Philosophy's Movement Toward Cognitive Science

By Dr. Charles Wallis

Last revision: 3/10/2013

Chapter 5
The 20th Century and the Semantic Twist

5.1 Introduction

Recall that ontological frameworks provide a general framework within which theorists specify domains of inquiry and construct theories to predict, manipulate, and explain phenomena within the domain. Once researchers have articulated an ontological framework with sufficient clarity, they begin to formulate and test theories. Chapter three ends with the suggestion that oppositional substance dualists face two major challenges in transitioning from the articulation of their ontological framework to formulating and testing theories purporting to predict, manipulate, and explain mental phenomena. On the one hand, oppositional substance dualists have problems formulating theories providing predictions, manipulations, and explanations of the continual, seamless interaction between the mental and the physical. On the other hand, the very nature of a mental substance--substance defined so as to share no properties with physical substance--gives rise to additional challenges. Specifically, how does one utilize the categories, types, and interrelationships of this mental substance to formulate theoretical mechanisms through which one can predict, manipulate, and explain the dynamic changes in mental phenomena?

Chapter four looks at the question, "do monistic physicalists fare any better?" Recall, physicalist theories—theories formulated within monistic physicalism--must meet the challenge of formulating theories specifying physical mechanisms that plausibly predict, manipulate, and explain how physical substance, physical properties, and/or physical processes give rise to mental properties and processes. Chapter four traces the development of scientific psychology from Wundt's voluntarism through psychological behaviorism. The chapter emphasizes how psychology develops an experimental tradition in large through adaptation of approaches from astronomy, navigation, and physiology. Experimental traditions include a repertoire of operationalization techniques and devices as well as a repertoire of experimental designs, tools for data analysis, and an appreciation of experimental control. For instance, the chronoscope and chronometer allow precise measurement of reaction times and control hammer provides a mechanism for precise calibration of the chronoscope and chronometer to insure reliable inter-subjective measurements. The introduction and development of introspection and its associated experimental design from physiology—both through its successful adaptations and its failings provide psychologists with important lessons in experimental design. Of particular importance, psychologists realize the potential for experimenter and subject bias and the need for calibration techniques for operationalizations. Together this convergence of categorizations together with tractable and reliable operationalizations allowing theorists to define a domain—learning and memory—as well as to adopt and adapt experimental techniques that allow theorists to gain traction in the tasks of predicting, manipulating, and explaining mental phenomena in one aspect of one mental domain—learning and memory. Finally, the introduction of statistical techniques by Gustav Fechner[1] and especially their use by Hermann Ebbinghaus[2] helps theorists to analyze data with significant intersubjective variability and better measure the fit of theoretic models with data.[1-10] Ultimately, much more powerful statistical tools enter the experimental tradition from the works of Ronald Fisher[11-15] (e.x. null hypothesis testing,[16] z-distribution,[17] and

frequentist inferential[18] interpretations and methods generally), William Gossett (aka student)[19-21] (e.x. t-testing[22]), Jerzy Neyman[23-33] (e.x. randomized experimental design, stratified sampling of significant subpopulations,[26] The Neyman-Pearson lemma for hypothesis testing,[25] and the confidence interval[34]), Karl Pearson[35-39] (e.x. Chi-squared distribution[40]), and Egon Pearson[25, 29, 30, 33, 41-43] (e.x. The Neyman-Pearson lemma for hypothesis testing[25] and Pearson's chi-squared test[43]). This confluence of descriptive and experimental elements gives rise to behaviorism in psychology.

This chapter and lecture outline what I call the "semantic twist." The semantic twist marks a dramatic shift in philosophic methodology and conceptualization that fundamentally alters the conception of the mind-body problem as well as the methodology within the philosophy of mind. It also marks a sharp, but largely unrecognized division between philosophic approaches to the philosophy of mind. This chapter portrays the overt confluence from which the semantic twist emerges. It also outlines the covert division with philosophy of mind resulting from the semantic twist. Thus, the narrative begins with an historical exposition to facilitate an appreciation of the forces that ultimately culminate in the semantic twist. As a result, the exposition begins with the rise of logical empiricism as a philosophy of science, tracing the inspiration for the view to the dramatic developments in physics as well as in logic and mathematics at the turn of the 20th century.

With the outlines of logical empiricism in place the chapter and lecture traces the influence of those developments upon the philosophy of mind. Specifically, the chapter focuses on the confluence of psychological behaviorism, philosophy of language, and philosophy of science in the formulating and advocating the philosophical doctrine known variously as logical behaviorism, philosophical behaviorism and analytical behaviorism. Analytical behaviorism represents a shift in the philosophic understanding of the mind-body problem as well as a corresponding shift in philosophic methodology.

Philosophers from Descartes until the semantic twist focus primarily upon two projects. First, philosophers emphasize developing and advocating various versions of two ontological frameworks for theorizing about the mind—oppositional substance dualism and monistic physicalism. Second, philosophers debate the relative potential of these two general types of ontological frameworks to give rise to adequate theoretical explanations of mental phenomena. After the semantic twist, most philosophers seek to understand how monistic physicalism can accommodate mental phenomena. Specifically, philosophers seek to advocate monistic physicalism by subsuming mental phenomena within the physical—not through positing physicalistic theories providing mechanistic explanations of mental phenomena—but through semantic reduction. In other words, philosophers adopt the project of demonstrating how ordinary, pre-theoretic talk about the mind expresses nothing over and above what one can express using physicalistic language. As a result, philosophers adopt the methodology of demonstrating the viability of monistic physicalism by showing that the meanings of ordinary language mental terms can be specified completely using only physicalistic terms. Since philosophers do not formulate physicalistic theories of mental phenomena, they rely primarily upon scientific results to provide the data upon which they base their reduction. Moreover, since the new philosophic project does not directly involve transitioning from the articulation of an ontological framework to formulating and testing theories purporting to predict, manipulate, and explain mental phenomena, the new philosophic project is best understood as attempting to reduce one ontological framework—oppositional substance dualism—to another ontological framework—monistic physicalism. The doctrine of logical behaviorism represents the first in a series of such attempts at semantic reduction. As future lectures indicate, the project of semantic reduction—or rejection thereof--occupies most of the philosophy of mind for the 20th century.

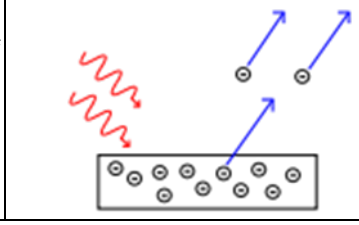
Ultimately, the doctrine of logical behaviorism succumbs to two central lines of criticism. On the one hand, critics like Putnam deny the viability of attempts to identify mental states and properties with the effects of those mental states and properties. These theorists essentially adopt a direct reference theory of reference for mental terms in that they claim that the reference of mental terms such as belief or pain consists of the mental state itself regardless of its typical causes and effects. Often such theorists adopt a phenomenological essentialism regarding many of these terms. Specifically, such theorists look to conscious mental states—especially qualitative conscious experiences like pain--asserting that the conscious phenomenological experience provides a direct referential link to the state. Pains, on this line, are painful and this feature alone defines these states. For example, Thomas Nagel denies that science can formulate adequate theories of consciousness mental states because such theories cannot capture "what it is like" to have such mental states.[44-49] Putnam adopts this line of argument in "Brains and Behavior"[50] when presents a series of counterfactual thought experiments in which, he suggests, one can intuitively judge that the mental states in counterfactual examples count as pains despite being dissociated from their typical causes, their typical effects, or both.[50-54] On the other hand, critics such as Chisholm adopt a descriptivist theory of reference for such mental state terms. Chisholm argues that attempts to define mental state terms like belief in terms of their typical overt physical causes and effects fails precisely because such states have no typical causes and effects absent their relationships to other mental state terms. Thus, argues Chisholm, one cannot define mental state terms in isolation. Mental state terms constitute a closed holistic lexicon or conceptual scheme.[55-57] Thus, three features of mental states drive the rejection of logical behaviorism. First, the meanings of many mental terms seem essentially or importantly tied to qualitative subjective experience as opposed to overt behaviors. Thus, many people find the awfulness of pain essential to being in pain, but few find verbal demonstrations essential to being in pain. Second, many mental properties such as ennui (Listlessness or dissatisfaction associated with inoccupation or an absence of excitement.) seem to lack any definitive set of behavioral effects without seeming meaningless or less meaningful than other mental terms. Third, mental terms do not operate, for the most part, in isolation from one another. Rather, the interactions of mental states with other mental states mediate the connections between the typical behavioral causes and typical behavioral effects--even for those mental terms that appear to have more or less criterial overt behavioral causes and effects.

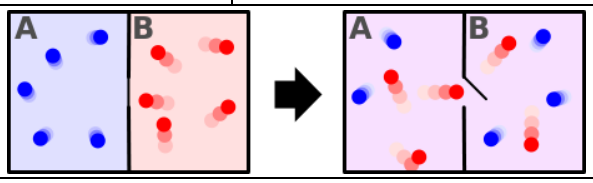
5.2 The Scientific Explosion of the Early 20th Century

The productive confluence of experiment and categorization at the beginning of the 20th century is not unique to scientific psychology. The end of the 19th century and the beginning of the 20th century witnesses the rise of a newly robust science in many fields. Physics in particular witnesses a number of dramatic advances that tear apart the older orthodoxy. Within a period of approximately sixteen years the groundwork for atomic physics, quantum mechanics, and space-time physics falls into place. In 1901 Max Plank[58] publishes "On the Law of Distribution of Energy in the Normal Spectrum"[59] (Zur Theorie des Gesetzes der Energieverteilung im Normalspektrum) in which he introduces Plank's Law to calculate the electromagnetic radiation emitted by a black body[60] in thermal equilibrium at a given temperature. Plank's paper introduces the idea of quantum theory to physics. Albert Einstein's[61] miracle year in 1905 sees him publish three famous and foundational papers. "On a Heuristic Viewpoint Concerning the Production and Transformation of Light,"[62] ("Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt") adapts Plank's work on black body radiation to explain the photoelectric effect.[63] "Investigations on the Theory of Brownian Movement,"[64] ("Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in

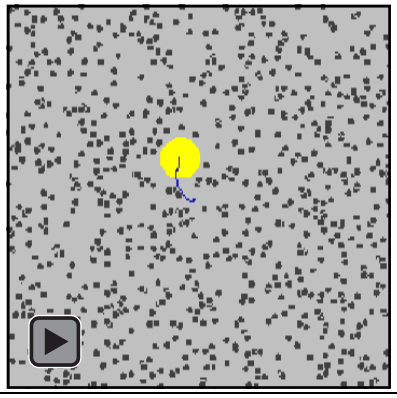
ruhenden Flüssigkeiten suspendierten Teilchen") describes the motion of pollen molecules in a liquid using statistical mechanics.[65] Importantly, Einstein demonstrates the existence of atoms (the reality of which were debated) by showing how one can count them using an ordinary microscope. These two papers taken together lay the groundwork for the coming atomic physics and for quantum mechanics. Finally, "On the Electrodynamics of Moving Bodies," ("Zur Elektrodynamik bewegter Körper")[66] introduces what we now know

(Right) The photoelectric effect describes the emission of electrons by various types of metals, solids, gases, and liquids when exposed to short wavelength, high frequency electromagnetic radiation (e.x. UV light)
From: Wikipedia

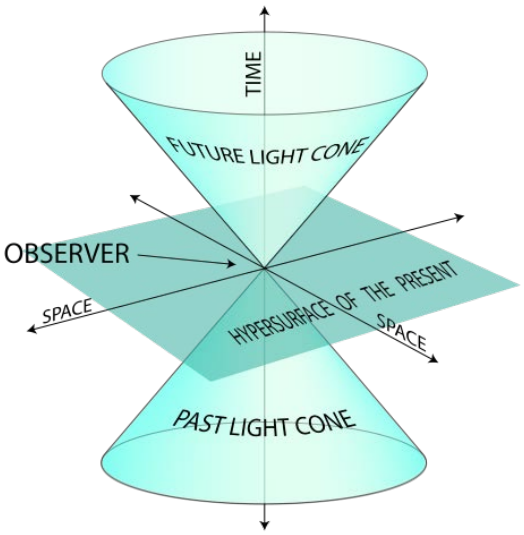




(Above) Diagram illustrating the differential distribution of energy in a medium. Statistical mechanics utilizes probability theory to predict such differences in distribution. For instance, according to statistical mechanics there is a non-zero probability that all of the oxygen molecules in the classroom will shift to the upper left corner of the room. From: Wikipedia



(Right) Animation illustrating the movement of a large molecule as it collides with smaller molecules of varying direction and velocity. Brownian motion consists of the movement of a particle in a gas or liquid caused by the energy transferred from collisions with the molecules of atoms of that liquid.
Adapted from: Wikipedia



(Above) Diagram depicting the observer-relative inertial reference frame used by Einstein in special relativity to explain such phenomena as time-dilation, length expansion, and the composition of velocities—each of which is refers to the differences between observer measurements across different inertial reference frames. For instance, time dilation refers to the variance between observer's measurements of the time lapse between events. From: Wikipedia

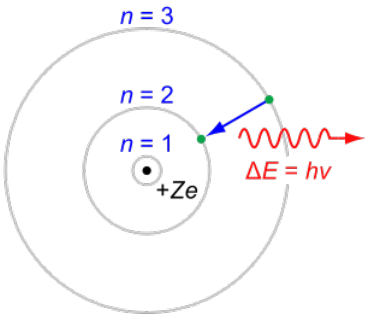
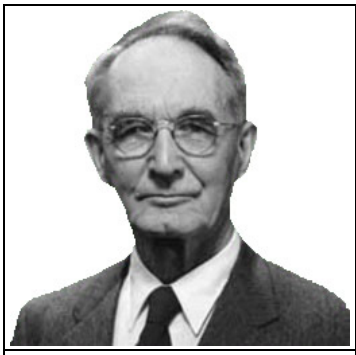
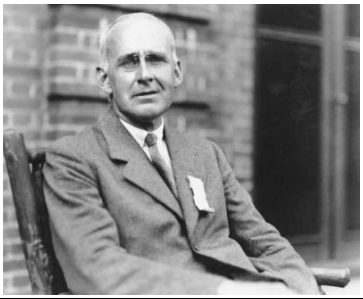
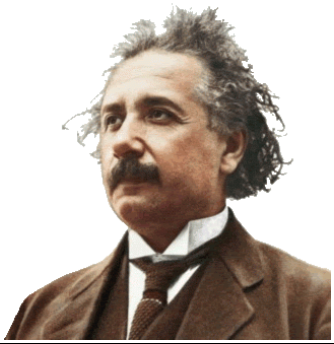
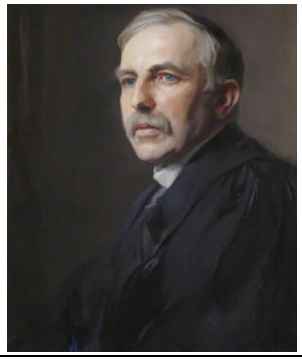


Diagram depicting the Bohr model of the atom in which electrons rotate in fixed circular orbits around a nucleus. From: Wikipedia

as the theory of special relativity. More specifically, Einstein reconciles Maxwell's work in electromagnetism with classical mechanics by introducing the principle of relativity and the principle of the invariance of the speed light. Einstein's former mathematics professor, Hermann Minkowski,[67] publishes "Space and Time"[68] ("Raum und Zeit") in 1908 in which Minkowski provides a space-time geometry to subserve special relativity. Ernest Rutherford[69] publishes "The Scattering of α and β Particles by Matter and the Structure of the Atom"[70] in 1911. In 1913 Neils Bohr publishes "On the Constitution of Atoms and Molecules" parts 1,[71] 2,[72] and 3[73] in which he modifies Rutherford's account within the framework of quantum mechanics. The resulting theory of atomic structure goes under several names; The Solar System Model, The Bohr-Rutherford Model, and The Bohr Model. In 1916 Einstein publishes, "The Foundation of the General Theory of Relativity,"[74] ("Die Grundlage der allgemeinen Relativitätstheorie") outlining the theory of general relativity[75] and completing the

reconceptualization of gravitational physics. In 1919 Arthur Eddington[76] travels to the African island of Principe provides photographic evidence (specifically, light bending around the sun) during the May 29,

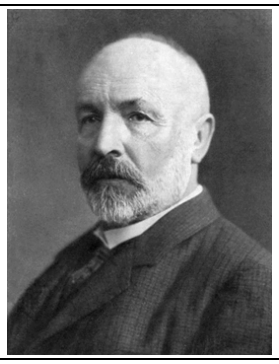
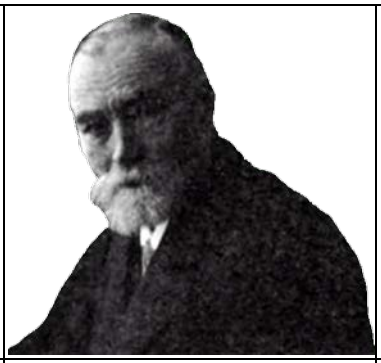
			
Percy Williams Bridgeman (1882-1961) Adapted from: nndb.com	Niels Bohr (1885-1962) Adapted from: Wikipedia	Arthur Stanley Eddington (1882–1944) Adapted from: optcorp.com	Albert Einstein Adapted from: Biography.com
			
James Clerk Maxwell (1777–1851) From: BBC	Herman Minkowski (1864-1909) Adapted from: The Space-Time Society	Max Plank(1858-1947) Adapted from: Feira De Cencias	Ernest Rutherford (1831-1937) Adapted from: BBC

1919 solar eclipse. Finally, American physicist Percy Williams Bridgman[77] forwards the doctrine of operationalism[78, 79] or operationism in his 1927 *The Logic of Modern Physics*.[80] The book and its author intend the doctrine for physics primarily, though it inspires a number of psychologists including the neo-behaviorist Edward Chace Tolman.[81] Bridgeman, inspired by general relativity and his own prowess as an experimental physicist, identifies theoretical concepts with the (single) unique procedure for their measurement. The doctrine remains somewhat ambiguous regarding its status as a theory of meaning, though it naturally lends itself to such an interpretation. Bridgeman interacts with two prominent early logical positivists, Otto Neurath[82, 83] and Moritz Schlick[84] regarding his theory.

5.3 The Logical and Mathematical Explosion of the Early 20th Century

The strides in logic and mathematics at the turn of the 19th century rival those in physics and the sciences. Gottlob Frege[85] publishes *Begriffsschrift*[86] in 1879. In *Begriffsschrift* Frege adopts Georg Cantor's[87-89] naïve set theory and presents the first rigorous axiomatized first- and second-order predicate logic including functions. Frege's takes as his ultimate goal the derivation of mathematics from logic, thereby reducing the former to the latter--a project called logicism.[90] Logicism represents one approach to the overarching project of providing an axiomatic treatment of all of mathematics on the model of Euclid's *Elements*. More precisely, the project then underway seeks to axiomatize basic arithmetic on the natural numbers.[91] In 1899 David Hilbert[92] publishes Foundations of Geometry[93] (Grundlagen der Geometrie) in which he offers an axiomatization of the geometry of Euclidean solids (3d Euclidean geometry). An American graduate student, Robert Lee Moore,[94] develops and publishes an alternative axiomatization in 1907.[95] Bertrand Russell[96] and Albert North

Whitehead[97] publish *Principia Mathematica*[98] in three volumes in 1910,[99] 1912,[100] and 1913.[101] Principia attempts to axiomatize mathematics (arithmetic on the natural numbers) in the logicist tradition. The development of second-order logic and the

			
Georg Cantor (1845-1918) Adapted from: Wikipedia	Gottlob Frege (1848-1925) Adapted From: Wikipedia	David Hilbert (1862-1943) Adapted from: scienceworld.wolfram.com	Alfred North Whitehead (1861-1947) Adapted from: Wikipedia
			
Bertrand Russell (1872-1970) Adapted from: Subversivethinking.com	Alonzo Church (1903-1995) Adapted from: Princeton	Kurt Gödel (1906-1978) Adapted from: My Space	Alan Turing (1912-1954) Adapted from: University of Bristol

progress towards axiomatizing mathematics creates a sense that logic and mathematics is on the verge of completion. This sense continues until Kurt Gödel[102] publishes "On Formally Undecidable Propositions of 'Principia Mathematica' and Related Systems"[103] ("Über formal unentscheidbare Sätze der 'Principia Mathematica' und Verwandter Systeme") in 1931 in which he demonstrates that any axiomatic inference system capable of expressing the truths of basic arithmetic on the natural numbers must be either inconsistent or incomplete. Hilbert, an axiomatization enthusiast, famously suggests that mathematicians can save much of the benefits of axiomatization if one can demonstrate a general technique to identify unsolvable problems (the elements rendering any axiomatization incomplete). However, "An Unsolvable Problem of Elementary Number Theory" by Alonzo Church[104, 105] and "On Computable Numbers, with an Application to the Entscheidungsproblem" by Alan Turing[106-108] demonstrate the impossibility of this last hope for the axiomatization project.

5.4 The Rise Logical Empiricism

Some philosophers conceive of the dramatic advances in science, mathematics, and logic as a lens through which one can see the outlines of a coherent picture of knowledge, science, and philosophy. Thus, in Vienna and in Berlin two groups of philosophers and scientists begin to extrapolate from the developments in science, math, and logic to frame a philosophy of science. These philosophers and scientists eventually articulate and advocate the philosophical doctrine of logical empiricism (also known as logical positivism). The individual members of this group of philosophers do not march in ideological lockstep. However, I will portray them

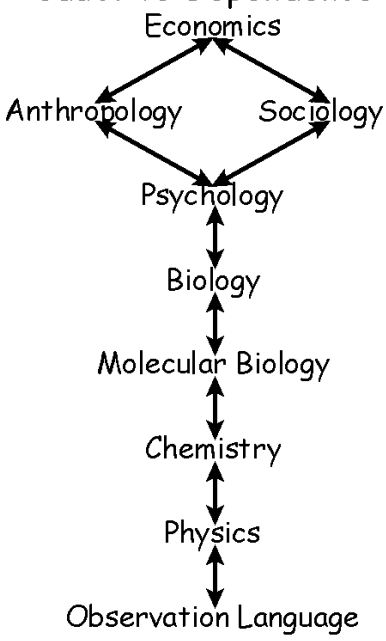
homogeneously for the purposes of exposition. The picture painted here does not distort the views of individuals too dramatically.

The logical empiricists hold four key doctrines. First, they hold what is now called the verification criteria of meaning. Second, they hold that scientific laws are universal, exceptionless statements. Third, they adhere to the doctrine of the unity of science, i.e., they held that the structure of science consisted in a nested hierarchy of axiom systems in which the higher, less fundamental sciences (the special sciences) consisted of laws that one could reduce to one or more lower sciences by ideological reduction of the higher science terms to those of the lower science. Finally, the logical empiricists hold that the role of philosophy of science is to rationally reconstruct the sciences so as to reveal their logical structure, empirical foundations, and epistemic justification. I will outline each doctrine, its sources, and its implications within logical empiricism.

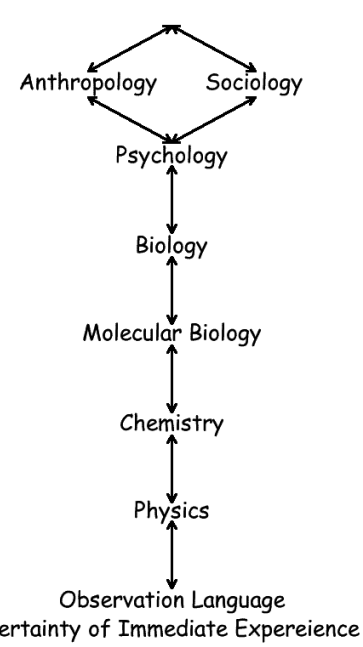
The logical empiricists from Vienna and Berlin include both philosophers and scientists. They view the explosion of scientific progress from the beginnings of the scientific revolution, and particularly the explosion at the beginning of the 20th century, as deriving primarily from tying theories and theoretical terms to rigorous empirical measurement and experimentation. Many of the logical empiricists view this practice of operationalism in the sciences in stark contrast from the prevailing philosophy of German idealism. German idealism seeks to create philosophical systems through the process of dialectic and apriori speculation. The positivists view German idealism as stagnant and vacuous. Thus, the logical empiricists identify progressive, productive theorizing with the method of operationalization employed by the sciences, and come to adopt an interpretation of operationalization as their doctrine of meaning. Indeed, an integral part of the logical empiricist reductionist program in science as well as their rejection of metaphysical speculation lies in their doctrine regarding the meaning of theoretic terms. The earliest version of the positivist doctrine of meaning usually goes under the name of the verifiability theory of meaning,[109, 110] the verificationist theory of meaning, or simply verificationism. This doctrine holds that the meaning of a proposition or theoretic term consists solely in the method of its verification. This doctrine along with the moniker of positivism traces back to Auguste Comte[111] (1798-1857), though positivists like Schlick[112-114] and Neurath[115, 116] also have extensive familiarity with operationalist the writings of Bridgeman.[80] The verificationist doctrine strikes out against vacuous metaphysical speculation in that verificationism implies that no statements have meaning unless one can cash-out their meaning in terms of their conditions of verification. The early positivist writings often invoke this principle to critique philosophic problems as pseudo-problems. The verificationist theory of meaning also fits well with the notion of an interpretation function providing semantics for a formal language. Such interpretation functions act to pick out the class of objects in the domain that satisfy the predicate in the formal language.

The overall picture many logical empiricists embrace, at least early on, portrays science as a hierarchical set of axiomatic systems. Specifically, as a set of universal, exceptionless laws together with operational or bridge laws that serve to tie theoretic terms to the particular domain (see illustrative diagrams below) and/or to the theoretical terms of lower-level theories. This structure comes from the sciences themselves as well as from the logical and mathematical work by Hilbert, Frege, Russell, and Whitehead. Indeed, as noted above the work of these philosophers and mathematicians creates a great sense of optimism that mathematicians and logicians will find and axiomatization for all of logic and mathematics. In this way, Euclid's influence reaches its full bloom—his *Elements* provides the paradigmatic structure for all of logic and mathematics. The logical

empiricists make the final step in supposing that even the sciences should find their best expression as an axiom system in which the axioms are physical laws. Thus, the logical empiricists hold that the logical structure of each science is an axiom system. Moreover, these individual sciences cum axiom systems are unified; higher, less basic sciences like psychology or sociology reduce to lower level sciences and finally to the laws of physics. That is, the terms of higher level sciences reduce to the terms of successively lower-level theories. Ultimately, the theoretical terms of physics itself find their meaning through bridge laws that link the theoretical terms of physics to the experimental operations used to detect and/or measure the presence or amount of the referents of those terms. As a result, experimental operations thereby define the referents of the theoretical terms of physics in an ontologically neutral observation language. This result, then transfers throughout the entire hierarchy so that all theoretic terms of all sciences ultimately trace their meanings, either directly or indirectly, to conditions expressible in an ontologically neutral observation language.



Animated diagram depicting the sort of inter-theoretic structure proposed by the logical empiricists. Higher, less basic sciences like sociology eventually reduce to successively lower sciences until all sciences ultimately find reduction into physics, which itself them cashes out the meanings of its terms in an ontologically neutral observation language. Click on picture to view animation.



Animated diagram depicting the epistemic dependence of science. Much like Descartes' foundationalism, each science traces its epistemic merit to the lower sciences to which it is reduced. Ultimately, all of the structure rests upon the certainty of immediate experience and the intuitive steps of logical proofs. Click on picture to view animation.

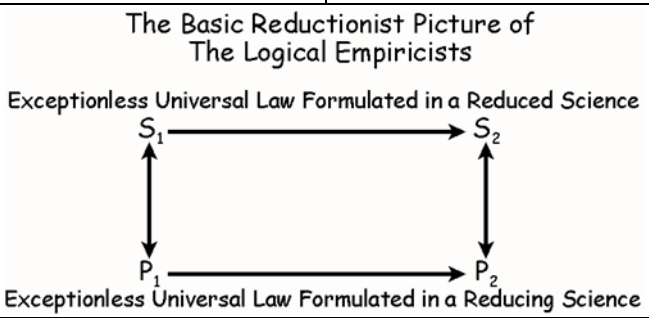
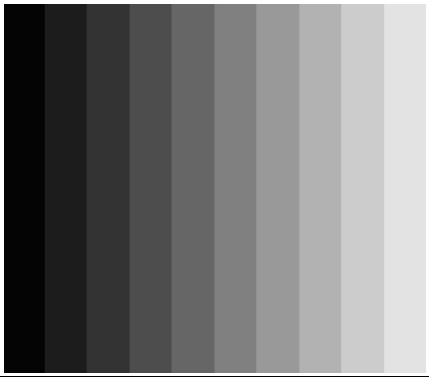


Diagram depicting the general picture of inter-theoretic reduction imagined by the logical empiricists. Terms in the theory at the higher level are reduced (ideally) analytically to terms in the reducing theory. Exceptionless universal laws in the higher reduced theory thereby become subsumed by the laws in the lower reducing theory.

This picture of the structure of knowledge has two great advantages in the eyes of many logical empiricists. First, it provides an epistemic picture whereby all science finds its epistemic grounding in the immediacy of experience. No theories or theoretical posits have any other basis. Second, and in a related vein the empiricists purge as meaningless all terms and theories that lack specifiable conditions for verification. Thus, science progresses by formulating categorizations and tying those categorizations to specifiable operations for their verification through observation (i.e., interpretation functions). Likewise, all human knowledge must consist of theories expressed in categories tied to specifiable operations for their verification through observation. Knowledge, contra Kant, does not presuppose ontology—it remains as ontologically neutral as possible.

Logical empiricists refer to their hierarchy of axiom systems conception of the nature of scientific theories and their interrelationships as the unity of science.[117] The logical empiricists, especially those in Vienna, are deeply influenced by Ernst Mach,[118] an Austrian physicist and philosopher, as well as by the works of Max Planck,[58] the German theoretical physicist who introduces the idea of quantum theory into physics. Mach also develops a philosophy of science and makes contributions to physiology and psychology.

<table>
<tr><td>  </td><td>  </td></tr>
<tr><td>Mach bands: Mach bands appear as if the color bands curve inward or that each band is a gradient. However, each band is a solid color. Each band reflects different amounts of light with the darker bands reflecting less and lighter bands reflecting more. Caption and image from: Retinal Illusions</td><td>Ernst Mach (1838-1916)
Adapted from: Wikipedia</td></tr>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td>Rudolph Carnap (1891-1970)
Adapted from: Wikipedia</td><td>Herbert Feigl (1902-1988)
Adapted from: University of Minnesota</td><td>Max Planck (1858-1947)
Adapted from: feiradeciencias.com</td></tr>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td>Otto Neurath (1882-1945)
Adapted from: medienportal</td><td>Hans Reichenbach (1891-1953)
Adapted from: motorera.com</td><td>Mortiz Schlick (1882-1936)
Adapted from: Wikipedia</td></tr>
</table>

Indeed, the Vienna philosophers originally call their group Verein Ernst Mach (the Ernst Mach Society) in 1928, but they ultimately adopt the moniker Vienna Circle.[119, 120] The group publishes their manifesto, *Wissenschaftliche Weltauffassung. Der Wiener Kreis* (*The Scientific Conception of the World. The Vienna Circle*) in 1929.[121] A kindred school with common members exists in Berlin, known both as and the Berlin Circle.[119, 122, 123] This group includes such luminaries as Paul Oppenheim[124] and Hans Reichenbach.[123, 125] Both groups are strongly influenced by their common belief that human knowledge and especially science form part of a long evolutionary process creating a hierarchical set of sciences all of which ultimately reduce to physics.

For instance, Rudolph Carnap's[126] classic work, *Der Logische Aufbau der Welt* (*The Logical Structure of the World Pseudoproblems in Philosophy*),[127] provides readers with the most sophisticated and systematic attempt to reconstruct science as a series of hierarchical axiom systems that reduce to one another and ultimately to observations framed in an ontologically neutral observation language. Similarly, Otto Neurath[82, 83] edits multiple volumes of *Foundations of the Unity of Sciences*[128] and *International Encyclopedia of Unified Science*.[129] These works set as their goal the organization and presentation of science as a unified body of knowledge. The logical empiricists do not suppose that the structure of a hierarchy of axiom systems actually represents the practice of scientists as they develop their theories. Rather, they suppose that this structure represents a rational reconstruction of the sciences that makes explicit and rigorous the logical structure and epistemic dependence of each science and the sciences as a whole.

The logical empiricists share a common disdain for metaphysical speculation and a desire to further human understanding through rigorous epistemological doctrines addressing methodological issues and minimizing ontological issues. In many ways they turn the focus of philosophy of mind towards philosophy of science and issues of scientific methodology. Likewise, they follow the methodological lead of behaviorists in reexamining the proper understanding of mental properties and processes. However, their focus on theoretic terms and meaning gives rise to the semantic twist in the philosophy of science.

5.5 Logical Behaviorism

In reaction to the developments in science, mathematics, logic, and especially psychology many philosophers of mind alter their focus from formulating and defending various ontological frameworks to understanding the relationship between scientific theories of the mind and ordinary conceptions of the mind. It is during the early 20th century that the emphasis in philosophy of mind—though still focused almost exclusively upon ontological issues—turns towards the developments in science for inspiration. Within philosophy itself a number of scientifically inspired general strategies emerge in the 20th century for trying to flesh-out a monistic physicalist framework. This movement towards closer integration between philosophy and science also marks a shift in methodological emphasis.

During this period philosophers begin increasingly to think of theories not simply in terms of theoretical posits, but in terms of the relationships between categories of scientific theories and the terms of ordinary language and of perceptual experiences. As a result, during this time philosophical theorists become increasingly interested in semantic reduction. For instance, whereas earlier philosophers focus upon ontological frameworks, most 20th century strategies for offering monistic physicalist explanations involve directly identifying mental terms with physical terms. The underlying inference driving such identifications lies in the notion that by directly equating mental and physical terms one indirectly identifies the referents of those terms--mental phenomena and physical phenomena. In other words, 20th century philosophers locate the explanatory problem for the monistic physicalist in an inability to recognize or gather sufficient evidence for the co-referential nature of mental and physical terms.

Two general approaches to pursuing this general strategy emerge within philosophy during the first half of the 20th century. On the one hand, theorists try to identify the meaning of mental terms with sets of overt, observable, physical behaviors definitive of those terms. On the other hand, theorists seek to identify the reference of mental property, process, and entity terms with the reference of physical property, process, and

entity terms through something akin to analytical reduction. The next chapter turns to this second strategy, often called type-type reductionism. The remainder of this chapter focuses upon the first strategy.

Theorists call the first systematic attempt to flush-out the first strategy for asserting that mental properties are just physical properties logical behaviorism. Logical behaviorism (also called analytical behaviorism and philosophical behaviorism) represents the first attempt to systematically address the difficulties for physicalism within the scientific framework of the time. It is important to note that philosophers of starkly different methodological orientations follow this line of theoretical speculation. Indeed, historians identify Gilbert Ryle[130, 131] and Carl Hempel[132, 133] as the two most prominent figures in logical and/or analytic behaviorism. Ryle is a philosopher of language, particularly of ordinary language. Ryle holds that researchers can dissolve many philosophical problems through the correct analysis of the ordinary language terms that theorists employ the formulation of those problems. In his classic book, *The Concept of Mind,* Ryle argues extensively that mind-body oppositional dualism results from a category mistake—an incorrect use of language:[134]

> My destructive purpose is to show that a family of radical category-mistakes is the source of the double-life theory. The representation of a person as a ghost mysteriously ensconced in a machine derives from this argument. Because, as is true, a person's thinking, feeling, and purposive doing cannot be described solely in the idioms of physics, chemistry, and physiology, therefore they must be described in counterpart idioms. As the human body is a complex organized unit, so the human mind must be another complex organized unit, though one made of a different sort of stuff and with a different sort of structure. (p.18)

In contrast, Carl Hempel is a philosopher of science and a logical positivist/empiricist. Logical behaviorists like Hempel who embrace logical empiricism seek to build upon real progress by experimentalists like Pavlov, Watson, and Skinner as well as by scientists across a wide swath of the sciences. Logical positivists and empiricists believe that terms get their meaning through their conditions for verification and that science provides one with the most rigorous and explicit methodological definitions of terms through operationalizations—the procedures that scientists use to detect and measure theoretical entities, properties, etc.. Logical positivists and empiricists also tend to hold a doctrine called the unity of the sciences. The unity of the sciences asserts that one can ultimately reduce all sciences to the most basic science, physics. That is, one can reduce the terms of sciences like elemental chemistry to the terms of atomic physics. Moreover, logical empiricists see a further benefit from such semantic reductions—the terminological reduction demonstrates that the laws in the reduced science follow from or merely represent special instances of more fundamental laws in the fundamental science.

Most historians cite Gilbert Ryle's book, *The Concept of Mind* (1949)[134] as the first tract in logical behaviorism and assign Hempel's "The Logical Analysis of Psychology" (1935,1949) [135] to the second position. However, Hempel published his article, though in French, over 14 years earlier than Ryle's book. Both works have historical significance because they share a common shift of emphasis that continues to shape thinking about the mind in philosophy. Both Ryle and Hempel seek to defuse the seeming difficulties in understanding how mental properties arise from or are identical to physical properties by arguing that the meanings of mental terms are exhausted by behavioral terms. In other words, establishing monistic physicalism involves escaping referential opacity. Hempel tells readers,[135]

> All psychological statements which are meaningful, that is to say, which are in principle verifiable, are translatable into statements that do not involve psychological concepts, but only the concepts of physics. The statements of psychology are consequently physicalistic statements. (p.18)

Similarly, Ryle asserts,[134]

> In this chapter I try to show that when we describe people as exercising qualities of mind, we are not referring to occult episodes of which their overt acts and utterances are effects; we are referring to those overt acts and utterances themselves. (p.25)

While Hempel aims primarily to address scientific and ontological issues, Ryle sees his work in a different light. Ryle tries to provide an analysis of the concepts of ordinary language. Both philosophers, however, trace the seeming difficulties associated with the equation of mental processes and properties with physical properties and processes to an improper understanding of the true meanings of mental terms. Ryle asserts that,[134]

> This book offers what may with reservations be described as theory of mind. But it does not give new information about minds. We possess already a wealth of information about minds, information which is neither derived from, nor upset by, the arguments of philosophers. The philosophical arguments which constitute this book are intended not to increase what we know about minds, but to rectify the logical geography of the knowledge which we already possess. (p.7)

Additionally, Ryle's emphasis on intelligent behavior marks a differentiation between mental properties and non-mental properties which has come to serve as an important standard in the philosophy of mind, and which later allows for the initial explanatory focus of cognitive science on cognition. Specifically, philosophers differentiate between mental properties and states that are strongly (or even definitively) phenomenal in nature, called qualia or qualitative mental states, and mental properties or states that are primarily (or even definitively) intentional, called intentional states or propositional attitudes. Examples of the former (qualia) include pains, itches, seeing red, anger etc.. Examples of the latter (intentional states) include beliefs and desires. Intentional states may have some phenomenal aspects, but intentional states are importantly, even fundamentally representational. That is, intentional states represent objects, properties, relations and/or events in the world.

Thus, one can see that logical behaviorists—both the ordinary language variety and the logical empiricist variety--as seeking to understand the meaning and hence the reference of psychological terms like belief and desire in terms of the behaviors of intelligent creatures. Nevertheless, philosophers often misrepresent logical behaviorism as a unitary movement with a strongly shared set of background theoretical commitments. Logical behaviorists do share a commitment to science, and specifically to the promise of behaviorism in psychology. They also share a desire to capture the meanings of mental terms in behavioristic terms thereby identifying the referents of mental terms with the referents of physical terms.

However, logical behaviorism marks a significant point of divergence in the philosophy of mind. On the one hand, the logical empiricists give rise to an orientation in the philosophy of mind that seeks to understand the new and rapidly advancing sciences in terms of the theoretic posits, explanatory schemas, and methodological practices of those sciences. These theorists likely now identify themselves as philosophers of psychology or

cognitive science. On the other hand, Ryle and other philosophers of language devote their efforts primarily to understanding the ascription conditions of ordinary language terms describing the mind, mental properties, and mental processes. These theorists, like Ryle himself, seek to understand the world by clarifying the ontological posits and theories implicit in ordinary language as used in everyday life. Ryle describes himself, for example, as philosophical cartographer.[136, 137] Ryle likewise begins his discussion in *The Concept of Mind* by telling his readers that, "The philosophical arguments which constitute this book are intended not to increase what we know about minds but to rectify the logical geography of the knowledge we already possess."(p.1) [134]

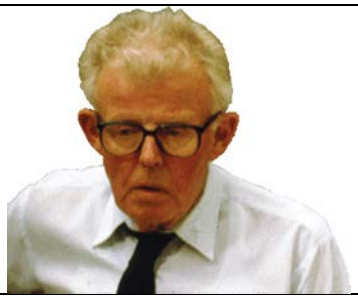
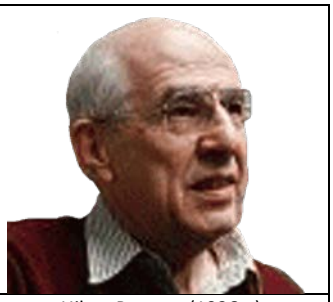
No matter what motivations lead logical behaviorists to advocate their doctrine, logical behaviorism faces three significant difficulties. First, the meanings of many mental terms seem essentially or importantly tied to qualitative subjective experience as opposed to overt behaviors. Thus, many people find the awfulness of pain essential to being in pain, but few find verbal demonstrations essential to being in pain. A person paralyzed by curare will not exhibit the normal behavioral effects of pain when stabbed in the arm. However, it seems improbable to suppose that such a person feels no pain. Likewise, actors really do suffer for their art according to logical behaviorists in that these actors actually suffer when overtly behaving as if they were suffering. Second, many mental properties such as aibohphobia (a fear of palindromes), ankylophobia (fear of stiff or immobile joints) and malaise (a vague feeling of discomfort, one cannot precisely identify, but which is often described as a sense that things are "just not right.") seem to lack any definitive set of behavioral effects. These terms do not seem meaningless or less meaningful than other mental terms, yet they do not exhibit a small group of overt behaviors that one might consider criterial of the state. Third, mental terms do not operate, for the most part, in isolation from one another. Rather, the connections between the typical behavioral causes and typical behavioral effects--even for those mental terms that appear to have more or less criterial overt behavioral causes and effects--are mediated by the interactions of mental states with other mental states. This last point finds emphasis in the work of Roderick Chisholm criticizing logical behaviorism and in the latter work of Hilary Putnam outlining functionalism.[52-57] For instance, one cannot determine the causes and effects of your belief that this text is remarkably dry in isolation from your interest in the subject, your desire to do well in the class, etc.. If you love dry and boring texts, you may read all night. If you are hungry, your belief may result in your getting a chocolate bar. The seeming interconnection between mental terms leads Putnam and others to formulate a new approach to theorizing called functionalism discussed later in this text. As Chisholm tells his readers:[57]

> Nevertheless, difficulties in principle seem to be involved when we attempt to extend the preparatory-stimulus theory to human behavior. [Logical behavioristic reductions of mental terms to collections of stimuli and responses]
>
> These difficulties concern the specification of the occasions upon which the appropriate fulfillments or disruptions must occur. According to our paradigm, these must be caused by the occurrence, or nonoccurrence, of the referent. But it is easy to think of elementary human sign situations where the appropriate events do not occur in the manner required. And to accommodate our definition to such cases, we seem required to make qualifications which reintroduce the intentional concepts we are trying to eliminate. [Other mental terms] (p.61)

Likewise, Chisholm later asserts that:[55]

> …when we wish to describe anyone's believing, seeing, knowing, wanting, and the like, either (a) we must use language which is intentional or (b) we must use a vocabulary we don't need when we talk about non-psychological facts. (p.132)

Theorists explore the general difficulties facing approaches like Ryle's and Hempel's in the technical literature even before Ryle publishes *The Concept of Mind*. The verification theory of meaning and the difficulties involved in the inter-theoretic reduction that the logical empiricists initially advocate begins to attract the great minds of philosophy and science long before the 1950s. However, Putnam's "Psychological Concepts, Explication, and Ordinary Language"[54] (1957) and Chisholm's "Intentionality and the Theory of Signs" [57] (1952) serve to make explicit and popularize the implications of these technical problems for logical behaviorism. Chisholm's classic paper adopts a descriptivist theory of reference for such mental state terms. Chisholm argues that attempts to define mental state terms like belief in terms of their typical overt physical causes and effects fails precisely because such states have no typical causes and effects absent their relationships to other mental state terms. Thus, argues Chisholm, one cannot define mental state terms in isolation. Mental state terms constitute a closed holistic lexicon or conceptual scheme.[55-57] In Psychological Concepts Putnam agrees that mental terms cannot be defined in isolation. He adopts a technical trick to specify a definite description of each mental term utilizing its interrelationships with other mental states and connections to typical causes and typical effects. Putnam's technique here as well as how he manages to maintain his direct reference position while utilizing definite descriptions will become clearer in the chapter on functionalism. For now, suffice it to say that Putnam claims that definite descriptions directly refer to mental states because mental states consist of all and only those things satisfying the definite description.

			
Gilbert Ryle (1900-1976) Adapted from: Corpuscular Philosophy	Carl Gustav Hempel (1905-1997) Adapted from: Today in Science	Roderick Chisholm (1916-1999) Adapted from: Laurence.edu	Hilary Putnam (1926-) Adapted from: matematica

In "Brains and Behavior" Putnam straightforwardly denies the viability of attempts to identify mental states and properties with the effects of those mental states and properties, adopting a direct reference theory of reference for mental terms according to which the reference of mental terms such as belief or pain consists of the mental state itself regardless of its typical causes and effects. Often such theorists adopt a phenomenological essentialism regarding many of these terms. Specifically, such theorists look to conscious mental states—especially qualitative conscious experiences like pain--asserting that the conscious phenomenological experience provides a direct referential link to the state. Pains, on this line, are painful and this feature alone defines these states. Putnam adopts this line of argument in "Brains and Behavior"[50] when presents a series of counterfactual thought experiments in which, he suggests, one can intuitively judge that the mental states in counterfactual examples count as pains despite being dissociated from their typical causes, their typical effects, or both.[50-54]

These challenges together with the limitations and difficulties emerging in methodological behaviorism or simply behaviorist psychology combine to lead theorists to reject the behavior gambit. Monistic physicalist ontological frameworks for understanding the mind, mental properties, and mental processes must include more than mere overt behaviors and their probabilistic associations. By the later 1950s and early 1960s theorists actively seek to develop alternative methods of reducing mentalistic terms to the terms consistent with monistic physicalistic ontological frameworks for philosophy and psychology.

Bibliography

1. Wikipedia. Gustav Fechner. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
2. Wikipedia. Hermann Ebbinghaus. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
3. Ebbinghaus H. *Über das Gedächtnis*. Leipzig: Verlag Von Dunker & Humblot; 1885.
4. Ebbinghaus H. *Memory: A Contribution to Experimental Psychology*. New York: Columbia University Teachers College; 1913.
5. Stigler SM. A Historical View of Statistical Concepts in Psychology and Educational Research. *American Journal of Education.* 1992;101(1):60-70.
6. Fechner GT. Outline of a New Principle of Mathematical Psychology (1851). *Psychological Research.* 1987;49(4):203-207.
7. Fechner GT. Some Thoughts on the Psychophysical Representation of Memories, (1882). *Psychological Research.* 1987;49(4):209-212.
8. Fechner GT. My Own Viewpoint on Mental Measurement (1887). *Psychological Research.* 1987;49(4):213-219.
9. Fechner GT. Elemente der Psychophysik Vol 1. Leipzig, Germany (Boston, MA): Druck Und Verlag von Breitkopf Und Härtel (Internet Archive); 1860.
10. Fechner GT. Elemente der Psychophysik Vol 2. Leipzig, Germany (Boston, MA): Druck Und Verlag von Breitkopf Und Härtel (Internet Archive); 1860 (2011).
11. Fisher RA. On the Mathematical Foundations of Theoretical Statistics. *Philosophical Transactions of the Royal Society of London. Series A, Containing Papers*

of a Mathematical or Physical Character. 1922;222:309-368.
12. Fisher RA. Statistical Methods for Research Workers. Oxford England: Oliver & Boyd (original), Classics in the History of Psychology; 1925.
13. Fisher RA. *The Design of Experiments*. Oxford England: Oliver & Boyd; 1935.
14. Fisher RA. Note on Dr. Berkson's Criticism of Tests of Significance. *Journal of the American Statistical Association.* 1943;38:103-104.
15. Wikipedia. Ronald Fisher. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
16. Wikipedia. Null Hypothesis. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
17. Wikipedia. Fisher's z-distribution. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
18. Wikipedia. Frequentist Inference. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
19. Wikipedia. William Sealy Gosset. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
20. Gossett W. The Probable Error of a Mean. *Biometrika.* Vol 6. York, Canada: University of York Department of Mathematics; 1908 (2008):1-25.
21. Zabell SL. On Student's 1908 Article "The Probable Error of a Mean". *Journal of the American Statistical Association (University of Minnesota, Morris).* Vol 103; 2008:1-7.
22. Wikipedia. Student's t-distribution. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
23. Wikipedia. Jerzy Neyman. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
24. Splawa-Neyman J. Contribution to the Theory of Small Samples Drawn From a Finite Population. *Biometrika.* 1926;17:472-479.
25. Wikipedia. Neyman–Pearson lemma. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
26. Wikipedia. Stratified Sampling. *Wikipedia*. San Fancisco, CA: The Wikimedia Foundation; 2013.

27. Neyman J. On the Two Different Aspects of the Representative Method: The Method of Stratified Sampling and the Method of Purposive Selection. *Journal of the Royal Statistical Society.* 1934;97(4):558-625.

28. Neyman J, Iwaszkiewicz K, Kolodziejczyk S. Statistical Problems in Agricultural Experimentation. *Supplement to the Journal of the Royal Statistical Society.* 1935;2(2):107-180.

29. Neyman J, Pearson ES. On the Use and Interpretation of Certain Test Criteria for Purposes of Statistical Inference: Part I. *Biometrika.* 1928;20A(1/2):175-240.

30. Neyman J, Pearson ES. On the Problem of the Most Efficient Tests of Statistical Hypotheses. *Philosophical Transactions of the Royal Society of London. Series A, Containing Papers of a Mathematical or Physical Character.* 1933;231(ArticleType: research-article / Full publication date: 1933 / Copyright © 1933 The Royal Society):289-337.

31. Neyman J. On the Correlation of the Mean and the Variance in Samples Drawn from an "Infinite" Population. *Biometrika.* 1926;18(3/4):401-413.

32. Neyman J. Outline of a Theory of Statistical Estimation Based on the Classical Theory of Probability. *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences.* 1937;236(767):333-380.

33. Neyman J, Pearson ES. On the Use and Interpretation of Certain Test Criteria for Purposes of Statistical Inference: Part II. *Biometrika.* 1928;20A(3/4):263-294.

34. Wikipedia. Confidence Interval. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.

35. Wikipedia. Karl Pearson. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.

36. Pearson K. On the Criterion that a Given System of Deviations from the Probable in the Case of a Correlated System of Variables is such that it can be Reasonably Supposed to have Arisen from Random Sampling. *Philosophical Magazine.* 1900;50:157-175.

37. Pearson K. Mathematical Contributions to the Theory of Evolution. III. Regression, Heredity, and Panmixia. *Philosophical Transactions of the Royal Society of London. Series A, Containing Papers of a Mathematical or Physical Character.* 1896;187(ArticleType: research-article / Full publication date: 1896 / Copyright © 1896 The Royal Society):253-318.

38. Plackett RL. Karl Pearson and the Chi-Squared Test. *International Statistical Review / Revue Internationale de Statistique.* 1983;51(1):59-72.

39. Pearson K. Contributions to the Mathematical Theory of Evolution. II. Skew Variation in Homogeneous Material. *Philosophical Transactions of the Royal Society of London. A.* 1895;186(ArticleType: research-article / Full publication date: 1895 / Copyright © 1895 The Royal Society):343-414.

40. Wikipedia. Chi-squared distribution. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.

41. Wikipedia. Egon Pearson. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.

42. Pearson ES. On the Variations in Personal Equation and the Correlation of Successive Judgments. *Biometrika.* 1922;14:23-102.

43. Wikipedia. Pearson's Chi-squared Test. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.

44. Chalmers D. Absent Qualia, Fading Qualia, Dancing Qualia. In: Metzinger T, ed. *Conscious Experience*. Throverton: Imprint Academic 1995:309-330.

45. Chalmers D. Facing Up to the Problem of Consciousness. *Originally in Journal of Consciousness Studies*. Canberra, AU: Australian National University; 1995.

46. Jackson F. What Mary Didn't Know. *Journal of Philosophy.* 1986;83(5):291-293.

47. Nagel T. What is it like to be a Bat. *Philosophical Review.* 1974;83(4):435-450.

48. Nagel T. *The View From Nowhere*; 1986.

49. Nagel T. What is the Mind–Body Problem? *Experimental and Theoretical Studies of Consciousness.* Oxford England: John Wiley & Sons; 1993:1-13.

50. Putnam H. Brains and Behavior. In: Block N, ed. *The Philosophy of Psychology* Vol 1. Boston, MA: MIT Bradford; 1980.

51. Zemach E. Putnam's Theory on the Reference of Substance Terms. In: Pessin A, Goldberg S, eds. *The Twin Earth Chronicles*. Armonk, NY: M.E. Sharpe; 1996:60-68.

52. Putnam H. Psychological Predicates (also published as The Nature of Mental States). In: Capitan WH, Merrill DD, eds. *Art, Mind and Religion*. Pittsburgh, PA: University of Pittsburgh Press; 1967:37-48.

53. Putnam H. Minds and Machines. In: Hook S, ed. *Dimensions of Mind*. New York, NY: New York University Press; 1960:148-180.

54. Putnam H. Psychological Concepts, Explication, and Ordinary Language. *The Journal of Philosophy.* 1957;54(4):94-100.
55. Chisholm R. Sentences About Believing. *Proceedings of the Aristotelian Society.* 1956;56:125-148.
56. Chisholm R. Note on Carnap's Meaning Analysis. *Philosophical Studies.* 1955;6(6):87-89.
57. Chisholm R. Intentionality and the Theory of Signs. *Philosophical Studies: An International Journal for Philosophy in the Analytic.* 1952;3(4):56-63.
58. Wikipedia. Max Plank. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
59. Plank M. On the Law of Distribution of Energy in the Normal Spectrum (Zur Theorie des Gesetzes der Energieverteilung im Normalspektrum). *Annalen der Physik (Kyoto University).* Vol 4. Berlin, Germany (Kyoto, Japan): Annalen der Physik; 1901:553-559.
60. Wikipedia. Black Body. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
61. Wikipedia. Albert Einstein. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
62. Einstein A. On a Heuristic Viewpoint Concerning the Production and Transformation of Light. *University Reader in Theoretical Physics*. New Your, NY: Pergamon Press Ltd. (University of Berlin); 1905 (1967).
63. Wikipedia. Photoelectric Effect. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
64. Einstein A. Investigations on the Theory of Brownian Movement. *Investigations on the theory of Brownian Movement*. Berlin, Germany: Dover Publishing (University of Berlin); 1905 (1956).
65. Wikipedia. Statistical Mechanics. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
66. Einstein A. On the Electrodynamics of Moving Bodies. *Fourmilab*. Lignières, Switzerland: Fourmilab; 1905
67. Wikipedia. Herman Minkowski. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
68. Minkowski H. Space and Time (Raum und Zeit). *Jahresberichte der Deutschen Mathematiker-Vereinigung (Wikisource).* 1908:75-88.
69. Wikipedia. Ernest Rutherford. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
70. Rutherford E. The Scattering of α and β Particles by Matter and the Structure of the Atom. *Philosophical Magazine (lawebdefisica.com).* 1911;21(6):669-688.
71. Bohr N. On the Constitution of Atoms and Molecules. *Philosophical Magazine (lawebdefisica.com).* 1913;26(1):1-12.
72. Bohr N. On the Constitution of Atoms and Molecules, Part II. *Philosophical Magazine (lawebdefisica.com).* 1913;26(476):1-26.
73. Bohr N. On the Constitution of Atoms and Molecules, Part III Systems containing several nuclei. *Philosophical Magazine* 1913;26:857-875.
74. Einstein A. The Foundation of the General Theory of Relativity. *Annalen der Physik (Internet Archive)*: Internet Archive; 1916 (2006).
75. Wikipedia. General Relativity. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
76. Wikipedia. Arthur Eddington. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
77. Wikipedia. Percy Williams Bridgman. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
78. Chang H. Operationalism. *Stanford Encyclopedia of Philosophy*. Stanford, CA: The Metaphysics Research Lab 2009.
79. Wikipedia. Operationalization. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
80. Bridgeman PW. The Logic of Modern Physics. New York, NY: Macmillan (University of Washington); 1927.
81. Wikipedia. Edward C. Tolman. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
82. Cat J. Otto Neurath. *Stanford Encyclopedia of Philosophy*. Stanford, CA The Metaphysics Research Lab 2010.
83. Wikipedia. Otto Neurath *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
84. Wikipedia. Moritz Schlick. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
85. Wikipedia. Gottlob Frege. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation 2013.
86. Frege G. Begriffsschrift Bibliotheque nationale de France; 1879.
87. Wikipedia. Georg Cantor. *Wikipedia*. San FRancisco, CA: The Wikimedia Foundation; 2013.
88. Cantor G. Über eine Eigenschaft des Inbegriffes aller reelen algebraischen Zahlen *Journal für die Reine und Angewandte Mathematik.* 1874;77:258–262.
89. Cantor G. Gesammelte Abhandlungen Mathematischen und Philosophischen Inhalts. In: Zermelo E, ed. Berlin, Germany (Goettingen, Germany): Verlag Von Julius Springer (University of Goettingen); 1932.
90. Wikipedia. Logicism. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
91. Wikipedia. Natural Number. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.

92. Wikipedia. David Hilbert. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
93. Hilbert D. Foundations of Geometry (Grundlagen der Geometrie). Salt Lake City, Utah: Project Gutenburg; 1899 (2005).
94. Wikipedia. Robert Lee Moore. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
95. Moore R. Geometry in Which the Sum of the Angles of Every Triangle is Two Right Angles, Soc. 8 (1907), 369-378. *Transactions of the American Mathematical Society.* 1907;8(1907):369-378.
96. Wikipedia. Bertrand Russell *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
97. Wikipedia. Albert North Whitehead. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
98. Wikipedia. Principia Mathematica. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
99. Russell B, Whitehead AN. Principia Mathematica*.* Vol One. London, England (Ann Arbor, Michigan): Cambridge University Press (University of Michigan); 1910.
100. Russell B, Whitehead AN. Principia Mathematica*.* Vol Two. London, England (Ann Arbor, Michigan): Cambridge University Press (University of Michigan); 1912.
101. Russell B, Whitehead AN. Principia Mathematica*.* Vol Three. London, England (Ann Arbor, Michigan): Cambridge University Press (University of Michigan); 1913.
102. Wikipedia. Kurt Gödel *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
103. Gödel K. On Formally Undecidable Propositions of 'Principia Mathematica' and Related Systems (Über formal unentscheidbare Sätze der 'Principia Mathematica' und Verwandter Systeme). *Monatshefte für Mathematik und Physik (Jacq Krol).* Vol 38; 1931:173-198.
104. Wikipedia. Alonzo Church. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
105. Church A. An Unsolvable Problem of Elementary Number Theory. *American Journal of Mathematics.* 1936;58:345-363.
106. Wikipedia. Alan Turing. *Wikipedia*. San Francsico, CA: The Wikimedia Foundation; 2013.
107. Hodges A. The Alan Turing Home Page; 2013.
108. Turing A. On Computable Numbers, with an Application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society, Series 2.* 1936;42:230-265.
109. Wikipedia. Verificationism. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
110. Wikipedia. Verification theory. *Wikipedia*. SAn Francisco, CA: The Wikimedia Foundation; 2013.
111. Wikipedia. Auguste Comte. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
112. Schlick M. General Theory of Knowledge (Allgemeine Erkenntnislehre) Berlin, Germany: Verlag von Julius Springer; 1918.
113. Schlick M. Meaning and Verification. *The Philosophical Review.* 1936;45(4):339-369.
114. Schlick M. On the Relation Between Psychological and Physical Concepts. In: Feigl H, Sellars W, eds. *Readings in Philosophical Analysis*. New York, NY: Appleton-Century Crofts Inc.; 1949.
115. Neurath O. Protokollsätze. *Erkenntnis.* 1932;3(1):204-214.
116. Neurath O. Physicalism: The Philosophy of the Viennese Circle. *Monist.* 1931;41:618-623.
117. Cat J. The Unity of Science. *Stanford Encyclopedia of Philosophy.* Vol Fall 2010 Edition. San Francisco: Stanford encyclopedia of Philosophy; 2007.
118. Wikipedia. Ernst Mach. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
119. Uebel T. Vienna Circle. *Stanford Encyclopedia of Philosophy*. Stanford, CA: The Metaphysics Research Lab; 2011.
120. Wikipedia. Vienna Circle. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
121. Circle TV. Wissenschaftliche Weltauffassung: Der Wiener Kreis [The Scientific Conception of the World: The Vienna Circle] 1 Dedicated to Moritz Schlick In: Sarkar S, ed. *The Emergence of Logical Empiricism: from 1900 to the Vienna Circle*. New York Garland Publishing; 1996:321–340.
122. Wikipedia. Berlin Circle. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
123. Rescher N. The Berlin School of Logical Empiricism and Its Legacy. Pittsburgh, PA: University of Pittsburgh; 2006.
124. Wikipedia. Paul Oppenheim. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
125. Wikipedia. Hans Reichenbach. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
126. Wikipedia. Rudolf Carnap. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
127. Carnap R. *Der Logische Aufbau der Welt (The Logical Structure of the World. Pseudoproblems in Philosophy)*. Leipzig: Felix Meiner Verlag; 1929.
128. Neurath O, ed. *Foundations of the Unity of Sciences, vol. 1-10*. Chicago: University of Chicago Press; 1938.

129. Neurath O, ed. *International Encyclopedia of Unified Science: Foundations of the Unity of Science; the Development of Rationalism and Empiricism, Vol 2*: UNIV OF CHICAGO PR; 1941.
130. Wikipedia. Gilbert Ryle. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
131. Tanney J. Gilbert Ryle. *The Stanford Encyclopedia of Philosophy*. Stanford, CA: The Metaphysics Research Lab 2008.
132. Wikipedia. Carl Gustav Hempel. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
133. Fetzer J. Carl Hempel. *The Stanford Encyclopedia of Philosophy*. Stanford, CA: The Metaphysics Research Lab 2010.
134. Ryle G. *The Concept of Mind.* Vol Barnes and Noble. New York, NY; 1949.
135. Hempel CG. The Logical Analysis of Psychology. *Revue de Synthese.* 1935;10:21-42.
136. Ryle G. Ordinary Language. *Philosophical Review.* 1953;LXII:167-186.
137. Ryle G. Abstractions. *Dialogue: Canadian Philosophical Review.* 1962;1(0012-2173, 0012-2173):5-16.