# What is Science?

A/PROF ALAN GIJSBERS

# Science

From Latin *scientia* = knowledge

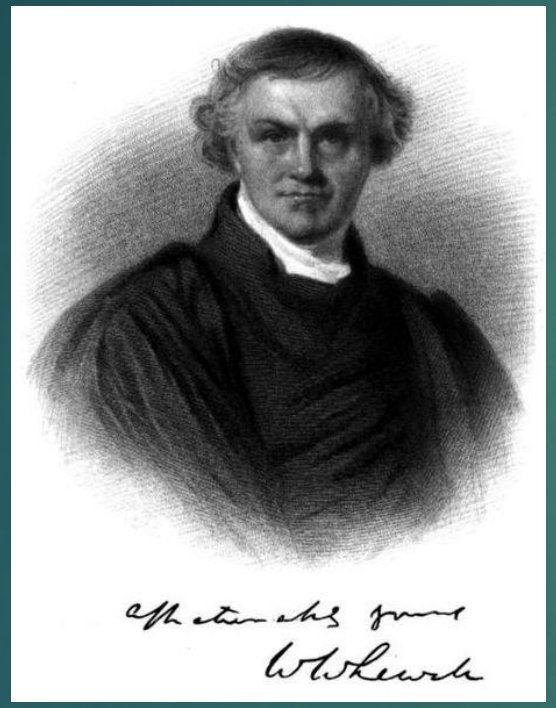
1. a. The systematic study of man [sic] and his [sic] environment based on deductions and inferences which can be made and the general laws which can be formulated, from reproducible observations and measurements of events and parameters within the universe.

   b. The knowledge so obtained.

2. Systematic knowledge in general
3. A particular brand of knowledge.
4. Skill; proficiency

Macquarie Dictionary
2nd Ed 1987.

# SCIENTISTS



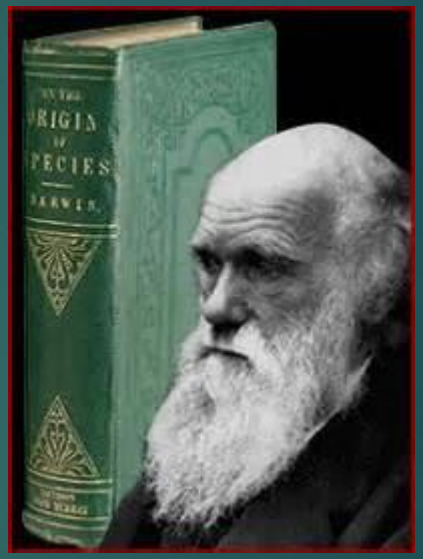
"As we cannot use physician for a cultivator of physics, I have called him a physicist. We need very much a name to describe a cultivator of science in general. I should incline to call him a Scientist. Thus we might say, that as an Artist is a Musician, Painter, or Poet, a Scientist is a Mathematician, 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 1st 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…"

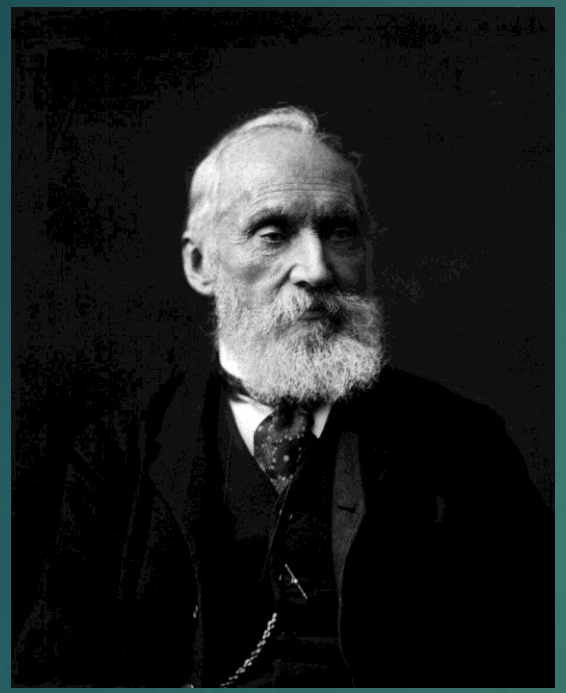
George Steiner *Real Presence* London Faber 1989

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
- Theories
- Models
  - Esp Mathematical models
- Hermeneutics – Narratives

$E = mc^2$

$F = ma$

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

# Standard Model of Subatomic Particles!

$$\mathcal{L} = -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{8}tr(\mathbf{W}_{\mu\nu}\mathbf{W}^{\mu\nu}) - \frac{1}{2}tr(\mathbf{G}_{\mu\nu}\mathbf{G}^{\mu\nu}) \quad \text{(U(1), SU(2) and SU(3) gauge terms)}$$

$$+(\bar{\nu}_L, \bar{e}_L)\,\tilde{\sigma}^\mu i D_\mu \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} + \bar{e}_R \sigma^\mu i D_\mu e_R + \bar{\nu}_R \sigma^\mu i D_\mu \nu_R + (\text{h.c.}) \quad \text{(lepton dynamical term)}$$

$$-\frac{\sqrt{2}}{v}\left[(\bar{\nu}_L, \bar{e}_L)\,\phi M^e e_R + \bar{e}_R \bar{M}^e \bar{\phi} \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}\right] \quad \text{(electron, muon, tauon mass term)}$$

$$-\frac{\sqrt{2}}{v}\left[(-\bar{e}_L, \bar{\nu}_L)\,\phi^* M^\nu \nu_R + \bar{\nu}_R \bar{M}^\nu \phi^T \begin{pmatrix} -e_L \\ \nu_L \end{pmatrix}\right] \quad \text{(neutrino mass term)}$$

$$+(\bar{u}_L, \bar{d}_L)\,\tilde{\sigma}^\mu i D_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} + \bar{u}_R \sigma^\mu i D_\mu u_R + \bar{d}_R \sigma^\mu i D_\mu d_R + (\text{h.c.}) \quad \text{(quark dynamical term)}$$

$$-\frac{\sqrt{2}}{v}\left[(\bar{u}_L, \bar{d}_L)\,\phi M^d d_R + \bar{d}_R \bar{M}^d \bar{\phi} \begin{pmatrix} u_L \\ d_L \end{pmatrix}\right] \quad \text{(down, strange, bottom mass term)}$$

$$-\frac{\sqrt{2}}{v}\left[(-\bar{d}_L, \bar{u}_L)\,\phi^* M^u u_R + \bar{u}_R \bar{M}^u \phi^T \begin{pmatrix} -d_L \\ u_L \end{pmatrix}\right] \quad \text{(up, charmed, top mass term)}$$

$$+\overline{(D_\mu \phi)} D^\mu \phi - m_h^2[\bar{\phi}\phi - v^2/2]^2/2v^2. \quad \text{(Higgs dynamical and mass term)}$$

# 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

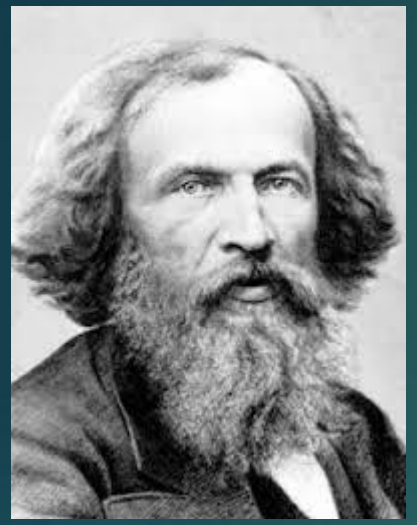
(Quickly discounted as too limited a description of the scientific process)

# 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



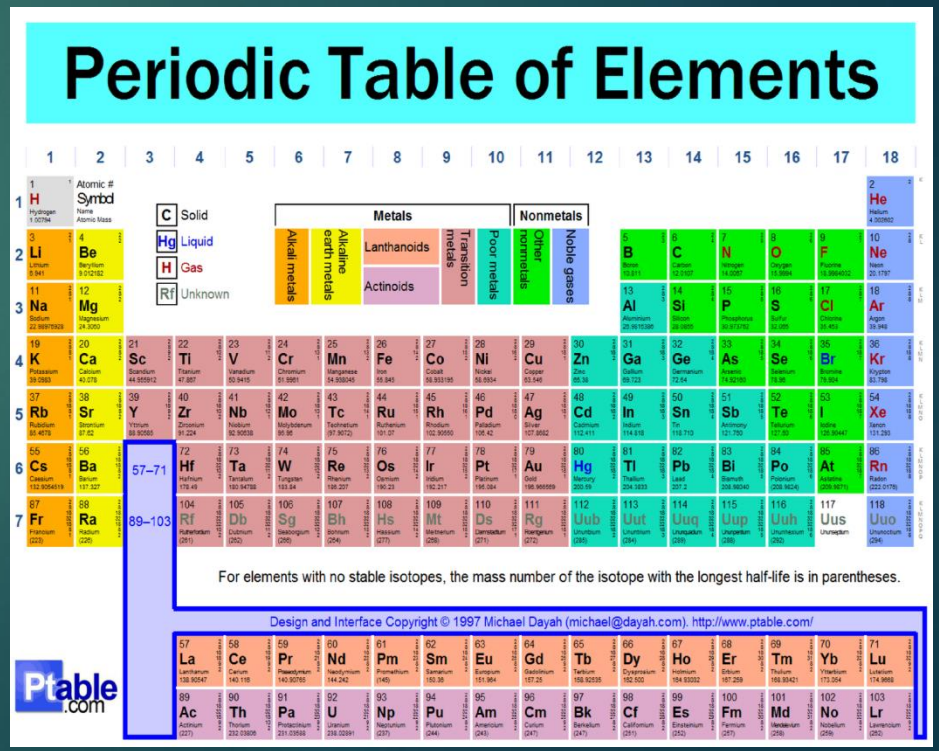
Dmitri Mendeleev
1834-1907

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



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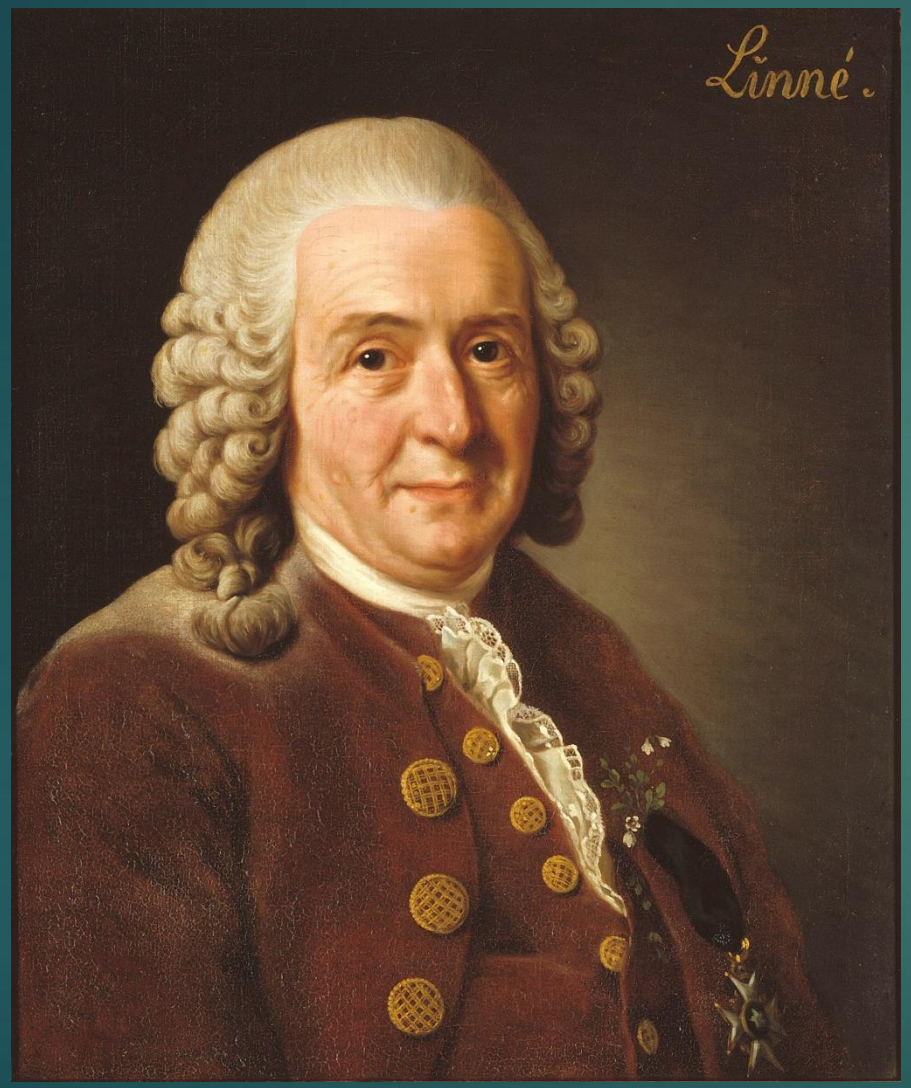



CAROLI LINNÆI

EQUITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. & BOTAN. PROFESS. UPSAL.;
ACAD. UPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.

# SYSTEMA NATURÆ

PER

*REGNA TRIA NATURÆ,*

SECUNDUM

CLASSES, ORDINES,
GENERA, SPECIES,

CUM

*CHARACTERIBUS, DIFFERENTIIS,*
*SYNONYMIS, LOCIS.*

TOMUS I.

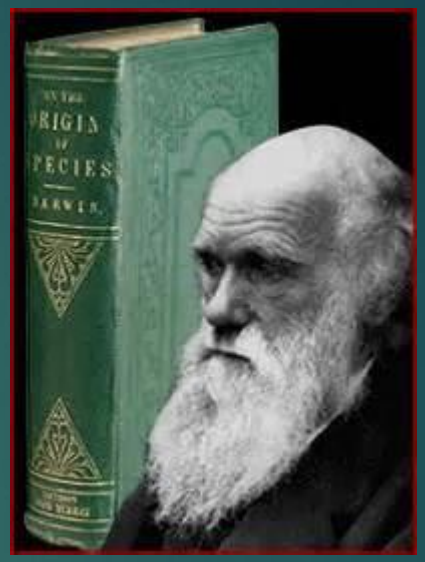
EDITIO DECIMA, REFORMATA.

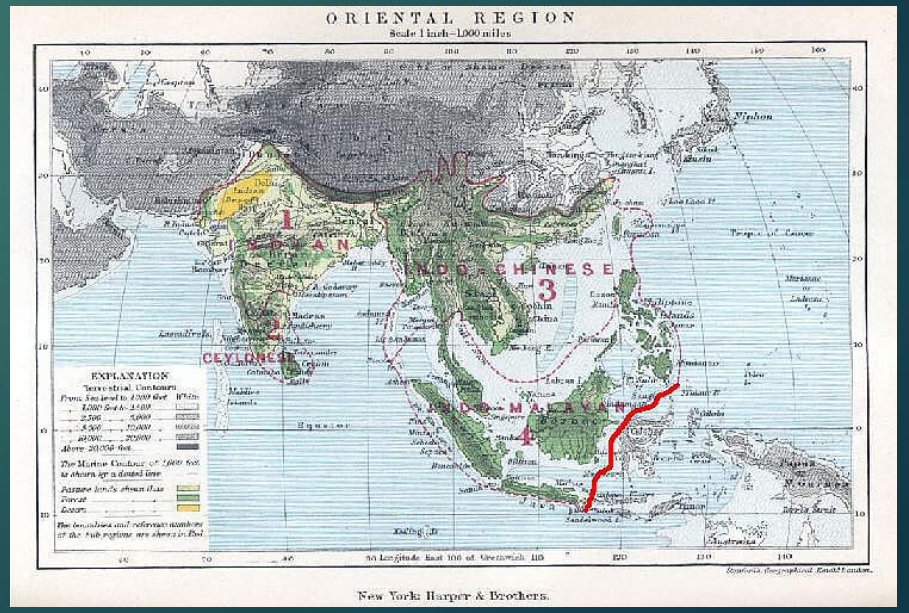
*Cum Privilegio S:æ R:æ M:tis Sveciæ.*

*HOLMIÆ,*
IMPENSIS DIRECT. LAURENTII SALVII,
1758.

# classification

Source: Project Gutenberg, commons upload on 5 June 2006 via Wikimedia Commons





# 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?"

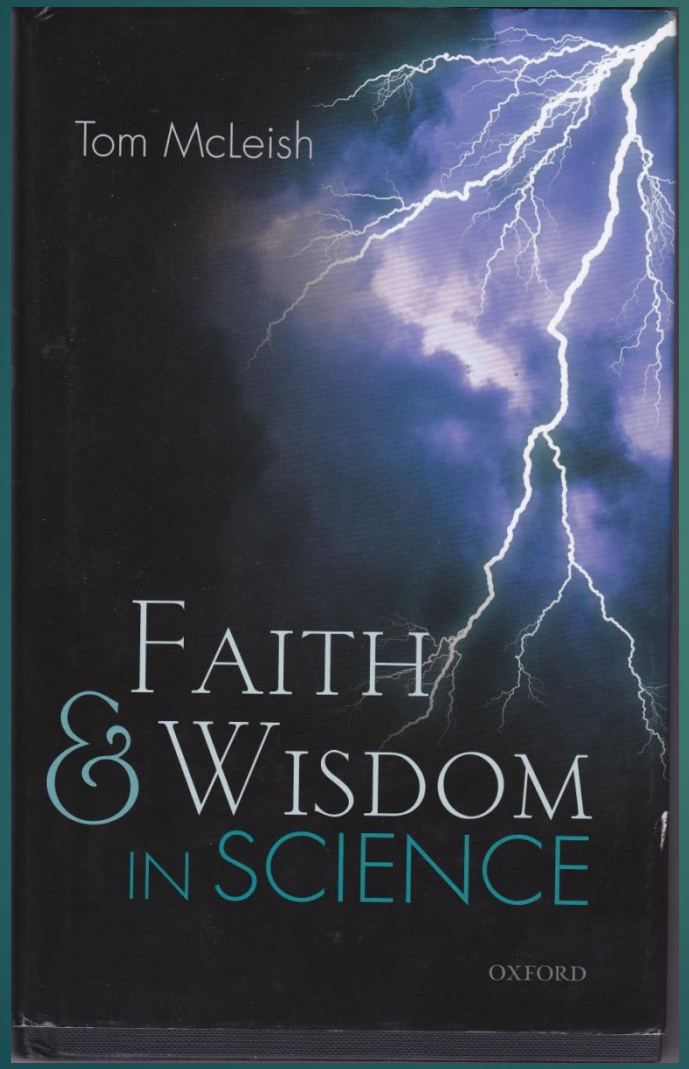
These are iterations – not just a single set of observations and conclusions

# Natural philosophy

- Philia (φιλια) love  Sophia (σοφια) 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 (15th C) to the centres of learning of the Middle Ages, Bishop Grosseteste (13th C) Venerable Bede (9th C) Gregory of Nyssa (4th 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
  - 16th Century cosmology
  - 20th 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

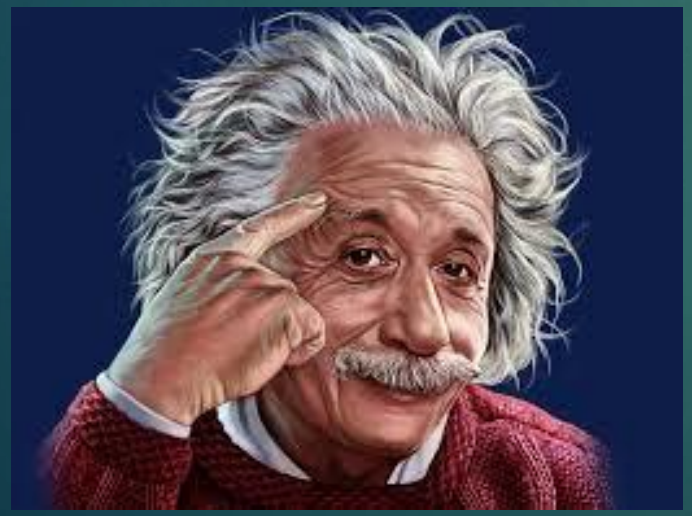
By what creative imagination do we develop flourishing research questions?

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