cs</b> Cesium 132.90545196	56 <b>Ba</b> Barium 137.327	57–71 Lanthanoids										72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.94788	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.222	78 <b>Pt</b> Platinum 195.084	79 <b>Au</b> Gold 196.966569	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.3833	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.9804	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222.0176)
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	89–103 Actinoids										104 <b>Rf</b> Rutherfordium (261)	105 <b>Db</b> Dubnium (262)	106 <b>Sg</b> Seaborgium (266)	107 <b>Bh</b> Bohrium (264)	108 <b>Hs</b> Hassium (277)	109 <b>Mt</b> Meitnerium (268)	110 <b>Ds</b> Darmstadtium (271)	111 <b>Rg</b> Roentgenium (272)	112 <b>Uub</b> Ununbium (285)	113 <b>Uut</b> Ununtrium (284)	114 <b>Uuq</b> Ununquadium (289)	115 <b>Uup</b> Ununpentium (288)	116 <b>Uuh</b> Ununhexium (292)	117 <b>Uus</b> Ununseptium (294)	118 <b>Uuo</b> Ununoctium (294)
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.																										
Design and Interface Copyright © 1997 Michael Dayah (michael@dayah.com). <a href="http://www.ptable.com/">http://www.ptable.com/</a>																										
57 <b>La</b> Lanthanum 138.90547	58 <b>Ce</b> Cerium 140.118	59 <b>Pr</b> Praseodymium 140.90768	60 <b>Nd</b> Neodymium 144.242	61 <b>Pm</b> Promethium (145)	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.964	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.92535	66 <b>Dy</b> Dysprosium 162.502	67 <b>Ho</b> Holmium 164.93032	68 <b>Er</b> Erbium 167.259	69 <b>Tm</b> Thulium 168.93421	70 <b>Yb</b> Ytterbium 173.054	71 <b>Lu</b> Lutetium 174.967												
89 <b>Ac</b> Actinium (227)	90 <b>Th</b> Thorium 232.0377	91 <b>Pa</b> Protactinium 231.03688	92 <b>U</b> Uranium 238.02891	93 <b>Np</b> Neptunium (237)	94 <b>Pu</b> Plutonium (244)	95 <b>Am</b> Americium (243)	96 <b>Cm</b> Curium (247)	97 <b>Bk</b> Berkelium (247)	98 <b>Cf</b> Californium (251)	99 <b>Es</b> Einsteinium (252)	100 <b>Fm</b> Fermium (257)	101 <b>Md</b> Mendelevium (258)	102 <b>No</b> Nobelium (259)	103 <b>Lr</b> Lawrencium (262)												



# classification







# The aim of classification

To find hidden patterns which then can help to answer the question:

“Why is it so?”

But before asking why it is so, we need to ask

“What is?”

These are iterations – not just a single set of observations and conclusions

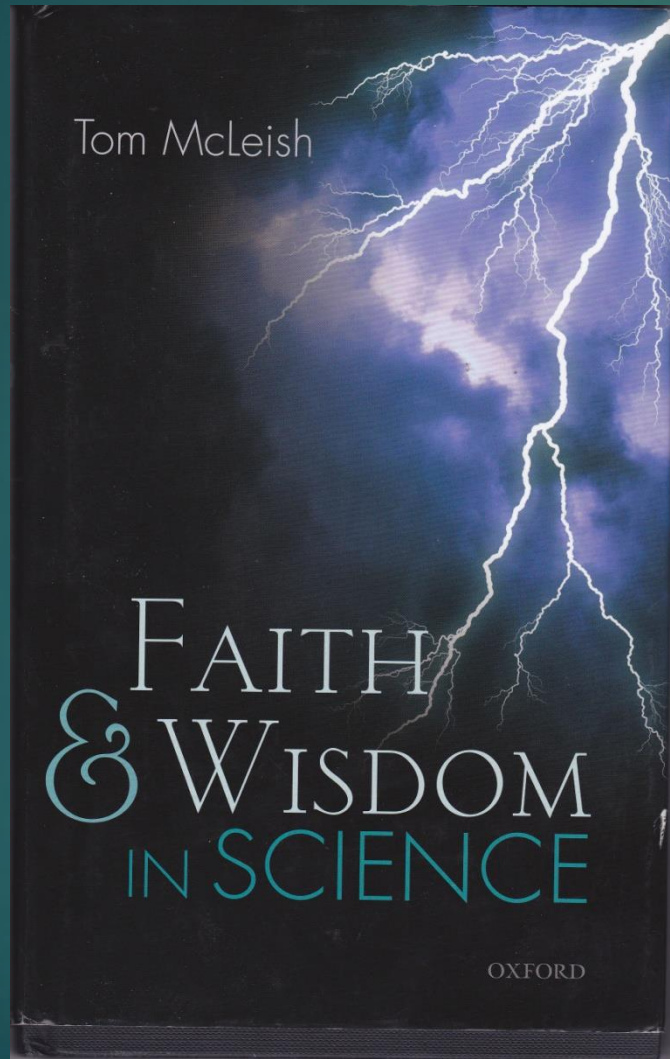
# Natural philosophy

- ▶ Philia (φιλία) love Sophia (σοφία) wisdom
- ▶ Hence natural philosophy: love of the wisdom of nature
- ▶ Natural philosophy can be traced back way before the enlightenment, the reformation, the renaissance, to Grenada (15<sup>th</sup> C) to the centres of learning of the Middle Ages, Bishop Grosseteste (13<sup>th</sup> C) Venerable Bede (9<sup>th</sup> C) Gregory of Nyssa (4<sup>th</sup> C), through to the New and then before that the First Testament...and of course to the Greeks, the Chinese and the Indians... All seeking to grapple with the mix of order and chaos in nature, and the miracle whereby we animate beings can understand the “sheer inhuman otherness of matter.”\*

\*Which for us medicos includes the challenging mystery of disease processes in humans.



# Natural philosophy



- ▶ [As a result of the survey of natural philosophy in history and scripture]
- ▶ “We have found no room for a clinical monolithic scientific methodology of established fact and proof to the exclusion of human values of doubt, faith and belief” (T. McLeish, Ch 7, 2014)
- ▶ Modern science is then replaced by **astute questions** within belief systems seeking to understand natural phenomena (God’s world) and to answer, “Why is it so?”

# Abraham Kaplan

Logic in use

vs

Reconstructed logic

*The Conduct of Inquiry: methodology for behavioural science.* 1964.  
Transaction Publishing edition new Brunswick NJ. 1998.



# By what criteria do I persuade my peers?

- ▶ Who are my peers?
  - ▶ Students – graduate
  - ▶ Researchers – persuade colleagues to commit money to my project
  - ▶ Publishers – peer reviewers
- ▶ All live within a plausibility structure

# Paradigm Shifts

- ▶ Reworking of current perceptions into a new paradigm
  - ▶ 16<sup>th</sup> Century cosmology
  - ▶ 20<sup>th</sup> Century physics
- ▶ What drives paradigm shifts?
- ▶ What causes the changed paradigm, plausibility structure?

# Paradigm Shifts

A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it.

Max Planck 1858-1947

*A scientific Autobiography* 1949.

Science advances one funeral at a time.

# Persuasion Beyond Peers

- ▶ Plausibility structures within disciplines
- ▶ Plausibility structures beyond science
  - ▶ Those in authority (especially funding authorities)
  - ▶ The wider public – the democratising of power

# Hypothesis Generating

Developing the 'logic' in use

By what creative imagination do we develop flourishing research questions?

What emotional trajectory goes on through the first flowering of a possible question to its testing, failed attempts before (hope against hope!) success?!!

“The mere formulation of a problem is far more essential than its solution, which may merely be a matter of mathematical or experimental skills.

To raise new questions, new possibilities,  
to regard or problems from a new angle, requires creative  
imagination and marks real advances in science

I am enough of an artist to draw freely upon my imagination.

Imagination is more important than knowledge. Knowledge is limited.

Imagination encircles the world.”



# Conclusions

- ▶ The subject determines the method
- ▶ In understanding the sheer inhuman otherness of matter, the key is an astute question
- ▶ That understanding needs to persuade your peers
- ▶ There is a wider public who also need persuasion



End