

**BEYOND
CRYSTALS**
The Dialectic
of Materials and
Information



Dualities

(Each duality has its particular characteristics for transformation back and forth)

Material / Information

Practice / Theory

Wave / Particle

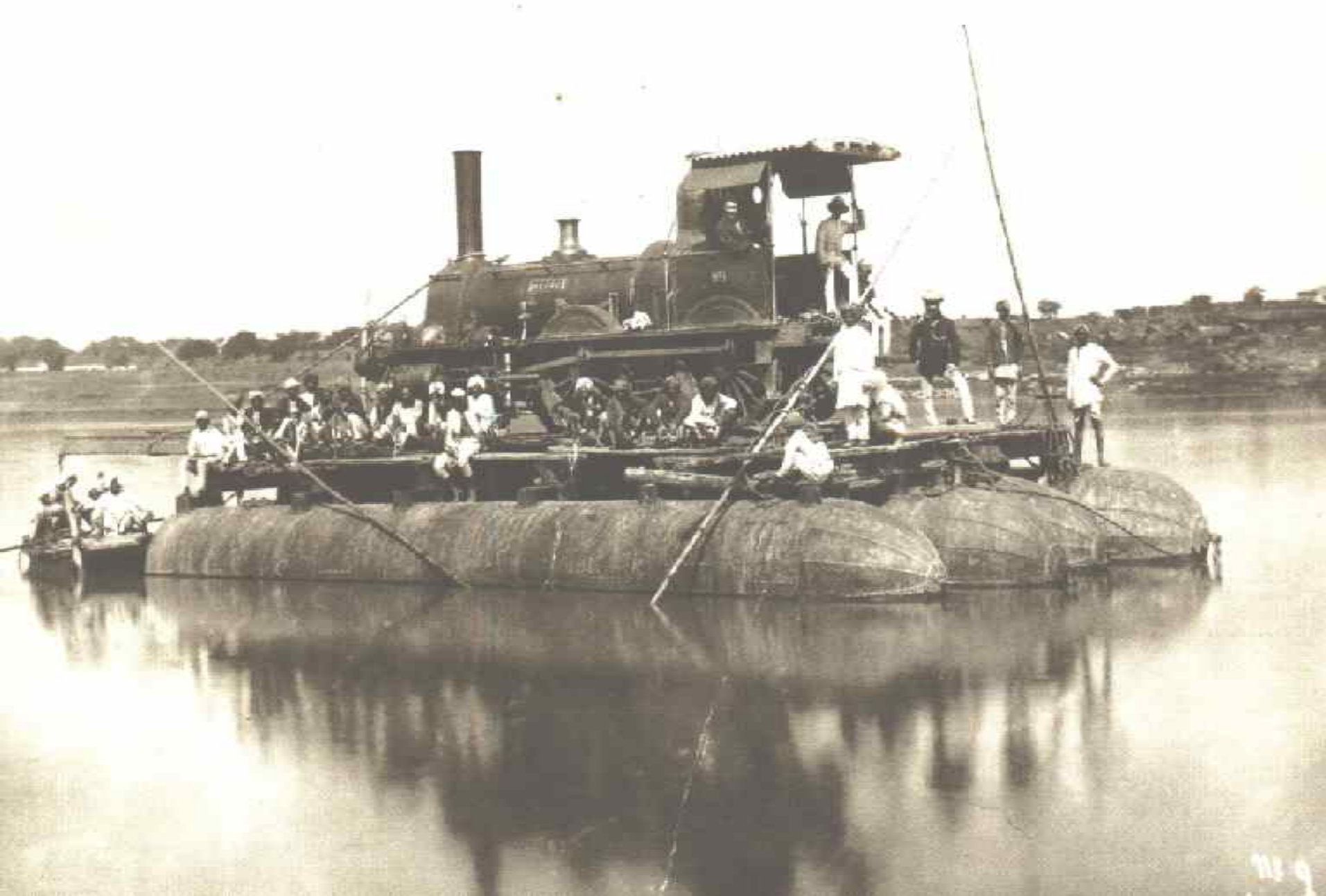
Fourier transform

Projection (reversed by generalised inverse matrix)

Real situation / Language description

Translation (Russian/English language)

Phenotype / genotype (Protein / DNA)



Test of theory is practice. A good theory has Survival value.

Physical World

Arrangements of atoms

Superposition of waves

Interacting systems

Particle

Information structures

Mathematics

Language

Data structures
(both dynamic and static)

Wave function Ψ

(“the unreasonable effectiveness of mathematics” -
Eugene Wigner 1960)

Orthodox (“classical”) crystallography

- equilibrium structures
- ‘absolute’ identity of units and of surroundings
- long range order, 230 Space groups

Beyond crystals

- dissipative structures, energy fluxes, **SYSTEMS**
- local energy minima located by information (address)
- curved structures; **hierarchic structures**; process
- local order; local symmetries; approx. identity

Observation of structure (static and dynamic)

Orthodox crystallography

- X-ray crystal structure analysis (XRD)

Generalised structure analysis

- Electron microscopy (and AFM developments)

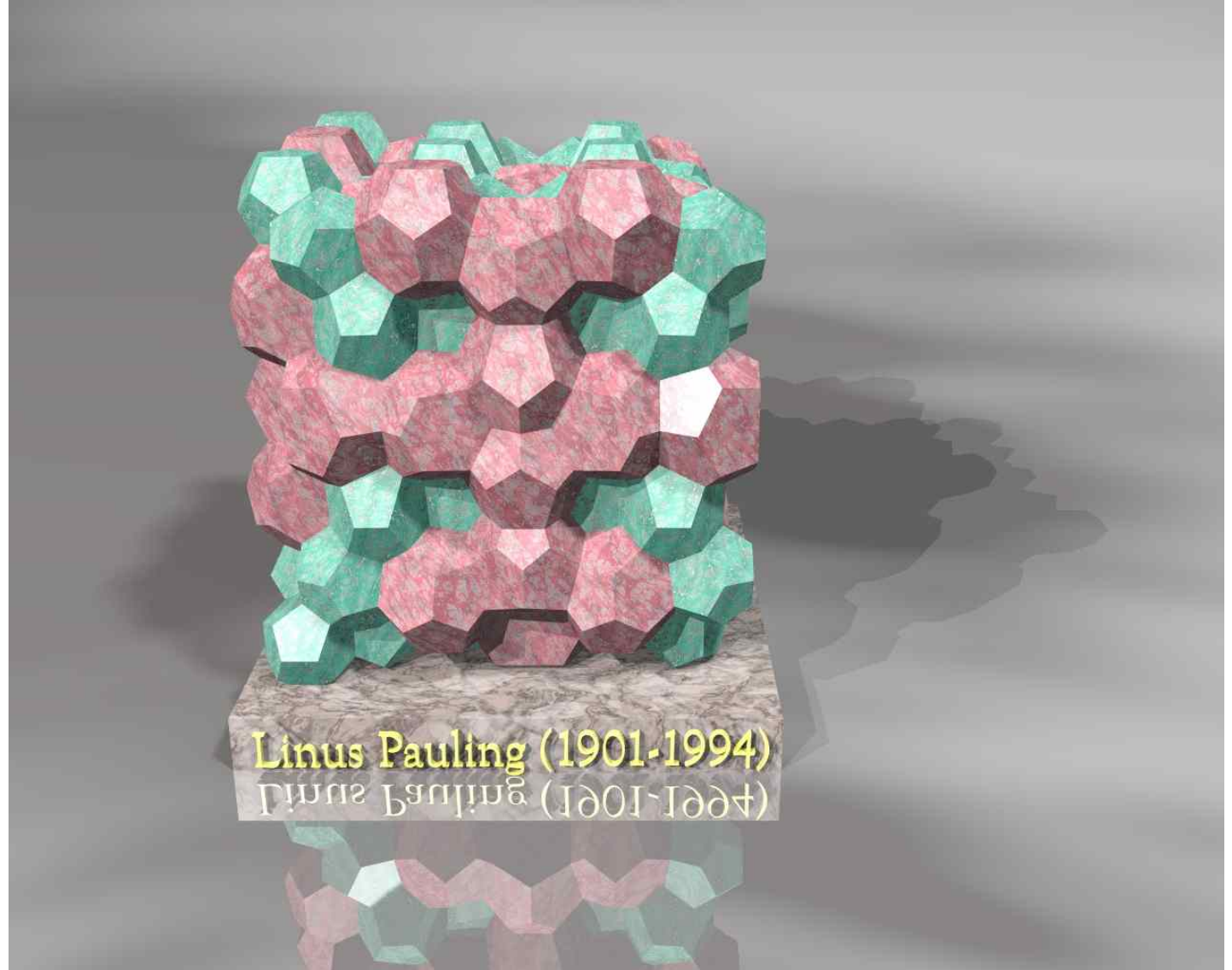
(Resistance to novelty: resistance of microscopists to Abbe's theory: late recognition of Zernike's phase contrast microscopy as extending Abbe's theories. Resistance of XRD people to use of phases of scattered radiation).

A CRYSTAL

is a structure, the description of which is very much smaller than the structure itself.

(Most general definition)

(The International Union of Crystallography give a retrograde definition of a crystal as a structure giving a diffraction pattern with discrete points. That is, with periodicities) This characterises a structure by the method for observing it and imposes the characteristic limitations of the observer.



Structure of Mg₃₂(Al,Zn)₄₉ found by Pauling's "stochastic" method but where is the information ? Is there a "gene" ?

Aspects of the physical world may be represented as mathematics.

Informational structures may be represented as physical structures.

Manipulation in the physical world - trial and error, experiment, measurement.

Manipulation in the informational world
– discussion, computation, “data mining”. (e.g. If a set of assumptions leads to a contradiction then something is wrong. - A. Turing and the Enigma machine)

“DIALECTICS”

the emergence of truth from the confrontation of opposing arguments

- resolution with critical experiment (following Francis Bacon) as the judge.



DIALECTIC = Method used by Ancient Greeks, Jesuits, G. F. W. Hegel, Marx and Engels, and doctorate examiners, Proposer v. *Advocatus diaboli*, leads to a solution at a local optimum.

Dialectical Development

Real Space

Representational Space

MATERIAL

↔

INFORMATION

→

Projection

→

↑

↓

Comparison

Manipulation

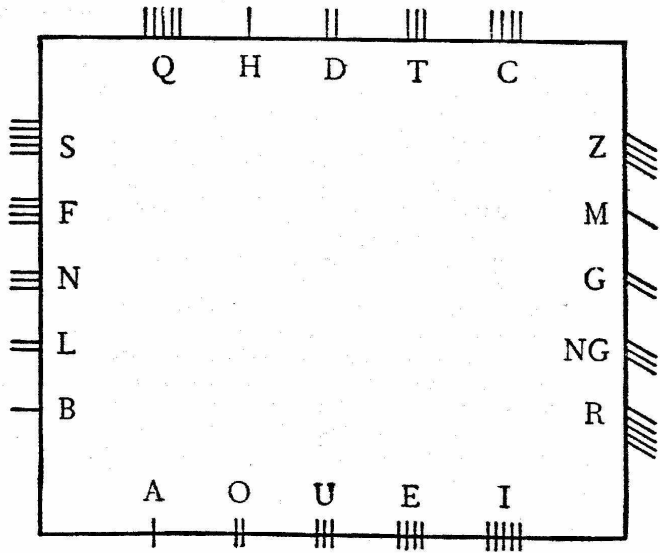
↑

↓

←

Restoration

←

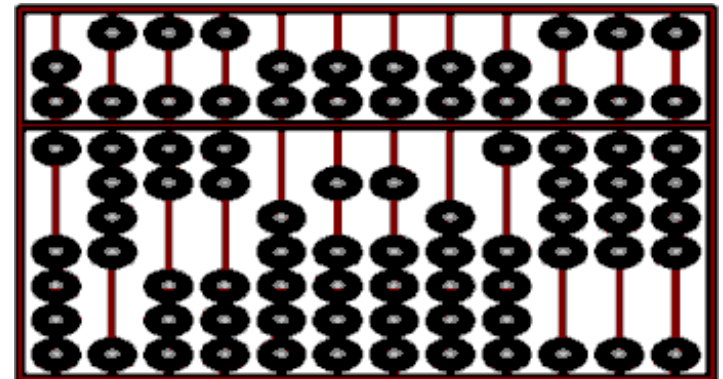


Informational structures:

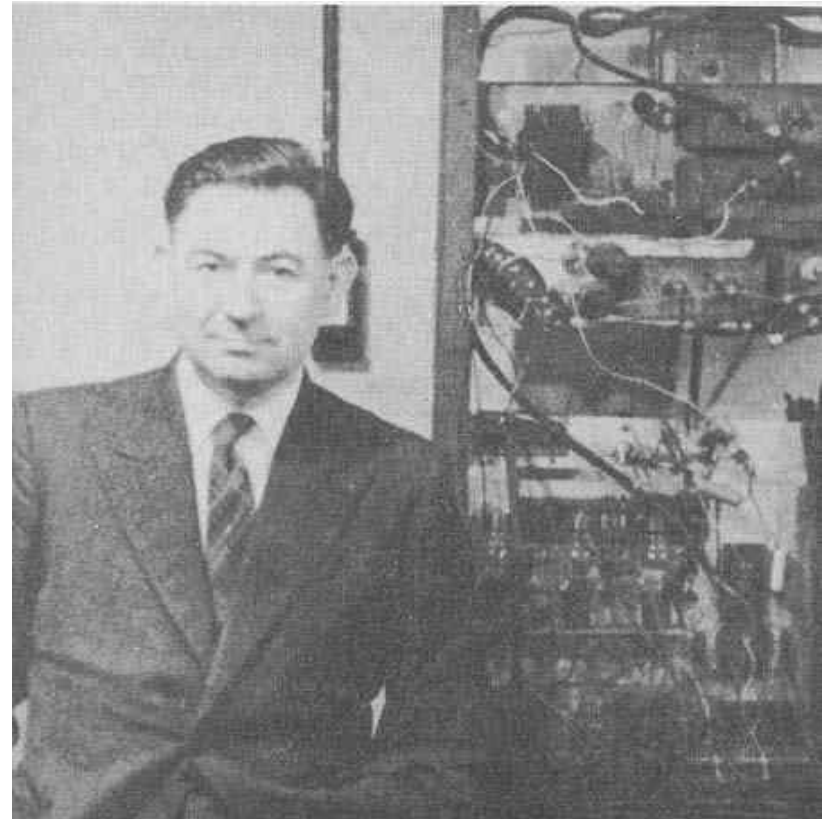
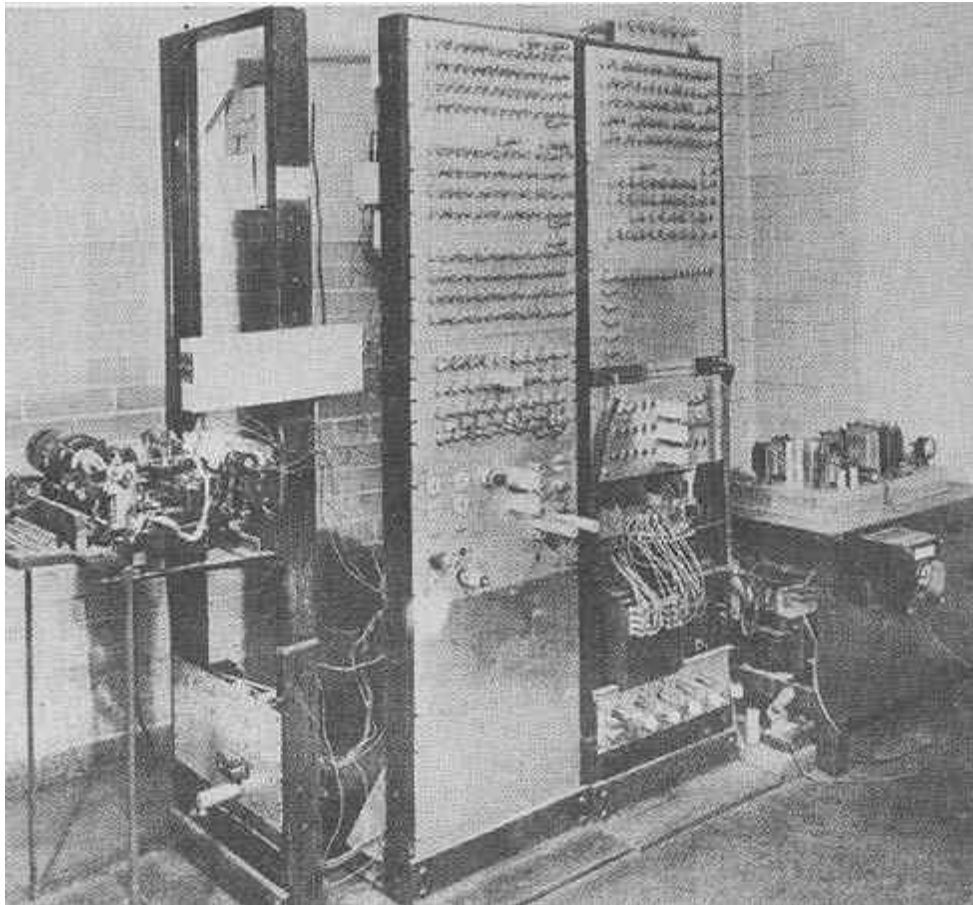
(above) the Ogham alphabet.
(Ireland 9th cent.)(economy!)

(up. right) Mayan inscription
from Mexico. (redundancy!)

Abacus - metastable structure



A.D.Booth and his machine
at Birkbeck College, London
about 1952



“The Computer”
- for the manipulation of
information and the
control of machinery

Energy landscapes

Waddington's epigenetic landscape

N-dimensional Configuration space
(with increasing complexity a phase diagram becomes useless and is replaced by an address in configuration space).

Morse characterisation of its topology.

How to search for solutions:

EVOLUTION has evolved because it is the best system for exploring configuration space. It requires a separation between *structure* and *description*, which engage in a dialogue.

The GENETIC ALGORITHM. (John Holland)(the mathematical equivalent of biological evolution)

but, will quantum computing go straight to the answer ?

DARWINIAN EVOLUTION – in information space

“How do you get so many good ideas,
Dr. Pauling ?” - “I just take all my ideas
and throw away the bad ones”.

.

Curved surfaces (excluded by periodicity)

- two sides, which may be structurally different
- importance of micelles defining **inside** and **outside**
- curvature components

bend, twist, splay from local forces

- Gaussian curvature $\mathbf{k}_1 \mathbf{k}_2$ ($k = 1/(\text{radius of curvature})$)
- Mean curvature $(\mathbf{k}_1 + \mathbf{k}_2)/2$
- Topology (Euler characteristic, etc.)

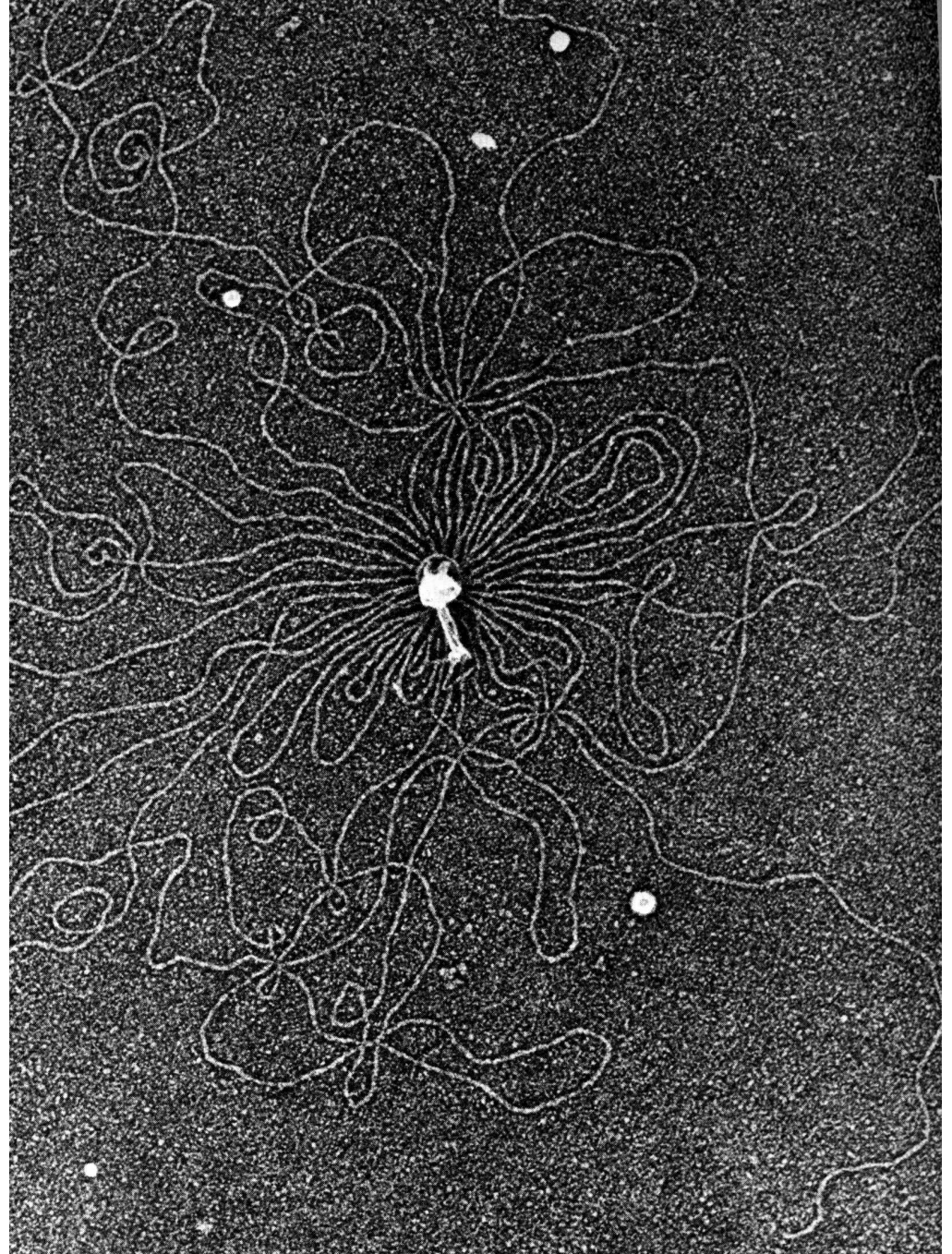
Living materials

- symbiotic and hierarchic mixture of structural and informational components
- flux of energy and material → structuration
- an INSIDE and an OUTSIDE (Vesicles)
- “It is not birth, marriage, or death, but **gastrulation**, which is truly the most important time in your life.” (Lewis Wolpert, 1986) (= local control of curvature leads to morphogenesis.)

A. Kleinschmidt
(1962)

T4 bacteriophage
(with negative staining)

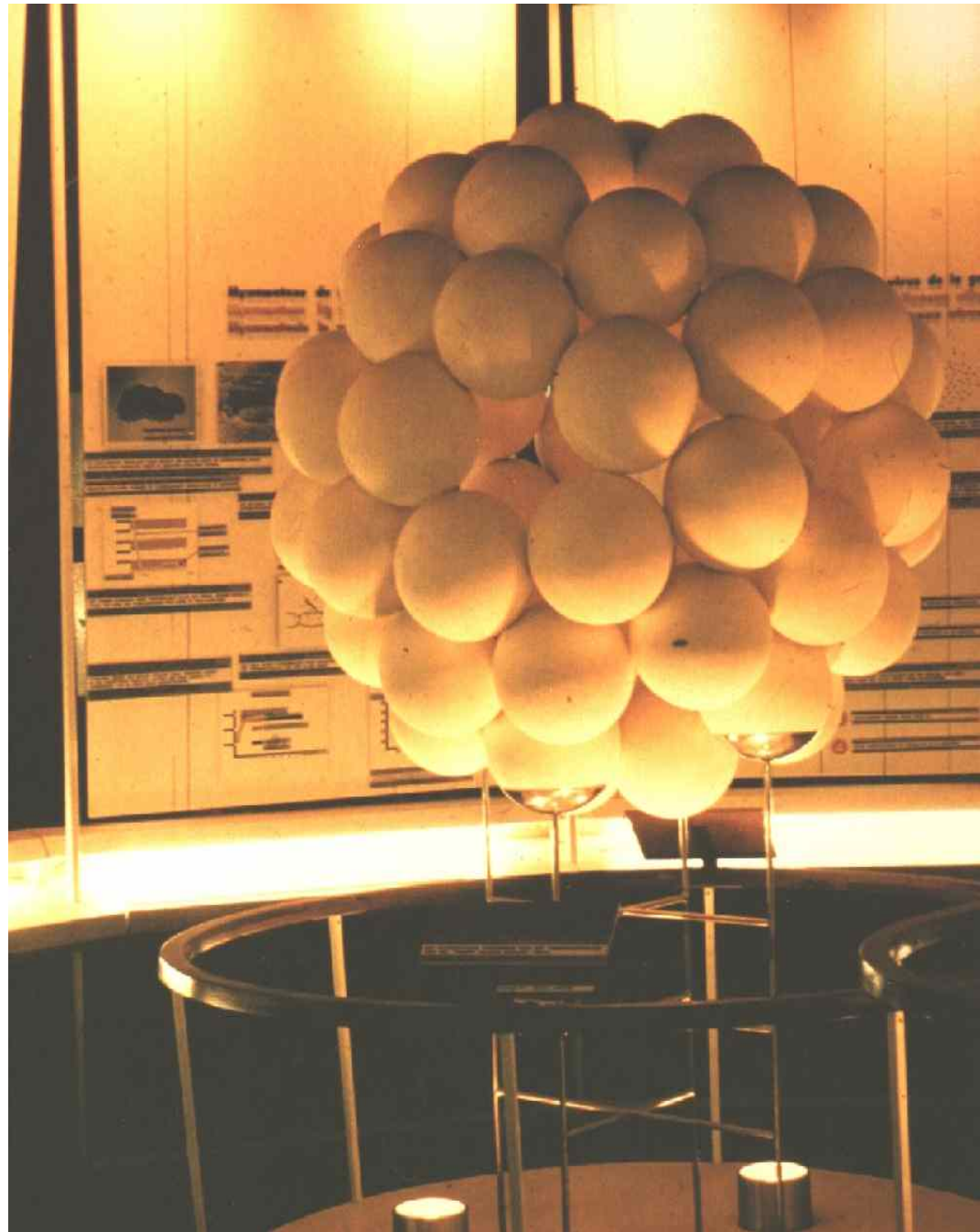
The first visualisation of
an informational structure



Poliomyelitis virus particle

R. Franklin and A.
Klug, 1958

(model by John
Ernest) (A virus
represents a
short circuit
down an energy
gradient in the
biochemical
pathways space.)

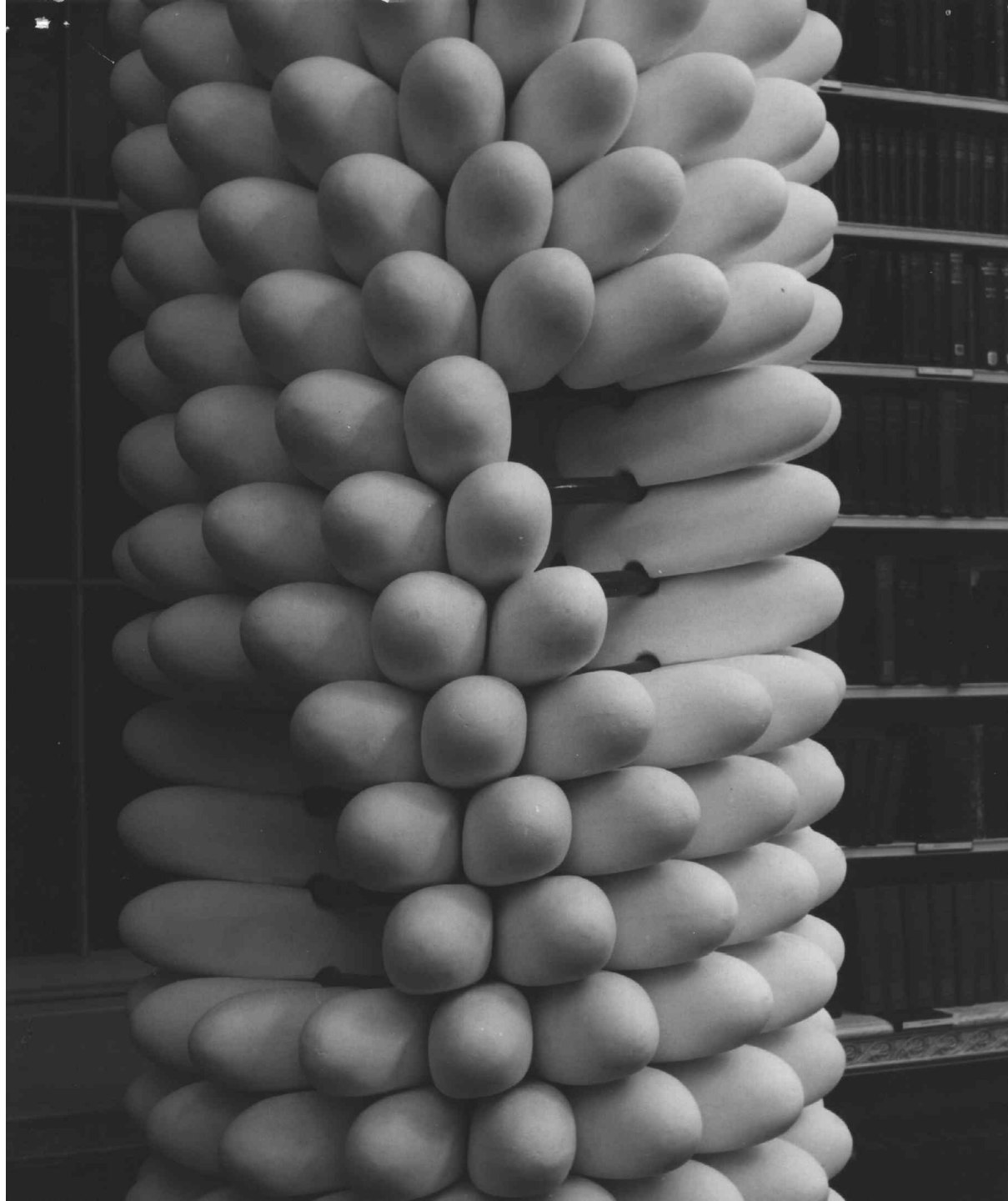


**Tobacco
Mosaic Virus
[TMV]**

(Rosalind Franklin,
Aaron Klug, Ken
Holmes)

(Model by John
Ernest 1958)

(The informational
sub-structure has
also a structural
role.)



What information is there in the inorganic structure?

- Factor analysis of data banks
- Place in phase diagram
- Conformational entropy ? W. H. Zurek ?
- Algorithmic Complexity
- Description of structure
- Cellular automaton as a generalisation of local interactions in an energy flux
- De-localised information

Systems

- Belousov-Zhabotinski reactions
- Cellular automata (Wolfram)
- Chaotic solutions
- Viruses
- Craig Venter and “Synthia”
- Robotics (nanoscale upwards)
- Self-reproduction (v. Neumann)(separate reproduction of material and of program)

Freeman Dyson's Vision

(New York Review of Books 19 July 2007)

(N. Goldenfield and C. Woese, Nature, **445**, 369, (25 Jan. 2007))

Dialogue of material/information is at a new stage. Nanotechnology

Both information and material are transmitted and transformed with unprecedented speed through the actions of human beings. Perhaps even, there may be eventually no other species.

Human culture is transmitted as open source, non-Darwinian software.

Three stages over 4 billion years

1) Initial period of 'life'

Archaeo-bacteria with common gene pool
(rapid 'horizontal gene transfer')

("Primitive Communism")

2) Sequestration of genes in individuals.

Slow Darwinian evolution.

("Private intellectual property")

3) Modern synthetic biology. Control of genes and proteins. Rapid production of novel organisms in biological eco-systems

("Utopian communism ? Totalitarianism ? Global capitalism ? ")

The Quantum Substrate

– perhaps solution and synthesis

- Observer subsumed into landscape ?
- Evolution of self-consciousness ?
- Wave/particle duality resolved ?
- Artificial intelligence ?
- Quantum computation, (A. Zeilinger) ?



Now St. Petersburg, August 2007 !