HOPOS

The History of the Philosophy of Science from the Scientific Revolution to 1900

(PHIL/HPS 93812)

Don Howard
Spring 2024

Isaac Newton

Emile Meyerson

Don Howard was mentioned in a **post**.

Wayne Myrvold
February 23 ·

MC Hammer is now tweeting Don Howard.

MC HAMMER
@MCHammer

Albert Einstein as a Philosopher of Science

Einstein's philosophical habit of mind, cultivated by undergraduate training and lifelong dialogue, had a profound effect on the way he did physics.

Don A. Howard

Nowadays, explicit engagement with the philosophy of science plays almost no role in the training of physicists or in physics research. What little the student learns

Thornton, Einstein wrote in a contribution to *Albert Einstein: Philosopher-Scientist*, "The reciprocal relationship of epistemology and science is of noteworthy kind. They ar

He had been saying the same thing for nearly 30 years. He knew from his experience at the forefront of the revolutions in early 20th-century physics that having cultivated a philosophical habit of mind had made him a better physicist.

A few years after his letter to

You, Stathis Psillos, Carl Hoefer and 31 others 12 Comments

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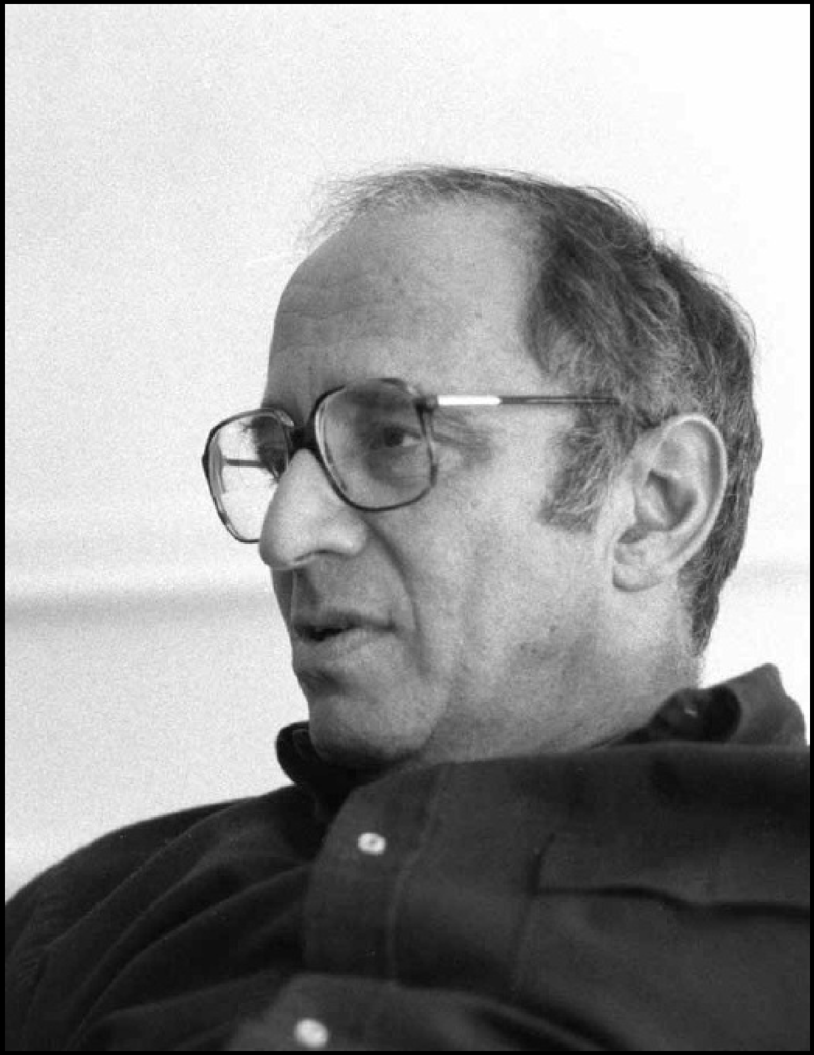
The History of HOPOS

The “Oppositional” Narrative

The neo-Positivist orthodoxy that dominated the field in the 1950s and 1960s caused the divorce of history and philosophy of science, pushing those who championed integration to the margins of the discipline.

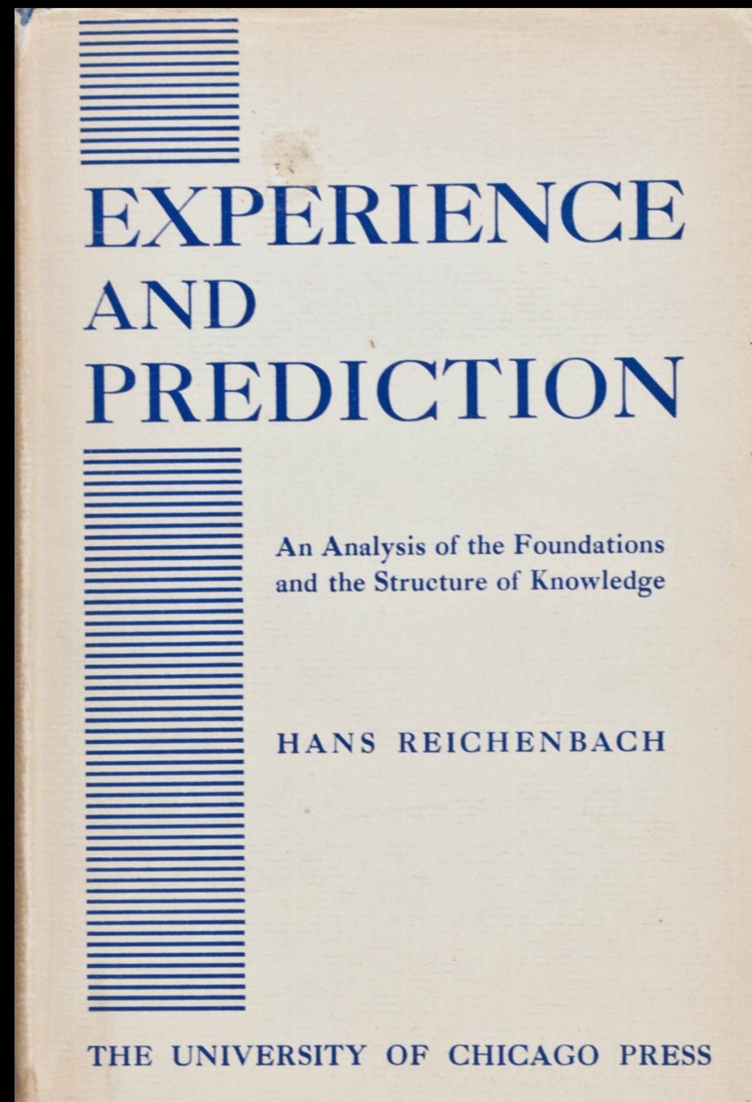
As exemplified by the career of Thomas Kuhn, who was denied promotion to full professor in philosophy at Berkeley in 1961 while being promoted to full professor in history.



The Challenge Was Real

Reichenbach had canonized the distinction between the "context of discovery" and the "context of justification" in 1938, consigning history to the former and restricting the task of the philosophy of science to the latter.

Hans Reichenbach, *Experience and Prediction: An Analysis of the Foundations and the Structure of Knowledge* (Chicago: University of Chicago Press, 1938).



In the 1960s, A Few Universities Promoted an Integrated Approach to HPS, Including My Own Institution, the University of Notre Dame

Mainly this was due to the legacy of Ernan McMullin at Notre Dame, but it drew also from the strong history of science tradition in our Program of Liberal Studies.

It is no accident that Notre Dame was the first university to award Kuhn an honorary degree in 1973.

There Were Other Contrarians in the 1960s - A "Hoosier School"?

The Indiana University HPS department is a noteworthy example.

"History of science without philosophy of science is blind. . . . Philosophy of science without history of science is empty."

THE IRRELEVANCE OF HISTORY OF SCIENCE TO PHILOSOPHY OF SCIENCE *

I

THERE is but one question before us: can a philosopher utilize historical facts without collapsing into the "genetic fallacy"? If he can, will his analyses be improved?

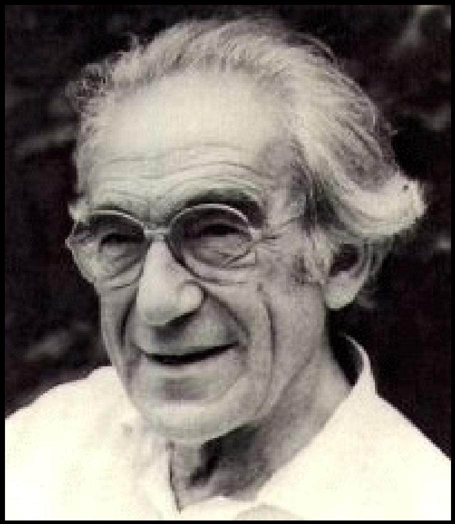
Failure to answer this question has vitiated many discussions concerned with the role of historical facts within philosophy of science, as well as the role of logical analysis within history of science. Some philosophers have set their sights on *Weltphilosophie*, noting that every historian has one. Explicitly or implicitly it controls his selection of salient subjects, his alignment of data, his conception of the over-all objectives of the scientific enterprise, and his evaluations of the heroes and villains within the history of science. That the historian's interpretation is shaped by covert cosmic commitments is clear in the writings of Waddington, Bernal, and Needham. It is apparent also in the works of Whewell, Meyerson, and Poincaré. Moreover, unspoken and unspectacular *Weltphilosophien* provide the intellectual reticulum in terms of which we must view even our most honored "objective" historians of science—Tannery, Duhem, Sarton, and Koyré. As has been suggested recently by Professor R. Cohen at the Xth International Congress of History of Science, to be

* To be presented in a symposium on "The Mutual Relevance of the History and the Philosophy of Science" at the fifty-ninth annual meeting of the American Philosophical Association, Eastern Division, December 28, 1962.

Norwood Russell Hanson, "The Irrelevance of History of Science to Philosophy of Science," *Journal of Philosophy* 59 (1962), 574-586.

Of Course There Was Also Cambridge HPS . . .

Mary Hesse

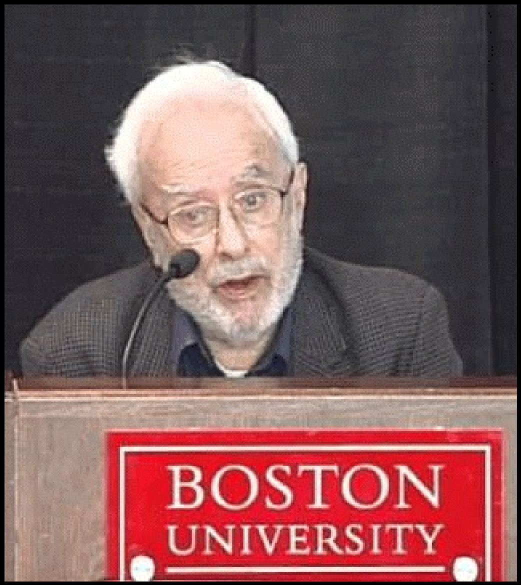


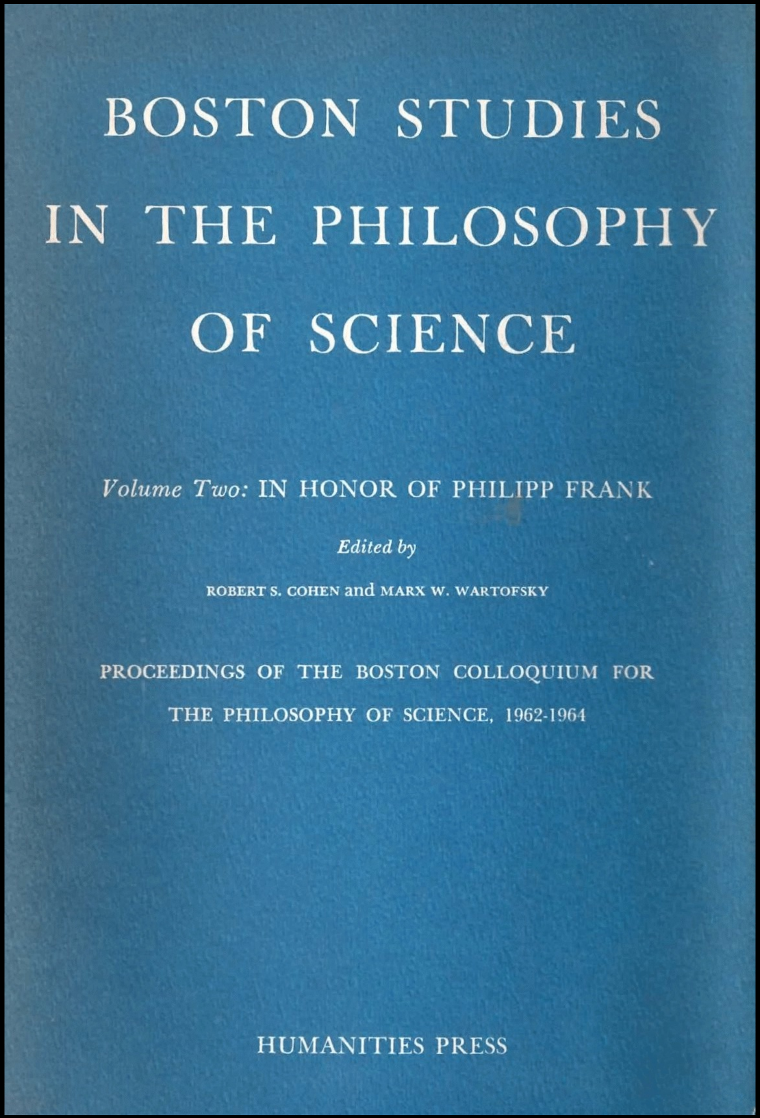
Gerd Buchdahl

Gerd Buchdahl, *Metaphysics and the Philosophy of Science: The Classical Origins from Descartes to Kant* (Cambridge, MA: MIT Press, 1969).

And Mention Should Be Made of Boston University's Center for Philosophy and History of Science

In the 1960s, Robert Cohen, Marx Wartofsky, and Abner Shimony built there a space within which integrated HPS flourished.

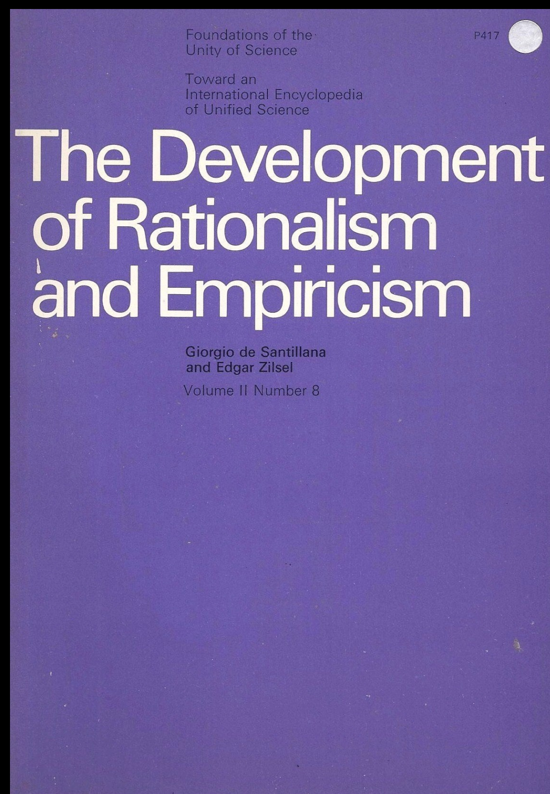


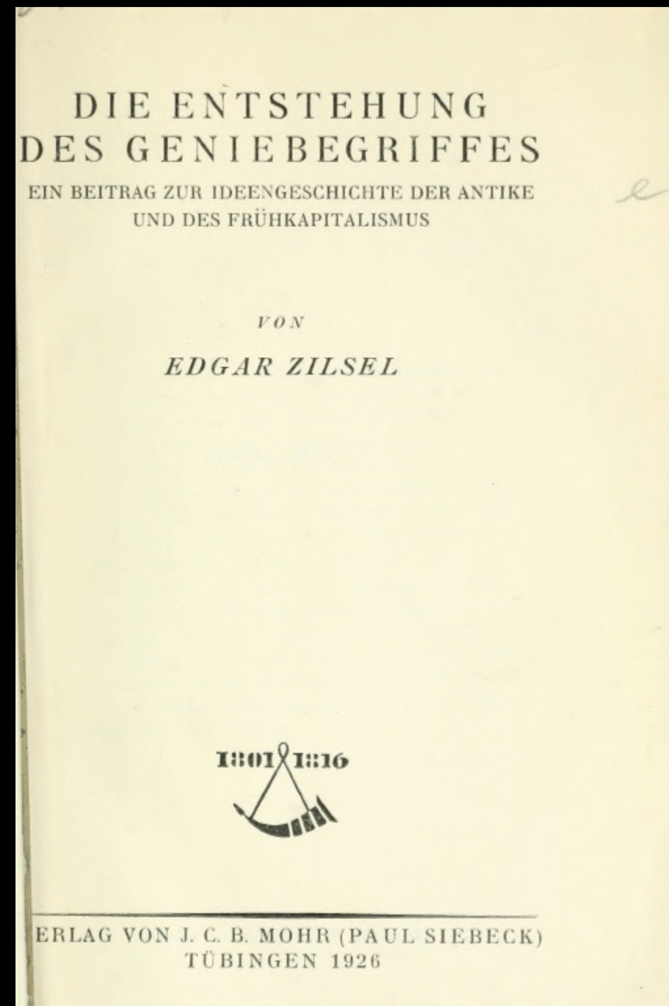


It Must Be Noted, of Course, that Reichenbach Did Not Speak for Everyone Associated with the Vienna Circle

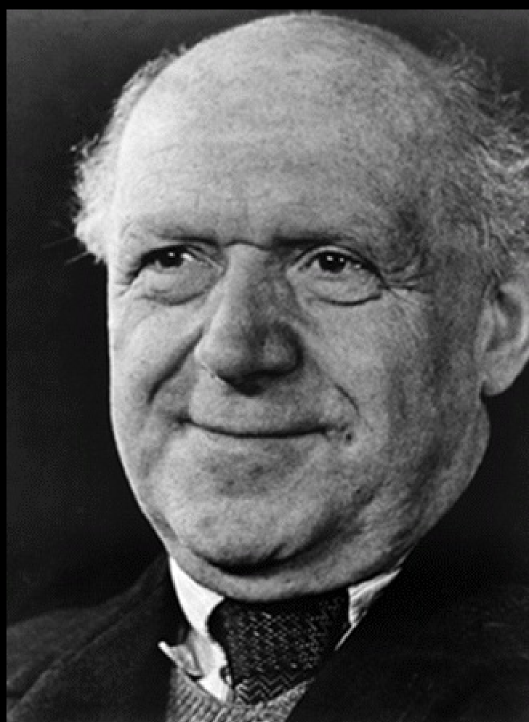
Edgar Zilsel, *Die Entstehung des Geniebegriffes* (Tübingen: J.C.B. Mohr, 1926).

Giorgio de Santillana and Edgar Zilsel, *The Development of Rationalism and Empiricism*, Foundations of the Unity of Science, II. 8 (Chicago: University of Chicago Press, 1941).

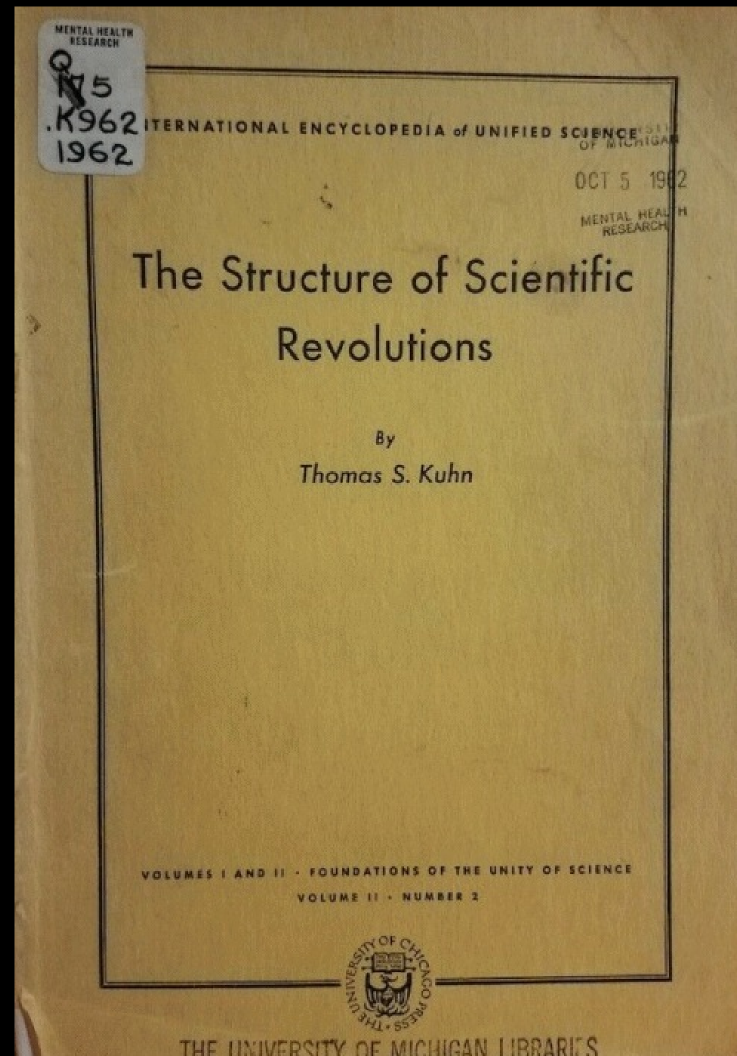




Moreover, Kuhn's *Structure of Scientific Revolutions* Was First Published as Part of the Neurath, Carnap, et al. *International Encyclopedia of Unified Sciences*



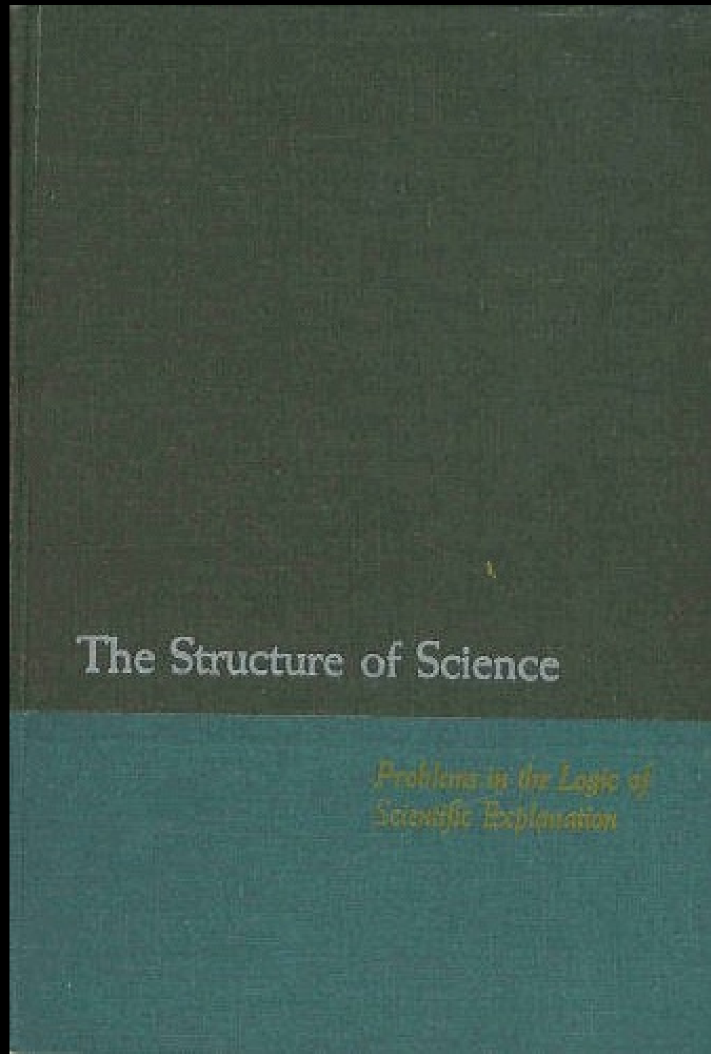
Otto Neurath



Still, the Dominant View in the 1960s Was Neo-Positivist Formalism

Ernest Nagel, *The Structure of Science: Problems in the Logic of Scientific Explanation* (New York: Harcourt, Brace & World, 1961).

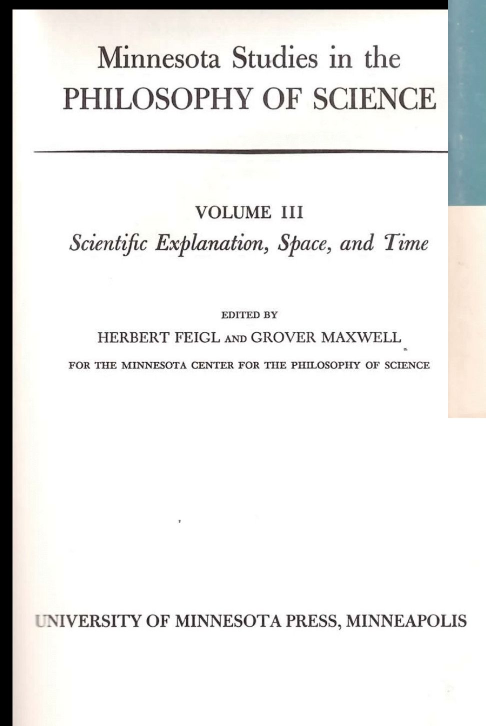
Ernest Nagel

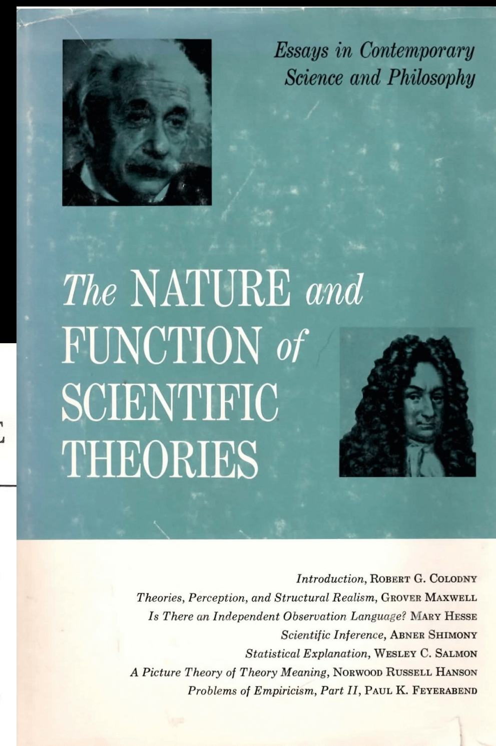


And the Other, Major Programs Pretty Much Toed the Line

Herbert Feigl's Minnesota Center for Philosophy of Science.

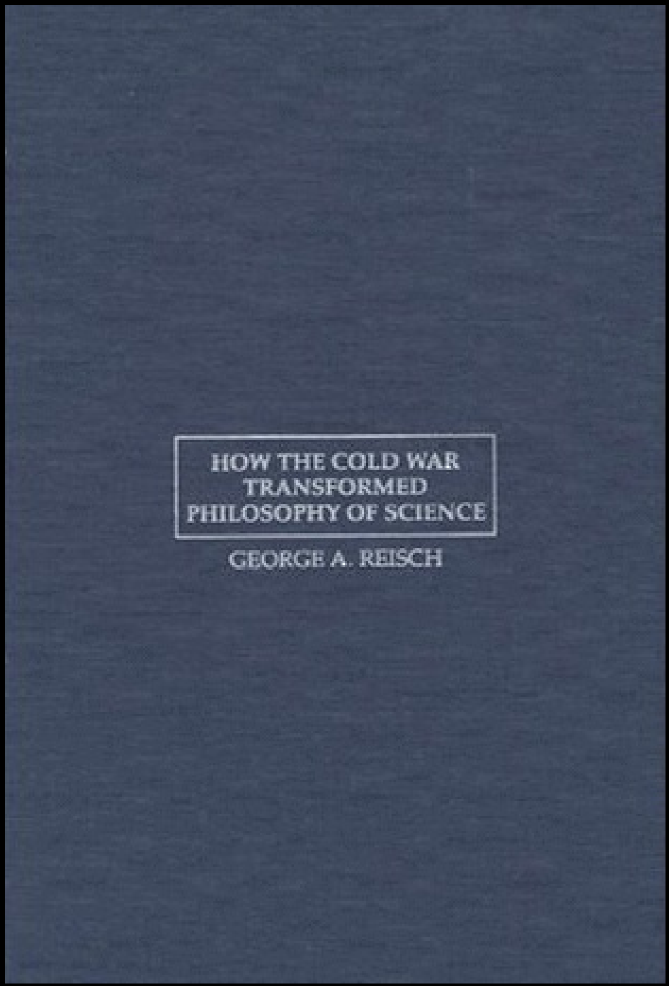
Adolf Grünbaum's History and Philosophy of Science Department at Pittsburgh.





Some of Us Have Worked on the History of This Phenomenon

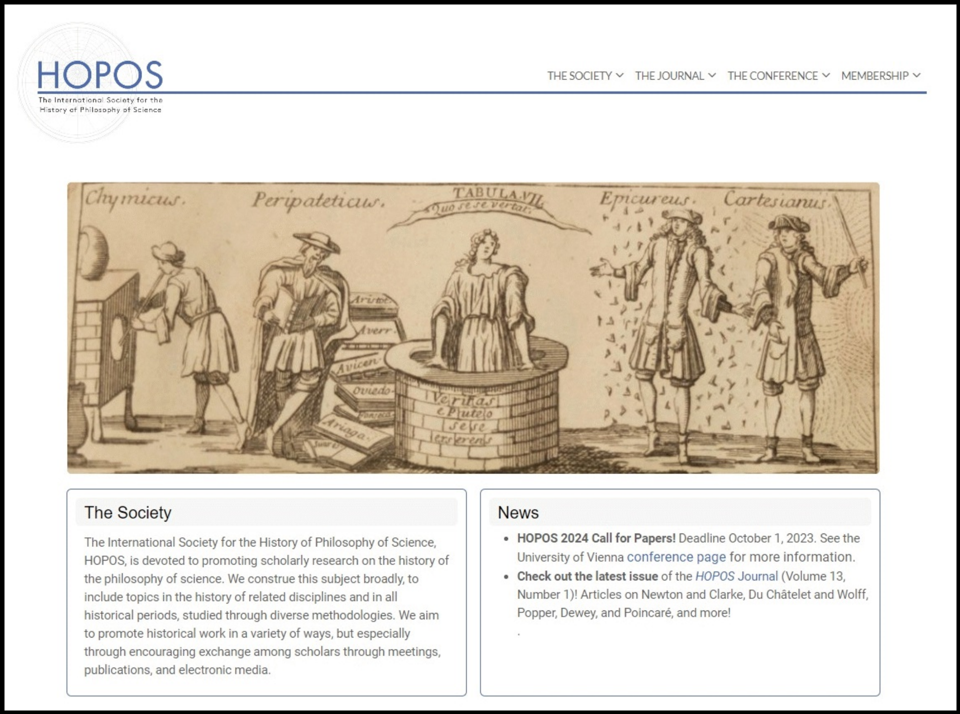
George Reisch, *How the Cold War Transformed Philosophy of Science: To the Icy Slopes of Logic* (New York: Cambridge University Press, 2005).

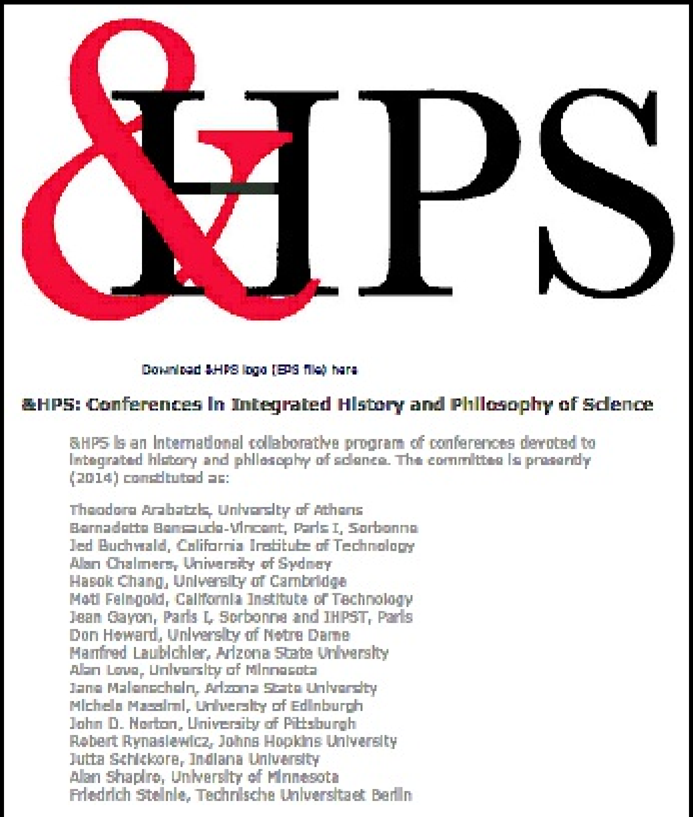


See also:

Don Howard, "Two Left Turns Make a Right: On the Curious Political Career of North American Philosophy of Science at Mid-century," in *Logical Empiricism in North America*. Alan Richardson and Gary Hardcastle, eds. (Mnnneapolis: University of Minnesota Press, 2003), 25-93.

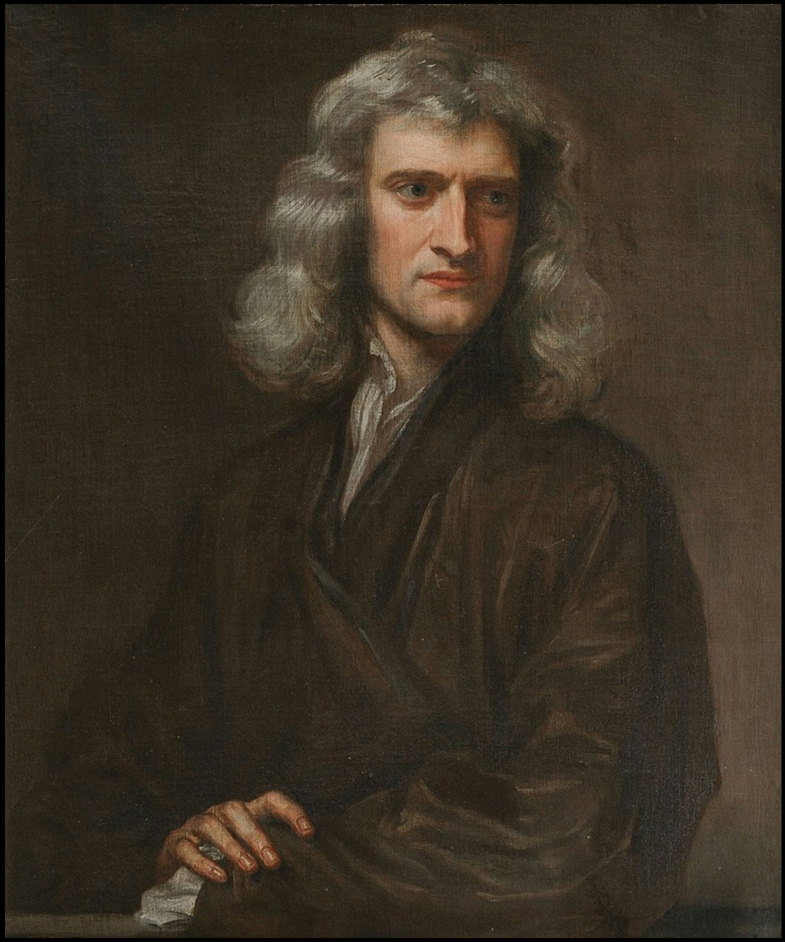
And Some of Us Have Worked Hard to Spread the Gospel of HOPOS and Integrated HPS Far and Wide

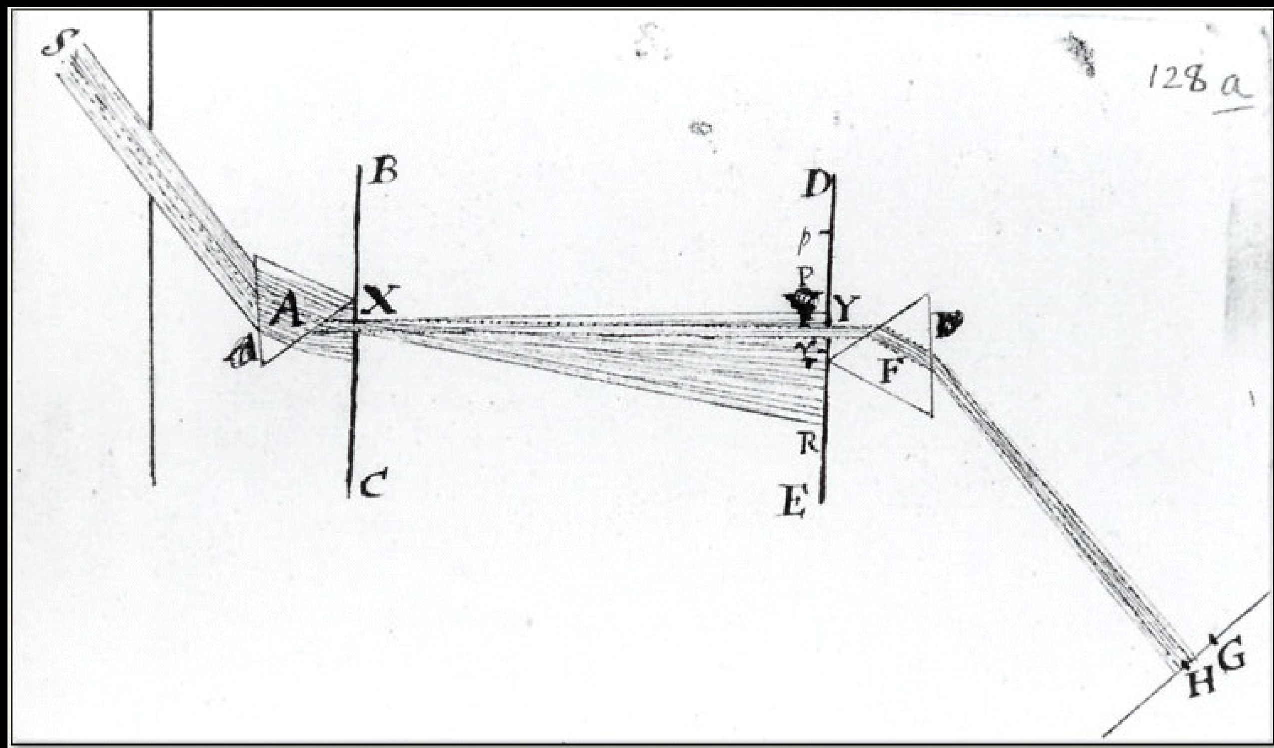




Isaac Newton (1642/3-1726/7)

1642 – Born, Woolsthorpe in Lincolnshire
1661 – Enters Trinity College, Cambridge
1665 – Graduates
1665-1667 – The Plague Year
1667 – Elected a Fellow of Trinity College
1668 – Lucasian Professor of Mathematics, Cambridge, Fellow of the Royal Society
1687 – *Philosophiae Naturalist Principia Mathematica*
1689 – Member of Parliament for Cambridge
1695 – Warden of the Mint
1699 – Master of the Mint
1701 – Member of Parliament for Cambridge
1701 – Resigned from Cambridge
1703 – President of the Royal Society
1704 – *Opticks*
1705 – Knighted by Queen Anne
1727 – Dies, London

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Gottfried Wilhelm Leibniz
(1646 - 1716)

1646 – Born, Leipzig
1661 – Enrolls at the University of Leipzig
1662 – Bachelor's Degree in Philosophy
1663 – *Disputatio Metaphysica de Principio Individui*
1664 – Master's Degree in Philosophy
1665 – Bachelor's Degree in Law
1666-1675 – Various Duties in Mainz
1672 – Travels to Paris and Meets Huygens
1675-1716 – Various Duties in Hannover
1684 – *Nova methodus pro maximis et minimis*
1686 – *Discours de métaphysique*
1704 – *Nouveaux essais sur l'entendement humain*
1710 – *Théodicée*
1714 – *Monadologie*
1716 – Died, Hannover

Samuel Clarke (1675 - 1729)

1675 – Born, Norwich
1691 – Enters Caius College, Cambridge
1695 – Graduates
1698-1710 – Chaplin to the Bishop of Norwich
1697 – Latin Translation of Jacques Rohault's *Traité de physique*
1699 – *Three Practical Essays on Baptism, Confirmation, and Repentance*
1704 & 1705 – Boyle Lectures, Cambridge
1706 – Latin Translation of Newton's *Opticks*
1712 – *Scripture Doctrine of the Trinity*
1714 – Investigated for Heresy
1714 – Friendship with Queen Caroline, wife of King George II
1717 – *A Collection of Papers, Which Passed between the Late Learned Mr. Leibnitz, and Dr. Clarke, In the Years 1715 and 1716 Relating to the Principles of Natural Philosophy and Religion*
1718 – Mastership of Wigston's Hospital, Leicester
1727 – Offered the Mastership of the Mint
1729 – Died, London

A

Collection of PAPERS,

Which passed between the late Learned

Mr. *LEIBNITZ*,

AND

Dr. *CLARKE*,

In the Years 1715 and 1716.

Relating to the

PRINCIPLES

OF

Natural Philosophy and Religion.

With an APPENDIX.

To which are added,

LETTERS to Dr. CLARKE concerning Liberty and Necessity; From a Gentleman of the University of *Cambridge*: With the Doctor's ANSWERS to them.

ALSO

REMARKS upon a Book, Entituled, *A Philosophical Enquiry concerning Human Liberty.*

By SAMUEL CLARKE, D. D.
Rector of St. *James's Westminster.*

LONDON: Printed for JAMES KNAPTON, at the *Crown* in St. *Paul's Church-Yard.* MDCCXVII.

Einstein to Erwin Schrödinger, 28 February 1925.

In the Bose statistics employed by me, the quanta or molecules are not treated as being independent of one another. . . . A complexion is characterized through giving the number of molecules that are present in each individual cell. The number of the complexions so defined should determine the entropy. According to this procedure, the molecules do not appear as being localized independently of one another, but rather they have a preference to sit together with another molecule in the same cell. One can easily picture this in the case of small numbers. [In particular] 2 quanta, 2 cells:

Bose-statistics

	1st cell	2nd cell
1st case	●●	–
2nd case	●	●
3rd case	–	●●

independent molecules

	1st cell	2nd cell
1st case	I II	–
2nd case	I	II
3rd case	II	I
4th case	–	I II

According to Bose the molecules stack together relatively more often than according to the hypothesis of the statistical independence of the molecules.

Albert Einstein. “Quanten-Mechanik und Wirklichkeit.” *Dialectica* 2(1948), 320-324.

If one asks what is characteristic of the realm of physical ideas independently of the quantum-theory, then above all the following attracts our attention: the concepts of physics refer to a real external world, *i.e.*, ideas are posited of things that claim a “real existence” independent of the perceiving subject (bodies, fields, *etc*.), and these ideas are, on the other hand, brought into as secure a relationship as possible with sense impressions. Moreover, it is characteristic of these physical things that they are conceived of as being arranged in a space-time continuum. Further, it appears to be essential for this arrangement of the things introduced in physics that, at a specific time, these things claim an existence independent of one another, insofar as these things “lie in different parts of space.” Without such an assumption of the mutually independent existence (the “being-thus”) of spatially distant things, an assumption that originates in everyday thought, physical thought in the sense familiar to us would not be possible. Nor does one see how physical laws could be formulated and tested without such a clean separation. Field theory has carried out this principle to the extreme, in that it localizes within infinitely small (four-dimensional) space-elements the elementary things existing independently of one another that it takes as basic, as well as the elementary laws it postulates for them.

For the relative independence of spatially distant things (*A* and *B*), this idea is characteristic: an external influence on *A* has no *immediate* effect on *B*; this is known as the “principle of local action,” which is applied consistently only in field theory. The complete suspension of this basic principle would make impossible the idea of the existence of (quasi-) closed systems and, thereby, the establishment of empirically testable laws in the sense familiar to us.

Einstein to Max Born, 18 March 1948

I just want to explain what I mean when I say that we should try to hold on to physical reality. We are, to be sure, all of us aware of the situation regarding what will turn out to be the basic foundational concepts in physics: the point-mass or the particle is surely not among them; the field, in the Faraday-Maxwell sense, might be, but not with certainty. But that which we conceive as existing (“real”) should somehow be localized in time and space. That is, the real in one part of space, A, should (in theory) somehow “exist” independently of that which is thought of as real in another part of space, B. If a physical system stretches over the parts of space A and B, then what is present in B should somehow have an existence independent of what is present in A. What is actually present in B should thus not depend upon the type of measurement carried out in the part of space, A; it should also be independent of whether or not, after all, a measurement is made in A.

If one adheres to this program, then one can hardly view the quantum-theoretical description as a complete representation of the physically real. If one attempts, nevertheless, so to view it, then one must assume that the physically real in B undergoes a sudden change because of a measurement in A. My physical instincts bristle at that suggestion.

However, if one renounces the assumption that what is present in different parts of space has an independent, real existence, then I do not at all see what physics is supposed to describe. For what is thought to be a “system” is, after all, just conventional, and I do not see how one is supposed to divide up the world objectively so that one can make statements about the parts.

John Locke (1632 - 1704)

1632 – Born, Wrinton, Somerset
1652 – Enters Christ Church, Oxford
1656 – Bachelor’s Degree
1658 – Master’s Degree
1667 – Personal Physician to Lord Ashley, London
1667-1675 – Secretary of the Board of Trade
1675 – Master’s Degree in medicine
1675-1679– Tutor in Europe to Caleb Banks
1679-1683 – Composes most of *Two Treatises of Goverment*
1683-1689 – Refugee in the Netherlands
1689-1704 – Member of the Household of Lady Masham, Essex
1689-1690 *Two Treatises of Goverment* and *An Essay Concerning Human Understanding*
1691 – *Some Considerations on the Consequences of the Lowering of Interest and the Raising of the Value of Money*
1695 – *The Reasonableness of Christianity, as Delivered in the Scriptures* and *A Vindication of the Reasonableness of Christianity*
1704 – Died, High Laver, Essex

David Hume (1711 - 1776)

1710 – Born, Edinburgh
1722-1724/1725 – Edindburgh University
1729-1734 – Mental Breakdown
1735 – Merchant's Assistant, La Flèche, Anjou
1740 – *A Treatise of Human Nature*
1741 – *Essays Moral and Political*
1741 – Failed Attempt at a Professorship at Edinburgh
1746-1749 – Secretary to General James St. Clair, Turin and Vienna
1748 – *An Enquiry Concerning Human Understanding*
1751 – *An Enquiry Concerning the Principles of Morals*
1754-1762 – *The History of England*
1767 – Under Secretary of State for the Northern Department.
1763-1765 – Secretary to the British Embassy, Paris
1776 – Died, Edinburgh

Thomas Reid (1710 - 1796)

1710 – Born, Strachan, Aberdeen
1723 – Enters University of Aberdeen
1726 – Graduates with a Master's degree
1731 – Licensed to Preach in the Church of Scotland
1737-1751 – Minister at New Machar, Aberdeen
1752 – Professorship at Aberdeeen
1764 – *An Inquiry Into the Human Mind on the Principles of Common Sense*
1764 – Professor of Moral Philosophy, Glasgow
1781 – Resigned to Have More Time for Writing
1783 – Co-founder of the Royal Society of Edinburgh
1785 – *Essays on the Intellectual Powers of Man*
1788 – *Essays on the Active Powers of Man*
1796 – Died, Glasgow

Immanuel Kant (1724 - 1804)

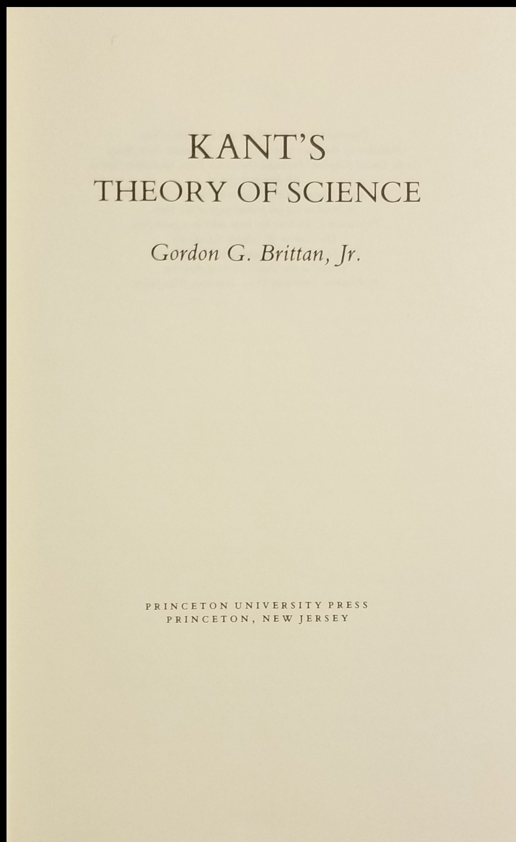
1724 – Born, Königsberg, Prussia
1740 – Enters University of Königsberg
1746 – Leaves University of Königsberg
1746-1754 – Tutor in Various Locations in East Prussia
1755 – Completes Degree at Königsberg
1755-1770 – Privatdozent at Königsberg
1770 – Chair of Logic and Metaphysics at Königsberg
1770 – *De mundi sensibilis atque intelligibilis forma et principiis* (*Inaugural Dissertation*)
1781 – *Kritik der reinen Vernunft*
1783 – *Prolegomena zu einer jeden künftigen Metaphysik*
1784 – *Beantwortung der Frage: Was ist Aufklärung?*
1785 – *Grundlegung zur Metaphysik der Sitten*
1786 – *Metaphysische Anfangsgründe der Naturwissenschaft*
1787 – *Kritik der reinen Vernunft*, second edition
1788 – *Kritik der praktischen Vernunft*
1790 – *Kritik der Urteilskraft*
1796 – Retired from Königsberg
1797 – *Metaphysik der Sitten*
1804 – Died, Königsberg, Prussia

Critik der reinen Vernunft

von

Immanuel Kant
Professor in Königsberg.

Riga,
verlegts Johann Friedrich Hartknoch
1781.



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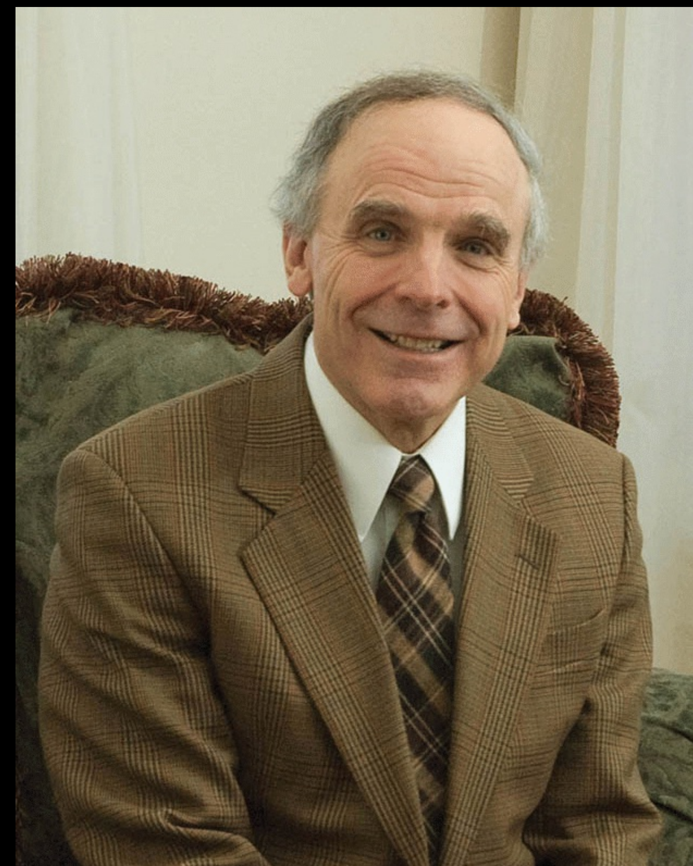
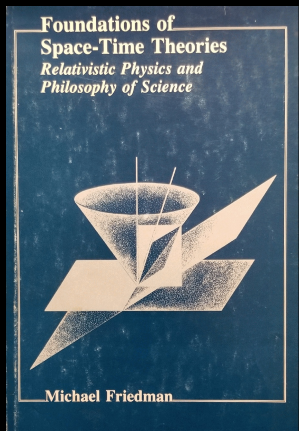


Gordon Brittan



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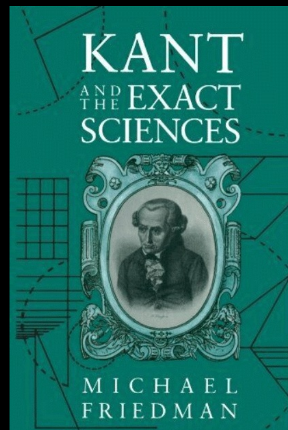

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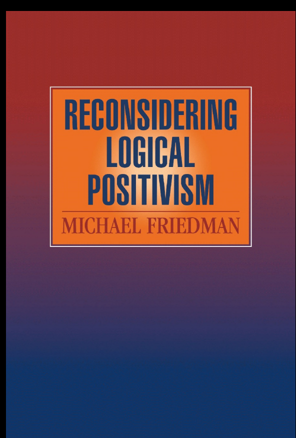
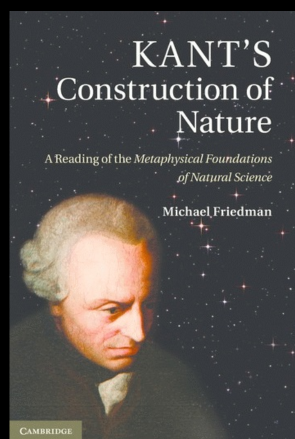


1999

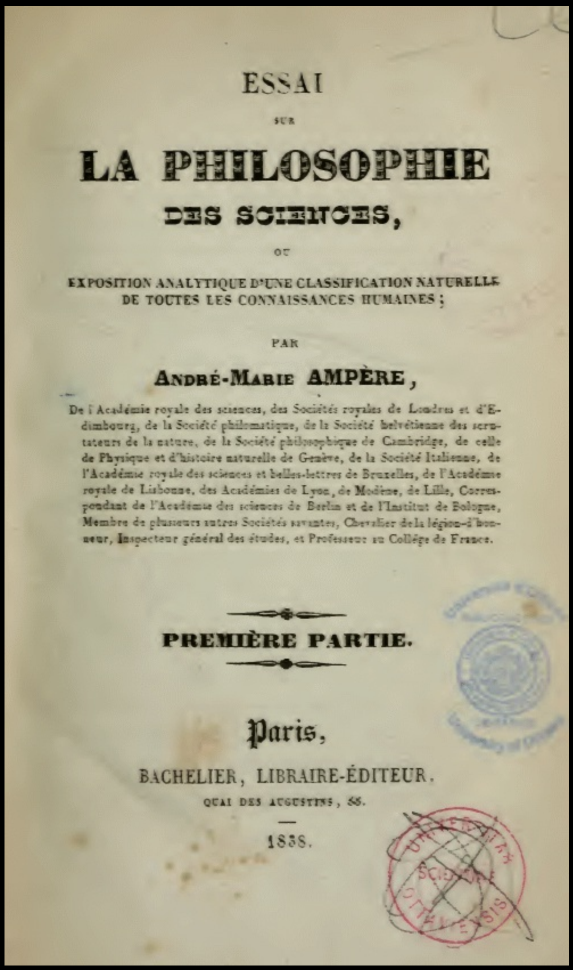


2013

Michael Friedman (1947 -)

Auguste Comte (1798 -1857)

1798 – Born, Montpellier
1814-1816 – École Polytechnique; no degree
1817-1824 – Secretary to Henri de Saint-Simon
1822 – *Plan de travaux scientifiques nécessaires pour réorganiser la société*
1825 – Marries Caroline Massin, a seamstress
1827 – Attempted suicide
1830-1842 – *Cours de Philosophie Positive*, 5 vols.
1842 – Divorced from Caroline Massin
1844 – Begins Romance with French Intellectual, Clotilde de Vaux, who inspired Comte's idea for a "Religion of Humanity'
1846 – Death of Clotilde de Vaux
1851-1854 – *Système de politique positive*, 4 vols.
1857 – Died, Paris



ESSAI

SUR

LA PHILOSOPHIE

DES SCIENCES,

OU

EXPOSITION ANALYTIQUE D'UNE CLASSIFICATION NATURELLE DE TOUTES LES CONNAISSANCES HUMAINES;

PAR

ANDRÉ-MARIE AMPÈRE,

De l'Académie royale des sciences, des Sociétés royales de Londres et d'Edimbourg, de la Société philomatique, de la Société helvétienne des scrutateurs de la nature, de la Société philosophique de Cambridge, de celle de Physique et d'histoire naturelle de Genève, de la Société Italienne, de l'Académie royale des sciences et belles-lettres de Bruxelles, de l'Académie royale de Lisbonne, des Académies de Lyon, de Modène, de Lille, Correspondant de l'Académie des sciences de Berlin et de l'Institut de Bologne, Membre de plusieurs autres Sociétés savantes, Chevalier de la légion-d'honneur, Inspecteur général des études, et Professeur au Collége de France.

PREMIÈRE PARTIE.

Paris,

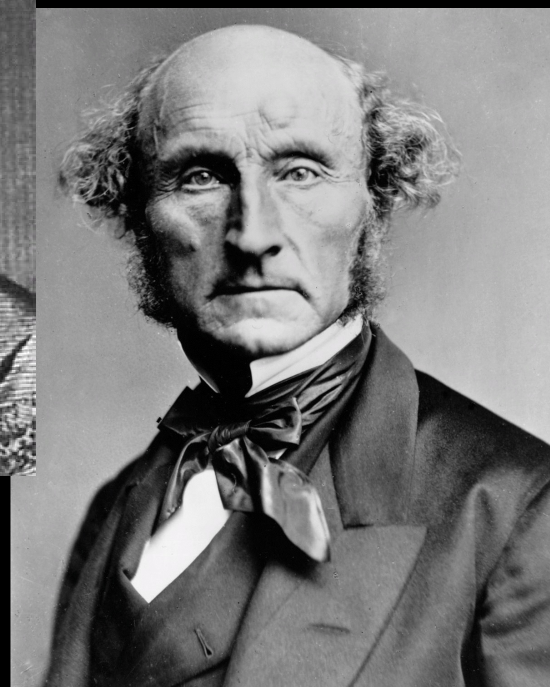
BACHELIER, LIBRAIRE-ÉDITEUR,

QUAI DES AUGUSTINS, 55.

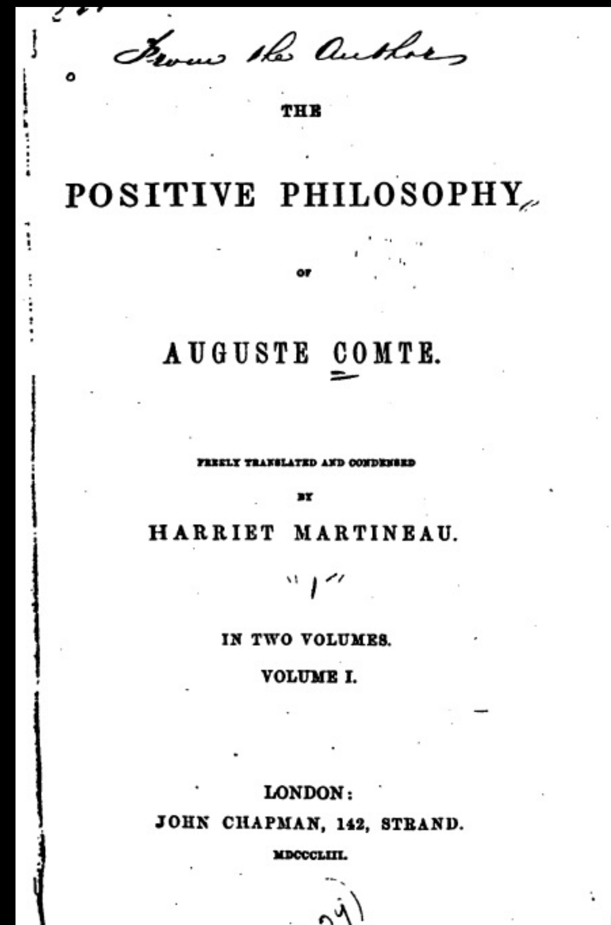
1838.

André-Marie Ampère. *Essai sur la philosophie des sciences*. 2 vols. Paris: Bachelier, 1835.

Harriet Martineau



John Stuart Mill



From the Author

THE

POSITIVE PHILOSOPHY

OF

AUGUSTE COMTE.

FREELY TRANSLATED AND CONDENSED

BY

HARRIET MARTINEAU.

IN TWO VOLUMES.

VOLUME I.

LONDON:

JOHN CHAPMAN, 142, STRAND.

MDCCCLIII.

The Positive Philosophy of Auguste Comte, Harriet Martineau, trans, 1853, 2 vols.

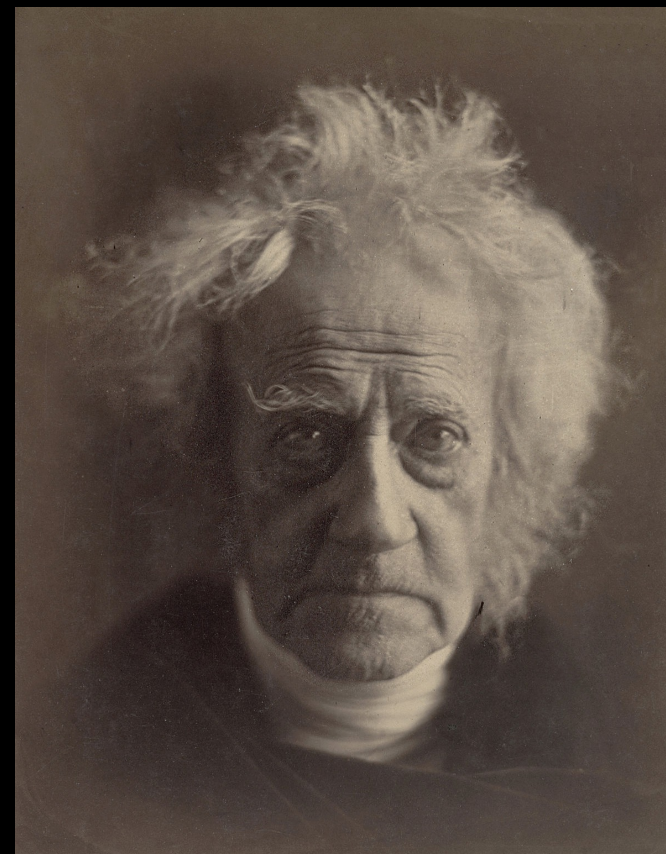
Chapelle de l'Humanité, Paris

Positivist Temple, Porto Alegre, Brazil

Flag of Brazil

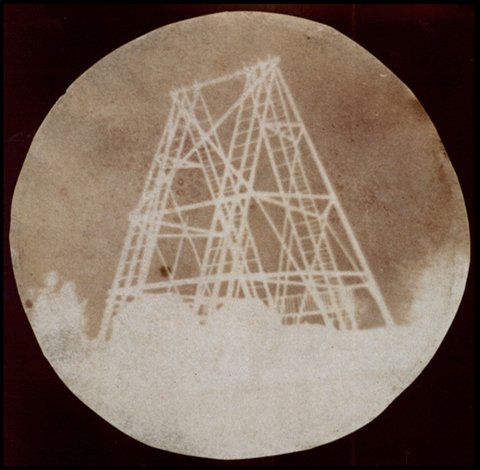
John Herschel (1792 -1871)

1792 – Born, Slough, Buckinghamshire
1809-1813 – Eton College and St. John's College, Cambridge
1812 – Founds the Cambridge Analytical Society with Charles Babbage and George Peacocke
1820 – Co-founder of the Royal Astronomical Society; President 1827–29, 1839–41 and 1847–49
1821 – Copley Medal from the Royal Society
1831 – *A Preliminary Discourse on the Study of Natural Philosophy*
1833-1838 – South Africa Expedition
1838 – 1st Baronet of Slough
1847 – *Results of Astronomical Observations, Made during the Years 1834-38 at the Cape of Good Hope*
1849 – *Outlines of Astronomy*
1850-1856 – Master of the Mint
1864 – *General Catalogue of Nebulae and Clusters*
1871 – Died, Collingwood, near Hawkhurst, Kent

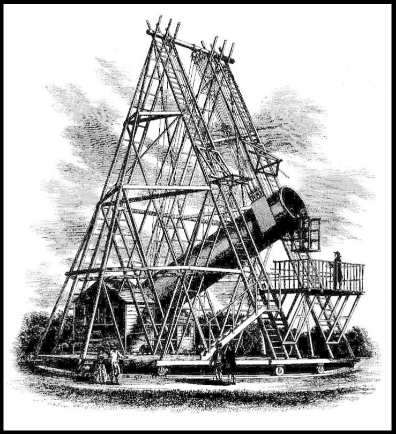


Disa Cornuta (L.) Sw. by Margaret & John Herschel

A Calotype of a Model of the Lunar Crater Copernicus, 1842

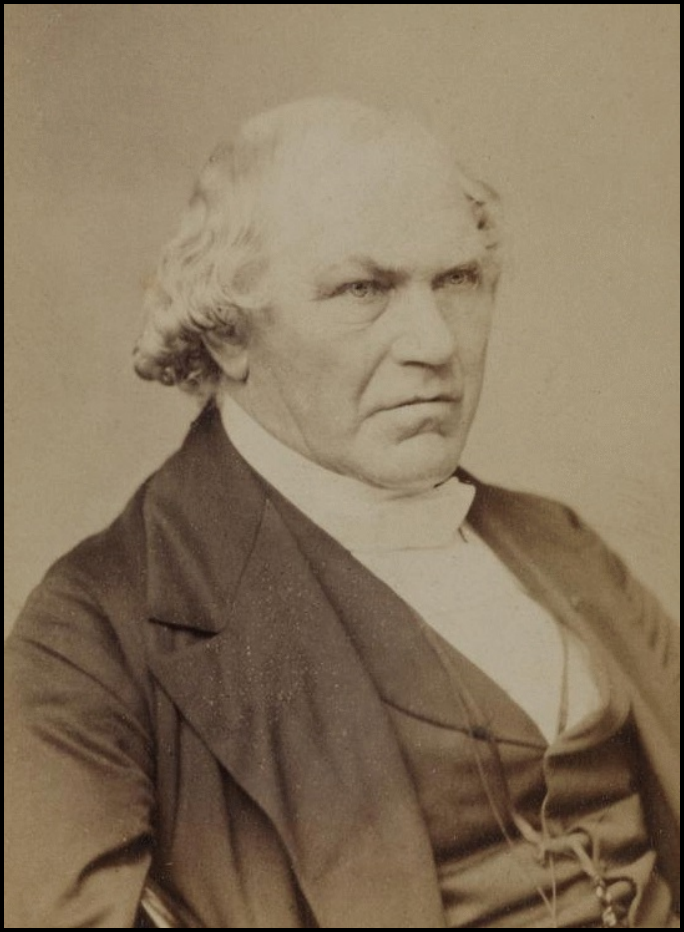


Herschel's First Glass-plate Photograph, 1839, Showing the Mount of His Father's 40-foot Telescope



William Whewell (1794 -1866)

1794 – Born, Lancaster
1812-1816 – Trinity College, Cambridge
1816 – Fellow and Tutor, Trinity College
1819 – *An Elementary Treatise on Mechanics*
1820 – Fellow of the Royal Society
1823 – *A Treatise on Dynamics*
1828-1832 – Professor of Minerology, Cambridge
1833 – *Astronomy and General Physics Considered with Reference to Natural Theology*, the third Bridgewater Thesis
1833 – Coins the word, “Scientist”
1837 – *History of the Inductive Sciences, from the Earliest to the Present Times*, 3 vols.
1838-1855 – Knightbridge Professor of Philosophy, Cambridge
1840 – *The Philosophy of the Inductive Sciences: Founded Upon Their History*, 2 vols.
1849 – *Of Induction, with Especial Reference to Mr. J. Stuart Mill's System of Logic*
1858 – *The History of Scientific Ideas*, 2 vols.
1858 – *Novum Organon renovatum*
1860 – *On the Philosophy of Discovery*
1866 – Died, Cambridge



THE

PHILOSOPHY

OF THE

INDUCTIVE SCIENCES,

FOUNDED UPON THEIR HISTORY.

BY THE

REV. WILLIAM WHEWELL, B.D.,

FELLOW OF TRINITY COLLEGE, AND PROFESSOR OF MORAL PHILOSOPHY IN THE UNIVERSITY OF CAMBRIDGE, VICE-PRESIDENT OF THE GEOLOGICAL SOCIETY OF LONDON.

IN TWO VOLUMES.

Λαμπάδια ἔχοντες διαδώσουσιν ἀλλήλοις.

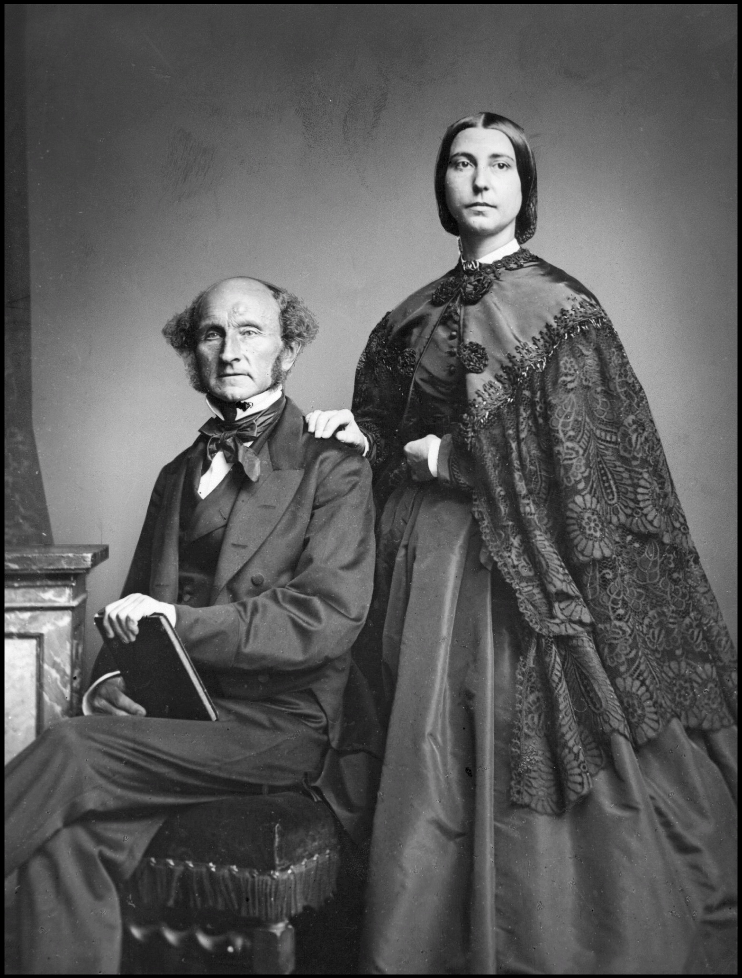
VOLUME THE FIRST.

LONDON:
JOHN W. PARKER, WEST STRAND.
CAMBRIDGE: J. AND J. J. DEIGHTON.

M.DCCC.XL.

John Stuart Mill (1806 -1873)

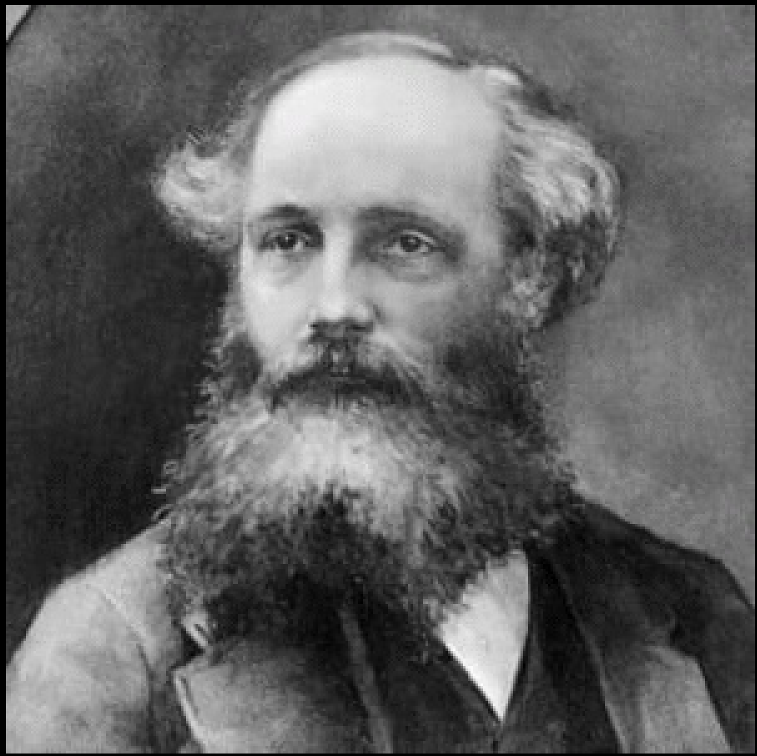
1806 – Born, Pentonville, Middlesex
1823-1858 – Staff of the East India Company
1826 – Nervous Breakdown
1830 – Meets and Falls in Love with Harriet Taylor
1843 – *A System of Logic*
1848 – *The Principles of Political Economy: With Some of Their Applications to Social Philosophy*
1851 – Marries Harriet Taylor
1858 – Harriet Taylor Dies
1859 – *On Liberty*
1863 – *Utilitarianism*
1865 – *An Examination of Sir William Hamilton's Philosophy*
1865-1868 – Rector of St. Andrews University
1865-1868 – Member of Parliament for Westminster
1873 – Died, Avignon

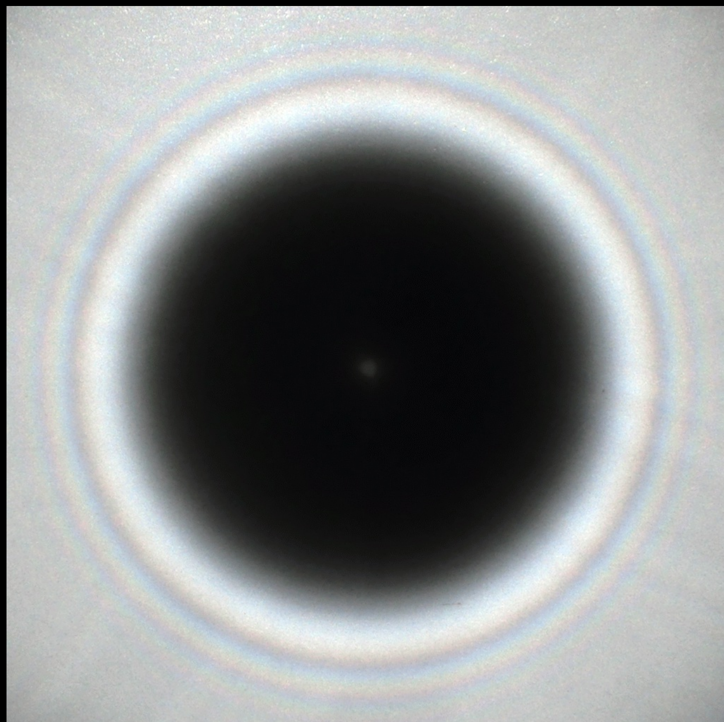


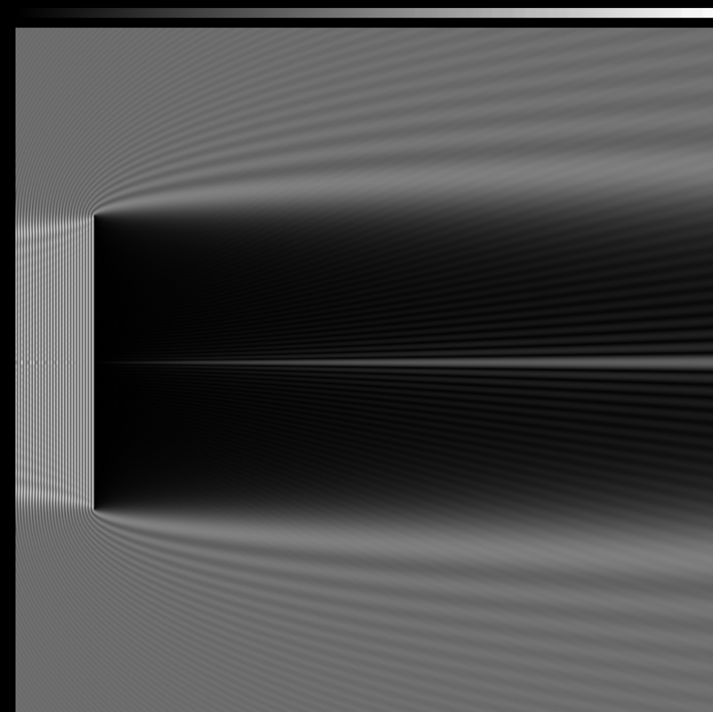
John Stuart Mill and Harriet Taylor
1858

James Clerk Maxwell (1831 -1879)

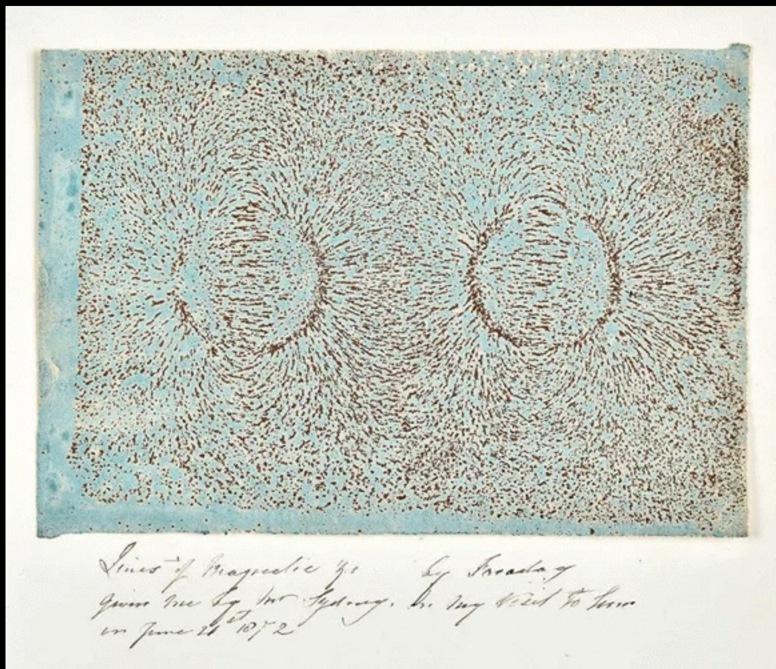
1831 – Born, Edinburgh
1847-1850 – University of Edinburgh
1850-1854 – Trinity College, Cambridge
1855 – Fellow of Trinity College
1855, 1856 – "On Faraday's Lines of Force"
1856-1860 – Chair of Natural Philosophy, Marischal College, Aberdeen
1861 – "On Physical Lines of Force"
1860-1865 – Chair of Natural Philosophy, King's College, London
1864 – "A Dynamical Theory of the Electromagnetic Field"
1866 – "On the Dynamical Theory of Gases"
1871=1879 – Cavendish Professor of Physics, Cambridge
1873 – *A Treatise on Electricity and Magnetism*
1879 – Died, Cambridge

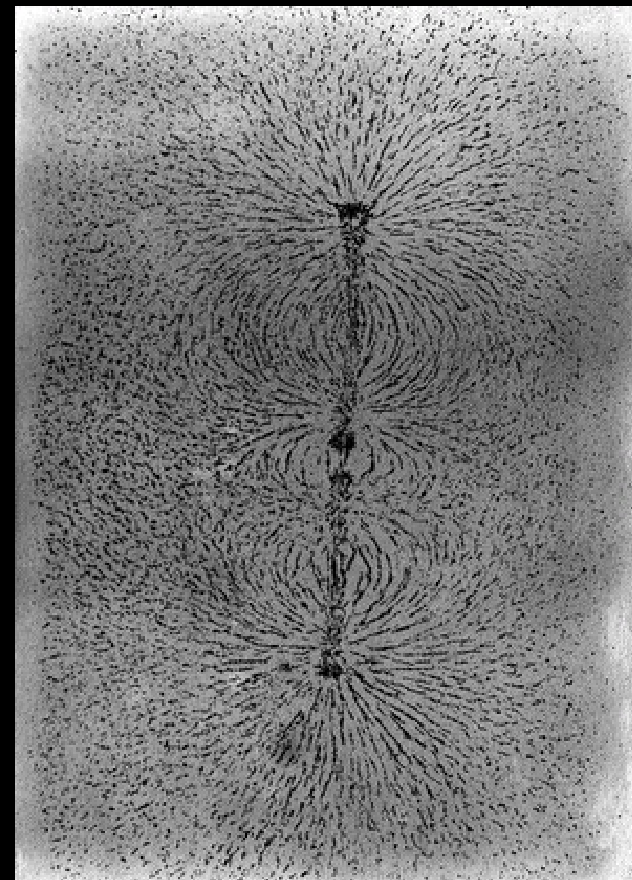






Arago's Spot – First Predicted by
Fresnel in 1816





Faraday – Magnetic Lines of Force

Maxwell's Equations

$$\nabla \cdot E = \frac{\rho}{\varepsilon_0}$$

Gauss's Law: The electric field's mapping is equal to the charge density divided by the permittivity of free space. The relationship between electric field and electric charge

$$\nabla \cdot B = 0$$

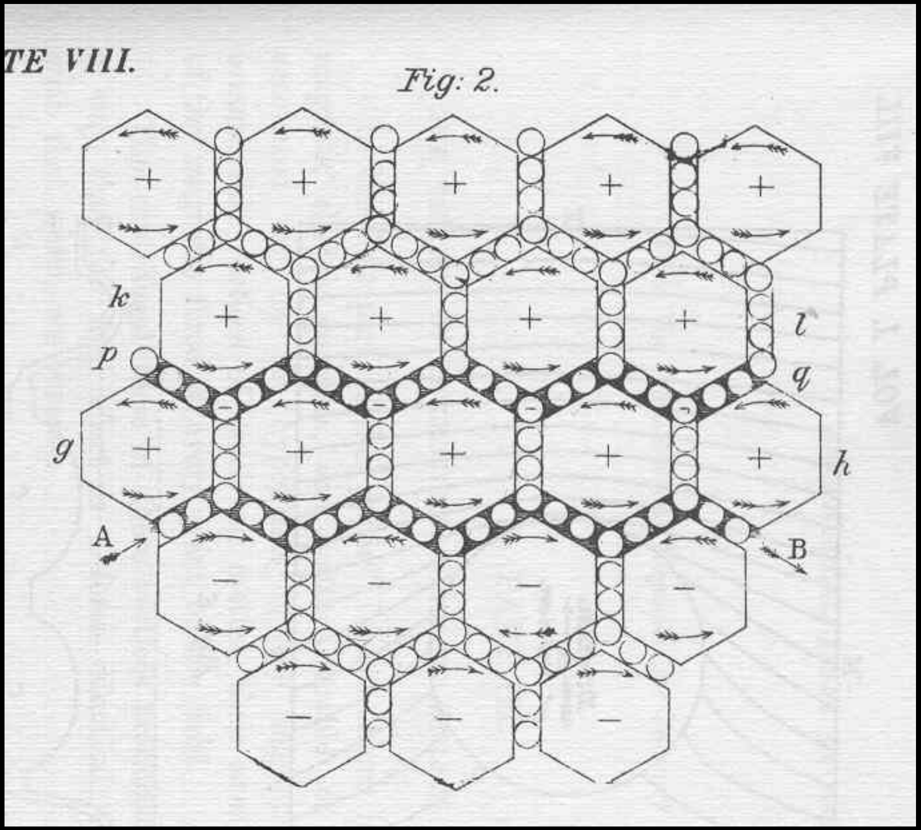
Gauss's Law for Magnetism: The net magnetic flux out of any closed surface is zero. There is no such thing as a magnetic monopole

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

We can make an electric field by changing a magnetic field

$$\nabla \times B = u_0 J + \mu_0 \varepsilon_0 \frac{\partial E}{\partial t}$$

We can make a magnetic field with a changing electric field or with a current



Maxwell's Vortex Model of the
Electromagnetic Ether

Boltzmann Edits Maxwell

Maxwell, himself, on the heuristic and psychological role of models

James Clerk Maxwell, "On Faraday's Lines of Force." *Transactions of the Cambridge Philosophical Society*, 10, Part 1 (1856), 27-83. [Read December 10, 1855 and February 11, 1856.]

[Maxwell gives examples from optics and kinetic theory. About the analogy between light and the vibrations of an elastic medium Maxwell writes:]

The other analogy, between light and the vibrations of an elastic medium, extends much further, but, though its importance and fruitfulness cannot be over-estimated, we must recollect that it is founded only on a resemblance *in form* between the laws of light and those of vibrations. By stripping it of its physical dress and reducing it to a theory of "transverse alternations," we might obtain a system of truth founded strictly on observation, but probably deficient both in the vividness of its conceptions and the fertility of its method.

. . .

It is by the use of analogies of this kind that I have attempted to bring before the mind, in a convenient and manageable form, the mathematical ideas which are necessary to the study of the phenomena of electricity.

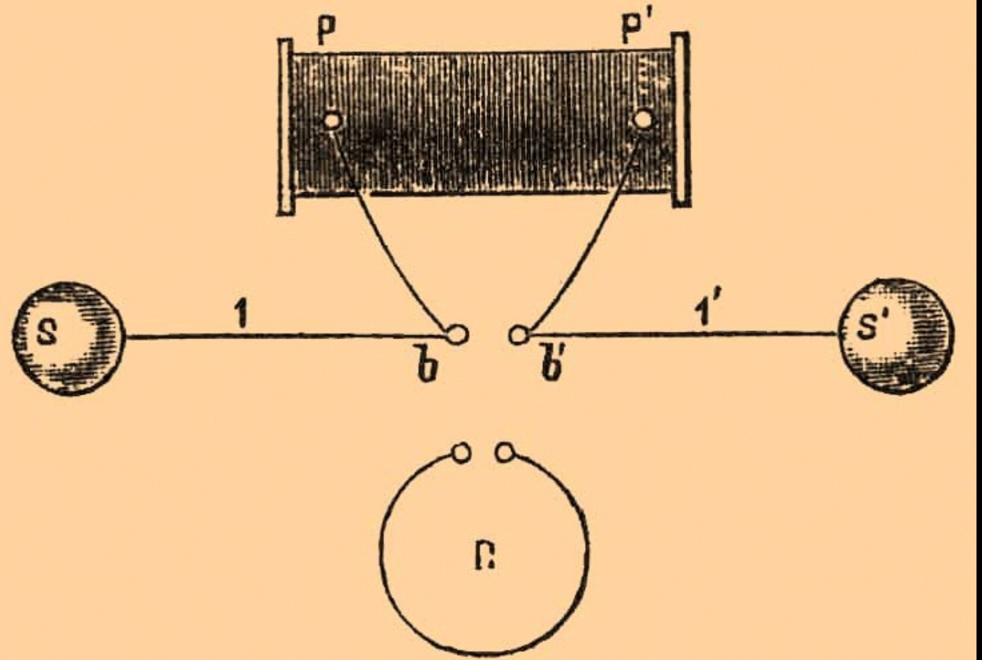
Hermann von Helmholtz (1821 -1894)

1821 – Born, Potsdam, Prussia
1838-1842 – Medical Degree, Berlin
1843-1848 – Military Service
1847 – *Über die Erhaltung der Kraft*
1848 – Professor of Physiology, Berlin
1849-1855 – Professor of Physiology, Königsberg
1855 – *Ueber das Sehen des Menschen*
1855-1858 – Chair of Physiology, Bonn
1858-1870 – Chair of Physiology, Heidelberg
1867 – *Handbuch der Physiologischen Optik*
1870- 1894 – Chair of Physics, Berlin
1877 – *Über die akademische Freiheit der deutschen Universitäten*
1878 – *Die Thatsachen in der Wahrnehmung*
1894 – Died, Charlottenburg, Germany
1897 – *Vorlesungen über die elektromagnetische Theorie des Lichts*
1898 – *Vorlesungen über die mathematischen Principien der Akustik*
1903 – *Vorlesungen über Theorie der Wärme*
1907 – *Vorlesungen über Elektrodynamik und Theorie des Magnetismus*

Helmholtz’s Ophthalmoscope

Heinrich Hertz (1857 -1894)

1857 – Born, Hamburg
1880 – Physics Ph.D., Berlin
1880-1883 – Assistant to Helmholtz, Berlin
1883-1885 – Privatdozent, Theoretical Physics, Kiel
1885-1889 – Professor of Physics, Karlsruhe
1886-1889 – Experiments on Electromagnetic Waves
1889-1894 – Professor of Physics, Bonn
1894 – Died, Bonn
1894 – *Die Prinzipien der Mechanik in neuem Zusammenhange dargestellt*



Фиг. 1.

Hertz's Apparatus for Demonstrating the Existence of Electromagnetic Waves

Translating Hertz's *Die Prinzipien der Mechanik* – Three Problems

The crucial passage:

Wir machen uns innere Scheinbilder oder Symbole der äusseren Gegenstände, und zwar machen wir sie von solcher Art, dass die denknotwendigen Folgen der Bilder stets wieder die Bilder seien von den naturnotwendigen Folgen der abgebildeten Gegenstande.

The standard English translation:

We form for ourselves images or symbols of external objects; and the form which we give them is such that the necessary consequents of the images in thought are always the images of the necessary consequents in nature of the things pictured.

Einleitung.

Es ist die nächste und in gewissem Sinne wichtigste Aufgabe unserer bewuſsten Naturerkenntnis, daſs sie uns befähige, zukünftige Erfahrungen vorauszusehen, um nach dieser Voraussicht unser gegenwärtiges Handeln einrichten zu können. Als Grundlage für die Lösung jener Aufgabe der Erkenntnis benutzen wir unter allen Umständen vorangegangene Erfahrungen, gewonnen durch zufällige Beobachtungen oder durch absichtlichen Versuch. Das Verfahren aber, dessen wir uns zur Ableitung des Zukünftigen aus dem Vergangenen und damit zur Erlangung der erstrebten Voraussicht stets bedienen, ist dieses: Wir machen uns innere Scheinbilder oder Symbole der äuſseren Gegenstände, und zwar machen wir sie von solcher Art, daſs die denknotwendigen Folgen der Bilder stets wieder die Bilder seien von den naturnotwendigen Folgen der abgebildeten Gegenstände. Damit diese Forderung überhaupt erfüllbar sei, müssen gewisse Übereinstimmungen vorhanden sein zwischen der Natur und unserem Geiste. Die Erfahrung lehrt uns, daſs die Forderung erfüllbar ist und daſs also solche Übereinstimmungen in der That bestehen. Ist es uns einmal geglückt, aus der angesammelten bisherigen Erfahrung Bilder von der verlangten Beschaffenheit abzuleiten, so können wir

Translating Hertz's *Die Prinzipien der Mechanik* – Three Problems

The crucial passage:

Wir machen uns innere Scheinbilder oder Symbole der äusseren Gegenstände, und zwar machen wir sie von solcher Art, dass die denknotwendigen Folgen der Bilder stets wieder die Bilder seien von den naturnotwendigen Folgen der abgebildeten Gegenstande.

The standard English translation:

We form for ourselves images or symbols of external objects; and the form which we give them is such that the necessary consequents of the images in thought are always the images of the necessary consequents in nature of the things pictured.

First:

"denknotwendigen Folgen" means logically necessary consequences whereas "naturnotwendigen Folgen" means nomically necessary effects

Second:

"Scheinbild" does not mean image.

From Langenscheidt's *German-English Dictionary*, 5th ed., 1990, vol. 2, p. 1312

Scheinbild *n* illusion phantasm fantasm phantom

Translating Hertz's *Die Prinzipien der Mechanik* – Three Problems

The crucial passage:

Wir machen uns innere Scheinbilder oder Symbole der äusseren Gegenstände, und zwar machen wir sie von solcher Art, dass die denknotwendigen Folgen der Bilder stets wieder die Bilder seien von den naturnotwendigen Folgen der abgebildeten Gegenstande.

The standard English translation:

We form for ourselves images or symbols of external objects; and the form which we give them is such that the necessary consequents of the images in thought are always the images of the necessary consequents in nature of the things pictured.

Third:

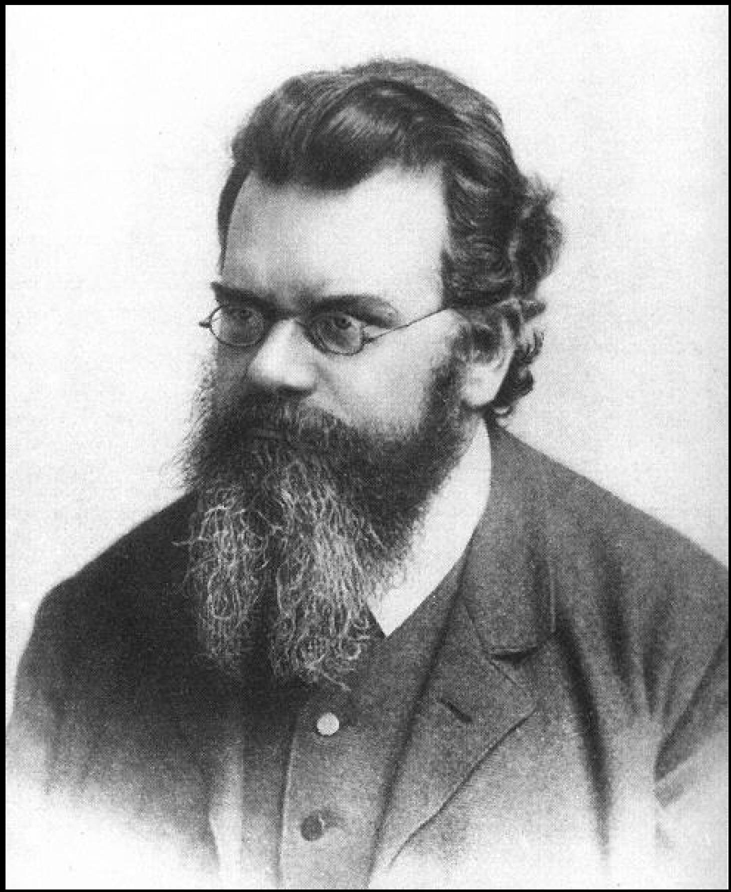
While the verb, "abbilden," is often used to mean "to picture," in mathematics it means "to map," so an Abbildung is a mapping, a matter of one-to-one correlations or correspondences

The take-home lesson:

If one means to do serious scholarship, one must always work from original sources, not translations, and one must be a master of the language

Ludwig Boltzmann (1844 -1906)

1844 – Born, Vienna
1866 – Ph.D. in Physics, Vienna
1866 – Assistant to Josef Stefan, Vienna
1867-1868 – Mathematics and Physics Teacher at the Akademisches Gymnasium, Vienna
1868-1869 – Privatdozent in Physics, Vienna
1869-1873 – Professor of Mathematical Physics, Graz
1873-1876 – Professor of Mathematics, Vienna
1876-1890 – Professor of Experimental Physics and Director of the Physical Institut, Graz
1877 – "Über die Beziehung zwischen dem zweiten Hauptsatz der mechanischen Wärmetheorie und der Wahrscheinlichkeitsrechnung . . ."
1890-1894 – Professor of Physics, Munich
1894-1900 – Professor of Theoretical Physics, Vienna
1896-1898 – Vorlesungen über Gastheorie, 2 Vols.
1900-1902 – Professor of Physics, Leipzig
1902-1906 – Professor of Theoretical Physics and Philosophy of Science, Vienna
1899, 1904, 1905 – Visits to Clark University, the St. Louis World Congress, and Berkeley
1906 – Death, Duino, Italy



Boltzmann Statistical Mechanics

The Boltzmann Principle

$S = k \ln W$

The *H*-Theorem

Boltzmann Edits Maxwell

Ostwalds Klassiker

Boltzmann's edition of *Ueber Faradays Kraftl-inien* appeared in 1895 as number 69. 96 pages of text and 32 pages of notes by Boltzmann.

His edition of *Ueber physikalische Kraftlinien* appeared in 1898 as number 102. 84 pages of text and 60 pages of notes by Boltzmann.

Ueber

FARADAY'S KRAFTLINIEN.

Von

JAMES CLERK MAXWELL.

(Transact. of t. Cambr. phil. soc. vol. 10, p. 27, gelesen am 10. Dec. 1855 und 11. Febr. 1856, Maxw. scient. pap. vol. 1, p. 155.)

Herausgegeben

von

L. Boltzmann.

LEIPZIG

VERLAG VON WILHELM ENGELMANN

1895.

Alexander Ziwet

Ueber

PHYSIKALISCHE KRAFTLINIEN.

Von

JAMES CLERK MAXWELL.

(Phil. Mag. 4. Ser. Bd. 21, S. 161, 281 und 338, 1861; Bd. 23, S. 12 und 85, 1862. Scient. Pap. Vol. I, S. 451.)

Herausgegeben

von

L. Boltzmann.

Mit 12 Figuren im Text.

LEIPZIG

VERLAG VON WILHELM ENGELMANN

1898.

Boltzmann Edits Maxwell

Maxwell, himself, on the heuristic and psychological role of models

James Clerk Maxwell, "On Faraday's Lines of Force." *Transactions of the Cambridge Philosophical Society*, 10, Part 1 (1856), 27-83. [Read December 10, 1855 and February 11, 1856.]

The first process therefore in the effectual study of the science, must be one of simplification and reduction of the results of previous investigations to a form in which the mind can grasp them. The results of this simplification may take the form of a purely mathematical formula or of a physical hypothesis. In the first case we entirely lose sight of the phenomena to be explained; and though we may trace out the consequences of given laws, we can never obtain more extended views of the connections of the subject. If, on the other hand, we adopt a physical hypothesis, we see the phenomena only through a medium, and are liable to that blindness and rashness in assumption which a partial explanation encourages. We must therefore discover some method of investigation which allows the mind at every step to lay hold of a clear physical conception, without being committed to any theory founded on the physical science from which that conception is borrowed, so that it is neither drawn aside from the subject in pursuit of analytical subtleties, nor carried beyond the truth by a favourite hypothesis.

In order to obtain physical ideas without adopting a physical theory we must make ourselves familiar with the existence of physical analogies. By a physical analogy I mean that partial similarity between the laws of one science and those of another which makes each of them illustrate the other.

Boltzmann Edits Maxwell

Maxwell, himself, on the heuristic and psychological role of models

James Clerk Maxwell, "On Faraday's Lines of Force." *Transactions of the Cambridge Philosophical Society*, 10, Part 1 (1856), 27-83. [Read December 10, 1855 and February 11, 1856.]

[Maxwell gives examples from optics and kinetic theory. About the analogy between light and the vibrations of an elastic medium Maxwell writes:]

The other analogy, between light and the vibrations of an elastic medium, extends much further, but, though its importance and fruitfulness cannot be over-estimated, we must recollect that it is founded only on a resemblance *in form* between the laws of light and those of vibrations. By stripping it of its physical dress and reducing it to a theory of "transverse alternations," we might obtain a system of truth founded strictly on observation, but probably deficient both in the vividness of its conceptions and the fertility of its method.

. . .

It is by the use of analogies of this kind that I have attempted to bring before the mind, in a convenient and manageable form, the mathematical ideas which are necessary to the study of the phenomena of electricity.

Boltzmann Edits Maxwell

Boltzmann on Maxwell's "epistemological" introduction.

Maxwell's Introduction demonstrates . . . that he was just as much a pathbreaker in epistemology as in theoretical physics. All of the new paths taken by epistemology in the following 40 years are already clearly presaged in these few pages, indeed, by means of the same analogies. Later epistemologists expressed all of this in greater detail, but also, for the most part, in a more one-sided way.

Boltzmann Edits Maxwell

Boltzmann on Maxwell's "epistemological" introduction.

Maxwell:

"The first process therefore in the effectual study of the science, must be one of simplification and reduction of the results of previous investigations to a form in which the mind can grasp them."

Boltzmann's note:

"An overly weak expression, however, of the principle of economy. (Cf. Mach, *Almanach der Wiener Acad. der Wissensch*. 1882."

Boltzmann Edits Maxwell

Boltzmann on Maxwell’s “epistemological” introduction.

Maxwell:

“If, on the other hand, we adopt a physical hypothesis, we see the phenomena only through a medium, and are liable to that blindness and rashness in assumption which a partial explanation encourages.”

Boltzmann’s note:

“Mach says exactly the same thing ‘On the Principle of Comparison in Physics’ (*Naturforscher-verhandlungen* 1894, p. 7 of the separatum): ‘It (the matter theory of heat) blinded Black’s followers.’”

Boltzmann Edits Maxwell

Boltzmann on Maxwell's "epistemological" introduction.

Maxwell:

"In order to obtain physical ideas without adopting a physical theory we must make ourselves familiar with the existence of physical analogies."

Boltzmann's note on the term "analogies":

"This word has since become a motto [Schlagwort]. Cf. Helmholtz, Studien zur Statik monozyklischer Systeme (*Berl. Ber*. März, Dec. 1884), or the just-cited essay of Mach's, also the translator's [Boltzmann's] 'Über die Methoden der theoretischen Physik.' *Catolog der math. Ausstellung zu München* 1892 and 1893."

Boltzmann Edits Maxwell

Boltzmann on Maxwell’s “epistemological” introduction.

Maxwell:

“The other analogy, between light and the vibrations of an elastic medium, extends much further, but, though its importance and fruitfulness cannot be over-estimated, we must recollect that it is founded only on a resemblance *in form* between the laws of light and those of vibrations. By stripping it of its physical dress and reducing it to a theory of “transverse alternations,” we might obtain a system of truth founded strictly on observation, but probably deficient both in the vividness of its conceptions and the fertility of its method.”

Boltzmann’s note on the expression “stripping it of its physical dress”:

“Hertz says exactly the same (Untersuch. über die Ausbreitung der elek. Kraft p. 31): ‘Scientific rigor requires that we distinguish the colorful dress that we throw over the theory from the plain and simple Form of nature itself.’ The clarity with which Maxwell had already then distinguished the fact of the periodic alternation in any transversally oriented state and the hypothesis of an oscillating motion is, in general, a proof of his insight in the epistemological domain.”

Boltzmann Edits Maxwell

Ludwig Boltzmann. “Über die Frage nach der objektiven Existenz der Vorgänge in der unbelebten Natur.” *Akademie der Wissenschaften* (Vienna). *Sitzungsberichte* 106, Part II (January 1897), 83ff.

We must aim at having ideas that are correct [predictively successful] and economical as well, that is, we are to be able always to reach the correct mode of action with the least expenditure of time and effort. The demand on any theory is that it be correct and economical; for on that very account it will then correspond to the laws of thought. I do not think that this needs to be set up as a special requirement, as Hertz has done. . . .

Processes in inanimate nature are for us mere ideas for representing regularities of certain complexes of phenomena. . . .

Processes in inanimate nature likewise exist for us merely in imagination, that is we mark them by certain thoughts and verbal signs, because this facilitates our construction of a world picture capable of foretelling our future sensations in inanimate nature.

Boltzmann Edits Maxwell

Ludwig Boltzmann. “Model.” *Encyclopaedia Britannica*. 10th ed. (1902),Vol. 30, 788-791.

Models in the mathematical, physical and mechanical sciences are of the greatest importance. Long ago philosophy perceived the essence of our process of thought to lie in the fact that we attach to the various real objects around us particular physical attributes - our concepts - and by means of these try to represent the objects to our minds. Such views were formerly regarded by mathematicians and physicists as nothing more than unfertile speculations, but in more recent times they have been brought by J. C. Maxwell, H. v. Helmholtz, E. Mach, H. Hertz and many others into intimate relation with the whole body of mathematical and physical theory. On this view our thoughts stand to things in the same relation as models to the objects they represent. The essence of the process is the attachment of one concept having a definite content to each thing, but without implying complete similarity between thing and thought; for naturally we can know but little of the resemblance of our thoughts to the things to which we attach them. What resemblance there is lies principally in the nature of the connexion, the correlation being analogous to that which obtains between thought and language, language and writing, the notes on the stave and musical sounds, &c.

Boltzmann Edits Maxwell

Ludwig Boltzmann. “Model.” *Encyclopaedia Britannica*. 10th ed. (1902),Vol. 30, 788-791.

In explaining magnetic and electrical phenomena it inevitably fell into somewhat artificial and improbable hypotheses, and this induced J. Clerk Maxwell, adopting the ideas of Michael Faraday, to propound a theory of electric and magnetic phenomena which was not only new in substance, but also essentially different in form. If the molecules and atoms of the old theory were not to be conceived of as exact mathematical points in the abstract sense, then their true nature and form must be regarded as absolutely unknown, and their groupings and motions, required by theory, looked upon as simply a process having more or less resemblance to the workings of nature, and representing more or less exactly certain aspects incidental to them. With this in mind, Maxwell propounded certain physical theories which were purely mechanical so far as they proceeded from a conception of purely mechanical processes. But he explicitly stated that he did not believe in the existence in nature of mechanical agents so constituted, and that he regarded them merely as means by which phenomena could be reproduced, bearing a certain similarity to those actually existing, and which also served to include larger groups of phenomena in a uniform manner and to determine the relations that held in their case.

Boltzmann Edits Maxwell

Ludwig Boltzmann. “Model.” *Encyclopaedia Britannica*. 10th ed. (1902),Vol. 30, 788-791.

The question no longer being one of ascertaining the actual internal structure of matter, many mechanical analogies or dynamical illustrations became available, possessing different advantages; and as a matter of fact Maxwell at first employed special and intricate mechanical arrangements, though later these became more general and indefinite. This theory, which is called that of mechanical analogies, leads to the construction of numerous mechanical models. Maxwell himself and his followers devised many kinematic models, designed to afford a representation of the mechanical construction of the ether as a whole as well as of the separate mechanisms at work in it: these resemble the old wave-machines, so far as they represent the movements of a purely hypothetical mechanism. But while it was formerly believed that it was allowable to assume with a great show of probability the actual existence of such mechanisms in nature, yet nowadays philosophers postulate no more than a partial resemblance between the phenomena visible in such mechanisms and those which appear in nature. Here again it is perfectly clear that these models of wood, metal and cardboard are really a continuation. and integration of our process of thought; for, according to the view in question, physical theory is merely a mental construction of mechanical models, the working of which we make plain to ourselves by the analogy of mechanisms we hold in our hands,and which have so much in common with natural phenomena as to help our comprehension of the latter.

Wilhelm Ostwald (1853 -1932)

1853 – Born, Riga
1875 – Master's Degree in Chemistry, University of Dorpat
1875-1881 – Assistant to Arthur von Oettingen in Physics and Carl Schmidt in Chemistry, Dorpat
1878 – Ph.D. in Chemistry, Dorpat
1881-1887 – Professor of Chemistry, Riga Politechnicum
1887-1906 – Professor of Physical Chemistry, Leipzig
1887-1922 – Founder and Editor of the *Zeitschrift für physikalische Chemie*
1889 – Founder and Editor of Ostwalds Klassiker der exakten Wissenschaften
1896-1903 – *Lehrbuch der allgemeinen Chemie*, 2 vols.
1909 – Nobel Prize in Chemistry
1932 – Died, Großbothen, Saxony

Ostwald’s Nobel Prize Certificate

Georg Helm (1851 -1923)

1851 – Born, Dresden
1867-1873 – Studies Mathematics and Natural Sciences in Dresden, Leipzig, and Berlin
1874-1888 – Teacher of Mathematics and Physics at the Annenschule, Dresden
1887 – *Die Lehre von der Energie, historisch-kritisch Entwickelt, nebst beiträgen zu einer allgemeinen Energetik*
1888-1892 – Professor of Analytical Geometry, Analytical Mechanics, and Mathematical Physics at the Dresden Politechnicum
1892-1906 – Professor of Mathematical Physics, Technische Hochschule, Dresden
1898 – *Die Energetik in ihrer geschichtlichen Entwicklung*
1906-1919 – Professor of Applied Mathematics, Technische Hochschule, Dresden
1923 – Died, Dresden

Wilhelm Ostwald. *Vorlesungen über Naturphilosophie. Gehalten im Sommer 1901 an der Universität Leipzig*. Leipzig: Veit & Comp, 1901.

[Quoting Julius Robert Mayer. *Bemerkungen über das mechanische Aequivalent der Wärme*. Heilbron: Johann Ulrich Landherr, 1851.]

The most important, if not to say the only rule for true natural scientific research is to remain mindful that our task is to *know* the phenomena before we may seek for explanations or inquire after higher causes. If a fact is once known in all of its aspects, then it is precisely thereby explained and the task of science is accomplished.

Julius Robert Mayer
1814-1878

Wilhelm Ostwald. *Vorlesungen über Naturphilosophie. Gehalten im Sommer 1901 an derUniversität Leipzig*. Leipzig: Veit & Comp, 1901.

The judgment of contemporaries about the two-sided foundation of the law of the conservation of energy was completely in favor of Helmholtz. The judgment of posterity will be otherwise. As we can convince ourselves on the basis of contemporary letters and the later writings of Mayer, it was for him a matter of a proof a law of nature that, in the final analysis, could only come about in an empirical manner, and he repudiated, again and again, all hypotheses about the so-called essence of the different energies. With Helmholtz the empirical proof is likewise, to be sure, the main point; but the derivation of the law from the mechanistic hypothesis appears to him so important and convincing, that he puts it at the beginning of his otherwise strictly empirical account.

Wilhelm Ostwald. *Vorlesungen über Naturphilosophie. Gehalten im Sommer 1901 an derUniversität Leipzig*. Leipzig: Veit & Comp, 1901.

There are, therefore, immutable, enduring results of science, and, alongside of them, transitory ones; how can one distinguish the two?

The answer is soon given: *Laws of nature are enduring, hypotheses are transitory*.

Hypotheses are, as we have seen, models that permit the representation of less familiar phenomena by means of more familiar ones. Naturally one chooses the models so that the familiar characteristics of the phenomena to be represented are thus represented by corresponding characteristics of the models. For the yet unfamiliar characteristics one cannot provide; but occasionally it happens that these too find their appropriate representation through the chosen model. Why can that not go on without limit, why can one not find a model that represents with equal perfection *all* characteristics of the phenomena? For that such a model cannot be found is only too certainly established by the unending series of failures in the history of science.

The answer lies in the fact that in employing the model in the representation of phenomena one introduces ingredients that belong to the *model*, but not to the *phenomena themselves*. Then between these foreign ingredients and the corresponding constituents of the phenomena the contradiction sooner or later emerges that reveals the model to be useless.

But can one not choose the model precisely so that a contradiction cannot arise? The answer to this question is a round *No*. For if the model and the object agreed in all respects, then they would be exactly the same, i.e., one can model a phenomenon perfectly only by means of itself. Every modeling by means of another phenomenon necessarily includes a foreign element, which at first remains untested, and therefore reveals no contradiction. But if the comparison between the model and reality is carried ever further, then the contradiction must inevitably come to light, and judgment is thereby passed.

Georg Helm. *Die Lehre von der Energie, historisch-kritisch entwickelt. Nebst Beiträgen zu einer allgemeinen Energetik*. Leipzig: Arthur Felix, 1887.

We can recognize only *one* proof of the energy principle, an inductive one. Its conclusion is characterized by the following main points:

1) A perpetuum mobile is impossible.
2) The different forms of energy are equivalent.

The second of these propositions is founded upon the phenomena of energy transformation, supported by mathematical results in mechanics, and by experimental proofs of equivalence.

But the perpetuum-mobile-principle is established as a result of experience intimately mixed up with our a priori ideas about the course of nature, like the physical principles of Newtonian mechanics: in simple cases one recognizes that every variant conception is either too complicated or false, whereas this one adapts itself to the phenomena in an unforced manner; but even in more complicated cases this conception leads to correct conclusions, as the success of the theoretical structure founded upon it proves.

Any further natural philosophical foundation of the perpetuum-mobile-principle based upon a monistic conception of the causal connection or upon a religious concept of conservation cannot be regarded as a compelling proof for exact science. . . . We banish such discussions to metaphysics.

Georg Helm. *Die Energetik nach ihrer geschichtlichen Entwickelung*. Leipzig: Veit & Comp, 1898.

But one does not, therefore, need to go as far as Ostwald has done, and simply reject models. . . . Energetics does not at all need to combat models as being *inimical*; for they are, in truth, *subordinate* to it, however independently they may behave. How, specifically, do we recognize whether a model proves correct? One says, by its agreement with experience, or by the agreement of its logical consequences with experience. But how then? Is not then the model qualitatively different from the fact that it models, how can one compare it or its consequences with the latter? Where is the *tertium comparationis*? Consider an example. One devises a model for describing thermal phenomena, a certain quantity that is not heat is supposed to represent the heat, another the temperature. What does it mean then to test in experience whether the model is usable? All of the traits of the model do not agree with our experiences of heat; otherwise it would not be a model. Which must agree in order to satisfy exact science? *Only energetics* provides the answer to this question. We can treat as heat only a quantity that can be conceived as an energy form, e.g., that submits to the principle of the conservation of energy; as temperature we can recognize only such a quantity as shares with the temperature, e.g., the property of being an intensive magnitude. In short, the traits that the model must reproduce are exactly those necessary for a perfect quantitative description of experience, exactly those portrayed in energetics. Thus, in every sense, energetics stands *over* the mechanical models, she is their judge; only through her critique is it determined whether the model is a correct description of reality, no empty play of the fantasy, but rather poetic truth. And without this critique, the adherence to received forms of intuition, the devising of new auxiliary representations merely to save the old models, would be idle scholasticism.

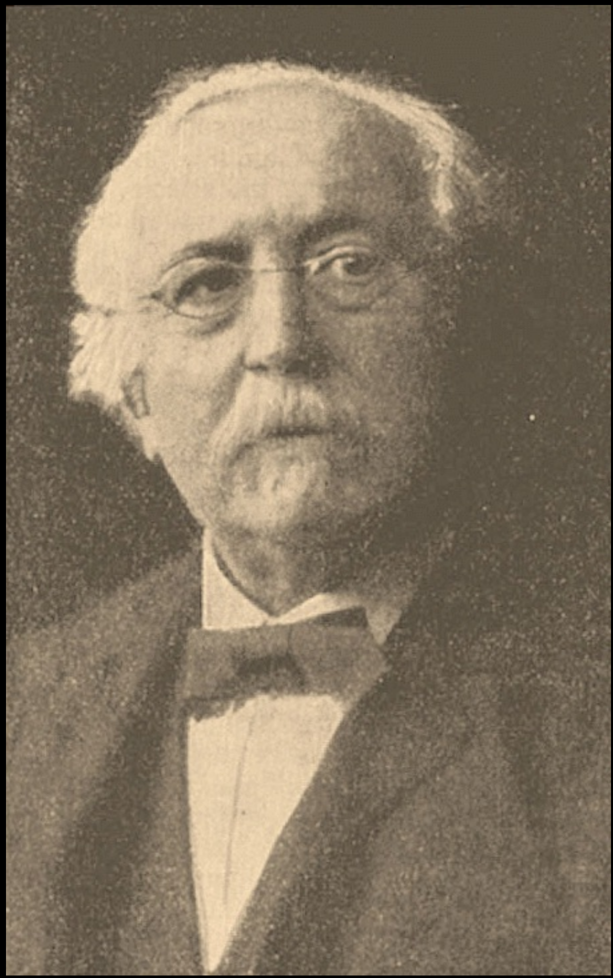
Georg Helm. *Die Energetik nach ihrer geschichtlichen Entwickelung*. Leipzig: Veit & Comp, 1898.

[Concerning the debate at the 1895 Lübeck Naturforscherversammlung]

What has been disputed and defended there concerning energetics *is the method of being able to speak about natural processes in a language free of models;* and in this method, energetics is unsurpassed.

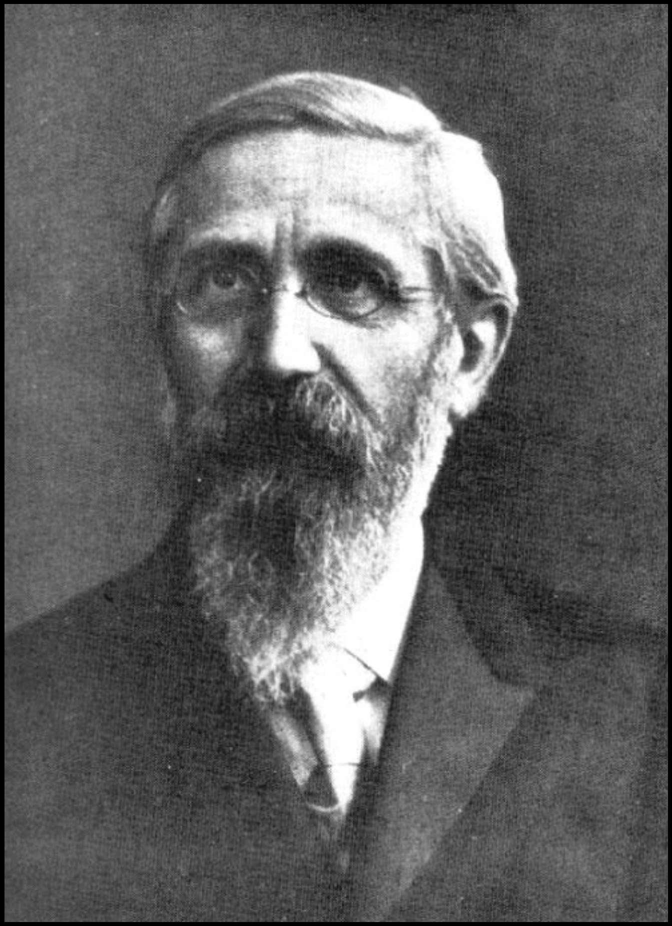
Hermann Cohen (1842 -1918)

1851 – Coswig, Anhalt, Germany
1861-1865 – Studies Jewish Religion, Ancient History, and Philosophy at Breslau, Berlin, and Halle. Ph.D. at Halle
1870 – Privatdozent, Marburg
1871 – *Kant´s Theorie der Erfahrung*
1873 – Professor of Philosophy, Marburg
1877 – *Kants Begründung der Ethik*
1883 – *Das Prinzip der Infinitesimal-Methode und seine Geschichte. Ein Kapitel zur Grundlegung der Erkenntniskritik*
1889 – *Kants Begründung der Aesthetik*
1902 – *Logik der reinen Erkenntnis*
1904 – *Ethik des reinen Willens*
1912 – *Aesthetik des reinen Gefühls*
1912 – Retired and Moved to Berlin
1918 – Died, Berlin
1918 – *Die Religion der Vernunft aus den Quellen des Judentums*



Paul Natorp (1854 -1924)

1854 – Born, Düsseldorf
1871-1876 – Studies Music, History, Philology, and Philosophy at Berlin, Bonn, and Straßburg. Ph.D. at Straßburg
1876-1881 – Private Tutor and Assistant Librarian, Marburg
1881 – Privatdozent, Marburg
1885 – Associate Professor of Philosophy, Marburg
1889 – *Sozialpädagogik. Theorie der Willenserziehung auf der Grundlage der Gemeinschaft*
1893 – Professor of Philosophy and Pedagogy, Marburg
1905 – *Allgemeine Pädagogik in Leitsätzen zu akademischen Vorlesungen*
1910 – *Die logischen Grundlagen der exakten Wissenschaften*
1922 – Retired
1924 – Died, Marburg



Ernst Cassirer (1874 -1945)

1874 – Born, Breslau (Wroclaw)
1892-1896 – Studies Law, German Literature, and Philosophy, Berlin
1896-1899 – Studies Philosophy, Marburg. Ph.D. 1899
1906 – *Das Erkenntnisproblem in der Philosophie und Wissenschaft der neueren Zeit*
1906-1919 – Privatdozent, Berlin
1910 – *Substanzbegriff und Funktionsbegriff. Untersuchungen über die Grundfragen der Erkenntniskritik*
1919 – *Zur Einstein'schen Relativitätstheorie. Erkenntnistheoretische Betrachtungen*
1919-1933 – Professor of Philosophy, Hamburg
1923-1929 – *Philosophie der symbolischen Formen*. 3 Vols.
1933-1935 – Guest Professor, Oxford
1935-1941 – Professor of Philosophy, Göteborg, Sweden
1937 – *Determinismus und Indeterminismus in der modernen Physik*
1941-1944 – Professor of Philosophy, Yale

1944-1945 – Professor of Philosophy, Columbia University
1945 – Died, New York

SUBSTANZBEGRIFF UND FUNKTIONSBEGRIFF

Untersuchungen über die Grundfragen der Erkenntniskritik

von

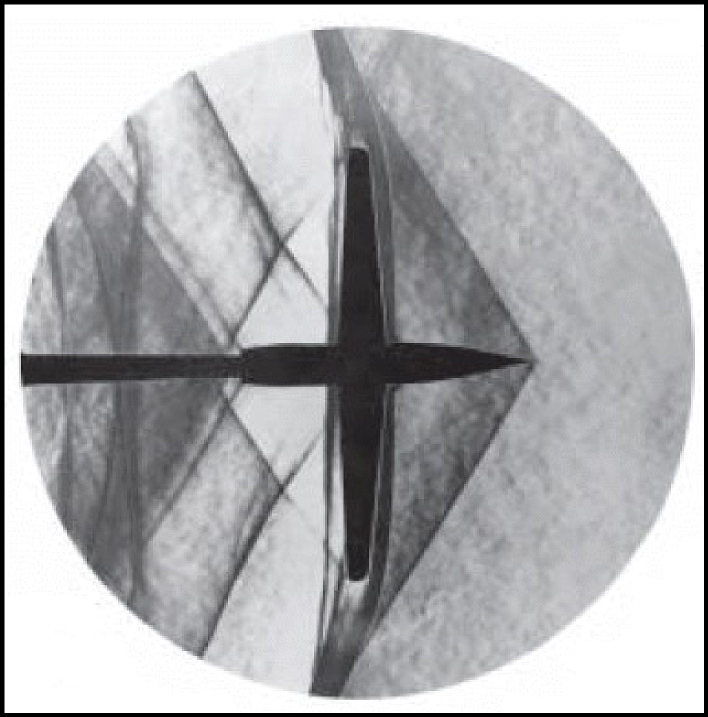
ERNST CASSIRER

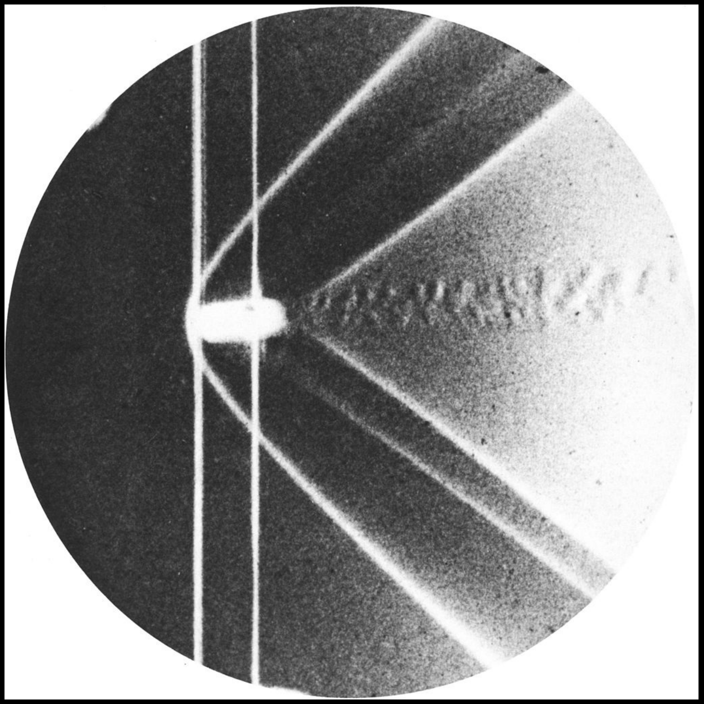
VERLAG VON BRUNO CASSIRER
BERLIN 1910

Ernst Mach (1838-1916)

1838 – Born, Brno, Moravia
1860 – Ph.D. Physics, Vienna
1861 – Privatdozent, Vienna
1864 – Professor of Mathematics, Graz
1866 – Professor of Physics, Graz
1867 – Professor of Experimental Physics, Prague
1883 – *Die Mechanik in ihrer Entwickelung historisch-kritisch dargestellt*
1886 – *Beiträge zur Analyse der Empfindungen*
1895 – Professor of "Philosophy, Especially the History of the Inductive Sciences"
1896 – *Die Principien der Wärmelehre. Historisch-kritisch entwickelt*
1901 – Retirement
1905 – *Erkenntnis und Irrtum. Skizzen zur Psychologie der Forschung*
1916 – Died, Munich

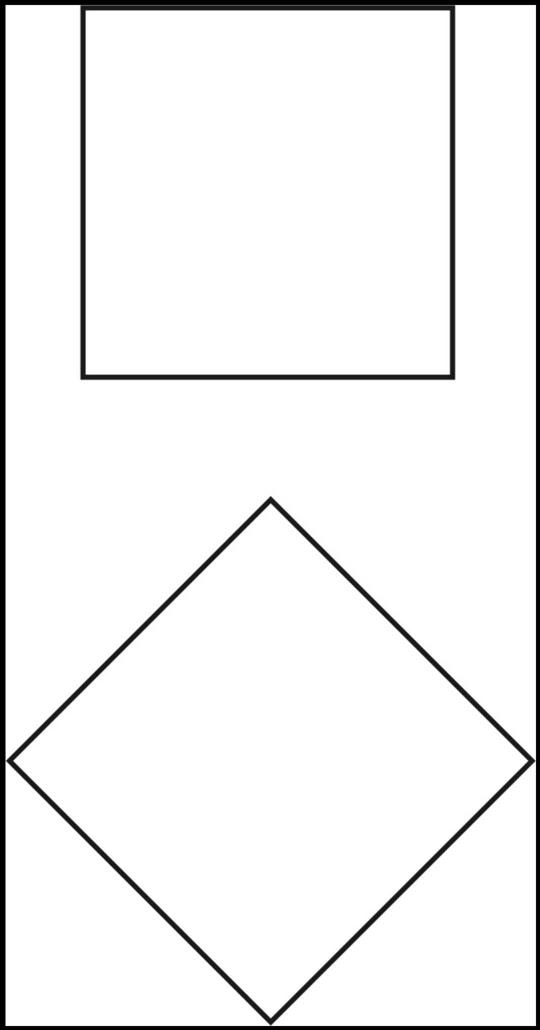
Mach’s Work in Physics





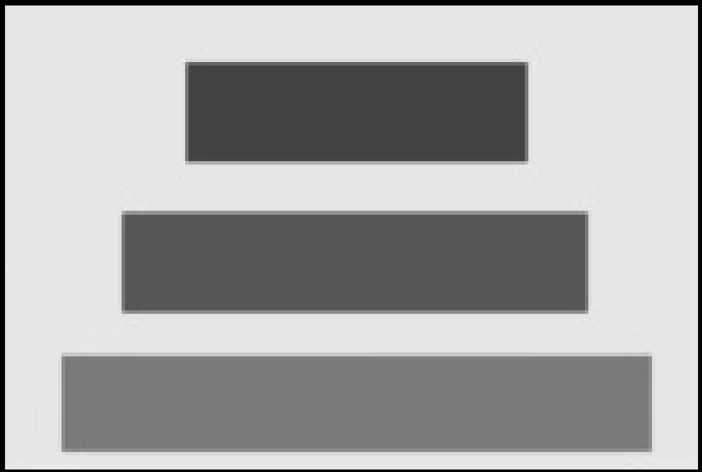
1886-1887, Study of Shock Waves Using Schlieren Photography

Mach's Work in Psycho-Physics



1861 - The Oblique Effect

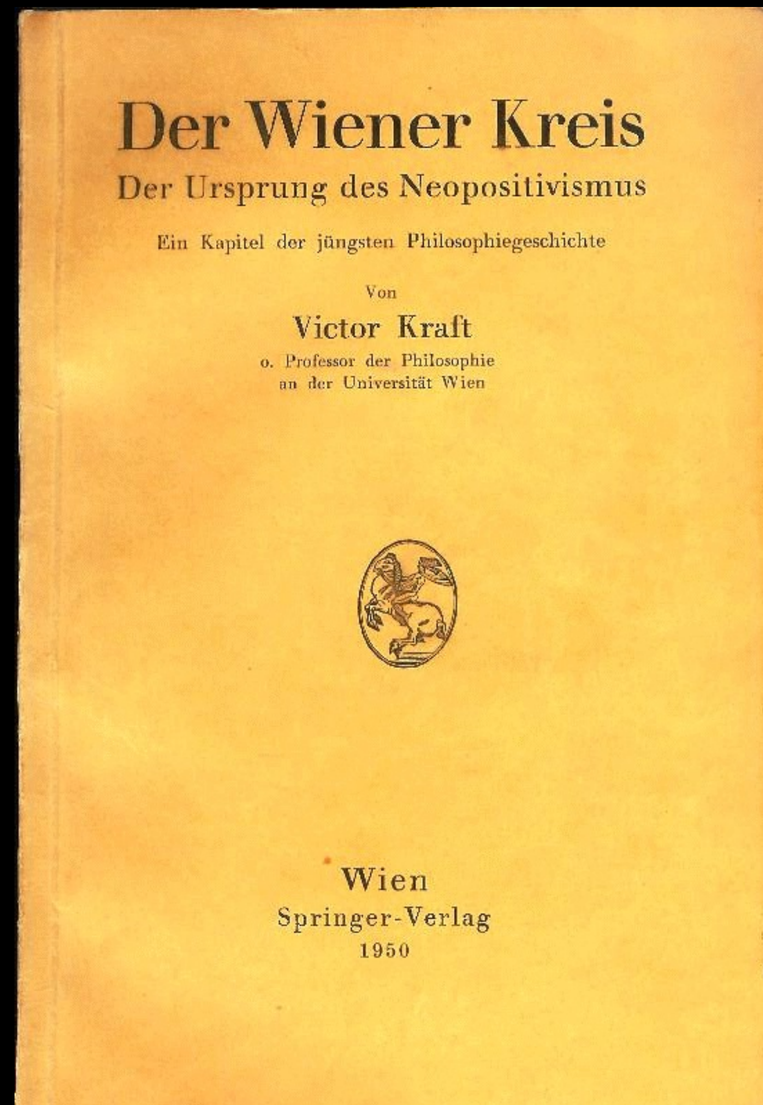
Mach’s Work in Psycho-Physics



1865 - Mach Bands

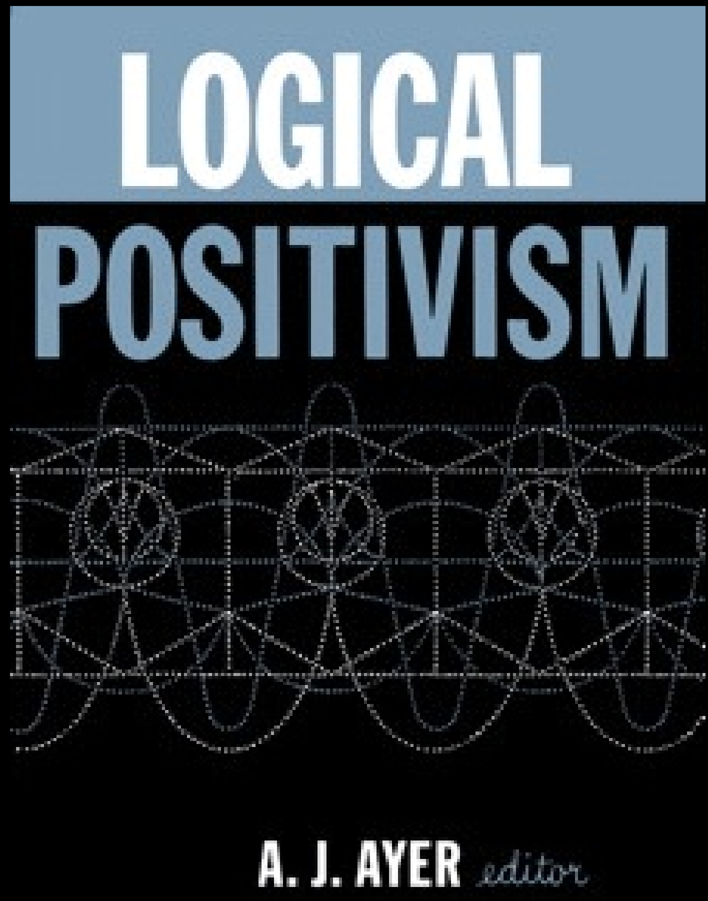
Most of the Twentieth-Century Historiography Made Mach Out to Be a Reductionist Phenomenalist

Victor Kraft, *Der Wiener Kreis. Der Ursprung des Neupositivismus. Ein Kapitel der jüngsten Philosophiegeschichte* (Vienna: Springer, 1950).



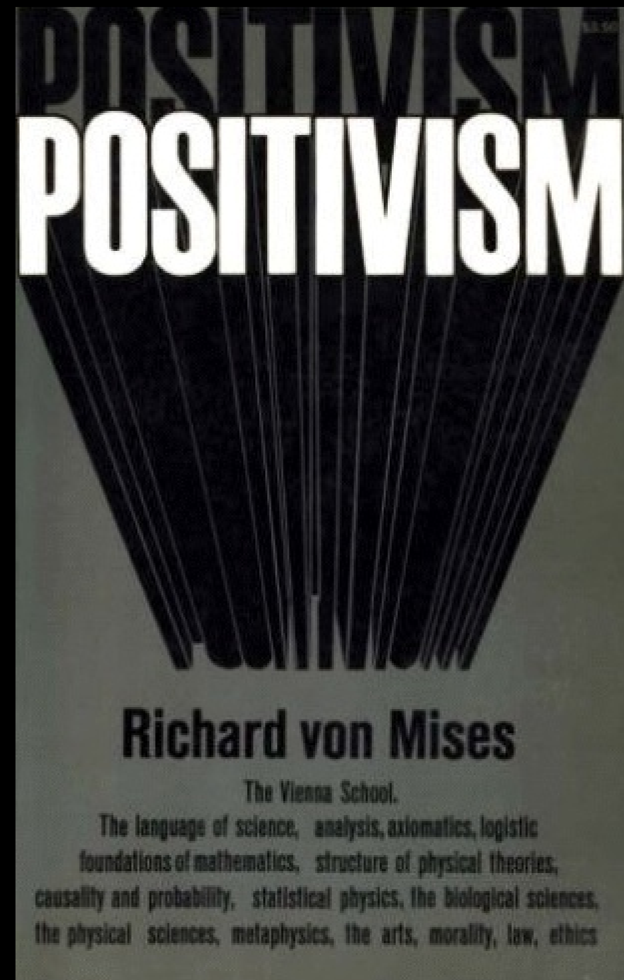
Most of the Twentieth-Century Historiography Made Mach Out to Be a Reductionist Phenomenalist

A. J. Ayer, ed., *Logical Positivism* (New York: The Free Press, 1959).



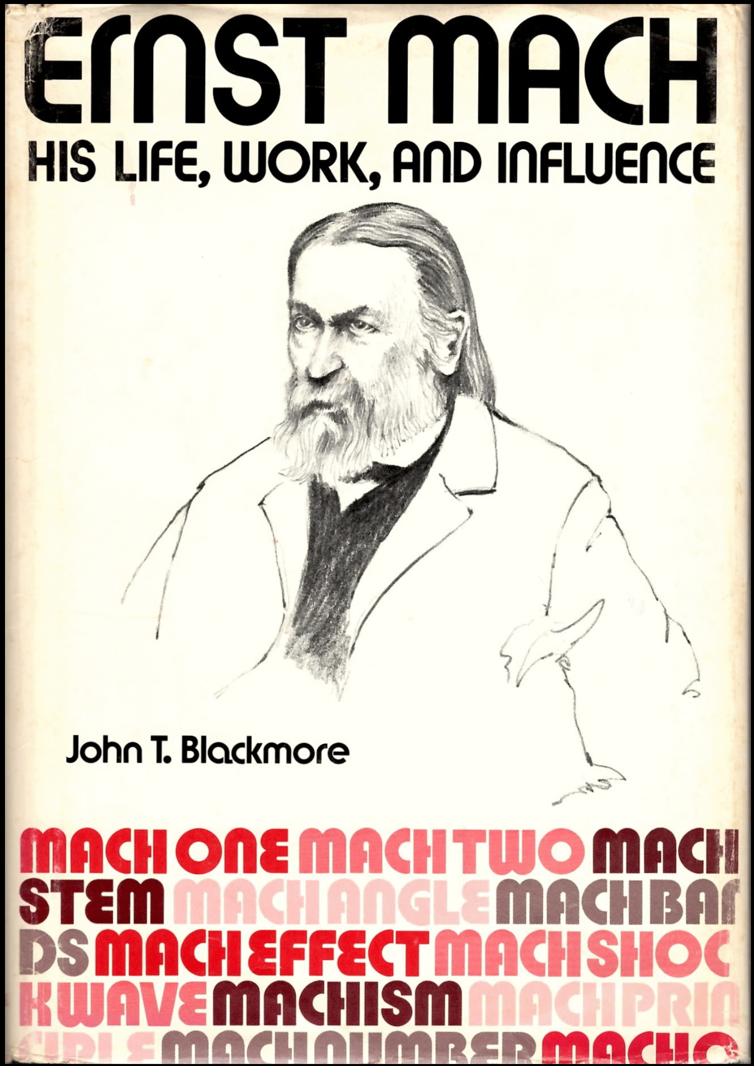
Most of the Twentieth-Century Historiography Made Mach Out to Be a Reductionist Phenomenalist

Richard von Mises, *Positivism: A Study in Human Understanding* (Cambridge, MA: Harvard University Press, 1951).



More than Anyone Else, It Was John Blackmore Who, in the Later Twentieth Century, Promoted this Reading

John Blackmore, *Ernst Mach: His Life, Work, and Influence* (Berkeley: University of California Press, 1972).

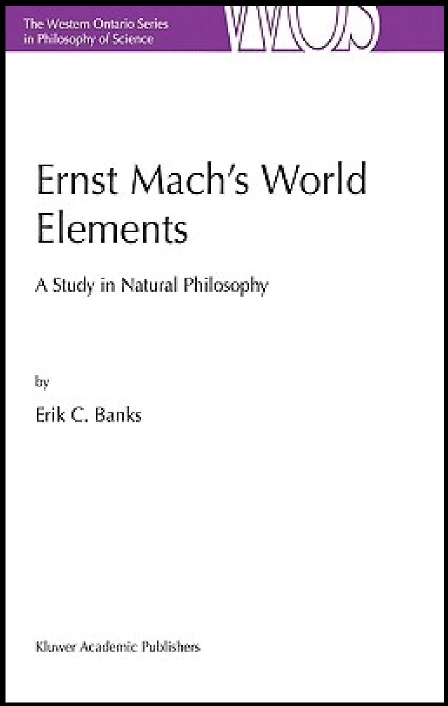


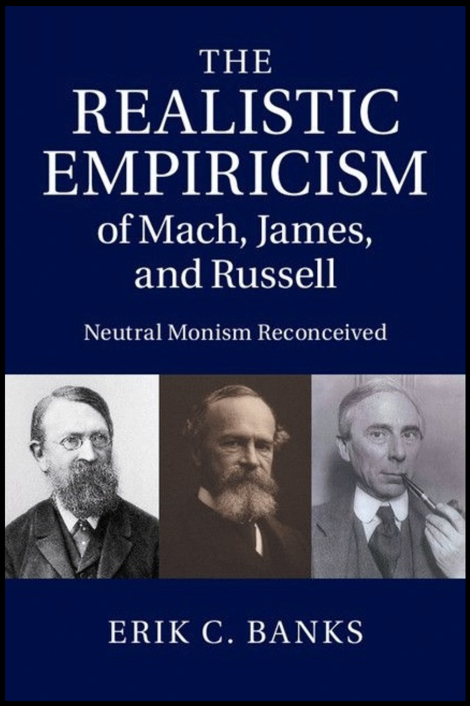
But We Are Now Seeing the Emergence of Superb New Scholarship on Mach

In my opinion, Erik Banks is now setting the gold standard.

Erik Banks, *Ernst Mach's World Elements: A Study in Natural Philosophy* (Boston and Dordrecht: Kluwer, 2003).

Erik Banks, *The Realistic Empiricism of Mach, James, and Russsell: Neutral Monism Reconsidered* (New York: Cambridge University Press, 2014).

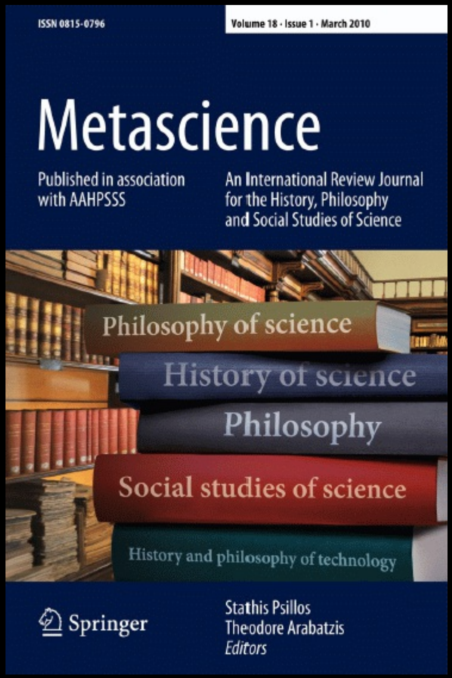




Banks on Blackmore's Influence

John Blackmore, over his long career of writing about the life, work and influence of Ernst Mach, has never been able to see anything of value in Mach's philosophical writings, and what is more, his historical coverage of Mach's career is often punctuated with tirades against what Blackmore calls Mach's "phenomenalism," the belief in the reality of human sense experience and literally nothing else. Blackmore reiterates that view in *Ernst Mach's Philosophy: Pro and Con*, his first book devoted exclusively to Mach's philosophy, along with a recent offering about *Ernst Mach's Prague*. In previous work, Blackmore has identified as an historian and claimed to avoid taking sides in philosophical disputes, but this has never been entirely true. It seems he cannot resist promulgating an erroneous, though widely shared, reading of Mach's philosophy that has damaged Mach's reputation for more than one hundred years, and one that I have tried to set straight in my (2003) and will again in this essay.

Erik Banks, "Sympathy for the Devil: Reconsidering Ernst Mach's Empiricism," *Metascience* 21 (2012), 321-330.



Mach on Duhem

The author shows how physical theory gradually transforms itself from a presumptive explanation on the basis of a vulgar or more or less scientific metaphysics into a system resting on a few principles, a system of mathematical propositions that economically describe and classify our experiences. In this process the explanatory picture changes many times, until finally it falls away entirely, while the descriptive part passes over into the new, more complete theory almost unchanged. . . . Duhem regards the model, like the picture, as a parasitic growth.

(Mach in the Foreword to the 1908 German translation of La *Théorie physique. Son objet et sa structure*)

Ziel und Struktur
der
physikalischen Theorien
von
Pierre Duhem
Korrespondierendem Mitglied des Institut de France
Professor der Theoretischen Physik an der Universität Bordeaux

Autorisierte Übersetzung von
Dr. Friedrich Adler
Privatdozenten an der Universität Zürich

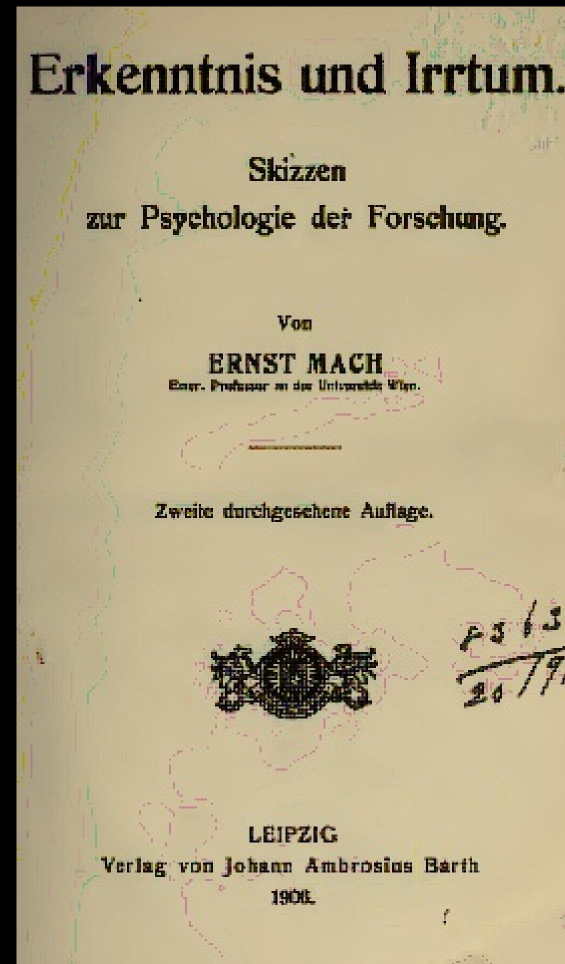
Mit einem Vorwort von
Ernst Mach

Leipzig
Verlag von Johann Ambrosius Barth
1908

Mach on Duhem

I was very pleased by Duhem's work, "La Throrie physique, son objet et sa structure" (1906). I had not yet hoped to find such thoroughgoing agreement on the part of physicists. Duhem repudiates any metaphysical conception of questions in physics; he views the conceptually-economical determination of the factual as the aim of physics. . . . The agreement between us is all the more precious to me, since Duhem arrived at the same results wholly independently.

(Mach in the Foreword to the 1906 second edition of *Erkenntnis und Irrtum*)



Erkenntnis und Irrtum.

Skizzen
zur Psychologie der Forschung.

Von
ERNST MACH
Emer. Professor an der Universität Wien.

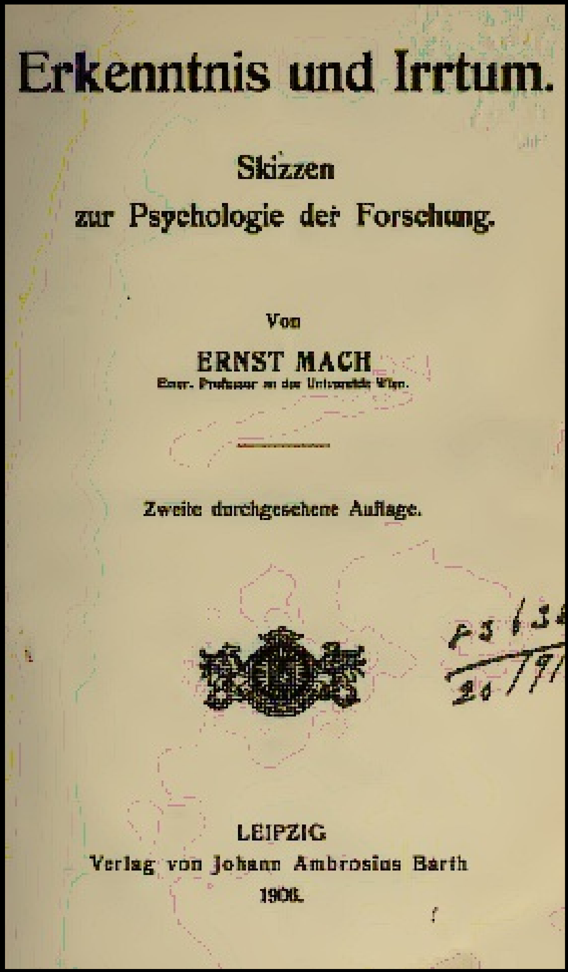
Zweite durchgesehene Auflage.

LEIPZIG
Verlag von Johann Ambrosius Barth
1906.

Mach on Duhem

Claude Bernard advises us to disregard all theory in experimental investigations, to leave theory at the door. Duhem rightly objects that this is impossible in physics, where experiment without theory is incomprehensible . . . . In fact, one can only recommend that attention be given to whether or not the experimental result is on the whole compatible with the assumed theory. Cf. Duhem (La Throrie physique, pp. 297f)

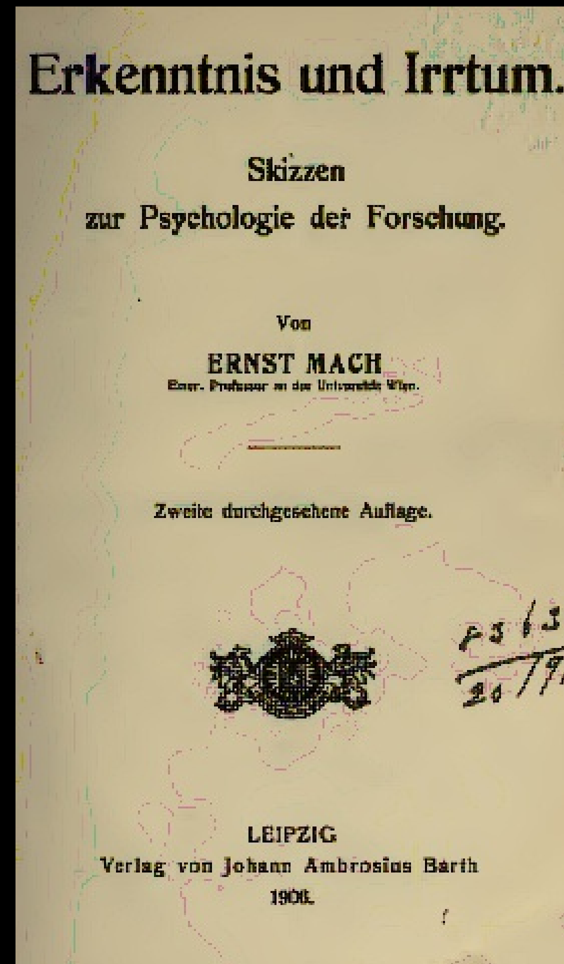
(Mach p. 202, n. 3 in the 1906 second edition of *Erkenntnis und Irrtum*)



Mach on Duhem

Duhem (La Throrie physique, pp. 364f) explains that hypotheses are not so much *chosen* by the researcher, arbitrarily and at will, but rather *force* themselves *upon* the researcher in the course of historical development, under the impress of facts that are gradually becoming known. Such a hypothesis usually consists of a whole complex of ideas. If a result then arises, e.g., through an ‘experimentum crucis’, that is incompatible with a hypothesis, then for the time being one can only regard it as contradicting the *entire complex of ideas.* On this latter point cf. Duhem, l.c., pp. 311f

(Mach p. 244, n. 1 in the 1906 second edition of *Erkenntnis und Irrtum*)


Erkenntnis und Irrtum.

Skizzen
zur Psychologie der Forschung.

Von
ERNST MACH
Emer. Professor an der Universität Wien.

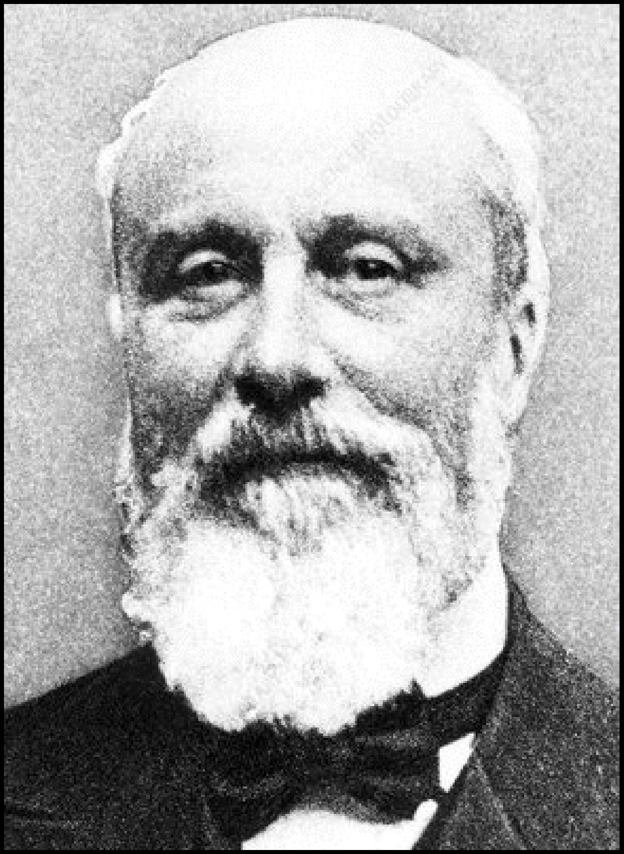
Zweite durchgesehene Auflage.

LEIPZIG
Verlag von Johann Ambrosius Barth
1906.

PHIL 93812 – HOPOS

Pierre Duhem (1861-1916)

1861 – Born, Paris
1882-1888 – Ecole Normale Supérieure, Ph.D, in Applied Mathematics
1887 – Maitre de Conférences, Lille
1893 – Professor of Physics, Renne
1894 – Professor of Theoretical Physics, Bordeaux
1902 – *Le Mixte et la Combinaison Chimique. Essai sur l'Évolution d'une Idée*
1903 – *Les Origines de la Statique*
1905 – *L'Évolution de la Mécanique*
1906 – *La Théorie Physique. Son Objet et sa Structure*
1908 – *Sauver les Phénomènes. Essai sur la Notion de Théorie Physique de Platon à Galilée*
1913-1959 – *Le Système du Monde. Histoire des Doctrines Cosmologiques de Platon à Copernic*
1916 – *La Science Allemande*
1916 – Died, Cabrespine



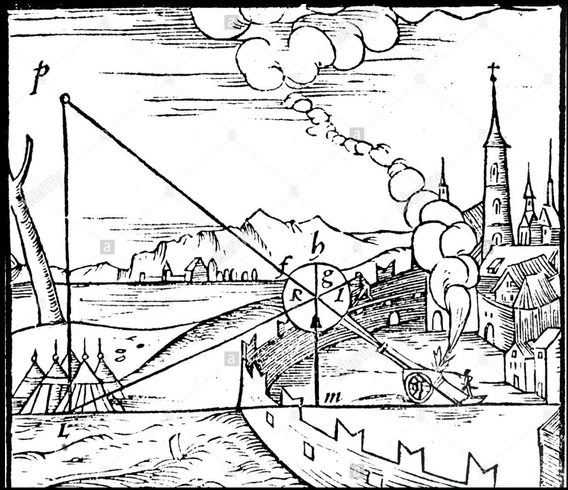
The First Duhem Thesis

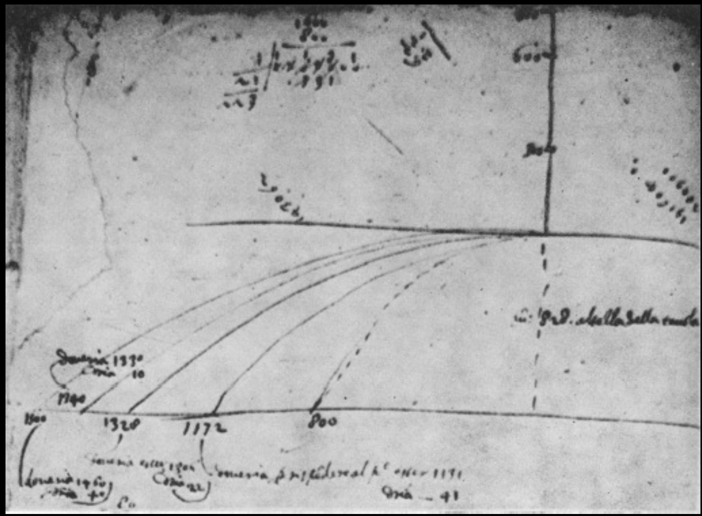
There was no scientific revolution, just a continuous development from medieval and renaissance to early modern natural philosophy.

Example: From impetus to inertia.

Impetus is an active principle.

Inertia is a passive tendency.

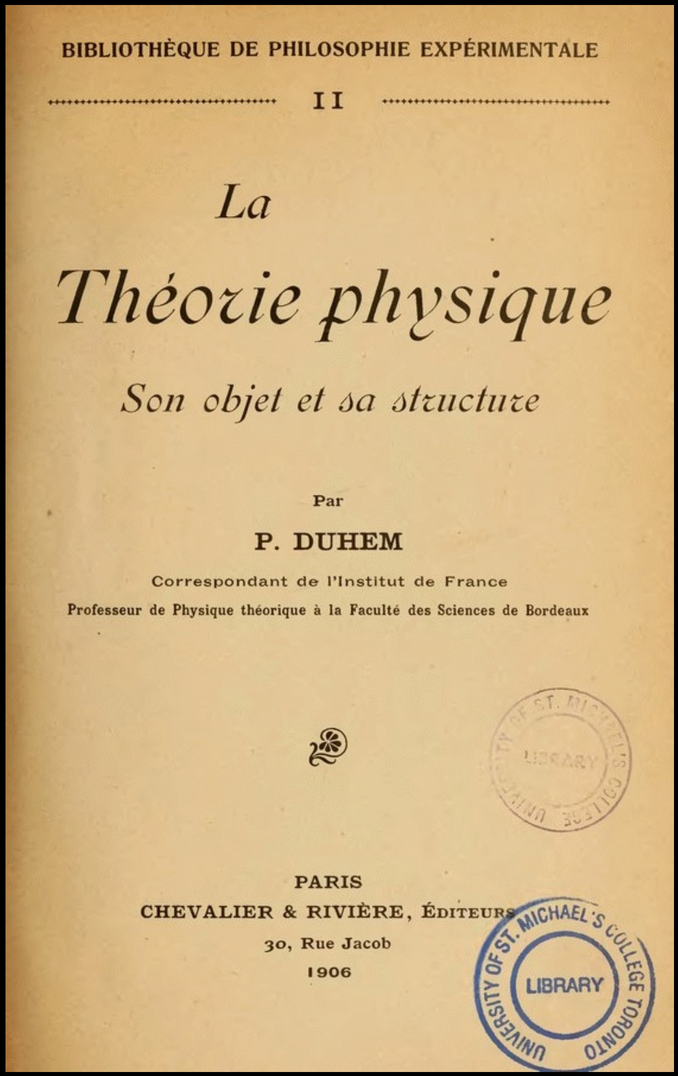




The Duhem Thesis in Philosophy

The Aim and Structure of Physical Theory (1906)

- Theories always tested only as wholes; individual hypotheses never tested in isolation
- Theory choice always underdetermined by logic and empirical evidence
- Bon sens – educated good sense or common sense – is trusted to lead us to the "natural classification"



The Duhem Thesis in Philosophy

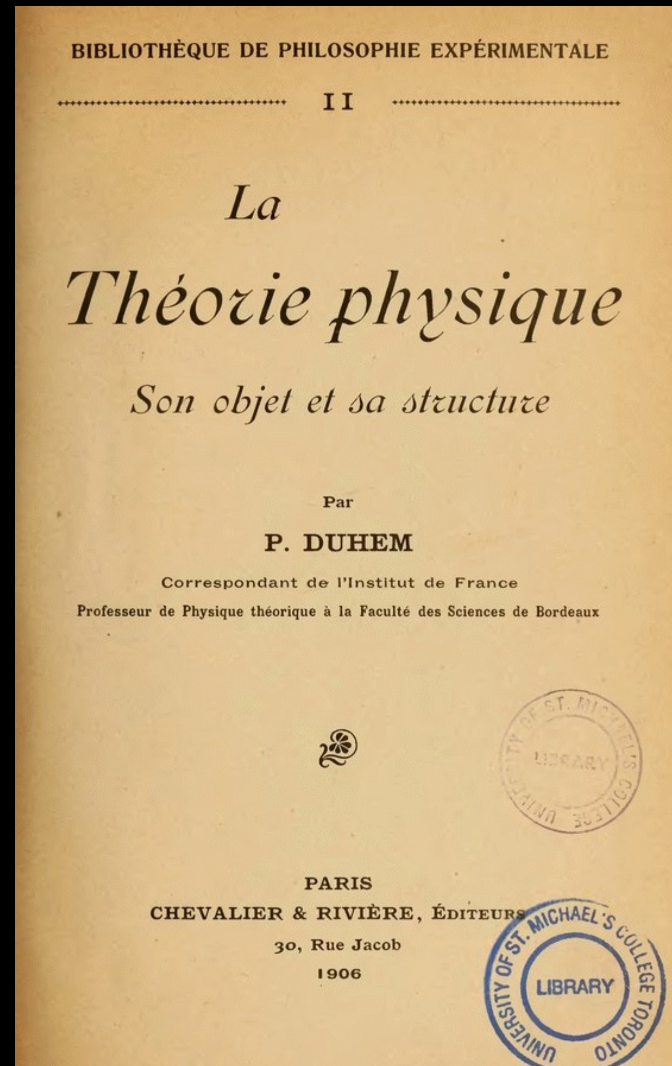
H – hypothesis

C_1, C_2, C_3, etc. – auxiliary conditions

O – observation report

Simple (-minded?) Falsification

$$
\begin{array}{l}
H \Rightarrow O \\
\sim O \\
\therefore \sim H
\end{array}
$$



BIBLIOTHÈQUE DE PHILOSOPHIE EXPÉRIMENTALE

II

La

Théorie physique

Son objet et sa structure

Par

P. DUHEM

Correspondant de l'Institut de France

Professeur de Physique théorique à la Faculté des Sciences de Bordeaux

PARIS

CHEVALIER & RIVIÈRE, ÉDITEURS

30, Rue Jacob

1906

The Duhem Thesis in Philosophy

H – hypothesis

C_1, C_2, C_3, etc. – auxiliary conditions

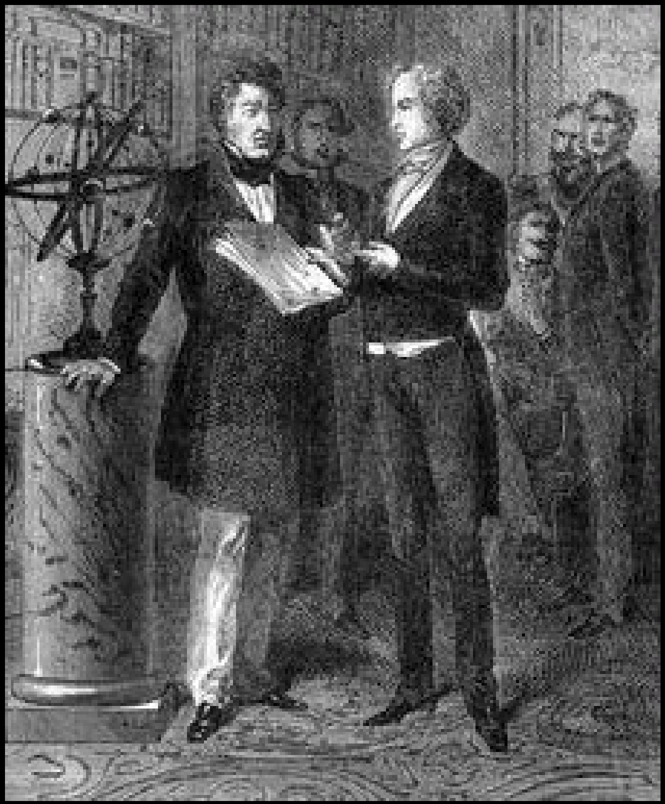
O – observation report

Simple (-minded?) Falsification

$$
\begin{array}{l}
H \Rightarrow O \\
\sim O \\
\therefore \sim H
\end{array}
$$

Assuming a More Realistic Model of Theory Testing

$$
\begin{array}{l}
H \;\&\; C_1, C_2, C_3, \ldots \Rightarrow O \\
\sim O \\
\therefore \sim H \vee \sim C_1 \vee \sim C_2 \vee \sim C_3 \vee \ldots
\end{array}
$$



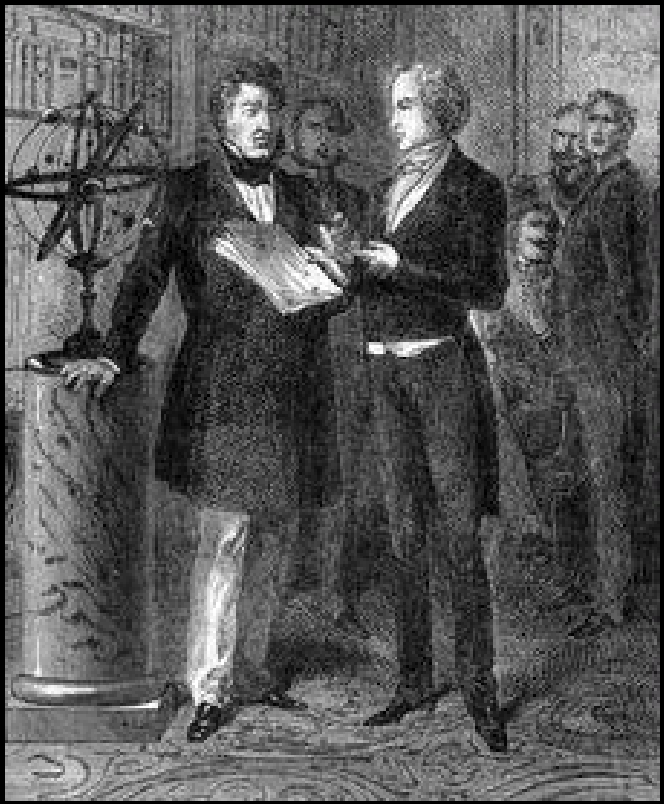
Urbain Le Verrier (1811-1877) Explaining the Discovery of Neptune to King Louis Philippe, 1846

The Duhem Thesis in Philosophy

There will always be a multiplicity of equally well confirmed total theories:

T1: $\sim H \,\&\, C_1 \,\&\, C_2 \,\&\, C_3 \vee \ldots$
T2: $H \,\&\, \sim C_1 \,\&\, C_2 \,\&\, C_3 \vee \ldots$
T3: $H \,\&\, C_1 \,\&\, \sim C_2 \,\&\, C_3 \vee \ldots$
T4: $H \,\&\, C_1 \,\&\, C_2 \,\&\, \sim C_3 \vee \ldots$
T5: $H \,\&\, \sim C_1 \,\&\, \sim C_2 \,\&\, C_3 \vee \ldots$
etc.

Choice among these is sometimes a matter of convention

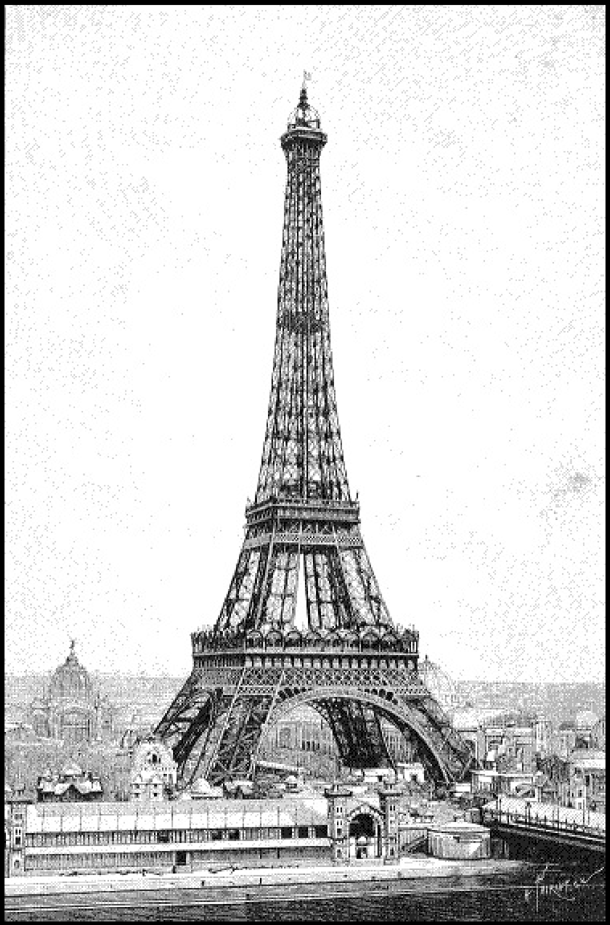


Urbain Le Verrier (1811-1877) Explaining the Discovery of Neptune to King Louis Philippe, 1846

The Physics of a Believer

"Physique de croyant," *Annales de philosophie chrétienne* (1905)

- Conventionalism circumscribing the limits of science
- The challenge to a Catholic philosopher-scientist in highly secularized, third republic France, rebuilding itself after the Franco-Prussian War (1870-1871) on a high-tech foundation of science and engineering



Eiffel Tower, 1889

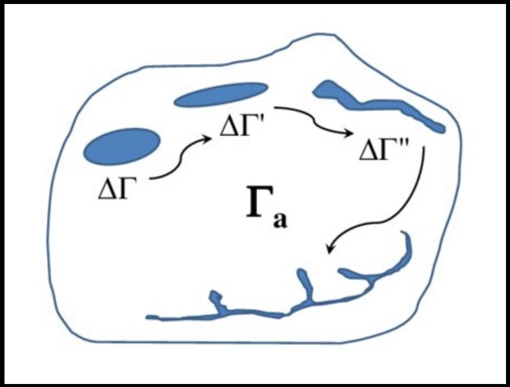
Henri Poincaré (1854-1912)

1854 – Born, Nancy
1873-1875 – École Polytechnique, Mathematics
1875-1878 – École des Mines, Mining Engineering
1879 – Ph.D., Mathematics, Sorbonne
1879 – Inspector, Corps des Mines, Vesoul
1879 – Lecturer, Mathematics, Caen
1881 – Professor of Mathematics, Sorbonne
1881 – Ministry of Public Service
1893 – Chief Engineer, Corps des Mines
1902 – *La Science et l'Hypothèse*
1905 – *La Valeur de la Science*
1908 – *Science et Méthode*
1910 – Inspector General, Corps des Mines
1912 – Died, Paris
1913 – *Dernières Pensées*

Henri Poincaré

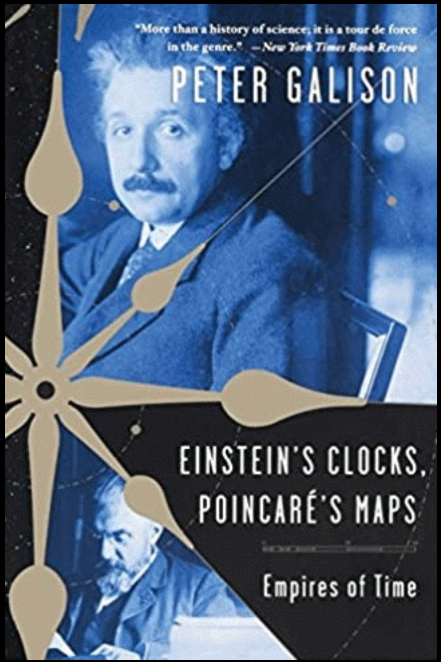
Poincaré Recurrence Theorem, 1890

A closed, conservative system, starting at any point in its phase space, will eventually return to a point arbitrarily close to that initial state.



Bureau des Longitudes, International Time Zones, Clock Synchronization, 1893

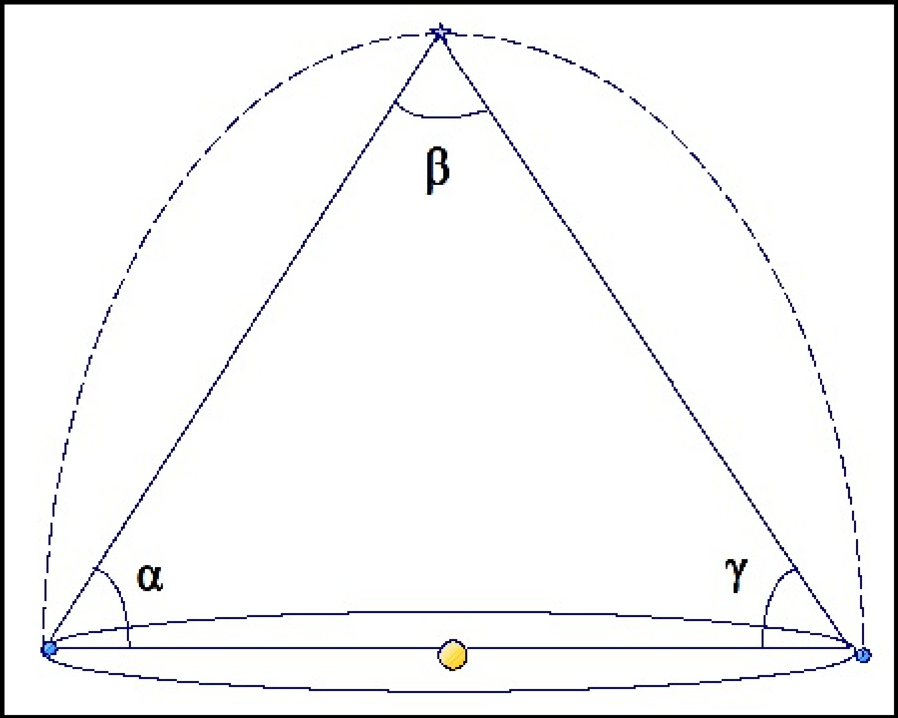
Principle of Relativity, Conventionality of Simultaneity, 1898-1904



Poincaré’s Geometrical Conventionalism

What do we infer when

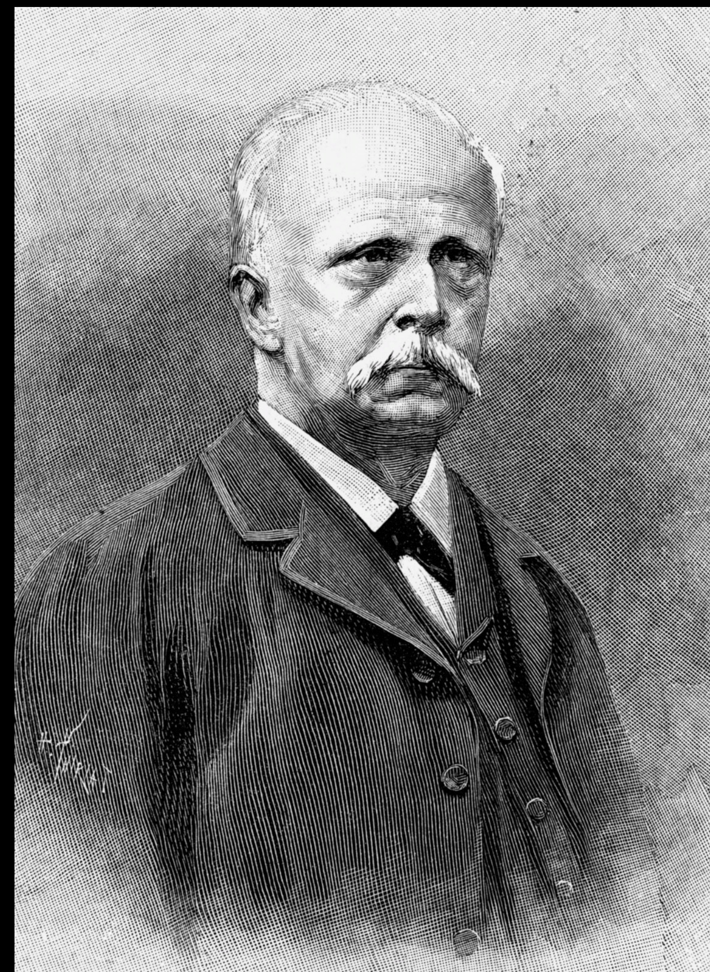
$\alpha + \beta + \gamma \neq 180°$



Poincaré’s Geometrical Conventionalism

Postulate of Free Mobility - Transcendental Argument for Necessity of Spaces with Constant Curvature.

Only in such spaces do objects remain self-congruent under transport.



Hermann von Helmholtz (1821-1894)

Émile Meyerson (1859-1933)

1859 – Born, Lublin
1880-1882 – Heidelberg and Berlin, Chemistry
1882-1884 – Collège de France, Chemistry
1884-1889 – Director of Dye Factory, Argenteuil
1889-1897 – Foreign News Editor, Agence Havas
1897-1933 – Director General of the Jewish Colonization Association
1908 – *Identité et réalité*
1918-1933 – The Meyerson Circle: Alexandre Koyré, Hélène Metzger, André Metz, André Lalande, Léon Brunschvicg, Lucien Lévy-Bruhl, Louis de Broglie and Paul Langevin.
1921 – *De l'explication dans les sciences*
1924 – *La déduction relativiste*
1931 – *Du cheminement de la pensée*
1933 – *Réel et déterminisme dans la physique quantique*
1933 – Died, Paris
1936 – *Essais*