

**BOOK I is also an e-book titled
Philosophy of Science: An Introduction
available through most internet booksellers**

INTRODUCTION TO PHILOSOPHY OF SCIENCE

CHAPTER 1. Overview

Both successful science and contemporary philosophy of science are pragmatic. In science, as in life, realistic pragmatism is what works successfully. This introductory e-book is a concise summary of the elementary principles of the contemporary pragmatist philosophy of science, the philosophy that the twentieth century has bequeathed to the twenty-first century.

1.01 Aim of Philosophy of Science

The aim of contemporary pragmatist philosophy of science is to discover principles that explain successful practices of basic-science research, in order to advance contemporary science by application of the principles.

Basic science creates new language: new theories, new laws and new explanations. Applied science uses scientific explanations to change the real world, e.g., new technologies, new social policies and new therapies. Philosophy of science pertains to **basic-science** practices and language.

1.02 Computational Philosophy of Science

Computational philosophy of science is the design, development and application of computer systems that proceduralize and mechanize productive basic-research practices in science.

Philosophy of science has changed. Mechanized information processing has permeated almost every science, and is now belatedly intruding into philosophy of science. Today computerized discovery systems facilitate investigations in philosophy of science in a new specialty called “computational philosophy of science”.

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The pragmatist philosophers Charles Sanders Peirce and Norwood Russell Hanson had described a **nonprocedural** analysis for developing theories. Some called this nonprocedural practice “abduction”, others “retroduction”. Today in computational philosophy of science **procedural** strategies for developing new theories are coded into computer systems.

1978 Nobel-laureate economist Herbert Alexander Simon, a founder of artificial intelligence, called such systems “discovery systems”. In the 1970’s Hickey called the mechanized approach “metascience”. In the 1980’s philosopher of science, Paul Thagard, called it “computational philosophy of science”, a phrase that is more descriptive and therefore will probably prevail.

Philosophers of science can no longer be content with more rehearsing of the Popper-Kuhn debates of half a century ago, much less more debating ancient futile issues such as realism vs idealism.

Mechanized simulation of successful episodes in the history of science is often used to test the plausibility of the discovery-system designs. But the proof of the pudding is in the eating. Application of computer systems at the frontier of a science to propose new empirically superior theories further tests the systems, where prediction is also production. Now philosophers of science must practice what they preach by participating in basic-science research and producing results. Application of discovery systems gives the philosopher of science a participatory and consequential rôle in basic-science research.

1.03 Two Perspectives on Language

Philosophy of language supplies a coherent analytical framework that integrates contemporary philosophy of science. Philosophers have long distinguished two perspectives in philosophy of language called “**object language**” and “**metalanguage**”.

Object language is discourse about the nonlinguistic reality including domains that the particular sciences investigate as well as most of everyday discourse.

Metalanguage is language about language, either object language or metalanguage.

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Much of the discourse in philosophy of science is in the metalinguistic perspective. Important metalinguistic terms include “theory”, “law”, “test design”, “observation report” and “explanation”, which are classifications of language. In the contemporary pragmatist philosophy a “**Theory**” is a universally quantified hypothesis *proposed* for empirical testing, and a “**Test design**” is a universally quantified discourse *presumed* for empirical testing a theory, in order to identify the subject of the theory and to describe the procedures for performing the test. The computer instructions coded in discovery systems are also metalinguistic expressions, because these systems input, process and output object language for the sciences.

1.04 Dimensions of Language

Using the metalinguistic perspective, philosophers analyze language into what Rudolf Carnap called “dimensions” of language. They are **syntax**, **semantics**, **ontology**, and **pragmatics**.

Syntax refers to the structure of language. Syntax is arrangements of syntactical symbols such as linguistic ink marks on paper display syntactical structure. Examples of syntactical symbols include terms such as words and mathematical variables and the sentences and mathematical equations constructed with the terms.

Syntactical rules regulate construction of grammatical expressions such as sentences and equations usually arranged by concatenation into strings of terms.

Semantics refers to the meanings associated with syntactical symbols. Syntax without semantics is systematic but literally meaningless. Adding meanings to the symbols makes the syntax “semantically interpreted”.

Semantical rules describe the meanings associated with elementary syntactical symbols. In the metalinguistic perspective belief in the truth of semantically interpreted universally quantified sentences such as the stereotypic “Every raven is black” enables the sentences to function as semantical rules displaying the complex meanings of their component descriptive terms. Belief in the statement “Every raven is black” makes the phrase “black raven” redundant, thus displaying the meaning of “black” as a component part of the meaning of “raven”. The lexical entries in a unilingual dictionary exemplify an inventory of the semantical rules.

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Ontology refers to the aspects of reality described by semantically interpreted sentences believed to be true, especially belief due to experience or systematic empirical testing. This is the thesis of ontological relativity. Ontology is typically of greater interest to philosophers than to linguists.

Semantics is knowledge of reality; ontology is **reality as known**. Semantics is the perspectivist signification of reality; ontology is the aspects of reality signified by semantics. Ontology is the aspect of mind-independent reality that is cognitively captured by the perspective revealed by the semantics.

Not all discourses are equally realistic; they are as realistic as they are empirically adequate. And since all semantics is relativized and ultimately comes from sense stimuli, there is no semantically interpreted syntax of language that is utterly devoid of any associated ontology.

Pragmatics in philosophy of science refers to how scientists use language, namely **to create** and **test theories**, and thereby develop scientific laws used in test designs for future testing and in scientific explanations.

1.05 Classification of Functional Topics

Basic-science research practices can be classified into four topics that include the essential functions performed in basic research. They are also topics typically discussed in the literature of philosophy of science.

The institutionalized aim of basic science is the culturally shared aim that guides development of explanations, which in turn are the final products of basic-scientific research. The institution of science has evolved considerably over the last several centuries, and will continue to evolve in unforeseeable ways with the future advancement of science.

Discovery refers to the processes of constructing new theories. Pragmatists define theory language pragmatically, *i.e.*, functionally, as universally quantified statements expressible in conditional form including equations (a.k.a. “models”) that are proposed for empirical testing.

Theories are universally quantified hypotheses proposed for empirical testing.

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Criticism refers to the decision criteria used for the evaluation of theories. Pragmatists accept **only** the empirical criterion. **Empirical testing is the pragmatics of theory language**, and it uses *modus tollens* conditional deductive argument form. A scientific law is an empirically tested and nonfalsified theory.

Test-designs are universally quantified discourse presumed for empirical testing a theory, in order to identify the subject of the theory and to describe the procedures for performing the test.

Explanation is language that describes the occurrence of individual events and conditions as caused by the occurrence of other described events and conditions according to law statements. It uses *modus ponens* conditional deductive argument form, which includes universally quantified statements expressible in conditional form that are scientific laws. Whenever possible the explanation is predictive.

1.06 Classification of Modern Philosophies

Twentieth-century philosophies of science may be classified into three generic types. They are **romanticism**, **positivism** and **contemporary pragmatism**. Romanticism is a philosophy for social and cultural sciences. Positivism is a philosophy for all sciences inspired by Newtonian physics. Contemporary pragmatism is a philosophy for all sciences inspired by quantum physics. Each type has many representative authors advocating philosophies expressing similar concepts for such metalinguistic terms as “theory”, “law” and “explanation”. Philosophies within each generic classification have their differences, but are much more similar to each other than to those of the two other types. These various concepts are related as follows:

	Aim of Science	Discovery	Criticism	Explanation
Romanticism				
Positivism				
Pragmatism				

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CHAPTER 2. Modern Philosophies

This chapter sketches three generic types of twentieth-century philosophy of science in terms of the four functional topics. Philosophy of language will be taken up in Chapter 3. Then all these elements will be integrated in a discussion of the four functional topics in Chapter 4.

2.01 Romanticism

Romanticism has effectively no representation in the natural sciences today, but it is still widely represented in the social sciences including economics and sociology. It has its roots in the eighteenth-century German idealist philosophers including notably Immanuel Kant and especially Georg Hegel with the latter's exclusive emphasis on ideas in culture. The idealist philosophies are of purely antiquarian interest to most philosophers of science today. Romantics have historically defaulted to the positivist philosophy for the natural sciences, but they reject imitating the positivist philosophy for the social sciences.

Aim of science:

For romantics the aim of the social sciences is an investigation of culture that yields an “interpretative understanding” of “human action”, by which is meant explanation of social interactions in terms of subjective mental states, i.e., ideas and motives, views and values that are culturally shared by members of social groups.

Romantics maintain that there is a fundamental difference between sciences of nature and sciences of culture.

This concept of the aim of science and of explanation is called a “foundational agenda”, because it requires reduction of the social sciences to a social-psychology foundation, i.e., description of observed social behavior by reference to social-psychological mental states.

Discovery:

For romantics the creation of “theory” in social science may originate in either the social scientist's introspective reflection on his own ideas and motivations originating in his actual or imaginary

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experiences, which ideas and motives are imputed to social members, or empirical survey research findings reporting social members' expressed ideas and motivations.

Romantics define “social theory” as language describing **subjective** mental states, notably culturally shared ideas and motivations.

Some romantics call the vicarious imputations based in introspective reflection “substantive reasoning” or “interpretative understanding”. But all romantic social scientists deny that social theory can be developed by data analysis exclusively or by observation of overt behavior alone.

Romantics therefore oppose their view of the aim of science to that of the positivists' such as the sociologist George Lundberg and the behavioristic psychologist B.F. Skinner. Romantics say they explain consciously purposeful and motivated “human action”, while the behaviorists say they explain publicly observable “human behavior”. Some romantics call the study of human action “hermeneutics”.

Criticism:

For romantics the criterion for criticism is “convincing interpretative understanding” that “makes substantive sense” of conscious motivations, which are deemed to be the underlying “causal mechanisms” of observed human action.

Causality is an ontological concept, and all romantics impose their mentalistic ontology as a prior criterion for criticism, while making empirical or statistical analyses at most optional and supplementary.

Furthermore many romantic social scientists demand the criterion that a social theory must be identifiable in the particular investigator's own introspectively recognized subjective personal experience. In Max Weber's terms this is called *verstehen*. It is the thesis that empathetic insight is a special and valuable tool in the study of human behavior, which is without counterpart in the physical sciences. It effectively makes all sociology what has been called “pop sociology” or “folk sociology”.

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Explanation:

For romantics maintain only “theory” that describes subjective motives can “explain” conscious human action.

Motives are the “mechanisms” identified in “causal” explanations, which are also therefore called “theoretical” explanations. Observed regularities are deemed incapable of “explaining”, even if they enable correct predictions.

Some formerly romantic social scientists such as the Institutional economist Wesley Mitchell and the functionalist sociologist Robert Merton have chosen to focus on objective outcomes rather than subjective motives.

2.02 Positivism

Historically positivism was a reaction against romanticism, but more recently it has been relegated to history of philosophy. Positivism’s origins are in the eighteenth-century British empiricist philosophers including notably David Hume. But not until the late nineteenth century did positivism get its name from the French philosopher Auguste Comte, who also founded sociology.

The “neopositivists” were the last incarnation of positivism. They attempted to use the symbolic logic fabricated by Bertrand Russell and Alfred Whitehead early in the twentieth century, because they had fantasized that the Russellian truth-functional symbolic logic could serve philosophy, as mathematics has served physics. They are therefore also called “logical positivists”.

Contrary to romantics, positivists believe that all sciences including the social sciences share the same philosophy of science. They therefore reject the romantics’ dichotomy of sciences of nature and sciences of culture. And the positivists’ ideas about science originated in their reflection upon Newtonian physics.

Aim of science:

For positivists the aim of science is to produce explanations having objectivity grounded in language describing observations.

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Their concept of the aim of science is thus also called a “foundational agenda”, although the required foundation is quite different from that of the romantics.

Discovery:

Positivists believed that empirical laws are inferentially discovered by inductive generalization based on repeated observations.

They define empirical laws as universally quantified statements containing only “observation terms” describing observable entities and/or phenomena.

Early positivists such as Ernst Mach recognized only empirical laws for valid scientific explanations. But after Einstein’s achievements neopositivists such as Rudolf Carnap recognized hypothetical theories for valid scientific explanations, if the theories could be linguistically related to language used to report the relevant observations.

Unlike empirical laws, theories are not produced by induction from singular observations. **Positivists believed that theories are discovered by creative imagination, but they left unexplained the creative process of developing theories.**

The neopositivists define theories as universally quantified statements containing any “theoretical terms”, *i.e.*, terms that do not describe observable entities or phenomena.

Criticism:

The positivists’ criterion for criticism is publicly accessible observation expressed in language containing only “observation terms”, which are terms that describe only observable entities or phenomena.

Positivists maintain that theories are indirectly and tentatively warranted by empirical laws, when valid laws can be logically derived from the theories.

Like Hume they deny that either laws or theories can be permanently validated empirically, but they require that the general laws be founded in observation as a condition for the objectivity needed for valid science. They

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maintain that particularly quantified observation statements describing singular events are incorrigible and beyond revision.

Positivists reject the romantics' *verstehen* thesis of criticism. They argue that empathy is not a reliable tool, and that the methods of obtaining knowledge in the social sciences are the same as those used in the physical sciences. They note that subjective *verstehen* may easily involve erroneous transfer of the idiosyncrasies of the observer's experiences to the subject of observation.

Explanation:

Positivists and specifically Carl Hempel advocate the "covering-law" schema for explanation.

According to Hempel's "covering-law" thesis of explanation, statements predicting observable individual events are derived deductively from observation-language statements describing observable individual events together with "covering", i.e., universally quantified empirical laws.

This concept of explanation has also been called the "deductive-nomological model".

Positivists also maintained that theories explain laws, when the theories are premises from which the empirical laws are deductively derived as theorems by the mediation of "correspondence rules", also called "bridge principles". Correspondence rules are sentences that relate the theoretical terms in a theory to the observation terms in the empirical laws.

2.03 Contemporary Pragmatism

We are now said to be in a "postpositivist" era in the history of Western philosophy, but this term merely says that positivism has been relegated to history; it says nothing of what has replaced it. What has emerged in reaction to positivism is a new coherent master narrative appropriately called "contemporary pragmatism", which was occasioned by reflection on quantum theory, and is currently the ascendant philosophy in American academia.

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This new pragmatism had earlier versions in the classical pragmatists, notably those of Charles Peirce, William James and John Dewey. Some theses in classical pragmatism such as the importance of belief have been carried forward into the new.

In contemporary pragmatism belief is strategic, because it controls relativized semantics, which signifies a correspondingly relativized realistic ontology to the degree that a belief is empirically adequate.

Especially important is Dewey's emphasis on participation and his pragmatic thesis that the logical distinctions and methods of scientific inquiry develop out of scientists' successful problem-solving processes.

The provenance of the contemporary pragmatist philosophy of science is 1932 Nobel-laureate physicist Werner Heisenberg's reflections on the language in his quantum-theory revolution in microphysics. There have been various alternative semantics and thus ontologies proposed for the quantum theory. Most physicists today have accepted one that has ambiguously been called the "Copenhagen interpretation".

There are two versions of the Copenhagen interpretation. Contrary to the alternative "hidden variables" view of David Bohm, **both** Copenhagen versions assert a thesis called "duality". The duality thesis is that the wave and particle manifestations of the electron are two aspects of the same entity, as Heisenberg says, rather than two separate entities, as Bohm says.

1922 Nobel-laureate Niels Bohr, founder of the Copenhagen Institute for Physics, proposed a version called "complementarity". His version says that the mathematical equations of quantum theory must be viewed instrumentally instead of descriptively, because only ordinary discourse and its refinement in the language of classical physics can describe physical reality. Instrumentalism is the doctrine that scientific theories are not descriptions of reality, but are merely useful linguistic instruments that enable correct predictions.

The quantum theory says that the electron has both wave and particle properties, but in classical physics the semantics of the terms "wave" and "particle" are mutually exclusive – a wave is spread out in space while a particle is a concentrated point. Therefore Bohr maintained that description

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of the electron's duality as both "wave" and "particle" is an indispensable semantic antilogy that he called "complementarity".

Heisenberg, a colleague of Bohr at the Copenhagen Institute, proposed his own version of the Copenhagen interpretation. His version also contains the idea of the wave-particle duality, but he said that the mathematical expression of the quantum theory is realistic and descriptive rather than merely instrumental. And since the equations describing both the wave and particle properties of the electron are mathematically consistent, he disliked Bohr's complementarity antilogy.

Years later Yale University's Russell Hanson said that Bohr maintained a "naïve epistemology". Duality is a thesis in physics while complementarity is a thesis in linguistics and philosophy of language. However, the term "complementarity" has since acquired some conventionality to signify duality, and is now ambiguous as to the issue between Bohr and Heisenberg, since physicists typically disregard the linguistic issue.

These two versions of the Copenhagen interpretation differ in their philosophy of language. Bohr's philosophy is called a "naturalistic" view of semantics, which requires what in his *Atomic Physics and the Description of Nature* (1934) he called "forms of perception". Heisenberg's philosophy is called an "artifactual" or a "conventionalist" view of semantics, in which the equations of the quantum theory supply the linguistic context, which defines the concepts that the physicist uses for observation.

1921 Nobel-laureate physicist Albert Einstein had influenced Heisenberg's philosophy of language, which has been incorporated into the contemporary pragmatist philosophy of language. And consistent with his relativized semantics Heisenberg effectively practiced ontological relativity and maintained that the quantum reality exists as "*potentia*" prior to determination by execution of a measurement operation. For Heisenberg indeterminacy is real. For more about Heisenberg and quantum theory the reader is referred to **BOOKs II** and **IV** at www.philsci.com.

Contemporary pragmatism is a general philosophy for all empirical sciences, both social and natural sciences. The distinctive linguistic philosophy of Einstein and especially Heisenberg as incorporated into the contemporary pragmatist philosophy of science may be summarized in three theses, which may be taken as basic principles in contemporary pragmatism:

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Thesis I: **Relativized semantics.**

The seminal work is “Quantum Mechanics and a Talk with Einstein (1925-1926)” in Heisenberg’s *Physics and Beyond*. There Heisenberg relates that in April 1925, when he presented his matrix-mechanics quantum physics to the prestigious Physics Colloquium at the University of Berlin, Einstein, who was in the assembly, afterward invited him to chat in his home that evening. In their conversation Einstein said that he no longer accepts the positivist view of observation including such positivist ideas as operational definitions. Instead he issued the aphorism: **“the theory decides what the physicist can observe”**.

Einstein’s view of observation contradicts the fundamental positivist thesis that there is a dichotomous separation between the semantics of observation language and that of theory language. Positivists believed that the objectivity of science requires that the vocabulary and semantics used for incorrigible observation must be uncontaminated by the vocabulary and semantics of speculative and provisional theory.

In the next chapter titled “Fresh Fields (1926-1927)” in the same book Heisenberg reports that Einstein’s discussion with him in Berlin had later occasioned his own reconsideration of observation. Heisenberg recognized that classical Newtonian physical theory had led him to conceptualize the observed track of the electron as continuous in the cloud chamber – an instrument for microphysical observation developed by 1927 Nobel-laureate C.T.R. Wilson – and to misconceive the electron as simultaneously having a definite position and momentum like all Newtonian bodies in motion.

Recalling Einstein’s aphorism that the theory decides what the physicist can observe, Heisenberg reconsidered what is observed in the cloud chamber. Einstein had failed to apply his aphorism to quantum theory, and rejected duality. But Heisenberg rephrased his question about the electron tracks in the cloud chamber using the concepts of the new quantum theory instead of those of the classical Newtonian theory. He reports that he asked himself: Can the quantum mechanics represent the fact that an electron finds itself approximately in a given place and that it moves approximately at a given momentum? In answer to this newly formulated question he found that these approximations could be represented mathematically. He then developed this mathematical representation, which he called the “uncertainty relations”, the historic contribution for which he received the Nobel Prize in 1932.

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Russell Hanson expressed Einstein's aphorism that the physical theory decides what the physicist can observe by saying observation is "theory-laden" and likewise Karl Popper by saying it is "theory-impregnated".

Paul Feyerabend also recognized employment of relativized semantics to create new observation language for discovery, and he called the practice "**counterinduction**". Feyerabend found that Galileo had practiced counterinduction in the *Dialogue Concerning the Two Chief World Systems* (1632), where Galileo reinterpreted apparently falsifying observations in common experience by using the concepts of the heliocentric theory instead of the concepts of the geocentric theory. Likewise Heisenberg also practiced counterinduction to reconceptualize the perceived sense stimuli observed as the electron track in the cloud chamber by using quantum concepts instead of classical Newtonian concepts.

"Counterinduction" is using the semantics of an apparently falsified theory to revise the test-design language that had supplied the semantics of the descriptive language for the falsifying observations, and thereby to produce new observation language.

Like Einstein, contemporary pragmatists say that the theory decides what the scientist can observe. Thus semantics is relativized in the sense that the meanings of descriptive terms used for reporting observations are not just names or labels for phenomena, but rather are determined by the context in which they occur. More specifically in "Five Milestones of Empiricism" in his *Theories and Things* the pragmatist philosopher of language Willard van Quine says that the meanings of words are abstractions from the truth conditions of the sentences that contain them, and that it was this recognition of the semantic primacy of sentences that give us contextual definition.

Most notably the defining context includes universally quantified statements that proponents believe to be true. The significance is that the acceptance of a new theory superseding an earlier one and sharing some of the same descriptive terms produces a semantical change in the descriptive terms shared by the theories and by their observation reports.

Thus Einstein for example changed the meanings of such terms as "space" and "time", which occur in both the Newtonian and relativity theories. And Heisenberg changed the meanings of the terms "wave" and

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“particle”. Feyerabend calls the semantical change due to the relative nature of semantics, “**meaning variance**”.

Thesis II: Empirical underdetermination.

Empirical underdetermination refers to the limited ability of the semantics of language at any given time to signify reality.

Measurement error and conceptual vagueness, which can be reduced indefinitely but never completely eliminated, exemplify the omnipresent and ever-present empirical underdetermination of descriptive language that produces observational ambiguity and theoretical pluralism. Einstein recognized that a plurality of alternative but empirically adequate theories could be consistent with the same observational description, a situation that in his autobiography he called “an embarrassment of riches”.

Additional context including law statements in improved test-design language contributes additional semantics to the observational description in the test designs, thus reducing while never completely eliminating empirical underdetermination. In his *Word and Object* Quine introduced the phrase “empirical underdetermination”, and wrote that the positivists’ theoretical terms are merely more empirically underdetermined than terms they called observation terms. Thus the types of terms are not qualitatively different.

Thesis III: Ontological relativity.

In his discussions about Einstein’s special theory of relativity in *Physics and Philosophy* and in *Across the Frontiers* Heisenberg describes the “decisive step” in the development of special relativity. That step was Einstein’s rejection of 1902 Nobel-laureate Hendrik Lorentz’s distinction between “apparent time” and “actual time” in the Lorentz-Fitzgerald contraction. Lorentz took the Newtonian concepts to describe real space and time. But in his relativity theory Einstein took Lorentz’s “apparent time” as physically real time, while altogether rejecting the Newtonian concept of absolute time as real time. In other words the “decisive step” in Einstein’s special theory of relativity consisted of Einstein’s taking the relativity theory realistically, **thus letting his relativity theory characterize the physically real, i.e., physical ontology.**

Also in “History of Quantum Theory” in his *Physics and Philosophy* Heisenberg describes his imitation of Einstein in his discovery experience

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for quantum theory. There he states that his thinking about the uncertainty relations consisted of turning around a question. Instead of asking himself how one can express in the Newtonian mathematical scheme a given experimental situation, he asked whether only such experimental situations can arise in nature as can be described in the formalism of his quantum mechanics. The new question is an ontological question with the answer supplied by his quantum theory.

Again in “Remarks on the Origin of the Relations of Uncertainty” in *The Uncertainty Principle and Foundations of Quantum Mechanics* Heisenberg explicitly states that a Newtonian path of the electron in the cloud chamber does not exist. And still again in “The Development of the Interpretation of the Quantum Theory” in 1945 Nobel-laureate Wolfgang Pauli’s *Niels Bohr and the Development of Physics*, Heisenberg says that he inverted the question of how to pass from an experimentally given situation to its mathematical representation. There he concludes that only those states that can be represented as vectors in Hilbert space can exist in nature and be realized experimentally. And he immediately adds that this conclusion has its prototype in Einstein’s special theory of relativity, when Einstein had removed the difficulties of electrodynamics by saying that the apparent time of the Lorentz transformation is real time.

Like Heisenberg in 1926, the contemporary pragmatist philosophers let the scientist rather than the philosopher decide ontological questions. And the scientist decides on the basis of empirical adequacy demonstrated in his empirically tested explanations. Many years later in his *Ontological Relativity* Quine called this thesis “ontological relativity”, as it is known today.

Ontological relativity did not begin with Heisenberg much less with Quine. Copernicus and Galileo practiced it when they both interpreted heliocentrism realistically thus accepting the ontology it describes – to the fateful chagrin of Pope Urban VIII. Heisenberg’s Copenhagen interpretation still prevails in physics today. But should future superior test designs and experiments result in falsification of his Copenhagen interpretation, then physicists’ practice of ontological relativity would make a newer empirically more adequate theory define the prevailing ontology in future microphysics.

The contemporary pragmatist concepts of the four functional topics are summarized as follows:

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Aim of science:

The successful outcome (and thus aim) of basic-science research is explanations, which are made by developing theories that satisfy empirical tests and are thereby theories that are thereby made scientific laws that function in scientific explanations and test designs.

Wherever possible the explanation should enable prediction of either future events or evidence of past events. And it is beneficial furthermore for the explanation to enable control of explained nonlinguistic reality by applied science such as new engineering technologies, new medical therapies and new social policies, where success makes pragmatism blatantly self-evident.

Discovery:

Discovery is the construction of new and empirically more adequate theories.

Contemporary pragmatism is consistent with computerized discovery systems, which aim to proceduralize and mechanize new theory construction, in order to advance contemporary science.

In the “Introduction” to his magisterial *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science* (1958), Yale University philosopher of science Norwood Russell Hanson wrote that earlier philosophers of science like the positivists had mistakenly regarded as paradigms of inquiry finished systems like Newton’s planetary mechanics instead of the unsettled, dynamic research sciences like contemporary microphysics. Hanson explains that the finished systems are no longer research sciences, although they were at one time. And he states that distinctions applying to the finished systems ought to be suspect when transferred to research disciplines, and that such transferred distinctions afford an artificial account of the activities in which Kepler, Galileo and Newton were actually engaged. He thus maintains that ideas such as “theory”, “hypothesis”, “law”, “causality” and “principle” if drawn from what he calls the finished “catalogue-sciences” found in undergraduate textbooks will ill prepare one for understanding research-science.

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Both romantics and positivists define “theory” semantically, while contemporary pragmatists define “theory” pragmatically, i.e., by its function in basic research.

Contemporary pragmatists define both theory and observation language pragmatically instead of semantically. The pragmatics of both types of language is empirical testing.

Theories are universally quantified statements that are proposed for testing.

Test-designs are universally quantified statements that are presumed for testing, to identify the subject of the test and to describe procedures for execution of the test, and they include universal statements that are semantical rules for the test-outcome statements that are asserted when the test outcome is produced and known.

The semantics of newly constructed theories reveal new perspectives and ontologies.

Scientific laws are former theories that have been tested with nonfalsifying test outcomes.

Observation language is particularly quantified test-design and test-outcome statements with their semantics defined in the universally quantified test-design language.

Unlike positivists, pragmatists do not recognize any natural observation semantics. For believers in a theory, the theory language may also contribute to the observational semantics, but that semantical contribution cannot operate in reporting the test outcome without violating the test’s contingency.

Contemporary pragmatists individuate theories semantically.

Two theory expressions are different theories either if the expressions have different test designs so they identify different subjects, or if the expressions make contrary claims about the same subject as defined by the same test design.

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Criticism:

Contemporary pragmatists recognize the empirical criterion as the only valid decision criterion that yields scientific progress.

On the pragmatist thesis of ontological relativity, semantics and ontologies can never trump the empirical criterion for criticism. Acceptance of ontologies is based upon empirical adequacy of a theory as demonstrated by empirical test outcomes. Thus contrary to romantics, pragmatists **permit** description of subjective mental states in social-science theories and explanations, but **never require** such description as a criterion for criticism. Or as Popper said, science is “subjectless”.

Pragmatists recognize the nontruth-functional hypothetical-conditional form of statement-schema for expressing proposed theories.

Pragmatists recognize the *modus tollens* falsifying argument for empirical testing of the theories.

Unlike the logical positivists, pragmatists do not recognize the Russellian truth-functional conditional logic for scientific criticism, because the logic of empirical testing is not truth-functional.

Explanation:

Explanation describes the occurrence of individual events and conditions as caused by the occurrence of other described events and conditions according to law statements.

Pragmatists recognize *modus ponens* nontruth-functional deductive logical argument with the hypothetical conditional statement form that includes universally quantified statements expressible in conditional form that are scientific laws. Whenever possible the explanation is predictive.

Laws are said to be “explained” in the sense that a set of logically related laws may form a deductive system partitioned into dichotomous subsets of explaining antecedent axioms and explained consequent theorems.

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CHAPTER 3. Philosophy of Language

Many and probably most of the central concepts and issues in philosophy of science involve philosophy of language. Therefore the following selected elements of contemporary pragmatist philosophy of language are discussed in relation to philosophy of science.

3.01 Synchronic and Diachronic Analysis

To borrow some terminology from Ferdinand de Saussure's classic *Course in General Linguistics* language analyses may be either **synchronic** or **diachronic**.

The **synchronic** view is **static**, because it exhibits the state of a language at a point in time like a photograph. And to borrow some terminology from Rudolf Carnap's *Meaning and Necessity* with a revised meaning, in computational philosophy of science the state of the language for a specific scientific problem is displayed synchronically in a "**semantical state description**". In the pragmatist's semantical state description statements both of theory language and of the law language in the relevant test design function as semantical rules that describe the meanings of their constituent descriptive terms.

The **diachronic** view on the other hand exhibits two chronologically successive states of the language for the same problem as defined by a test design, and shows semantical change over the interim period. Then the view is a **comparative-static** semantical analysis like "before" and "after" photographs. And if a transitional process between the two successive language states is also described, as in the computer code for a discovery system, then the diachronic view is **dynamic** like a motion picture.

3.02 Object Language and Metalanguage

Many philosophers of science such as Rudolf Carnap in his *Logical Syntax of Language* distinguish two levels of language, **object language** and **metalanguage**.

Object language is used to describe the nonlinguistic real world.

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Metalinguage is used to describe language, either object language or metalinguage.

The language of science is typically expressed in the object-language perspective, while much of the discourse in philosophy of science is in the metalinguistic perspective. Terms such as “theory” and “explanation” are examples of expressions in metalinguage.

3.03 Dimensions of Language

The metalinguistic perspective includes what may be called dimensions of language, which serve well as an organizing framework for philosophy of language. Four dimensions may be distinguished for philosophy of language. They are **A. syntax, B. semantics, C. ontology** and **D. pragmatics**. Most philosophers of science ignore the linguists’ phonetic and phonemic dimensions. And most linguists ignore ontology.

A. SYNTAX

3.04 Syntactical Dimension

Syntax is the system of linguistic symbols considered in abstraction from their associated meanings.

Syntax is the most obvious part of language. It is residual after abstraction from pragmatics, ontology, and semantics. And it consists only of the forms of expressions, so it is often said to be “formal”. Since meanings are excluded from the syntactical dimension, the expressions are also said to be semantically “uninterpreted”. And since the language of science is usually written, the syntax of interest consists of visible marks on paper or more recently linguistic displays on computer display screens the syntax of expressions is sometimes called “inscriptions”. Examples of syntax include the sentence structures of colloquial discourse, the formulas of pure or formal mathematics, and computer source codes such as **FORTRAN** or **LISP**.

3.05 Syntactical Rules

Syntax is a *system* of symbols. Therefore in addition to the syntactical symbols and structures, there are also rules for the system called “syntactical

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rules”. These rules are of two types: **formation rules** and **transformation rules**.

Formation rules are procedures described in metalanguage that regulate the construction of grammatical expressions out of more elementary symbols.

Formation rules order such syntactical elements as mathematical variables and operator signs, descriptive and syncategorematic terms, and the user-defined variable names and reserved words of computer source codes. Expressions constructed from the symbols in compliance with the formation rules for a language are called “grammatical” or “well formed formulas”, and include the computer instructions called “compiler-acceptable” and “interpreter-acceptable” source code.

When there exists an explicit and adequate set of syntactical formation rules, it is possible to develop a type of computer program called a “**mechanized generative grammar**”. A generative grammar produces grammatical expressions from inputs consisting of more elementary syntactical symbols. The generative-grammar computer programs input, process, and output object language, while the source-code instructions constituting the computer system are therefore metalinguistic expressions.

A mechanized generative grammar is a computer system that applies formation rules to more elementary syntactical symbols inputted to the system, and thereby outputs grammatically well formed expressions.

When a mechanized generative grammar is used to produce new scientific theories in the object language of a science, the computer system is called a “**discovery system**”. Typically the system also contains an empirical test criterion for the selection of a subset for output of the numerous theories generated.

A discovery system is a mechanized generative grammar that constructs and also may empirically test scientific theories as its output.

Transformation rules change grammatical sentences into other grammatical sentences.

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For example there are transformation rules for colloquial language that change a sentence from declarative to interrogative mood. The object language of science is typically expository, and philosophy of science therefore principally considers the declarative mood for the descriptive discourse as in theories and laws. The imperative mood is also of interest for describing procedural instructions in test designs for executing the tests.

Transformation rules are used in logical and mathematical deductions. But logic and mathematical rules are intended not only to produce new grammatical sentences but also to guarantee truth transferability from one set of sentences or equations to another to generate theorems, usually by the transformation rule of substitution that makes logic extensional.

In 1956 Herbert Simon developed an artificial-intelligence computer system named **LOGIC THEORIST**, which operated with his “heuristic-search” system design. This system developed deductive proofs of the theorems in Alfred N. Whitehead and Bertrand Russell’s *Principia Mathematica*. The symbolic-logic formulas are object language for this system. But Simon correctly denies that the Russellian symbolic logic is an effective metalanguage for the design of discovery systems.

Transformation rules are of greater interest to linguists, logicians and mathematicians than to contemporary philosophers of science, who recently have been more interested in formation rules for generative-grammar discovery systems.

3.06 Mathematical Language

The syntactical dimension of mathematical language includes mathematical symbols and the formation and transformation rules of the various branches of mathematics. Mathematics applied in science is object language for which the syntax is supplied by the mathematical formalism. Whenever possible the object language of science is mathematical rather than colloquial, because measurement values for variables enable the scientist to quantify the error in his theory, after estimates are made for the range of measurement error, usually by repeated execution of the measurement procedure.

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3.07 Logical Quantification in Mathematics

Mathematical expressions in science are universally quantified when descriptive variables have no associated numerical values, and are particularly quantified when numeric values are associated with any of the expression's descriptive variables either by measurement or by calculation.

Like categorical statements, mathematical equations are explicitly quantified logically as either universal or particular, even though the explicit indication is not by means of the syncategorematic logical quantifiers “every”, “some” or “no”. An equation in science is universally quantified logically when none of its descriptive variables are assigned numeric values. Universally quantified equations may contain mathematical constants as in some theories or laws. An equation is particularly quantified logically by associating measurement values with any of its descriptive variables. A variable may then be said to describe an **individual measurement instance**.

When a numeric value is associated with a descriptive variable by computation with measurement values associated with other descriptive variables in the same mathematical expression, the variable's calculated value may be said to describe an **individual empirical instance**. In this case the referenced instance has not been measured but depends on measurements associated with other variables in the same equation.

Individual empirical instances are calculated when an equation is used to make a numerical prediction. The individual **empirical** instance is the predicted value, which makes an empirical claim. In a test it is compared with an individual **measurement** instance, which is the test-outcome value made for the same variable. The individual empirical instance made by the predicting equation is not said to be empirical because the predicting equation is correct or accurate, but rather because the predicting equation makes an empirical claim, which may be falsified by the empirical test.

B. SEMANTICS

3.08 Semantical Dimension

Semantics is the meanings associated with syntactical symbols.

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Semantics is the second of the four dimensions, and it includes the syntactical dimension. Language viewed in the semantical metalinguistic perspective is said to be “semantically interpreted syntax”, which is merely to say that the syntactical symbols have meanings associated with them.

3.09 Nominalist vs. Conceptualist Semantics

Both nominalism and conceptualism are represented in contemporary pragmatism. There are several variations of nominalism, but all contemporary nominalist philosophers advocate a two-level semantics, which in written language consists only of syntactical structures and the ontologies that are referenced by the structures, or as Quine says “word and object”. The two-level semantics is also called a referential thesis of semantics, because it excludes any mid-level mental representations variously called ideas, meanings, significations, concepts or propositions. Therefore on the nominalist view language purporting to reference nonexistent fictional entities is semantically nonsignificant, which is to say it is literally meaningless.

On the alternative three-level view terms symbolize universal meanings, which in turn signify such aspects of extramental reality as attributes, and reference ontologies that include individual entities. When we are exposed to the extramental realities, they are distinguishable by the senses as perceived stimuli, which in turn are synthesized by the brain and registered in memory. The sense stimuli deliver information revealing similarities and differences in reality. The signified attributes are similarities found by perception, and the referenced entities manifesting the attributes are recognized by invariant continuities found in perceived change. The signification is always more or less vague, and the reference is therefore always more or less indeterminate or what Quine calls “inscrutable”. The three-level view is also called a conceptualist thesis of semantics.

The philosophy of nominalism was common among many positivists, although some like the logical positivist Carnap maintained a three-level semantics. In Carnap’s three-level semantics descriptive terms symbolize what he called “intensions”, which are concepts or meanings effectively viewed in simple supposition. The intensions in turn signify attributes and thereby reference in personal supposition what he called “extensions”, which are the individual entities identified by the signified attributes.

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While the contemporary pragmatism emerged as a critique of neopositivism, some philosophers carried the positivists' nominalism into contemporary pragmatism. Pragmatist philosophers such as Quine adopted nominalism. He rejected concepts, ideas, meanings, propositions and all other mentalistic views of knowledge due to the notational conventions of the Russellian predicate calculus, a logic that Quine liked to call "canonical". However, in his book *Word and Object* (1960) Quine also uses a phrase "stimulus meaning", which he defines as a disposition by a native speaker of a language to assent or dissent from a sentence in response to present stimuli. And he added that the stimulus is not just a singular event, but rather is a "universal", which he called a "repeatable event form".

Nominalism is by no means essential to or characteristic of contemporary pragmatism, and most contemporary pragmatists such as Hanson, Feyerabend and Kuhn, and most linguists except the behaviorists have opted for the three-level semantics, which is assumed herein. Also, computational philosophers of science such as Simon, Langley and Thagard, who advocate the cognitive-psychology interpretation of discovery systems instead of the linguistic-analysis interpretation, reject both nominalism and behaviorism. Behaviorism is positivism in the behavioral sciences.

Computational philosophers of science recognize the three-level semantics, and furthermore believe that they can model the mental level with computer systems. Thus in his book *Mind: Introduction to Cognitive Science* Thagard states that the central hypothesis of cognitive science is that the human mind has mental representations analogous to data structures and cognitive processes analogous to algorithms. Cognitive psychologists claim that their computer systems using data structures and algorithms applied to the data structures can model both the mind's concepts and its cognitive processes with the concepts.

3.10 Naturalistic vs. Artifactual Semantics

The artifactual thesis of the semantics of language is that the meanings of descriptive term are determined by their linguistic context consisting of universally quantified statements believed to be true.

This means that ontology, semantics and belief mutually determined.

The contemporary pragmatist philosophy of science is distinguished by a post-positivist philosophy of language, which has replaced the

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traditional naturalistic thesis with the artifactual thesis of semantics. The naturalistic thesis affirms an absolutist semantics according to which the semantics of descriptive terms is acquired ostensively and is fully determined by perceived reality and the processes of perception.

Thus on the naturalistic view descriptive terms function effectively as names or labels, a view that Quine ridicules with his phrase “myth of the museum” and “gallery of ideas”. Then after the meanings for descriptive terms are acquired ostensively, the truth of statements constructed with the descriptive terms is ascertained empirically.

On the artifactual semantical thesis sense stimuli reveal mind-independent reality as semantically signified ontology. Sense stimuli are conceptualized as the semantics that is determined by the linguistic context consisting of a set of beliefs that by virtue of its belief status has a defining rôle for the semantics. When the beliefs function as test-design statements, they may occasion falsification of a theory.

The artifactual semantical thesis together with the ontological relativity thesis revolutionized philosophy of science by relativizing both semantics and ontology to belief, especially empirically warranted belief. The outcome of this new linguistic philosophy is that ontology, semantics and belief are all mutually determined and thus interdependent.

3.11 Romantic Semantics

On the romantic view the positivist semantics may be acceptable for the natural sciences, but it is deemed inadequate for understanding “human action” in the behavioral and sociocultural sciences. Human action considered by the romantic social sciences has subjective meaning for the members of a group or society, because it is purposeful and motivating for their social interactions. **Therefore the semantics for these sciences explaining human action must include description of the culturally shared subjective meanings and motivations that the human actions have for the social-group members.**

Romantics call the resulting subjective meaning “**interpretative understanding**”. The social member’s voluntary actions are controlled by this interpretative understanding, the views and values that are internalized and shared among the members of a social group by the so-called “mechanisms” of socialization and social control. This understanding is

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accessed by the social scientist in the process of his research. Furthermore if the researcher is a member in the society or group he is investigating, the validity of his empathetically based and vicariously imputed interpretative understanding is enhanced by his personal experiences as a participant in the group or society's life.

3.12 Positivist Semantics

For positivists the ostensibly acquired meanings of descriptive terms used for reporting observations are causally determined by nature and acquired ostensibly by perception; they are primitive and simple. Positivists thus maintain a naturalistic semantics. These meanings were variously called "sensations", "sense impressions", "sense perceptions", "sense data" or "phenomena" by different positivists. For these often called "phenomenalists" the sense perceptions are the object of knowledge rather than constituting knowledge thus making many versions of positivism solipsistic.

In the case of a term such as "black" the child's ostensive acquisition of meaning might involve the child pointing his finger at a present instance of perceived blackness in some black object we call a "raven" bird. And then upon hearing the word "black" in repeated presentations of several other black objects, he associates the word "black" with his various experienced perceptions of the color black. Furthermore from the several early experiences expressible as "That raven is black" the young learner may eventually infer intuitively by natural inductive generalization that "Every raven is black." However, solipsistic phenomenalism makes sharing such experiences philosophically problematic.

There are three characteristic theses in positivist semantics. They are:

- **Meaning invariance.**
- **Analytic-synthetic dichotomy.**
- **Observation-theory dichotomy.**

3.13 Positivist Thesis of Meaning Invariance

What is fundamental to the naturalistic philosophy of semantics is the thesis that the semantics of observation terms is fully determined by the ostensive awareness that is perception. Different languages are conventional in their vocabulary symbols and in their syntactical structures and grammatical rules. But according to the naturalistic philosophy of semantics

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nature makes the semantics of observation terms the same for all persons who have received the same perceptual stimuli that occasioned their having acquired their semantics in the same circumstances by simple ostension. Thus the natural semantics of a univocal descriptive term used to report observations is invariant through time and is independent of different linguistic contexts in which the semantics may occur; it is primitive and atomistic. Positivists viewed this meaning invariance as the basis for objectivity in science.

3.14 Positivist Analytic-Synthetic Dichotomy

In addition to the descriptive observation terms that have primitive and simple semantics acquired ostensively, the positivist philosophers also recognized the existence of certain terms that acquire their meanings contextually and that have complex semantics. An early distinction between simple and complex ideas can be found in his *Essay Concerning Human Understanding* by the seventeenth-century British empiricist philosopher John Locke. The positivist recognized compositional meanings for terms occurring in three types of statements: **the definition, the analytic sentence and the theory:**

The **first type** of term having complex semantics that the positivists recognized occurs in the definition. The defined subject term or *definiendum* has a compositional semantics that is exhibited by the structured meaning complex associated with the several words in the defining predicate or *definiens*. For example “Every bachelor is a never-married man” is a definition, so the component parts of the word “bachelor” are “never-married” and “man”.

The **second type** occurs in the analytic sentence, which is an a priori or self-evident truth, a truth known by reflection on the interdependence of the meanings of its constituent terms. Analytic sentences contrast with synthetic sentences, which are a posteriori, *i.e.*, empirical, and are thus deemed to have independent meanings for their terms. The positivists view the analytic-synthetic distinction as a fundamental dichotomy between the two types of statements. A similar distinction between “relations of ideas” and “matters of fact” can be found in *An Enquiry Concerning Human Understanding* by the seventeenth-century British empiricist philosopher David Hume.

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An example of an analytic sentence is “Every bachelor is unmarried”. The semantics of the term “bachelor” is compositional and is determined contextually, because the idea of never having been married is by definition included as a component part of the meaning of “bachelor” thus making the phrase “unmarried bachelor” redundant. Contemporary pragmatists such as Quine in his famous paper “Two Dogmas of Empiricism” reject the positivist thesis of a priori truth. Quine maintains that all sentences are empirical.

3.15 Positivist Observation-Theory Dichotomy

Positivists alleged the existence of “observation terms”, which are terms that reference observed entities or phenomena. Observation terms are deemed to have simple, elementary and primitive semantics and to receive their semantics ostensively and passively. Positivists furthermore called the particularly quantified sentences containing only such terms “observation sentences”. For example the sentence “That raven is black” uttered while the speaker of the sentence is viewing a present raven, is an observation sentence.

In contrast to observation terms there is a **third type** of term having complex semantics that the positivists called the “theoretical term”. The term “electron” is a favorite paradigm for the positivists’ theoretical term. The positivists considered theoretical entities such as electrons to be postulated entities as opposed to observed entities like elephants. And they defined “theory” as sentences containing any theoretical terms. Many positivists view the semantics of the significant theoretical term as simple like the observation term even though its semantics is not acquired by observation. Carnap was a more sophisticated positivist. He said that the definition determines the whole meaning of the defined term, while the theory determines only part of the meaning of the theoretical term, such that the theoretical term can acquire more meaning as the science containing it develops.

Nominalists furthermore believe that theoretical terms are meaningless, unless these terms logically derive their semantics from observation terms. On the nominalists’ view terms purporting either unobserved entities or phenomena not known observationally to exist have no known referents and therefore no semantical significance or meaning. For example the phrase “tooth fairy” is meaningless, since tooth fairies are deemed mythical and thus never to have been observed. For nominalists

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theoretical terms in science receive their semantics by logical connection to observation language by “correspondence rules”, a connection that produced what positivists called “logical reduction to an observation-language reduction base”. Without such connection the theory is deemed to be meaningless and “metaphysical”.

Both the post-positivist Karl Popper and later the logical positivist Carl Hempel have noted that the problem of the logical reduction of theories to observation language is a problem that the positivists have never solved, because positivists cannot exclude what they considered to be metaphysical and thus meaningless discourse from the scientific theories currently accepted both by the neopositivists and by contemporary scientists.

In summary the positivists recognized the definition, the analytical sentence and the theory sentence as exhibiting composition in the semantics of their constituent subject terms.

3.16 Contemporary Pragmatist Semantics

Philosophers’ reflection on the development of quantum physics occasioned development of the contemporary pragmatist philosophy. A fundamental postulate in the contemporary pragmatist philosophy of language is the rejection of the naturalistic thesis of the semantics of language and its replacement with the artifactual thesis that relativizes all semantics and ontology to linguistic context consisting of universally quantified beliefs. The rejection of the naturalistic thesis is not new in linguistics, but it is fundamentally opposed to the positivism that preceded contemporary pragmatism.

3.17 Pragmatist Semantics Illustrated

Consider the following analogy illustrating relativized semantics. Our linguistic system is analogous to a mathematical simultaneous-equation system. The equations of the system are a constraining context that determines the variables’ numerical values constituting a solution set for the equation system. If there is not a sufficient number of constraining equations, the system is underdetermined such that there are an indefinitely large number of possible numerical solution sets.

In pure mathematics numerical underdetermination can be eliminated and the system can be made uniquely determinate by adding related

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independent equations, so there are just as many equations as there are variables. Then there is one uniquely determined solution set of numerical values for the equation system.

When applying such a mathematically uniquely determined equation system to reality as in basic science or in engineering, the pure mathematics functions as the syntax for a descriptive language, when the numerical values of the descriptive variables are measurements. But the measurement values make the mathematically uniquely determined equation system **empirically underdetermined** due to measurement errors, which can be reduced indefinitely but never completely eliminated. Then even for a mathematically uniquely determined equation system admitting only one solution set of numerical values, there is still an infinitely large number of possible measurement values falling within even a narrow range of empirical underdetermination due to measurement errors.

When the simultaneous system of equations expresses an empirical theory in a test, and if its solution-set numerical values fall within the estimated range of measurement error in the corresponding measurement values produced in the test, then the theory is deemed not falsified. But if the solution-set numerical values are outside the estimated range of measurement error in the measurement values, then the theory is deemed to have been falsified by all who accept the test design and its execution.

The language system is like a mathematically underdetermined equation system having an infinitely large number of solution sets for the system. A set of logically consistent beliefs constituting a system of universally quantified related statements is a constraining context that determines the semantics of the descriptive terms in the belief system. This is most evident in an axiomatized deductive system. Like the equation system's numerical values the language system's semantics for any "semantical solution set", as it were, are relativized to one another by the system's universal beliefs and have definitional force. But the semantics conceptualizing sense stimuli always contains some vagueness. Due to this vagueness the linguistic system is **empirically underdetermined** and admits to an indefinitely large number of relativized semantical sets for the system. There is no uniquely determinate belief system of concepts.

This vagueness does not routinely manifest itself or cause communication problems so long as we encounter expected or familiar experiences for which our conventionalized beliefs are prepared. But the

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language user may on occasion encounter a new situation, for which the existing relevant conventional beliefs cannot take into account. In such new situations the language user must make some decisions about the applicability of one or several of the problematic terms in their existing beliefs, and then add some new beliefs or reject some currently accepted beliefs, if the decision about applicability is not simply *ad hoc*.

Adding more universally quantified statements to the belief system reduces this empirical underdetermination by adding clarifying information, but the residual vagueness can never be completely eliminated. Our semantics captures determinate mind-independent reality, but the cognitive capture with our semantics can never be exhaustive. There is always residual vagueness in our semantics. Vagueness and measurement error are both manifestations of empirical underdetermination. And increased clarity reduces vagueness as increased accuracy reduces measurement error.

Relativized semantics also has implications for ontology. Mind-independent recalcitrant reality imposes the empirical constraint that makes our belief systems contingent, and in due course falsifies them. Our access to mind-independent reality is by language-dependent relativized semantics, which signifies a corresponding ontology. Ontology is the cognitively apprehended aspects of the fathomless plenitude that is mind-independent reality as described by the relativized semantics. Thus there are no referentially absolute or fixed terms. Instead descriptive terms are always fuzzy, *i.e.*, referentially indeterminate or as Quine says “inscrutable”, because their semantics is always empirically underdetermined.

Three noteworthy consequences of the artifactual thesis of relativized semantics are:

- Rejection of the positivist observation-theory dichotomy,
- Rejection of the positivist thesis of meaning invariance.
- Rejection of the positivist analytic-synthetic dichotomy.

3.18 Rejection of the Observation-Theory Dichotomy

All descriptive terms are empirically underdetermined, such that what the positivists called “theoretical terms” are simply descriptive terms that are more empirically underdetermined than what the positivists called “observation terms”.

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One of the motivations for the positivists' accepting the observation-theory dichotomy is the survival of the ancient belief that science in one respect or another has some permanent and incorrigible foundation that distinguishes it as true knowledge as opposed to mere speculation or opinion. In the positivists' version of this foundational agenda observational description is presumed to deliver this certitude, while theory language is subject to revision, which is sometimes revolutionary in scope. The positivists were among the last to believe in any such eternal verities as the defining characteristic of truly scientific knowledge.

More than a quarter of a century after Heisenberg said he could observe the electron in the Wilson cloud chamber, philosophers of science began to reconsider the concept of observation, a concept that had previously seemed inherently obvious. On the contemporary pragmatist view there are no observation terms that receive isolated meanings merely by simple ostension, and there is no distinctive or natural semantics for identifying language used for observational reporting. Instead every descriptive term is embedded in an interconnected system of beliefs, which Quine calls the "web of belief". A relevant subset of the totality of beliefs constitutes a context for determining any given descriptive term's meaning, and a unilingual dictionary's relevant lexical entries are a minimal listing of a subset of relevant beliefs for each univocal term. Thus the positivists' thesis of "observation terms" is rejected by pragmatists.

Quine said that all descriptive terms are empirically underdetermined, such that what the positivists called "theoretical terms" are simply descriptive terms that are more empirically underdetermined than what the positivists called "observation terms". All descriptive terms lie on a continuum of greater or lesser degree empirical of underdetermination. Contemporary pragmatists view the positivist problem of the reduction of theoretical terms to observation terms as a pseudo problem.

3.19 Rejection of Meaning Invariance

The semantics of every descriptive term is determined by the term's linguistic context consisting of a set of universally quantified statements believed to be true, such that a change in any of those contextual beliefs changes some component parts of the constituent terms' meanings.

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In science the linguistic context consisting of universally quantified statements believed to be true may include both theories awaiting empirical testing and law statements including test-design statements, which jointly contribute to the semantics of their shared constituent descriptive terms.

When the observation-theory dichotomy is rejected, the language that reports observations becomes subject to semantical change or what Feyerabend called “meaning variance”. For the convinced believer in a theory the statements of the theory contribute meaning parts to the semantics of descriptive language used to report observations, such that a revision of the theory changes part of the semantics of the relevant observational description.

3.20 Rejection of the Analytic-Synthetic Dichotomy

All universally quantified affirmations believed to be true are both analytic and empirical.

On the positivist view the truth of analytic sentences can be known a priori, i.e., by reflection on the meanings of the constituent descriptive terms, while synthetic sentences require empirical investigation to determine their truth status, such that their truth can only be known a posteriori. Thus to know the truth status of the analytic sentence “Every bachelor is unmarried”, it is unnecessary to take a survey of bachelors to determine whether or not any such men are currently married. However, determining the truth status of the sentence “Every raven is black” requires an empirical investigation of the raven bird population and then a generalizing inference.

On the alternative pragmatist view the semantics of all descriptive terms are contextually determined, such that all universally quantified affirmations believed to be true are analytic statements. But their truth status is not thereby known a priori, because they are also synthetic, *i.e.*, empirical, firstly known a posteriori by experience. This dualism implies that when any universally quantified affirmation is believed to be empirically true, the sentence can then be used analytically, such that the meaning of its predicate offers a partial analysis of the meaning of its subject term. To express this analytic-empirical dualism Quine used the phrase “analytical hypotheses”.

Thus “Every raven is black” is as analytic as “Every bachelor is unmarried”, so long as both statements are believed to be true. The meaning

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of “bachelor” includes the idea of being unmarried and makes the phrase “unmarried bachelor” redundant. Similarly so long as one believes that all ravens are in fact black, then the meaning of “raven” includes the idea of being black and makes the phrase “black raven” redundant. In science an important reason for belief is empirical adequacy demonstrated by a nonfalsifying empirical test outcome.

3.21 Semantical Rules

A semantical rule is a universally quantified affirmation believed to be true and viewed in logical supposition in the metalinguistic perspective, such that the meaning of the predicate term displays some of the component part or parts of the meaning of the subject term.

The above discussion of analyticity leads immediately to the idea of “semantical rules”, a phrase also found in the writings of such philosophers as Rudolf Carnap and Alonzo Church but with different meanings. In the contemporary pragmatist philosophy semantical rules are statements in the metalinguistic perspective, because they are about language. And their constituent terms are viewed in logical supposition, because as semantical rules the statements are about meanings as opposed to nonlinguistic reality. Semantical rules are enabled by the complex nature of the semantics of descriptive terms. But due to psychological habit that enables prereflective linguistic fluency, meanings are experienced wholistically, and reflective semantical analysis is needed to appreciate their componential nature.

3.22 Componential vs. Wholistic Semantics

Semantical change had vexed the contemporary pragmatists, when they initially accepted the artifactual thesis of the semantics of language. When they rejected a priori analytic truth, many of them mistakenly also rejected analyticity altogether. And when they accepted the contextual determination of meaning, they mistakenly took an indefinitely large context as the elemental unit of language for consideration. They typically construed this elemental context as consisting of either an explicitly stated whole theory with no criteria for individuating theories, or an even more inclusive “paradigm”, i.e., a whole theory together with many associated pre-articulate skills and tacit beliefs. This wholistic (or “holistic”) semantical thesis is due to using the psychological experience of meaning instead of making semantic analyses that enable recognition of the componential nature of meaning.

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On this wholistic view therefore a new theory that succeeds an alternative older one must, as Feyerabend maintains, completely replace the older theory including all its observational semantics and ontology, because its semantics is viewed as an indivisible unit. In his *Patterns of Discovery* Hanson attempted to explain such wholism in terms of Gestalt psychology. And following Hanson the historian of science Kuhn, who wrote a popular monograph titled *Structure of Scientific Revolutions*, explained the complete replacement of an old theory by a newer one as a “Gestalt switch”.

Feyerabend tenaciously maintained wholism, but attempted to explain it by his own interpretation of an ambiguity in Benjamin Lee Whorf’s thesis of linguistic relativity also known as the “Sapir-Whorf hypothesis” formulated jointly by Whorf and Edward Sapir, a Yale University Linguist. In his “Explanation, Reduction and Empiricism”, in *Minnesota Studies in the Philosophy of Science* and later in his *Against Method* Feyerabend proposes semantic “incommensurability”, which he says is evident when an alternative theory is not recognized to be an alternative. He cites the transition from Newtonian to Einstein’s relativity physics as an example of such incommensurability. The thesis of semantic incommensurability was also advocated by Kuhn, but he later revised the idea to admit partial or local incommensurability that enables “incommensurability with comparability”, but without successfully explaining how it can be partial.

Any wholistic semantical thesis including notably the semantic incommensurability thesis creates a pseudo problem for the decidability of empirical testing in science. It implies complete replacement of the semantics of the descriptive terms used for test design and observation. And complete replacement deprives the two alternative theories of any semantical continuity, such that their language cannot even describe the same phenomena or address the same problem. In fact the new theory cannot even be said to be an alternative to the old one, much less a more empirically adequate one. The empirical undecidability due to alleged semantical wholism would logically deny science both production of progress and recognition of its history of advancement. The untenable character of the situation is comparable to the French entomologist August Magnan whose book titled *Insect Flight* (1934) set forth an aerodynamic analysis proving that bees cannot fly. Bees do fly, and empirical tests do decide.

The thesis of componential semantics resolves the wholistic semantical muddle in the linguistic theses proffered by philosophers such as Kuhn and Feyerabend. Philosophers of science have overlooked

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componential semantics, but linguists have long recognized componential analysis in semantics, as may be found for example in George L. Dillon's *Introduction to Contemporary Linguistic Semantics*. Some linguists use the phrase "lexical decomposition". With the componential semantical thesis it is unnecessary to accept any wholistic view of semantics in philosophy much less any incommensurable discontinuity in language.

The expression of the componential aspect of semantics most familiar to philosophers of language is the analytic statement. But the pragmatists' rejection of the analytic-synthetic dichotomy with its a priori truth claim need not imply the rejection of analyticity as such. The contextual determination of meaning exploits the analytic-empirical dualism.

On the pragmatist view when there is a transition from an old theory to a new theory having the same test design, for the advocates of the old theory there occurs a semantical change in the descriptive terms shared by the old and new theories, due to the replacement of the meaning parts of the old theory with meaning parts from the new theory. When there is a semantical change in the descriptive terms in a system of beliefs due to a revision of some of the beliefs, some component parts of the terms' complex meanings remain unaffected, while other parts are dropped and new ones added. For empirical testing in science the component meaning parts that remain unaffected by the change from one theory to a later alternative one include those parts determined by the statements of test design shared by the two theories. Therein is found the semantical continuity that enables empirical testing of alternative theories to be decidable. **The meaning parts contributed by the test-design language remain unaffected.**

Thus a revolutionary change in scientific theory, such as the replacement of Newton's theory of gravitation with Einstein's, has the effect of changing only part of the semantics of the terms common to both the old and new theories. It leaves the semantics supplied by test-design language unaffected, so Arthur Eddington could test both Newton's and Einstein's theories of gravitation simultaneously by describing the same celestial photographic observations in his 1919-eclipse test. Thus contrary to Feyerabend there is no semantic incommensurability between these theories. And contrary to Feyerabend there is there no historical evidence that the advocates of Einstein's relativity theory had failed to recognize that Einstein's theory is an alternative to Newton's.

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Readers wishing to know more about the philosophies of Kuhn, Feyerabend, and Eddington's 1919-eclipse test are referred to **BOOK VI** at www.philsci.com.

3.23 Componential Artifactual Semantics Illustrated

The set of affirmations believed to be true and predicating characteristics universally and univocally of the term "raven" such as "Every raven is black" are semantical rules describing component parts of the complex meaning of "raven". But if a field ornithologist captures a red bird specimen that exhibits all the characteristics of a raven except its black color, he must make a decision. He must decide whether he will continue to believe "Every raven is black" and that he holds in his birdcage some kind of red nonraven bird, or whether he will no longer believe "Every raven is black" and that the red bird in his birdcage is a red raven. Thus a semantical decision must be made. Color could be made a criterion for species identification instead of the ability to breed, although many other beliefs would also then be affected, an inconvenience that is typically avoided as a disturbing violation of the linguistic preference that Quine calls the principle of "minimum mutilation" of the web of belief.

Use of statements like "Every raven is black" may seem simplistic for science (if not quite bird-brained). But as it happens, a noteworthy revision in the semantics and ontology of birds has occurred due to a five-year genetic study launched by the Field Museum of Natural History in Chicago, the results of which were reported in the journal *Science* in June 2008. An extensive computer analysis of 30,000 pieces of nineteen bird genes showed that contrary to previously held belief falcons are genetically more closely related to parrots than to hawks, and furthermore that falcons should no longer be classified in the biological order originally named for them. As a result of the new genetic basis for classification, the American Ornithologists Union has revised its official organization of bird species, and many bird watchers' field guides have been revised accordingly. Now well informed bird watchers will classify, conceptualize and observe falcons differently, because some parts of the meaning complex for the term "falcon" have been replaced with a genetically based conceptualization. Yet given the complexity of genetics some biologists argue that the concept of species is arbitrary.

Our semantical decisions alone neither create, nor annihilate, nor change mind-independent reality. But semantical decisions may change our

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mind-dependent linguistic characterizations of mind-independent reality and thus the ontologies, i.e., the various aspects of reality that the changed semantics reveals.

3.24 Semantic Values

Semantic values are the elementary component parts distributed among the meaning complexes associated with the descriptive terms of a language at a point in time.

For every descriptive term there are several semantical rules with each rule's predicate describing some component parts of the common subject term's meaning complex. A linguistic system therefore contains elementary components of meaning complexes that are shared by many descriptive terms, but are almost never uniquely associated with any single term, because all words have dictionary definitions analyzing the lexical entry's component parts. These elementary components may be called "semantic values".

Semantic values describe the most elementary ontological features of the real world that are distinguished by a language at a given point in time, and are the smallest elements in any meaning complex at the given point in time. The indefinitely vast residual reality not captured by any semantic values and that the language user's semantics is unable to signify at the given point in time constitutes the empirical underdetermination of the whole language at the given point in time.

Different languages have different semantics and therefore display different ontologies. Where the semantics of one language displays semantic values not contained in the semantics of the other, the languages are said to be semantically incommensurable. Translation is therefore made imprecise.

A science at different times in its history may also have semantically incommensurable language, when the later version contains semantic values not contained in the earlier. But such incommensurability is rare, because it is routinely possible to resort to what Hanson called "phenomenal seeing". And incommensurability does not occur in scientific revolutions understood as theory revision, because the revision is a reorganization of pre-existing information. When incommensurability occurs is it at times of discovery occasioning articulation of new semantic values due to new observations.

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3.25 Univocal and Equivocal Terms

The definitions of descriptive terms such as common nouns and verbs in a unilingual dictionary function as semantical rules. Implicitly they are universally quantified logically, and are always presumed to be true. Usually each lexical entry in a large dictionary such as the *Oxford English Dictionary* offers several different meanings for a descriptive term, because terms are routinely equivocal. Language economizes on words by giving them several different meanings, which the fluent listener or reader can distinguish in context. Equivocations are the raw materials for puns. There is always at least one semantical rule for the meaning complex for each univocal use of a descriptive term, because to be meaningful, the term must be part of the linguistic system of beliefs. If the use is conventional, it must be capable of a lexical entry in a dictionary, or else recognized by some clique as an argot.

A descriptive term's use is univocal, if no universally quantified negative categorical statement accepted as true can relate any of the predicates in the several universal affirmations functioning as semantical rules for the same subject term. Otherwise the term is equivocal. Thus if two semantical rules have the form "Every X is A" and "Every X is B", and if it is also believed that "No A is B", then the terms "A" and "B" symbolize parts of different meanings for the term "X", and "X" is equivocal. Otherwise "A" and "B" symbolize different parts of the same meaning complex associated with the univocal term "X".

A definition in a unilingual dictionary functions as a semantical rule. But the dictionary definition is only a minimal description of the meaning complex of a univocal descriptive term, and it is not the whole description. Univocal terms have many semantical rules, when many characteristics can be predicated universally to a given subject. Thus there are multiple predicates that universally characterize ravens, characteristics known to the ornithologist, and which may fill a paragraph or more in his ornithological reference book.

Descriptive terms can become, as it were, partially equivocal through time, when some parts of the term's meaning complex are unaffected by a change of defining beliefs, while other parts are simply dropped as archaic or are replaced by new parts contributed by new beliefs. In science this partial equivocation occurs when one theory is replaced by another newer one due to a test outcome, while the test designs for both

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theories remain the same. A term common to old and new theory may remain univocal only with respect to the parts contributed by the test-design language.

3.26 Signification and Supposition

Supposition enables identifying ambiguities not due to differences in signification that make equivocations, but instead are ambiguities due to differences in relating the semantics to its ontology.

The signification of a descriptive term is its meaning, and terms with two or more alternative significations are equivocal in the sense described in Section 3.25. The signification of a univocal term has different suppositions, when it describes ontology differently due to its having different functions in the sentences containing it.

Historically the **subject term in the categorical proposition is said to be in “personal” supposition, because it references individual entities, while the predicate term is said to be in “simple” supposition, because the predicate signifies attributes without referencing any individual entities manifesting the attributes. For this reason the predicate in the categorical proposition is not logically quantified with any syncategorematic terms such as “every” or “some”.** For example in “Every raven is black” the subject term “raven” is in personal supposition, while the predicate “black” is in simple supposition. So too for “No raven is black”.

Unlike semantical rules that describe signification, the supposition of descriptive terms in object language depends only on the rôle of the terms in a statement containing them and not on the truth of the statement. Thus the suppositions of the subject and predicate terms respectively are the same in the statement “Every raven is orange”, which is believed to be false, as they are in the statement “Every raven is black”, which is believed to be true.

Both personal and simple suppositions are types of “real” supposition, because they are different ways of talking about extramental reality. They operate in expressions in object language and thus describe ontologies as either attributes or the referenced individuals characterized by the signified attributes. Real supposition is contrasted with **“logical” supposition, in which the meaning of the term is referenced in the metalinguistic perspective exclusively as a meaning, *i.e.*, only semantics is referenced and**

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not extramental ontology. For example in “Blackness is a component part of the meaning of raven”, the terms “raven” and “blackness” in this statement are in logical supposition. Similarly to say in explicit metalanguage “‘Every raven is black’ is a semantical rule” to express “Black is a component part of the meaning of raven”, is again to use both “raven” and “black” in logical supposition.

Furthermore just to use “Every raven is black” as a semantical rule in order to exhibit its meaning composition without actually saying that it is a semantical rule, is also to use the sentence in the metalinguistic perspective and in logical supposition. The difference between real and logical supposition in such use of a sentence is not exhibited syntactically, but is pragmatic and depends on the intention of the writer or speaker. Whenever a universally quantified affirmation is used in the metalinguistic perspective as a semantical rule for analysis in the semantical dimension, both the subject and predicate terms are in logical supposition. Lexical entries in dictionaries are in the metalinguistic perspective and in logical supposition, because they are about language and are intended to describe meanings.

In all the above types of supposition the same univocal term has the same signification. But another type of so-called supposition proposed incorrectly in ancient times is “material supposition”, in which the term is referenced in metalanguage as a linguistic symbol in the syntactical dimension with no reference to a term’s semantics or ontology in object language. An example is “‘Raven’ is a five-letter word”. In this example “raven” does not refer either to the individual real bird or to its characteristics as in real supposition or to the universal concept of it as in logical supposition. Thus material supposition is not supposition properly so called, because the signification is different. It is actually an alternative meaning and thus a type of semantical equivocation. Some philosophers have used other vocabularies for recognizing this equivocation: Stanislaw Lesńiewski’s “use” (semantics) vs “mention” (syntax) and Rudolf Carnap’s “material mode” (semantics) vs “formal mode” (syntax).

3.27 Aside on Metaphor

A metaphor is a predication to a subject term that is intended to include only selected parts of the meaning complex conventionally associated with the predicate term, so the metaphorical predication is a true statement due to the exclusion of the remaining parts in the

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predicate's meaning complex that would make the metaphorical predication a false statement.

In the last-gasp days of decadent neopositivism some positivist philosophers invoked the idea of metaphor to explain the semantics of theoretical terms. And a few were closet Cartesians who used it in the charade of justifying realism for theoretical terms. The theoretical term was the positivists' favorite hobbyhorse. But both realism and the semantics of theories are unproblematic for contemporary pragmatists. In his "Posits and Reality" Quine said that all language is empirically underdetermined, and that the only difference between positing microphysical entities (like electrons) and macrophysical entities (like elephants) is that the statements describing the former are more empirically underdetermined than those describing the latter. Thus contrary to the neopositivists the pragmatists admit no qualitative dichotomy between the positivists so-called observation terms and their so-called theoretical terms.

As science and technology advance, concepts of microphysical entities like electrons are made less empirically underdetermined, as occurred for example with the development of the Wilson cloud chamber. While contemporary pragmatist philosophers of science recognize no need to explain so-called theoretical terms by metaphor or otherwise, metaphor is nevertheless a linguistic phenomenon often involving semantical change and it can easily be analyzed and explained with componential semantics.

It has been said that metaphors are both true and false. In a speaker or writer's conventional or "literal" linguistic usage the entire conventional meaning complex associated with a univocal predicate term of a universal affirmation is operative. But in a speaker or writer's metaphorical linguistic usage only some selected component part or parts of the entire meaning complex associated with the univocal predicate term are operative, and the remaining parts of the meaning complex are intended to be excluded, *i.e.*, suspended from consideration and ignored. If the excluded parts were included, then the metaphorical statement would indeed be false. But the speaker or writer implicitly expects the hearer or reader to recognize and suspend from consideration the excluded parts of the predicate's conventional semantics, while the speaker or writer uses the component part that he has selected for describing the subject truly.

Consider for example the metaphorical statement "Every man is a wolf." The selected meaning component associated with "wolf" that is

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intended to be predicated truly of “man” might describe the wolf’s predatory behaviors, while the animal’s quadrupedal anatomy, which is conventionally associated with “wolf”, is among the excluded meaning components for “wolf” that are not intended to be predicated truly of “man”.

A listener or reader may or may not succeed in understanding the metaphorical predication depending on his ability to select the applicable parts of the predicate’s semantics tacitly intended by the issuer of the metaphor. But there is nothing arcane or mysterious about metaphors, because they can be explained in literal (*i.e.*, conventional) terms to the uncomprehending listener or reader. To explain the metaphorical predication of a descriptive term to a subject term is to list explicitly those affirmations intended to be true of that subject and that set forth just those parts of the predicate’s meaning that the issuer intends to be applicable.

The explanation may be further elaborated by listing separately the affirmations that are not viewed as true of the subject, but which are associated with the predicated term when it is predicated conventionally. Or these may be expressed as universal negations stating what is intended to be excluded from the predicate’s meaning complex in the particular metaphorical predication, *e.g.*, “No man is quadrupedal.” In fact such negative statements might be given as hints by a picaresque issuer of the metaphor for the uncomprehending listener.

A semantical change occurs when the metaphorical predication becomes conventional, and this change to conventionality produces an equivocation. The equivocation consists of two literal meanings: the original one and a derivative meaning that is now a dead metaphor. As a dead man is no longer a man, so a dead metaphor is no longer a metaphor. A dead metaphor is a meaning from which the suspended parts in the metaphor have become conventionally excluded to produce a new “literal” meaning. Trite metaphors, when not just forgotten, metamorphose into new literals, as they become conventional.

3.28 Clear and Vague Meaning

Meanings are more or less clear and vague, such that the greater the clarity, the less the vagueness. Vagueness is empirical underdetermination, and can never be eliminated completely, since our concepts can never grasp reality exhaustively. But vagueness in the semantics of a descriptive term is reduced and clarity is increased by the

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addition of universal affirmations and/or negations accepted as true, to the list of the term's semantic rules with each rule having the term as a common subject. The clarification is supplied by the semantics of the predicates in the added universal affirmations and/or negations.

Adding semantical rules increases clarity by elaboration. Thus if the list of universal statements believed to be true are in the form "Every X is A" and "Every X is B", then clarification of X with respect to a descriptive predicate "C" consists in adding to the list either the statement in the form "Every X is C" or the statement in the form "No X is C". Clarity is thereby added by elaborating the meaning of "X".

Clarity is increased by adding semantical rules that relate any of the univocal predicates in the list of semantical rules for the same subject, thus by increasing coherence. Thus if the predicate terms "A" and "B" in the semantical rules with the form "Every X is A" and "Every X is B" are related by the statements in the form "Every A is B" or "Every B is A", then one of the statements in the list can be logically derived from the others. Awareness of the deductive relationship and the consequent display of structure in the meaning complex associated with the term "X" makes the complex meaning of "X" more coherent, because the deductive relation makes it more semantically integrated and thus enhances coherence. And the coherence also supplies a psychological satisfaction. **Clarity is thereby added by exhibiting semantic structure in a deductive system.**

These additional semantical rules relating the predicates may be negative as well as affirmative. Additional universal negations offer clarification by exhibiting equivocation. Thus if two semantical rules are in the form "Every X is A" and "Every X is B", and if it is also believed that "No A is B" or its equivalent "No B is A", then the terms "A" and "B" symbolize parts of different meanings for the term "X", and "X" is equivocal. Clarity is thereby added by the negation.

3.29 Semantics of Mathematical Language

The semantics for a descriptive mathematical variable is determined by its context consisting of universally quantified statements believed to be true including mathematical expressions in both theory language proposed for testing and test-design language presumed for testing.

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Both test designs and theories often involve mathematical expressions. Thus the semantics for the descriptive variables common to a test design and a theory may be supplied in part by mathematical expressions, such that the structure of their meaning complexes is partly mathematical. The semantics-determining statements in test designs for mathematically expressed theories may include mathematical equations, measurement language describing the subject measured, the measurement procedures, the metric units and any employed apparatus.

Some of these statements may resemble 1946 Nobel-laureate physicist Percy Bridgman's "operational definitions", because the statements describing the measurement procedures and apparatus contribute meaning to the descriptive term. But contrary to Bridgman, and as Carnap says in his *Philosophical Foundations of Physics*, each of several operational definitions for the same term does not constitute a separate definition for the term's concept for the measured subject, thereby making the term equivocal. Likewise pragmatists say that descriptions of different measurement procedures contribute different parts to the univocal meaning of the descriptive term, unless the different procedures produce different measurement values, where the differences are greater than the estimated measurement error in the same range of measurement.

3.30 Semantical State Descriptions

A semantical state description for a scientific profession is a synchronic display of the semantical composition of the various meanings of the partially equivocal descriptive terms in the alternative theories functioning as semantical rules and addressing a single problem defined by a common test design.

The above discussions in philosophy of language have focused on descriptive terms such as words and mathematical variables, and then on statements and equations that are constructed with the terms. For computational philosophy of science there is an even larger unit of language, which is the **semantical state description**.

In his *Meaning and Necessity* Carnap had introduced a concept of linguistic state description in his philosophy of semantical systems. Similarly in computational philosophy of science a state description is a semantical description but with different content and functions than Carnap's. The statements and/or equations supplying a discovery system's

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input state description and those constituting the output state description are semantical rules. Each alternative theory or law has its distinctive semantics for its constituent descriptive terms. A term shared by several alternative theories or laws is thus partly equivocal. But the term is also partly univocal due to the common test-design statements that are also semantical rules.

In computational philosophy of science the state description is a **synchronic** and thus a static semantical display. The state description contains language actually used in a science both in an **initial** state description containing object-language input to a discovery system, and in a **terminal** state description containing object-language output generated by a computerized discovery-system's execution. The initial state description represents the frontier of research for the specific problem. Both input and output state descriptions for a discovery-system run address only one problem identified by the test design, and thus for computational philosophers of science they represent only one scientific "profession".

A discovery-system is a mechanized finite-state generative grammar that produces sentences or equations from descriptive terms or variables. As a grammar it is creative in Noam Chomsky's sense, because when encoded in a computer language and executed, the system produces new statements, i.e. theories that have never previously been stated in the particular scientific profession. A discovery system is Feyerabend's principle of theory proliferation applied with mindless vengeance. To control the size and quality of the output, the system tests the empirical adequacy of those novel theories and likely rejects most of them. Associating measurement data with the inputted variables enables empirical testing, so that the system designs are typically one or another type of applied numerical methods.

For semantical analysis the state description consists of universally quantified statements and/or equations. The statements and/or equations from which the terms and/or variables were extracted including theories and test design are part of the state description although not for discovery system input, because they would prejudice the output. Statements and/or equations function as semantical rules in the generated output only. Thus for discovery-system input, the input state description is a listing of descriptive terms and/or variables extracted from the statements and/or equations of the several currently untested theories addressing the same unsolved problem as defined by a test design at a given point in time.

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Descriptive terms and/or variables extracted from the statements and/or equations of falsified theories can also be included to produce a cumulative state description for input, because the terms and/or variables from previously falsified theories represent available information at the historical or current point in time. Descriptive terms and/or variables salvaged from falsified theories have scrap value, because they may be recycled through the theory-developmental process. Furthermore terms and variables from tested and nonfalsified theories could also conceivably be included, just to see what new comes out. Empirical underdetermination permits scientific pluralism, and the world is full of surprises.

3.31 Diachronic Comparative-Static Analysis

A diachronic comparative-static display consists of two chronologically successive state descriptions of theory statements for the same problem defined by the same test design and therefore addressed by the same scientific profession. State descriptions contain statements and equations that operate as semantical rules displaying the meanings of the constituent terms and variables. Comparison of the statements and equations in the two chronologically separated state descriptions containing the same test design exhibits changes in meanings through time.

In computational philosophy of science this is a **comparative-static semantical analysis**, *i.e.*, a comparison of a discovery system's input and output state descriptions of theory statements. After the computer system is run the resulting output state description is of principal interest.

3.32 Diachronic Dynamic Analysis

The above discussions have described the synchronic and comparative-static diachronic perspectives. Both are static, because they apply to points in time. **The dynamic diachronic metalinguistic analysis not only consists of two state descriptions representing two chronologically successive language states sharing a common subset of descriptive terms in their common test design, but also exhibits a process of linguistic change between the two successive state descriptions.**

Such transitions in science are the result of two functions in basic research, namely theory development and theory testing. A change of state

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description into a new one is produced whenever a new theory is proposed or whenever a theory is eliminated by a falsifying test outcome.

3.33 Computational Philosophy of Science

Computational philosophy of science is the development of computerized discovery systems that can proceduralize explicitly the past achievements of successful scientists, and then apply the successfully mechanized procedures to the current state description of a science to develop a new state description containing one or several new and superior theories.

The discovery systems created by the computational philosopher of science represent diachronic dynamic metalinguistic analyses. They proceduralize a transitional process explicitly with the computerized system design, in order ultimately to accelerate the contemporary advancement of a science by mechanizing a transitional procedure. Then by applying the system to the current state description for the science they generate new theories. The discovery systems typically include empirical criteria for selecting a subset of the generated theories for output as tested and nonfalsified theories either for further predictive testing or for use as laws in explanations and test designs.

The computer is here to stay, and in this computer age computational philosophy of science is inevitable. The exponentially growing capacities of computer hardware and proliferation of computer-systems designs have already been enhancing the technical practices of basic-scientific research in many sciences, and philosophy of science cannot escape such developments. Presently few philosophy professors have the needed competencies to contribute to computational philosophy of science. And thus few curricula in philosophy departments encourage much less actually prepare students for contributing to this new and emerging area in philosophy of science. Computational philosophy of science will achieve ascendancy in twenty-first-century philosophy of science due to those who are opportunistic enough to master both the necessary system-development skills and the requisite working competencies in an empirical science. Lethargic and/or reactionary academics that dismiss it are fated to spend their careers evading it, as they are progressively marginalized.

In the “Introduction” to their *Empirical Model Discovery and Theory Evaluation: Automatic Selection Methods in Econometrics* (2014) David F.

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Hendry and Jurgen A. Doornik of Oxford University's Program of Economic Modeling at their Institute for New Economic Thinking write that automatic modeling has indeed "come of age." Hendry was head of Oxford's Economics Department from 2001 to 2007, and is presently Director of the Economic Modeling Program at Oxford's Martin School. And Doornik is a colleague at the Institute. These authors have developed a mechanized general-search algorithm they call **AUTOMETRICS** for determining the equation specifications for econometric models.

Our twenty-first century perspective shows that notwithstanding obstructionism by latter-day Luddites, computational philosophy of science has indeed "come of age". It is the future that has arrived, even when it is called by other names as practiced by scientists working in their special fields instead of being called "metascience" or "computational philosophy of science".

3.34 An Interpretation Issue

There is ambiguity in the literature as to what a state description represents and how the discovery system's processes are to be interpreted. The phrase "artificial intelligence" has been used in both interpretations but with slightly different meanings.

On the **linguistic analysis interpretation**, which is the view taken herein, the state description represents the language state for a language community constituting a single scientific profession defined by a test design. Like the diverse members of a profession, the system produces a diversity of new theories. **No psychological claims are made about intuitive thinking processes.** Computational philosophy of science so interpreted is a technique for a specialized type of linguistic analysis employing mechanized generative grammars.

The computer discovery systems are generative grammars that generate and test theories. The system inputs and outputs are both object-language state descriptions. The instructional code of the computer system is in the metalinguistic perspective, and exhibits diachronic dynamic procedures for theory development. As such the linguistic analysis interpretation is neither a separate philosophy of science nor a psychological agenda. It is compatible with the contemporary pragmatism and its use of generative grammars makes it closely related to computational linguistics.

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On the **cognitive-psychology** interpretation the state description represents the scientist's cognitive state consisting of mental representations and the discovery system represents the scientist's cognitive processes. The originator of the cognitive-psychology interpretation is Herbert Simon. In his *Scientific Discovery: Computational Explorations of the Creative Processes* and other works Simon writes that he seeks to investigate the psychology of discovery processes, and to provide an empirically tested theory of the information-processing mechanisms that are implicated in that process.

He states that an empirical test of the systems as psychological theories of human discovery processes would involve presenting the computer programs and some human subjects with identical problems, and then comparing their behaviors. But Simon admits that his book provides nothing by way of comparison with human performance. And in discussions of particular applications involving particular historic discoveries, he also admits that in some cases the historical scientists actually performed their discoveries differently than the way that the systems performed the rediscoveries.

Similarly in their "Processes and Constraints in Explanatory Scientific Discovery" in *Proceedings of the Thirteenth Annual Meeting of the Cognitive Science Society*. (2008) Langley and Bridewell, who advocate cognitive psychology, appear to depart from the cognitive psychology interpretation. They state that they have not aimed to "mimic" the detailed behavior of human researchers, but that instead their systems address the same tasks as scientists and carry out search through similar problem spaces. This much might also be said of the linguistic-analysis approach.

The academic philosopher Paul Thagard, who follows Simon's interpretation, originated the name "computational philosophy of science" in 1988 in his book *Computational Philosophy of Science*. Hickey admits that it is more descriptive than the name "metascience" that Hickey had proposed in his *Introduction to Metascience: An Information Science Approach to Methodology of Scientific Research* in 1976. Thagard defines computational philosophy of science as "normative cognitive psychology". The cognitive-psychology systems have successfully replicated developmental episodes in history of science, but the relation of their system designs to systematically observed human cognitive processes is still unexamined. And their outputted theories to date have not yet contributed to the current state of any science.

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The phrase “computational philosophy of science” does not commit one to either interpretation. Which interpretation prevails in academia will likely depend on which academic department productively takes up the movement. If the psychologists develop new and useful systems, the psychologicistic interpretation will prevail. If the philosophers take it up successfully, their linguistic-analysis interpretation will prevail.

Readers wishing to know more about Simon, Langley, and Thagard and about discovery systems and computational philosophy of science are referred to **BOOK VIII** at www.philsci.com.

C. ONTOLOGY

3.35 Ontological Dimension

Ontology is the aspects of mind-independent reality revealed by semantics.

Ontology is the metalinguistic dimension after syntax and semantics, and it presumes both of them. Semantics is description of reality; ontology is reality as described by semantics. Ontology is the reality correlative to what is signified by semantics. Semantically interpreted syntax describes ontology most realistically, when the statement is warranted empirically by repeated nonfalsifying test outcomes. In science ontology is more adequately represented when described by the semantics of either a scientific law or an observation report having its semantics defined by a law. The semantics of falsified theories display ontology less realistically due to the falsified theories’ demonstrated lesser empirical adequacy.

3.36 Metaphysical and Scientific Realism

Metaphysical realism is the thesis that there exists mind-independent reality, which is accessible to and accessed by human cognition.

In the section titled “Is There Any Justification for External Realism” in his *Mind, Language and Society: Philosophy in the Real World* University of California realist philosopher John R. Searle refers to metaphysical realism as “external realism”, by which he means that the world exists independently of our representations of it. He says that realism does not say how things are, but only that there is a way that they are. Thus the way that

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they are would include Heisenberg's "*potentia*" as the quantum theory describes reality with its indeterminacy relations and duality thesis. The theory describes microphysical reality as being that certain way and **not otherwise**, such that the theory is testable and falsifiable.

Searle denies that realism can be justified, because any attempt at justification presupposes what it attempts to justify. In other words all arguments for metaphysical realism are circular, because realism must firstly be accepted. Any attempt to find out about the real world at all presupposes that there is a way that things are. He goes on to affirm the picture of science as giving us objective knowledge of an independently existing reality, and that this picture is taken for granted in the sciences.

Similarly in "Scope and Language of Science" in *Ways of Paradox* Harvard University realist philosopher Willard van Quine writes that we cannot significantly question the reality of the external world or deny that there is evidence of external objects in the testimony of our senses, because to do so is to dissociate the terms "reality" and "evidence" from the very application that originally did most to invest these terms with whatever intelligibility they may have for us. And to emphasize the primal origin of realism Quine writes that we imbibe this primordial awareness "with our mother's milk". He thus affirms what he calls his "unregenerate realism". These statements by Searle, Quine and others of their ilk are not logical arguments or inferences; they are affirmations.

Hickey joins these contemporary realist philosophers. He maintains that metaphysical realism, the thesis that there exists mind-independent reality accessible to and accessed by cognition, is the "primal prejudice" that can only be affirmed or denied. And he affirms that it is a correct and universal prejudice, even though there are delusional psychotics and sophistic academics that are in denial. Contrary to Descartes and latter-day rationalists, metaphysical realism is neither a conclusion nor an inference nor an extrapolation. It cannot be proved logically, established by philosophy or science, validated or justified in any discursive manner including figures of speech such as analogy or metaphor. Hickey regards misguided pedantics who say otherwise as "closet Cartesians", because they never admit they are neo-Cartesians. The imposing, intruding, recalcitrant, obdurate otherness of mind-independent reality is immediately self-evident at the dawn of consciousness; it is a most rudimentary experience. Dogs and cats are infra-articulate and nonreflective realists. To dispute realism is to step through the looking glass into Alice's labyrinth of logomachy, of

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metaphysical jabberwocky where, as Schopenhauer believed, the world is a dream. It is to indulge in the philosophers' hallucinatory narcotic.

Scientific realism is the thesis that a tested and currently nonfalsified theory offers the most empirically adequate and thus most realistic description of reality at the current time.

After stating that the notion of reality independent of language is in our earliest impressions, Quine adds that it is then carried over into science as a matter of course. He writes that realism is the robust state of mind of the scientist, who has never felt any qualms beyond the negotiable uncertainties internal to his science.

Note that contrary to Feyerabend the phrase "scientific realism" does not mean scientism, the thesis that only science describes reality.

3.37 Ontological Relativity Defined

When metaphysical realism is joined with relativized semantics, the result is ontological relativity.

Ontological relativity in science is the thesis that the semantics of a theory or law and its constituent descriptive terms describe aspects of reality.

A scientific law is a tested and nonfalsified universally quantified statement that prior to its decisive testing had been a theory.

The ontology of a theory or law is as realistic as it is empirically adequate.

Understanding scientific realism requires consideration of ontological relativity. Ontological relativity is the subordination of ontology to empiricism. We cannot separate ontology from semantics, because we cannot step outside of our knowledge and compare our knowledge with reality, in order to validate a correspondence. But we can distinguish our semantics from the ontology it reveals, as we do when we distinguish logical and real suppositions respectively in statements. We describe mind-independent reality with our perspectivist semantics, and ontology is reality as it is revealed empirically more or less adequately by our semantics. Our semantics and thus ontologies cannot be exhaustive, but ontologies are more

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or less adequately realistic, as the semantics of descriptive language is more or less adequately empirical.

Prior to the evolution of contemporary pragmatism philosophers had identified realism as such with one or another particular ontology, which they erroneously viewed as the only ontology on the assumption that there can be only one ontology. Such is the error made by some physicists who believe that they are defending realism, when they defend the “hidden variable” interpretation of quantum theory. Such too is the error in Popper’s proposal for his propensity interpretation of quantum theory. As it happens, both Bohm and Heisenberg rejected the ontological thesis that the kind of existence familiar to us can be extrapolated into the atomic order of magnitude. And contrary to Einstein’s EPR thesis of a single uniform ontology for physics, Aspect, Dalibard, and Roger’s findings from their 1982 nonlocality experiments demonstrated empirically the Copenhagen interpretation’s semantics and ontology.

Advancing science has produced revolutionary changes. And as the advancement of science has produced new theories with new semantics exhibiting new ontologies, some prepragmatist scientists and philosophers found themselves attacking a new theory and defending an old theory, because they had identified realism with the ontology associated with the older falsified theory. As Feyerabend notes in his *Against Method*, scientists have criticized a new theory using the semantics and ontology of an earlier theory. Such a perversion of scientific criticism is still common in the social sciences where romantic ontologies are invoked as criteria for criticism.

With ontological relativity realism is no longer uniquely associated with any one particular ontology. The ontological-relativity thesis does not deny metaphysical realism, but depends on it. It distinguishes the mind-independent plenitude from the ontologies revealed by the descriptive semantics of more or less empirically adequate beliefs. Ontological relativity enables admitting change of ontology without resorting to instrumentalism, idealism, phenomenism, solipsism, any of the several varieties of antirealism, or any other such denial of metaphysical realism.

Thus ontological relativity solves the modern problem of reconciling conceptual revision in science with metaphysical realism. Ontological relativity enables acknowledging the creative variability of knowledge operative in the relativized semantics and consequently mind-dependent ontology that are defined in constructed theories, while at the same time

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acknowledging the regulative discipline of mind-independent reality operative in the empirical constraint in tests with their possibly falsifying outcomes.

Or as manifested linguistically, using the relativized semantics and ontology partially defined by the theory “Every X is Y” it is possible to articulate the falsifying observational test outcome “This X is not Y” with the semantics defined by the test-design language, even though *after* issuing the falsifying observational statement the consequent revision of belief in the theory “Every X is Y” occasions a partial change in the rejected theory’s descriptive semantics and its ontological claim.

In contemporary pragmatist philosophy of science metaphysical realism is logically prior to and presumed by all ontologies as the primal prejudice, while the choice of an ontology is based upon the empirically demonstrated adequacy of the theory describing the ontology. Indulging in futile disputations about metaphysical realism will not enhance achievement of the aims of either science or philosophy of science, nor will dismissing such disputations encumber achieving those aims. Thus ontological relativity leaves ontology to the scientist rather than the metaphysician. And the superior empirical adequacy of a new law yields the increased truth of a new law and the increased realism in the ontology that the new law reveals.

3.38 Ontological Relativity Illustrated

To illustrate ontological relativity consider the semantical decision about red ravens mentioned in the above discussion about componential artifactual semantics (Section 3.23). The decision is ontological as well as semantical. For the bird watcher who found a red but otherwise raven-looking bird and decides to reject the belief “Every raven is black”, the phrase “red raven” becomes a description for a type of existing birds. Once that semantical decision is made, red ravens suddenly populate many trees in the world, however long ago Darwinian Mother Nature had evolved the observed avian creatures. But if his decision is to persist in believing “Every raven is black”, then there are no red ravens in existence, because whatever kind of creature the bird watcher found and that Mother Nature had long ago evolved, the red bird is not a raven. The availability of the choice illustrates the artifactuality of the relativized semantics of language and the consequently relativized ontology that the relativized semantics reveals about mind-independent reality.

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Relativized semantics makes ontology no less relative whether the affirmed entity is an elephant, an electron, or an elf. Beliefs that enable us routinely to make successful predictions are deemed more empirically adequate and thus more realistic and truer than those less successfully predictive. And we recognize the reality of the entities, attributes or any other characteristics that enable those routinely successful predicting beliefs. Thus if positing evil elves conspiring mischievously enabled predicting the collapse of market-price bubbles more accurately and reliably than the postulate of euphoric humans speculating greedily, then we would decide that the ontology of evil elves is as adequately realistic as it was found to be adequately empirical, and we would busy ourselves investigating elves, as we would do with elephants and electrons for successful predictions about elephants and electrons. On the other hand were our price-predictions to fail, those failures would inform us that our belief in elves is as empirically inadequate as the discredited belief in the gnomes of Zurich, and we would decide that the ontology of elves is as inadequately realistic, as it was found to be inadequately empirical.

Consider another illustration. Today we reject an ontology of illnesses due to possessing demons as inadequately realistic, because we do not find ontological claims about possessing demons to be empirically adequate for effective medical practice. But it could have been like the semantics of “atom”. The semantics and ontology of “atom” have changed greatly since the days of the ancient philosophers Democritus and Leucippus. The semantics of “atom” has since been revised repeatedly under the regulation of empirical research in physics, as when J.J. Thompson discovered that the atom is not indivisible, and thus today we still accept a semantics and ontology of atoms. Similarly the semantics of “demon” might too have been revised to become as beneficial as the modern meaning of “bacterium”, had empirical testing regulated an evolving semantics and ontology of “demon”.

Both ancient and modern physicians may observe and describe some of the same symptoms for a certain infectious disease in a sick patient and both demons and bacteria are viewed as living agents, thus giving some continuity to the semantics and ontology of “demon” through the ages. But physicians’ medical understanding, diagnoses and remedies are quite different. If the semantics and ontology of “demon” had been revised under the regulation of increasing empirical adequacy, then today scientists might materialize (*i.e.*, visualize) demons with microscopes, physicians might write incantations (*i.e.*, prescriptions), and pharmacists might dispense

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antidemonics (*i.e.*, antibiotics) to exorcise (*i.e.*, to cure) possessed (*i.e.*, infected) sick persons. But then terms such as “materialize”, “incantation”, “antidemonics”, “exorcise” and “possessed” would also have acquired new semantics in the more empirically adequate modern contexts than the ancient medical beliefs. The descriptive semantics and ontology of “demon” would have been revised to exclude what we now find empirically to be inadequately realistic, such as a demon’s immateriality.

This thesis can be found in Quine’s “Two Dogmas of Empiricism” in his *Logical Point of View* even before he came to call it “ontological relativity”. There he says that physical objects are conceptually imported into the linguistic system as convenient intermediaries, as irreducible posits comparable epistemologically to the gods of Homer. But physical objects are epistemologically superior to other posits including the gods of Homer, because the former have proved to be more efficacious as a device for working a manageable structure into the flux of experience. As a realist, he might have added explicitly that experience is experience **of** something, and that physical objects are more efficacious than whimsical gods for making correct predictions.

Or consider the tooth-fairy ontology. In some cultures young children losing their first set of teeth are told that if they place a lost tooth under the pillow at bedtime, a tooth-fairy person having large butterfly wings will exchange the tooth for a coin as they sleep. The child who does so and routinely finds a coin the next morning, has an empirically warranted belief in the semantics describing a winged person that leaves coins under pillows and is called a “tooth fairy”. This belief is no less empirical than belief in the semantics positing an invisible force that pulls apples from their trees to the ground and is called “gravity”. But should the child forget to advise his mother that he placed a recently lost tooth under his pillow, he will rise the next morning to find no coin, and may become suspicious.

Then like the bird watcher with a red raven-looking bird, the child has semantical and ontological choices. He may continue to define “tooth fairy” as a benefactor other than his mother, and reject the tooth-fairy semantics and ontology as inadequately realistic. Or like the astronomers who concluded that the morning star and the evening star are the same luminary and not stellar, he may revise his semantics of “tooth fairy” to conclude that his mother and the tooth fairy are the same benefactor and not winged. But later when he publicly calls his mother “tooth fairy”, he will be encouraged to revise this semantics of “tooth fairy”, and to accept the more conventional

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ontology that excludes tooth fairies, as modern physicians exclude demons. This sociology of knowledge and ontology has been insightfully examined by the sociologists of knowledge Peter Berger and Thomas Luckmann in their *Social Construction of Reality*.

Or consider ontological relativity in fictional literature. “Fictional ontology” is an oxymoron. But fictional literature resembles metaphor, because its discourse is recognized as having both true and false aspects (Section 3.27). For fictional literature the reader views as true the parts of the text that reveal reality adequately, and the reader views as untrue the parts that are fictional. Sympathetic readers, who believe Mark Twain’s portrayal of the slavery ontology, recognize an ontology that is realistic about the racist antebellum South. And initially unsympathetic readers who upon reading Twain’s portrayal of Huckleberry Finn’s dawning awareness of fugitive slave Jim’s humanity notwithstanding Huck’s racist upbringing, may thus be led to accept the more realistic ontology that is without the dehumanizing fallacies of the South’s racism. Ontological relativity enables recognition that such reconceptualization can reveal a more realistic ontology not only in science but also in all discourse including even fiction.

Getting back to science, consider the Eddington eclipse test of Einstein’s relativity theory mentioned above in the discussion of componential semantics (Section 3.22). That famous astronomical test is often said to have “falsified” Newton’s theory. Yet today the engineers of the U.S. National Aeronautics and Space Administration (NASA) routinely use Newton’s physics to navigate interplanetary rocket flights through our solar system. Thus it must be said that Newton’s “falsified” theory is not completely false or NASA could never use it. The Newtonian ontology is realistic, but is now known to be less realistic than the Einsteinian ontology, because the former has been demonstrated to be less empirically adequate.

There is no semantically interpreted syntax that does not reveal some more or less realistic ontology; since all semantics is relativized and ultimately comes from sense stimuli, no semantically interpreted syntax is utterly devoid of ontological significance.

3.39 Causality

Cause and effect are ontological categories, which in science can be described by tested and nonfalsified nontruth-functional hypothetical-conditional statements thus having the status of laws. The nontruth-

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functional hypothetical-conditional statement claiming a causal dependency is an empirical universal statement. It is therefore never proved and is always vulnerable to future falsification. But ontological relativity means that a statement's empirical adequacy warrants belief in its ontological claim of causality, even if the relation is stochastic. Nonfalsification does not make the statement affirm merely a Humean constant conjunction. When in the progress of science a causal claim is empirically falsified by empirical testing, it is made evident thereby that the causality claim is less adequately true and thus less realistic than previously hypothesized.

3.40 Ontology of Mathematical Language

In the categorical proposition the logically quantified subject term references individuals and describes the attributes that enable identifying the referenced individuals, while the predicate term describes only attributes without referencing the instantiated individuals manifesting the attributes. The referenced extramental real entities and their semantically signified extramental real attributes constitute the ontology described by the categorical proposition that is believed to be true due to its experimentally or otherwise experientially demonstrated empirical adequacy. These existential conditions are expressed explicitly by the copula term "is" as in "Every raven **is** black".

However, the ontological claim made by the mathematical equation in science is not only about instantiated individuals or their attributes. The individual instances referenced by the descriptive variables in the applied mathematical equation are instances of individual measurement results, which are acquired by executing measurement procedures that yield numeric values for the descriptive variables. The individual measurement results are related to the measured reality by nonmathematical language, which includes description of the measured subject, the metric, the measurement procedures, and any apparatus described in test-design language. Also calculated and predicted values for descriptive variables describing effects in equations with measurement values for other variables describing causal factors make ontological claims, which are tested empirically. Untested theories make relatively more hypothetical quantitative causal claims. Tested and nonfalsified equations make quantitative causal laws.

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D. PRAGMATICS

3.41 Pragmatic Dimension

Pragmatics is the functions of language.

Linguists recognize the pragmatics of ordinary English when they distinguish the four moods, namely the declarative, interrogative, imperative and exclamatory moods. The intended mood can be indicated syntactically by word order and/or punctuation marks, and phonetically by inflection. The moods can be exemplified in the language of science, but philosophers of science make pragmatic distinctions that are more specifically functional for basic research in empirical science:

The pragmatics of basic research in science is theory construction and empirical testing, in order to produce laws and explanations.

Pragmatics is the metalinguistic dimension after syntax, semantics and ontology, and it presupposes all of them. The regulating pragmatics of basic science is set forth in the statement of the aim of science, namely to create explanations containing scientific laws by development and empirical testing of theories, which are deemed laws when not falsified by the currently most critically empirical test. Explanations and laws are accomplished science, while theories and testing are work in progress at the frontier of basic research. Understanding the pragmatics of science requires understanding theory development and testing.

3.42 Semantic Definitions of Theory Language

For the extinct neopositivist philosophers the term “theory” refers to universally quantified sentences containing “theoretical terms” that describe unobserved phenomena or entities. The nineteenth-century positivists such as the physicist Ernst Mach rejected theory, especially the atomic theory of matter in physics, because atoms had never been observed. These early positivist philosophers’ idea of discovery consisted of induction, which yields empirical generalizations rather than theories that contain theoretical terms.

Later the twentieth-century neopositivists believed that they could validate the meaningfulness of theoretical terms referencing unobserved microphysical particles such as electrons, and thus admit theories as valid

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science. But for discovery of theories they invoked human creativity and offered no description of the processes of theory creation.

The neopositivists viewed Newton's physics as paradigmatic of theoretical science. They therefore also construed "theory" to mean an axiomatic system, because Kepler's laws of orbital motion could be derived deductively as theorems from Newton's gravitational law.

For the anachronistic romantic philosophers and romantic social scientists on the other hand "theory" means language describing subjectively experienced mental states such as ideas and motivations. Some romantics portray the theory-creation process as consisting firstly of introspection by the theorist upon his own personal subjective experiences or imagination. Then secondly it consists of imputing vicariously his introspectively experienced ideas and motives to the social members under investigation. The sociologist Max Weber called this *verstehen*. Thus since the social scientist can recognize or at least imagine the imputed ideas and motives, the ideas and motives expressed by his theory are "convincing" to him.

3.43 Pragmatic Definition of Theory Language

Scientific theories are universally quantified statements including mathematical expressions (a.k.a. "models") that are proposed for empirical testing.

Unlike positivists and romantics, pragmatists define theory language pragmatically, *i.e.*, by its function in research, instead of syntactically as an axiomatic system or semantically by some distinctive content. This functionality supplies the definition of "theory" in the contemporary pragmatist philosophy of science. It contains the traditional idea that theories are hypotheses, but the reason for their hypothetical status is not due to either the positivist observation-theory dichotomy or the romantics' requirement of referencing subjective mental states. Theory language is hypothetical because interested scientists agree that in the event of falsification, it is the theory language that is falsified instead of the test-design language. Often theories are deemed to be more hypothetical, because their semantics is more empirically underdetermined.

Theory is a special function of language – empirical testing – rather than a special type of language.

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Scientists believe that the proposed theory statements are more likely to be productively revised than the presumed test-design statements, if a falsifying test outcome shows that revision is needed.

Pragmatically after a theory is tested, it ceases to be a theory, because it is either scientific law or rejected language, except for the skeptical scientist who wants further predictive testing. Designing empirical tests can tax the ingenuity of the most brilliant scientist, and theories may have lives lasting many years due to difficult problems formulating or implementing decisive test designs. Or as in a computerized discovery system with an empirical decision procedure, theories may have lives measured in milliseconds.

After a conclusive test outcome, the tested theory is no longer a theory, because the conclusive test makes the theory either a scientific law or falsified discourse.

Romantic social scientists adamantly distinguish theory from “models”. Many alternative supplemental speculations about motives, which they call “theory”, can be appended to a model that is has been tested. But it is the model that is empirically tested statistically or predictively. Pragmatically the language that is proposed for empirical testing is theory, such that when a model is proposed for testing, the model has the status of theory.

Some time after initial testing and acceptance, a scientific law may revert to theory status to be tested again. Centuries after Newton’s law of gravitation had initially been accepted as scientific law; it was tested in 1919 in the famous Eddington eclipse test of Einstein’s alternative general relativity theory. Thus for a brief time early in the twentieth century Newton’s theory was pragmatically speaking actually a theory again.

Thus the term “theory” is ambiguous; **archival** and **pragmatic** meanings can be distinguished. In the archival sense philosophers and scientists still may speak of Newton’s “theory” of gravitation, as is often done herein. The archival meaning is what in his *Patterns of Discovery* Hanson calls “completed science” or “catalogue science” as opposed to “research science”. The archival sense has long-standing usage and will be in circulation for a long time to come.

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But research scientists seeking to advance their science using theory in the archival sense are seeking an El Dorado. The archival sense is not the meaning that is needed to understand the research practices and historical progress of basic science. That is why philosophers today recognize the pragmatic meaning of “theory”, which is a transitional phase for a science. In the pragmatic sense Newton’s “theory” is now falsified physics in basic science and is no longer proposed for testing, although it is still used by aerospace engineers and others who can exploit its lesser realism, *i.e.*, lesser truth.

3.44 Pragmatic Definition of Test-Design Language

Pragmatically theory is universally quantified language that is proposed for testing, and test-design language is universally quantified language that is presumed for testing.

Accepting or rejecting the hypothesis that there are red ravens presumes a prior agreement about the semantics needed to identify a bird’s species. The test-design language defines the semantics that identifies the subject of the tested theory and the procedures for executing the test design. This semantics includes but is not limited to the language for describing the design of any test apparatus, the testing methods including any measurement procedures, and the characterization of the test’s initial conditions. The semantics for the independent characterization of the observed outcome resulting from the test execution is also defined in the test design language. The universally quantified test-design statements contribute these meaning components to the semantics of the descriptive terms common to both the test design and the theory.

Both theory and test-design language are believed to be true, but for different reasons. Experimenters testing a theory presume the test-design language is true with definitional force for identifying the subject of the test and for executing the test design. The advocates proposing or supporting a theory believe the theory statements are true with sufficient plausibility to warrant the time, effort and cost of testing with an expected nonfalsifying outcome. For these advocates both the theory statements and the test-design statements contribute component parts to the complex semantics of the descriptive terms that the theory and test-design statements share prior to testing.

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Often test-design concepts describing the subject of a theory are either not yet formulated or are too vaguely described and conceptualized to be used for effective testing. They are concepts that await future scientific and technological developments that will enable formulation of an executable and decisive empirical test. Formulating a test design capable of evaluating decisively the empirical merits of a theory often requires considerable ingenuity. Eventual formulation of specific test-design language enabling an empirical decision supplies the additional clarifying semantics that sufficiently reduces the disabling empirical underdetermination in the descriptive terms of the theory.

3.45 Pragmatic Definition of Observation Language

Observation language is test-design sentences that are given particular logical quantification for describing an individual test procedure and execution including the reporting of the test outcome.

After scientists have formulated and accepted a test design, the universally quantified language setting forth the design determines the semantics of its observation language. **Particularly quantified language cannot define the semantics of descriptive terms.** The observation language in a test is sentences or equations with particular logical quantification accepted as experimentally or experientially true and used for description, and it includes both the test-design sentences describing the initial conditions and procedures for an individual test execution and also the test-outcome sentences reporting the outcome of an executed test. This is a pragmatic concept of observation language, because it depends on the function of such language in the test. Contrary to positivists and earlier philosophers, pragmatists reject the thesis that there is any inherently or naturally observational semantics.

If a test outcome is not a falsification, then the universally quantified theory is regarded as a scientific law, and the theory contributes its semantics to the meaning complex associated with the descriptive terms in the universally quantified test-design sentences. Additionally the terms in the universally quantified test-design sentences contribute their semantics to the meaning complex of the theory's terms. These semantical contributions reduce vagueness, and do not depend on the logical derivation of test-design sentences from the theory sentences. But where such derivation is possible, coherence is increased and vagueness is thereby further reduced. Furthermore due to a mathematical derivation test-outcome measurement

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values may be changed to numerical values that still fall within the range of measurement error, and the measurement accuracy may be judged improved.

3.46 Observation and Test Execution

For the execution of the test all the statements involved have their quantification changed from universal to particular. The semantics for all the language involved in a test is defined by the universally quantified statements, since particularly quantified language does not define semantics. **The particularly quantified theory statements make the prediction for the test.** All the language needed to realize the initial conditions together with the test-outcome statements have their semantics defined by the universal statements in the test design. **The particularly quantified statements in the test design describing the subject of the theory are observation statements.** For a mathematically expressed theory particular logical quantification is accomplished by assigning values by measurement to the theory's descriptive variables to implement the test's initial conditions needed to calculate the one or several prediction variables, and then calculating the predicted numerical values.

After the test is executed, the statements in the test design reporting the test outcome are observation statements describing the observed results of the test. The prediction statements are not as such observation statements unless the test outcome is nonfalsifying. If the test is falsifying, the prediction statements are merely rejected language. For a mathematically expressed theory a nonfalsifying test outcome is a predicted magnitude that is manifestly larger than the estimated measurement error, such that the prediction is deemed to be as the test-outcome statements describe. Then the test is effectively decidable as nonfalsifying. Otherwise the test is falsifying, and the prediction values are simply rejected as erroneous prediction values.

3.47 Scientific Professions

In computational philosophy of science a “scientific profession” means the researchers who at a given point in time are attempting to solve the same scientific problem as defined by a test design. They are the language community represented by the input and output state descriptions for a discovery system application. On this definition of profession for discovery systems in computational philosophy of science, a profession is a much smaller group than the academicians in the field of the problem but is not limited to academicians.

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3.48 Semantic Individuation of Theories

Theory language is defined pragmatically, but theories are individuated semantically.

Theories are individuated semantically in either of two ways:

Firstly different expressions are different theories, because they address different subjects.

Different theory expressions having different test designs producing different measurements or observations are different theories with different subjects.

Secondly different expressions are different theories, because each makes contrary claims about the same subject.

The test-design language defines the subject and is the same for all of such contrary theories.

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CHAPTER 4. Functional Topics

The preceding chapters have offered generic sketches of the principal twentieth-century philosophies of science, namely romanticism, positivism and pragmatism. And they have discussed selected elements of the contemporary pragmatist philosophy of language for science, namely the object language and metalanguage perspectives, the synchronic and diachronic views, and the syntactical, semantical, ontological and pragmatic dimensions.

Finally at the expense of some repetition this chapter integrates those discussions into the four functional topics briefly examined in the overview chapter, namely the institutionalized aim of basic science, scientific discovery, scientific criticism, and scientific explanation.

4.01 Institutionalized Aim of Science

Over the last three hundred years empirical science has evolved into a social institution with its own distinctive and autonomous professional subculture of shared views and values.

The institutionalized aim of science is the cultural value system that regulates the scientist's performance of basic research.

Idiosyncratic motivations of individual scientists are historically interesting, but are largely of anecdotal interest to philosophers of science, except when such idiosyncrasies have produced results that have initiated an institutional change.

The literature of philosophy of science offers various proposals for the aim of science. The three modern philosophies of science mentioned above set forth different philosophies of language, which influence their diverse concepts of all four of the functional topics including the aim of science.

4.02 Positivist Aim

The positivists proposed a foundational agenda based on their naturalistic philosophy of language. Early positivists such as Ernst Mach proposed that science should aim for firm objective foundations by relying exclusively on observation, and should seek empirical generalizations that

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summarize the individual observations. They deemed theories to be at best temporary expedients and too hypothetical to be considered appropriate for science.

Early positivists aimed to create explanations having objective basis in observations and to make empirical generalizations summarizing the individual observations. They rejected speculative theories as unscientific.

After the acceptance of Einstein's relativity theory by physicists, the later positivists known as "neopositivists" acknowledged the essential role that hypothetical theory must have in the aim of science. Between the twentieth-century World Wars, Rudolf Carnap and his fellows in the Vienna Circle group of neopositivists attempted to justify theories in science by logically relating the so-called theoretical terms in the theories to the so-called observation terms that they believed should be the foundational logical-reduction base.

Many of these neopositivists were also called "logical positivists", because they attempted to use the symbolic logic developed by Bertrand Russell and Alfred N. Whitehead to accomplish the logical reduction of theory language to observation language. The logical positivists fantasized that this Russellian symbolic logic could serve philosophy as mathematics serves physics, and it became their *idée fixe*. For decades the symbolic logic ostentatiously littered the pages of the *Philosophy of Science* and *British Journal of Philosophy of Science* journals with its chicken tracks, and rendered their ostensibly "technical" papers fit for the bottom of a birdcage.

The positivists were self-deluded, because in fact the Russellian truth-functional logic does not adequately capture the hypothetical logic of empirical testing in science. For example the truth-functional truth table says that if the conditional statement's antecedent statement is false, then the conditional statement is defined as true. But in the practice of science a false antecedent statement means that execution of a test did not comply with the description of initial conditions thus invalidating the test, and is therefore irrelevant to the truth-value of the conditional statement that is the tested theory. Today truth-functional logic is not seriously considered by post-positivist philosophers of science much less by any practicing research scientists.

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Consequently the aim of these neopositivist philosophers was not the aim of practicing research scientists. Scientists do not use symbolic logic or seek any logical reduction for so-called theoretical terms. The extinction of positivism was in no small part due to the disconnection between the positivists' philosophical agenda and the actual practices and values of research scientists.

Later neopositivists aimed to justify explanatory theories by logically relating the theoretical terms in the theories to observation terms that they believed are a foundational reduction base.

Readers wishing to know more about positivism are referred to **BOOKS II and III** at www.philsci.com.

4.03 Romantic Aim

The aim of the *social sciences* is to develop explanations describing **social-psychological motives, in order to explain observed social interaction in terms of purposeful human action in society.**

The romantics have a subjectivist social-psychological reductionist aim for the social sciences, which is thus also a foundational agenda. This agenda is a thesis of the aim of the social sciences that is still embraced and enforced by many social scientists. **Both romantic philosophers and romantic scientists maintain that the sciences of culture differ fundamentally in their aim from the sciences of nature.** Romantics view the aim of the social sciences as the development of explanations in terms of subjective psychological motivations to explain observed social interaction in terms of purposeful human actions in society.

Some romantics call this type of explanation “interpretative understanding” and others call it “substantive reasoning”. Using this concept of the aim of social science they often say that an explanation must be “convincing” or must “make substantive sense” to the social scientist due to the scientist’s introspection upon his actual or imaginary personal experiences, especially when he is a participating member of the same culture as the social members he is investigating.

Examples of these romantics are sociologists like Talcott Parsons and his academic entourage, who advocate variations on the philosophy of the sociologist Max Weber, in which vicarious understanding called “*verstehen*”

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is a criterion for criticism that they believe trumps empirical evidence. *Verstehen* sociology is therefore also known as “folk sociology” or “pop sociology”. Enforcing this criterion has obstructed the evolution of sociology into a modern empirical science in the twentieth century. Cultural anthropologists furthermore reject *verstehen* as a fallacy of ethnocentrism.

The 1989 Nobel-laureate econometrician Trygve Haavelmo and his academic entourage of classical economists supply another example of romanticism. These econometricians do not reject the aim of prediction, simulation, optimization and policy formulation using statistical econometric models; with their econometric modeling they enable it. But they subordinate the selection of “explanatory” variables in their models to factors that are derived from their heroically imputed maximizing rationality theses, which identify the motivating factors explaining the decisions of the economic agents such as buyers and sellers in a market. Thus they exclude econometrics from discovery and limit its function to testing romantic “theory”. In his *Philosophy of Social Science* Alexander Rosenberg describes the economists’ theory of rational choice, *i.e.*, the use of the maximizing rationality theses, as “folk psychology formalized”.

Readers wishing to read more about the romantics including Parsons, Weber, Haavelmo and others in **BOOK VIII** at www.philsci.com.

4.04 More Recent Ideas

Most of the twentieth-century post-positivist proposals for the aim of science are less dogmatic than those listed above and arise from examination of important developmental episodes in the history of the natural sciences. Some noteworthy examples:

Einstein: Reflection on his relativity theory influenced Albert Einstein’s concept of the aim of science, which he set forth as his “programmatically aim of all physics” stated in his “Reply to Criticisms” in *Albert Einstein: Philosopher-Scientist* edited by Paul A. Schilpp. The aim of science in Einstein’s view is a comprehension as complete as possible of the connections among sense impressions in their totality, and the accomplishment of this comprehension by the use of a minimum of primary concepts and relations. Einstein did not reject empiricism, but he included a coherence agenda in his aim of science. This thesis also implies a uniform ontology for physics, and Einstein found statistical quantum theory to be “incomplete” according to his aim.

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Popper: Karl Popper was an early post-positivist philosopher of science and also critical of the romantics. Reflecting on Eddington's historic 1919 test of Einstein's relativity theory in physics he proposed in his *Logic of Scientific Discovery* that the aim of science is to produce tested and nonfalsified theories having greater universality and more information content than their predecessor theories addressing the same subject. His concept of the aim of science thus focuses on the growth of scientific knowledge. And in his *Realism and the Aim of Science* he maintains that realism explains the possibility of falsifying test outcomes in scientific criticism. The title of his *Logic of Scientific Discovery* notwithstanding Popper denies that discovery can be addressed by either logic or philosophy, but says instead that discovery is a proper subject for psychology. Cognitive psychologists today would agree.

Hanson: Norwood Russell Hanson reflecting on the development of quantum theory states in his *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science* that inquiry in research science is directed to the discovery of new patterns in data to develop new hypotheses for deductive explanation. He calls such practices "research science", which he opposes to "completed science" or "catalogue science", which is merely re-arranging established facts into more elegant formal axiomatic patterns. He follows Charles Peirce who called hypothesis formation "abduction". Today mechanized discovery systems search for patterns in data.

Kuhn: Thomas S. Kuhn, reflecting on the development of the Copernican heliocentric cosmology in his *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* maintained in his famous *Structure of Scientific Revolutions* that the prevailing theory, which he called the "consensus paradigm", has institutional status. He proposed that small incremental changes extending the consensus paradigm, to which scientists seek to conform, defines the institutionalized aim of science, which he called "normal science". On the other hand he said that scientists neither desire nor aim consciously to produce revolutionary new theories, which he called "extraordinary science." Kuhn therefore defined scientific revolutions as institutional changes in science, which he excludes from the aim of science.

Feyerabend: Paul Feyerabend reflecting on the development of quantum theory in his *Against Method* proposed that each scientist has his own aim, and that anything institutional is a conformist impediment to the advancement of science. He said that historically successful scientists

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always “break the rules”, and he ridiculed Popper’s view of the aim of science calling it “ratiomania” and “law-and-order science”. Therefore Feyerabend proposes that successful science is literally “anarchical”, and borrowing a slogan from the Marxist, Leon Trotsky, he advocates “revolution in permanence”.

Readers wishing to know more about the philosophies of Popper, Kuhn, Hanson and Feyerabend are referred to **BOOKs V, VI and VII** at www.philsci.com.

4.05 Aim of Maximizing “Explanatory Coherence”

Thagard: Computational philosopher of science Paul Thagard proposes that the aim of science is “best explanation”, a thesis that is also called “explanationism”. The thesis refers to an explanation that aims to maximize the explanatory coherence of one’s overall set of beliefs. This aim of science is thus explicitly a coherence agenda.

Thagard developed a computerized cognitive system **ECHO**, an acronym for “Explanatory Coherence by Harmony Optimization”, in order to explore the operative criteria in theory choice by mechanically simulating noteworthy past episodes in the history of science. His system described in his *Conceptual Revolutions* simulated the realization of the aim of maximizing “explanatory coherence” by replicating various episodes of theory choice. In his system “explanation” is an undefined primitive term. He applied his system **ECHO** to several revolutionary episodes in the history of science including (1) Lavoisier’s oxygen theory of combustion, (2) Darwin’s theory of the evolution of species, (3) Copernicus’ heliocentric astronomical theory of the planets, (4) Newton’s theory of gravitation, and (5) Hess’ geological theory of plate tectonics.

In reviewing his historical simulations Thagard reports that **ECHO** indicates that the criterion making the largest contribution historically to explanatory coherence in scientific revolutions is explanatory breadth – the preference for the theory that explains more evidence than its competitors. But he adds that the simplicity and analogy criteria are also historically operative although less important. He maintains that the aim of maximizing explanatory coherence with these criteria yields the “best explanation”.

Explanationism, maximizing the explanatory coherence of one’s overall set of beliefs, is inherently conservative. The **ECHO** system appears

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to document the historical fact that the coherence aim is psychologically satisfying and occasions strong motivation for accepting theories, while theories describing reality as incoherent with established beliefs are psychologically disturbing. Psychologists call this “motivated reasoning”. But progress in science does not consist of maximizing the scientist’s psychological contentment. Empiricism eventually overrides coherence when there is a conflict with new evidence. In fact defending coherence has historically had a reactionary effect. For example Heisenberg’s revolutionary indeterminacy relations, which contradict microphysical theories coherent with established classical physics including Einstein’s relativity theory, do not conform to **ECHO**’s maximizing-explanatory-coherence criterion.

Readers wishing to know more about the philosophy of Thagard are referred to **BOOK VIII** at www.philsci.com.

4.06 Contemporary Pragmatist Aim

The successful outcome (and thus the aim) of basic-science research is explanations made by developing theories that satisfy empirical tests, and that are thereby made scientific laws that function in scientific explanations and test designs.

The principles of contemporary pragmatism including its philosophy of language evolved through the twentieth century beginning with the autobiographical writings of Werner Heisenberg, one of the central participants in the historic development of quantum theory. This philosophy is summarized in Section **2.03** above in three central theses: relativized semantics, empirical underdetermination and ontological relativity, which are not repeated here. Readers wishing to know more about the philosophy of Heisenberg are referred to **BOOKS II and IV** at www.philsci.com.

The institutionally regulated activities of research scientists may be described succinctly in the pragmatist statement of the aim of science. The contemporary research scientist seeking success in his research may consciously employ the aim as what some social scientists call a “rationality postulate”. The institutionalized aim of science can be re-expressed as such a pragmatist “rationality postulate”:

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The institutionalized aim of science is to construct explanations by developing theories that satisfy empirical tests, and thereby make scientific laws that function in scientific explanations.

Pragmatically, however, rationality is not some incorrigible principle or intuitive preconception. The contemporary pragmatist statement of the aim of science is a postulate in the sense of an empirical hypothesis about what has been responsible for the historical advancement of basic research science. Therefore it is destined to be revised at some unforeseeable future time, when due to some future developmental episode in basic science, research practices are revised in some fundamental way. Then some conventional practices deemed rational today might be dismissed as misconceptions, and perhaps superstitions, as are the romantic and positivist beliefs today. The aim of science is more elaborately explained in terms of the other three functional topics as sequential steps in the development of explanations.

The institutionalized aim can also be expressed so as not to impute motives to the successful scientist, whose personal psychological motives may be quite idiosyncratic. Thus the contemporary pragmatist statement of the aim of science may instead be phrased in terms of a successful outcome instead of a conscious aim imputed to scientists. The successful outcome of basic-science research is an explanation produced by developing theories that satisfy critically empirical tests, and that are thereby made scientific laws that function in scientific explanations.

The empirical criterion is the **only** criterion acknowledged by the contemporary pragmatist, because it is the only criterion that accounts for the advancement of science. Historically there have been other criteria, but whenever there has been a conflict, eventually it is demonstrably superior empirical adequacy that has enabled a new theory to prevail. This is true even if the theory's ascendancy has taken many years or decades, or even if it has had to be rediscovered, such as the heliocentric theory of the ancient Greek astronomer Aristarchus of Samos.

4.07 Institutional Change

Change within the institution of science is change made under the regulation of the institutionalized aim of science. It consists of new theories, new test designs, new laws and new explanations.

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Institutional change is the historical evolution of scientific practices involving revision of the aim of science, which may entail revision of its criteria for criticism, its discovery practices, or its concept of explanation. Institutional changes are historically unique developments usually recognized only retrospectively and in due course conventionalized in science.

Institutional change in science must be distinguished from change within the institutional constraint. Philosophy of science examines both changes within the institution of science and historical changes of the institution itself. But institutional change is typically recognized only retrospectively due to the distinctively historical uniqueness of each episode and also due to the need for eventual conventionality for new basic-research practices to become institutionalized.

In the history of science institutionally deviate practices, innovative instruments and unconventional concepts that yielded successful results are initially recognized and accepted by only a few scientists. As Feyerabend emphasized in his *Against Method*, in the history of science successful scientists have often broken the prevailing methodological rules. But the successful departures eventually become conventionalized. By the time they are deemed acceptable to the peer-reviewed literature, reference manuals, encyclopedias and student textbooks, the institutional change is complete and has become the conventional wisdom.

Successful researchers have often failed to understand the reasons for their unconventional successes, and have advanced or accepted erroneous methodological ideas and philosophies of science to explain their successes. One of the most historically notorious such misunderstandings is Isaac Newton's "*hypotheses non fingo*", his denial that his law of gravitation is a hypothesis. Nearly three centuries later Einstein demonstrated otherwise.

4.08 Philosophy's Cultural Lag

Adequate understanding of successful departures from institutionalized basic research is elusive even for philosophers. There exists a time lag between the evolution of the institution of science and developments in philosophy of science, since the latter depend on the realization of the former. For example more than a quarter of a century passed between Heisenberg's philosophical reflections on the language of his indeterminacy relations in quantum theory and the consequent

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emergence and ascendancy of the contemporary pragmatist philosophy of science in academic philosophy.

4.09 Cultural Lags among Sciences

Not only are there cultural lags between the institutionalized practices of science and philosophy of science, there are also cultural lags among the several sciences. Philosophers of science have preferred to examine physics and astronomy, because historically these have been the most advanced sciences since the historic Scientific Revolution benchmarked with Copernicus and Newton.

Institutional changes occur with lengthy time lags due to such impediments as intellectual mediocrity, technical incompetence, risk aversion, or vested interests in the conventional ideas and the received wisdom. The newer social and behavioral sciences have remained institutionally retarded. Naïve sociologists and economists are blithely complacent in their amateurish philosophizing about basic social-science research, often adopting prescriptions and proscriptions that contemporary philosophers of science recognize as anachronistic and fallacious. The result has been the emergence and survival of retarding philosophical superstitions in these retarded sciences, especially to the extent that they have looked to their own less successful histories to formulate their ersatz philosophies of science.

Thus sociologists and economists continue to enforce a romantic philosophy of science, because they believe that sociocultural sciences must have fundamentally different philosophies of science than the natural sciences. Similarly behaviorist psychologists continue to impose the anachronistic positivist philosophy of science. On the contemporary pragmatist philosophy these sciences are institutionally retarded, because they erroneously impose preconceived semantical and ontological commitments as criteria for scientific criticism. Pragmatists can agree with Popper, who said that science is “subjectless” meaning that science is not defined by any particular semantics or ontology.

Pragmatists tolerate any semantics or ontology that romantics or positivists may include in scientific explanations, theories and laws, but pragmatists recognize only the empirical criterion for criticism.

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4.10 Scientific Discovery

“Discovery” refers to the development of new theories. Contemporary pragmatism is consistent with use of computerized discovery systems.

Discovery is the first step toward realizing the aim of science. The problem of scientific discovery for contemporary pragmatist philosophers of science is to describe and to proceduralize the development of universally quantified statements for empirical testing with nonfalsifying test outcomes, thereby making laws for use in explanations and test designs.

Much has already been said in the above discussions of philosophy of scientific language in Chapter 3 about the pragmatic basis for the definition of theory language, about the semantic basis for the individuation of theories, and about state descriptions. Those discussions will be assumed in the following comments about the mechanized development of new theories.

4.11 Discovery Systems

The discovery system produces a transition from an input-language state description containing currently available information to an output-language state description containing the generated and tested new theories.

In the “Introduction” to his *Models of Discovery* 1978 Nobel-laureate Herbert Simon, one of the founders of artificial intelligence, writes that dense mists of romanticism and downright knownothingness have always surrounded the subject of scientific discovery and creativity. Therefore the most significant development addressing the problem of scientific discovery has been the relatively recent mechanized discovery systems in computational philosophy of science.

The ultimate aim of the computational philosopher of science is to facilitate the advancement of contemporary sciences by participating in and contributing to the successful basic-research work of the scientist. The contemporary pragmatist philosophy of science thus carries forward John Dewey’s emphasis on participation. But few academic philosophers have the requisite computer skills much less a working knowledge of any empirical science for participation in basic research.

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Every useful discovery system to date has contained procedures both for constructional theory creation and for critical theory evaluation for quality control of the output and for restricting the size of the system's otherwise unmanageably large output. Theory creation introduces new language into the current state description to produce a new state description, while falsification eliminates language from the current state description to produce a new state description. Thus both theory development and theory testing enable a discovery system to offer a specific and productive diachronic dynamic procedure for linguistic change in empirical science.

The discovery systems do not merely implement an inductivist strategy of searching for repetitions of individual instances, notwithstanding that statistical inference is employed in some system designs. The system designs are mechanized procedural strategies that search for patterns in the input information. Thus they implement Hanson's thesis in *Patterns of Discovery* that in a growing research discipline inquiry seeks the discovery of new patterns in data. They also implement Feyerabend's "plea for hedonism" in *Criticism and the Growth of Knowledge* to produce a proliferation of theories. But while many are made, few are chosen due to the empirical testing routines in the systems.

4.12 Types of Theory Development

In his *Introduction to Metascience* (1976) Hickey distinguishes three types of theory development, which he calls **theory extension**, **theory elaboration** and **theory revision**.

Theory extension is the use of a currently tested and nonfalsified explanation to address a new scientific problem.

The extension could be as simple as adding hypothetical statements to make a general explanation more specific for the problem at hand. A more complex strategy for theory extension is analogy. In his *Computational Philosophy of Science* (1988) Thagard describes his strategy for mechanized theory development, which consists in the patterning of a proposed solution to a new problem by analogy with an existing explanation for a different subject. Using his system design based on this strategy his discovery system called **PI** (an acronym for "Process of Induction") reconstructed development of the theory of sound waves by analogy with the description of water waves. The system was his Ph.D. dissertation.

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In his *Mental Leaps: Analogy in Creative Thought* (1995) Thagard further explains that analogy is a kind of nondeductive logic, which he calls “analogic”. It firstly involves the “source analogue”, which is the known domain that the investigator already understands in terms of familiar patterns, and secondly involves the “target analogue”, which is the unfamiliar domain that the investigator is trying to understand. Analogic is the strategy whereby the investigator understands the targeted domain by seeing it in terms of the source domain. Analogic requires a “mental leap”, because the two analogues may initially seem unrelated. And the mental leap is called a “leap”, because analogic is not conclusive like deductive logic.

It may be noted that if the output state description generated by analogy such as the **PI** system is radically different from anything previously seen by the affected scientific profession containing the target analogue, then the members of that profession may experience the communication constraint to the high degree that is usually associated with a theory revision. The communication constraint is discussed below (Section 4.26).

Theory elaboration is the correction of a currently falsified theory to create a new theory by adding new factors or variables that correct the falsified universally quantified statements and erroneous predictions of the old theory. Langley’s system BACON is a sequential application of theory elaboration using Simon’s “heuristic search” algorithm.

The new theory has the same test design as the old theory. The correction is not merely *ad hoc* excluding individual exceptional cases, but rather is a change in the universally quantified statements. This process is often misrepresented as “saving” a falsified theory, but in fact it creates a new one.

For example the introduction of a variable for the volume quantity and development of a constant coefficient for the particular gas could elaborate Gay-Lussac’s law for gasses into the combined Gay-Lussac’s law, Boyle’s law and Charles’ law. Similarly Friedman’s macroeconomic quantity theory might be elaborated into a Keynesian liquidity-preference function by the introduction of an interest rate, to account for the cyclicity manifest in an annual time series describing the calculated velocity parameter and to display the liquidity trap phenomenon.

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Pat Langley's **BACON** discovery system implements theory elaboration. It is named after the English philosopher Francis Bacon (1561-1626) who thought that scientific discovery can be routinized. **BACON** is a set of successive and increasingly sophisticated discovery systems that make quantitative laws and theories from input measurements. Langley designed and implemented **BACON** in 1979 as the thesis for his Ph.D. dissertation written in the Carnegie-Mellon department of psychology under the direction of Simon. A description of the system is in Simon's *Scientific Discovery: Computational Explorations of the Creative Processes* (1987).

BACON uses Simon's heuristic-search design strategy, which may be construed as a sequential application of theory elaboration. Given sets of observation measurements for two or more variables, **BACON** searches for functional relations among the variables. **BACON** has simulated the discovery of several historically significant empirical laws including Boyle's law of gases, Kepler's third planetary law, Galileo's law of motion of objects on inclined planes, and Ohm's law of electrical current.

Theory revision is a reorganization of currently existing information to create a new theory. Hickey's **METAMODEL** system using what Simon called a "generate-and-test" design.

Its results may be radically different, so it might be undertaken after repeated attempts at both theory extension and theory elaborations have failed to correct a previously falsified theory. The source for the input state description for mechanized theory revision consists of the descriptive vocabulary from the currently untested theories addressing the problem at hand. The descriptive vocabulary from previously falsified theories may also be included as inputs to make an accumulative state description, because the vocabularies in rejected theories can be productively cannibalized for their scrap value. The new theory is most likely to be called revolutionary if the revision is great, because theory revision typically produces greater change to the current language state than does theory extension or theory elaboration thus producing psychologically disorienting semantical dissolution.

Hickey's **METAMODEL** discovery system synthesizes theory revisions. It constructed the Keynesian macroeconomic theory from U.S. statistical data available prior to 1936, the publication year of Keynes' revolutionary *General Theory of Employment, Interest and Money*. The applicability of the **METAMODEL** for this theory revision was already

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known in retrospect by the fact that, as 1980 Nobel-laureate econometrician Lawrence Klein wrote in his *Keynesian Revolution* (1947), all the important parts of Keynes theory can be found in the works of one or another of his predecessors. Hickey's **METAMODEL** discovery system described in his *Introduction to Metascience* (1976) is a mechanized generative grammar with combinatorial transition rules producing econometric models. The grammar is a finite-state generative grammar both to satisfy the collinearity restraint for the regression-estimated equations and to satisfy the formal requirements for executable multi-equation predictive models. The system tests for collinearity, statistical significance, serial correlation, goodness-of-fit properties of the equations, and for accurate out-of-sample retrodictions. Simon calls this combinatorial type of system a "generate-and-test" design.

Hickey also used his **METAMODEL** system in 1976 to develop a post-classical macrosociometric functionalist model of the American national society with fifty years of historical time-series data. To the shock, chagrin and dismay of academic sociologists it is not a social-psychological theory, and four sociological journals therefore rejected Hickey's paper describing the model and its findings about the national society's dynamics and stability characteristics. The paper is reprinted as "**Appendix I**" to **BOOK VIII** in www.philsci.com.

The academic sociologists' a priori ontological commitments to romanticism and social-psychological reductionism rendered the referees invincibly obdurate. Their criticisms also betrayed their Luddite mentality toward mechanized theory development. Later in the mid-1980's Hickey integrated his macrosociometric model into a Keynesian macroeconometric model to produce an institutionalist macroeconometric model for the Indiana Department of Commerce, Division of Economic Analysis.

4.13 Examples of Successful Discovery Systems

There are several examples of successful discovery systems in actual use. John Sonquist developed his **AID** system for his Ph.D. dissertation in sociology at the University of Chicago. His dissertation was written in 1961, when William F. Ogburn was department chairman, which was before the romantics took over the University of Chicago sociology department. He described the system in his *Multivariate Model Building: Validation of a Search Strategy* (1970). The system has long been used at the University of Michigan Survey Research Center. Now modified as the **CHAID** system using χ^2 Sonquist's discovery system is available commercially in SAS and

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SPSS statistical software packages. Its principal commercial application is for list processing for market analysis and for risk analysis as well as for academic investigations in social science. It is not only the oldest mechanized discovery system but also the most widely used in practical applications to date.

Robert Litterman developed his **BVAR** system for his Ph.D. dissertation in economics at the University of Minnesota. He described the system in his *Techniques for Forecasting Using Vector Autoregressions* (1984). The economists at the Federal Reserve Bank of Minneapolis have long used his system for macroeconomic and regional economic analysis. The State of Connecticut and the State of Indiana have also used it for regional economic analysis.

Having previously received an M.A. degree in economics Hickey had intended to develop his **METAMODEL** computerized discovery system for a Ph.D. dissertation in philosophy of science while a graduate student in the philosophy department of the University of Notre Dame, South Bend, Indiana. But the Notre Dame philosophers under the chairmanship of a Reverend Ernan McMullin were obstructionist to Hickey views, and Hickey dropped out. He then developed his computerized discovery system as a nondegree student at San Jose City College in San Jose, California.

For thirty years afterwards Hickey used his discovery system occupationally, working as a research econometrician in both business and government. For six of those years he used his system for Institutional macroeconomic modeling and regional econometric modeling for the State of Indiana Department of Commerce. He also used it for econometric market analysis and risk analysis for various business corporations including USX/United States Steel Corporation, BAT(UK)/Brown and Williamson Company, Pepsi/Quaker Oats Company, Altria/Kraft Foods Company, Allstate Insurance Company, and TransUnion LLC.

In 2004 TransUnion's Analytical Services Group purchased a perpetual license to use his **METAMODEL** system for their consumer credit risk analyses using their proprietary TrenData aggregated quarterly time series extracted from their large national database of consumer credit files. Hickey used the models generated by the discovery system to forecast payment delinquency rates, bankruptcy filings, average balances and other consumer borrower characteristics that constitute risk exposure for lenders, especially during the contractionary phase of the business cycle. He also

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used the system at Quaker Oats and Kraft Foods to discover the sociological and demographic factors responsible for the secular long-term market dynamics of food products and other nondurable consumer goods.

Readers wishing to know more about discovery systems and computational philosophy of science see **BOOK VIII** at www.philsci.com.

4.14 Scientific Criticism

Criticism pertains to the criteria for the acceptance or rejection of theories.

The only criterion for scientific criticism that is acknowledged by the contemporary pragmatist is the empirical criterion.

The philosophical literature on scientific criticism has little to say about the specifics of experimental design. Most often philosophical discussion of criticism pertains to the criteria for acceptance or rejection of theories and more recently to the decidability of empirical testing.

In earlier times when the natural sciences were called “natural philosophy” and social sciences were called “moral philosophy”, nonempirical criteria operated as criteria for the criticism and acceptance of descriptive narratives. Even today some philosophers and scientists have used their semantical and ontological preconceptions as criteria for the criticism of scientific theories including preconceptions about causality or specific causal factors. Such semantical and ontological preconceptions have misled them to reject new empirically superior theories. In his *Against Method* Feyerabend noted that the ontological preconceptions used to criticize new theories have often been the semantical and ontological claims expressed by previously accepted theories.

But what historically has separated the empirical sciences from their origins in natural and moral philosophy is the empirical criterion, and it is responsible for the advancement of science and for its enabling practicality in application. Whenever in the history of science there has been a conflict between the empirical criterion and any nonempirical criteria for the evaluation of new theories, it is eventually the empirical criterion that ultimately decides theory selection.

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Contemporary pragmatists accept relativized semantics, scientific realism, and thus ontological relativity, and they therefore reject all prior semantical or ontological criteria for scientific criticism including the romantics' mentalistic ontology requiring social-psychological reductionism.

4.15 Logic of Empirical Testing

An empirical test is a decision procedure consisting of a *modus tollens* deduction from a set of one or several universally quantified theory statements expressible in a nontruth-functional hypothetical-conditional schema proposed for testing together with an antecedent particularly quantified description of the initial test conditions, which jointly conclude to a consequent particularly quantified description of a produced (predicted) test-outcome event that is compared with the observed test-outcome description.

In order to express explicitly the dependency of the produced effect upon the realized initial conditions in an empirical test, the universally quantified theory statements can be schematized as a nontruth-functional hypothetical-conditional statement, *i.e.*, as a statement with the logical form "For every A if A, then C." The hypothetical-conditional statement represents a system of one or several universally quantified related theory statements or equations that describe a dependency of the occurrence of an event described by "C" upon the occurrence of an event described by "A". The dependency may be expressed as the range of stochastic boundary limits for the values of predicted probabilities. For advocates who believe in the theory, the hypothetical-conditional statement is the theory-language context that contributes meaning parts to the complex semantics of the theory's constituent descriptive terms including the terms common to the theory and test design. But the theory's semantical contribution cannot be operative in the test for the test to be independent of the theory.

The antecedent "A" also includes the set of universally quantified statements of test design that describe the initial conditions that must be realized for execution of an empirical test of the theory together with the description of the procedures needed for their realization. These statements are always presumed to be true or the test design is rejected as invalid. They contribute meaning parts to the complex semantics of the terms common to theory and test design, and do so independently of the theory's semantical contributions. The universal logical quantification indicates that any

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execution of the experiment is but one of an indefinitely large number of possible test executions, whether or not the test is repeatable at will.

When the test is executed, the logical quantification of “A” is changed to particular quantification to describe the realized initial conditions in the individual test execution. In a mathematically expressed theory the test execution consists in measurement actions and assignment of the resulting measurement values to the variables in “A”. In a mathematically expressed single-equation theory, “A” includes the independent variables in the equation of the theory. In a multi-equation system whether recursively structured or simultaneous, the exogenous variables are assigned values by measurement, and are included in “A”. In longitudinal models with dated variables the lagged-values of endogenous variables that are the initial condition for a test and that initiate the recursion through successive iterations to generate predictions, must also be included in “A”.

The consequent “C” represents the set of universally quantified statements of the theory that describe the predicted outcome of every correct execution of a test design. Its logical quantification is changed to particular quantification to describe the predicted outcome in an individual test execution. In a mathematically expressed single-equation theory, “C” is the dependent variable in the equation of the theory. When no value is assigned to any variable, the equation is universally quantified. When the prediction value of a dependent variable is calculated from the measurement values of the independent variables, it becomes particularly quantified. In a multi-equation theory, whether recursively structured or a simultaneous-equation system, the solution values for the endogenous variables are included in “C”. In longitudinal models with dated variables the current-dated values of endogenous variables that are calculated by solving the model through successive iterations are included in “C”.

The conditional statement of theory does not say “For every A and for every C if A, then C”. It only says “For every A if A, then C”. In other words the conditional statement of theory only expresses a sufficient condition for the production of the phenomenon described by C upon realization of the test conditions given by “A”, and not a necessary condition. Alternative test designs described in “A” are sufficient to produce “C”. This may occur for example, if there are theories proposing alternative causal factors for the same outcome described in “C”. Or if there are equivalent measurement procedures or instruments described in “A” that produce alternative measurements falling within the range of their

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measurement errors, such that the errors are small relative to the predicted values described by “C”.

Let another particularly quantified statement denoted “O” describe the observed test outcome of an individual test execution. The report of the test outcome “O” shares vocabulary with the prediction statements “C”. But the semantics of the terms in “O” is determined exclusively by the universally quantified test-design statements rather than by the statements of the theory, and thus for the test its semantics is independent of the theory’s semantical contribution. In an individual predictive test execution “O” represents observations and/or measurements made and measurement values assigned after the prediction is made, and it too has particular logical quantification to describe the observed outcome resulting from the individual execution of the test. There are three outcome scenarios:

Scenario I: If “A” is false in an individual test execution, then regardless of the truth of “C” the test execution is simply invalid due to a scientist’s failure to comply with its test design, and the empirical adequacy of the theory remains unaffected and unknown. The empirical test is conclusive only if it is executed in accordance with its test design. Contrary to the logical positivists, the truth table for the truth-functional Russellian logic is therefore not applicable to testing in empirical science, because in science a false antecedent, “A”, does not make the hypothetical-conditional statement true by logic of the test.

Scenario II: If “A” is true and the consequent “C” is false, as when the theory conclusively makes erroneous predictions, then the theory is falsified, because the hypothetical conditional “For every A if A, then C” is false. Falsification occurs when the statements “C” and “O” are not accepted as describing the same thing within the range of vagueness and/or measurement error, which are manifestations of empirical underdetermination. The falsifying logic of the test is the *modus tollens* argument form, according to which the conditional-hypothetical statement expressing the theory is falsified, when one affirms the antecedent clause and denies the consequent clause. This is the falsificationist philosophy of scientific criticism advanced by Charles S. Peirce, the founder of pragmatism, and later advocated by Karl Popper. Readers seeking more on Popper are referred to **BOOK V** at www.philsci.com.

The response to a falsification may or may not be attempts to develop a new theory. Scientists will not simply deny a falsifying outcome of a test,

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if they have accepted its test design and test execution. Characterization of falsifying anomalous cases is informative, because it contributes to articulation of a new problem that a new and more empirically adequate theory must solve. Some scientists may, as Kuhn said, simply believe that the anomalous outcome is an unsolved problem for the tested theory without attempting to develop a new theory. But such a response is either an *ipso facto* rejection of the tested theory, a *de facto* rejection of the test design or a disengagement from attempts to solve the problem. And contrary to Kuhn this procrastinating response to anomaly need not imply that the falsified theory has been given institutional status, unless the science itself is institutionally retarded. Readers seeking more on Kuhn are referred to **BOOK VI** at www.philsci.com.

Scenario III: If “A” and “C” are both true, the hypothetical-conditional statement expressing the tested theory is validly accepted as asserting a causal dependency between the phenomena described by the antecedent and consequent clauses. The hypothetical-conditional statement does not merely assert a Humean constant conjunction. Causality is an ontological category describing a real dependency, and the causal claim is asserted on the basis of ontological relativity due to the empirical adequacy demonstrated by the nonfalsifying test outcome. Because the nontruth-functional hypothetical-conditional statement is empirical, causality claims are always subject to future testing, falsification, and then revision. This is also true when the conditional expresses a mathematical function.

Furthermore if the test design is modified such that it changes the characterization of the subject of the theory, then even a nonfalsifying test outcome should be reconsidered and the theory should be retested for the new definition of the subject. If the retesting produces a falsifying outcome, then the new information in the modification of the test design has made the terms common to the two test designs equivocal and has contributed parts to alternative meanings. But if the test outcome is not falsification, the new information is merely new parts added to the univocal meaning of the terms common to the old and new test-design language. Such would be the case if the new information were what the positivists called a new “operational definition”, as for example a new and additional way to measure temperature for extreme values that cannot be measured by the old operation, but which yields the same temperature values within the range of measurement errors, where the alternative operations produce overlapping results.

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On the contemporary pragmatist philosophy a theory that has been tested is no longer theory, once the test outcome is known and the test execution is accepted as correct. If it has been falsified, it is merely rejected language. But if it has been tested with a nonfalsifying test outcome, then it is empirically warranted and thus deemed a scientific law until it is tested again and falsified. The law is still hypothetical because it is empirical, but it is less hypothetical than it had been as a theory proposed for testing. The law may thereafter be used either in an explanation or in a test design for testing some other theory.

For example the elaborate engineering documentation for the Large Hadron Collider at CERN, the *Conseil Européen pour la Recherche Nucléaire*, is based on previously tested science. After installation of the Collider is complete, the science in that engineering is not what is tested when the particle accelerator is operated for the microphysical experiments, but rather is presumed true and contributes to the test design language for experiments performed with the accelerator.

4.16 Test Logic Illustrated

Consider the simple case of Gay-Lussac's law for a fixed amount of gas in an enclosed container as a theory proposed for testing. The container's volume is constant throughout the experimental test, and therefore is not represented by a variable. The theory is $(T'/T)*P = P'$, where the variable P means gas pressure, the variable T means the gas temperature, and the variables T' and P' are incremented values for T and P in a controlled experimental test, where $T' = T \pm \Delta T$, and P' is the predicted outcome that is produced by execution of the test design.

The statement of the theory may be schematized in the hypothetical-conditional form "For every A if A, then C", where "A" includes $(T'/T)*P$, and "C" states the calculated prediction value of P' , when temperature is incremented by ΔT from T to T' . The theory is universally quantified, and thus claims to be true for every execution of the experimental test. And for proponents of the theory, who are believers in the theory, the semantics of T , P , T' and P' are mutually contributing to the semantics of each other, a fact that could be made explicit in this case, because the equation is monotonic such that each variable can be expressed mathematically as a function of all the others by simple algebraic transformations.

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“A” also includes the test-design statements. These statements describe the experimental set up, the procedures for executing the test and initial conditions to be realized for execution of a test. They include description of the equipment used including the container, the heat source, the instrumentation used to measure the magnitudes of heat and pressure, and the units of measurement for the magnitudes involved, namely the pressure units in atmospheres and the temperature units in degrees Kelvin (K). And they describe the procedure for executing the repeatable experiment. This test-design language is also universally quantified and thus also contributes meaning components to the semantics of the variables **P**, **T** and **T'** in “A” for all interested scientists who accept the test design.

The procedure for performing the experiment must be executed as described in the test-design language, in order for the test to be valid. The procedure will include firstly measuring and recording the initial values of **T** and **P**. For example let **T** be 200°K and **P** be 1.6 atmospheres. Let the incremented measurement value be recorded as $\Delta T = 200^\circ\text{K}$, so that the measurement value for **T'** is made to be 400°K. The description of the execution of the procedure and the recorded magnitudes are expressed in particularly quantified test-design language for this particular test execution. The value of **P'** is then calculated.

The test outcome consists of measuring and recording the resulting observed incremented value for pressure. Let this outcome be represented by particularly quantified statement **O** using the same vocabulary as in the test design. Only the universally quantified test-design statements define the semantics of **O**, so that the test is independent of the theory. In this simple experiment one can simply denote the measured value for pressure by the variable **O**. The test execution would also likely be repeated to enable estimation of the range of measurement error in **T**, **T'**, **P** and **O**, and the error propagated into **P'**. A mean average of the measurement values from repeated executions would be calculated for each of these variables. Deviations from the mean are estimates of the amounts of measurement error, and statistical standard deviations could summarize the dispersion of measurement errors about the mean averages.

The mean average of the test-outcome measurements for **O** is compared to the mean average of the predicted measurements for **P'** to determine the test outcome. If the values of **P'** and **O** are within the estimated ranges of measurement error, *i.e.*, are sufficiently close to 3.2 atmospheres as to be within the measurement errors, then the theory is

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deemed not to have been falsified. After repetitions with more extreme incremented values with no falsifying outcome, the theory will likely be deemed sufficiently warranted empirically to be called a law, as it is today.

4.17 Semantics of Empirical Testing

Much has already been said about the artifactual character of semantics, about componential semantics, and about semantical rules. In the semantical discussion that follows these concepts are brought to bear upon the discussion of empirical testing and test outcomes.

If a test has a nonfalsifying outcome, then the semantics of the tested theory is unchanged for the theory's developer and advocates. Since they had proposed the theory in the belief that it would not be falsified, their belief in the theory makes it function for them as a set of semantical rules. Thus for them both the theory and the test design are accepted as true, and after the nonfalsifying test outcome both sets of statements continue to contribute parts to the complex meanings of the descriptive terms common to both theory and test design, as before the test.

But when the test outcome is a falsification, there is a semantical change produced in the theory for the developer and advocates of the tested theory who accept the test outcome as a falsification. The unchallenged test-design statements continue to contribute semantics to the terms common to the theory and test design by contributing their parts to the meaning complexes of each of the common terms. But the component parts of those meanings contributed by the falsified theory statements are excluded from the semantics of those common terms for the proponents who no longer believe in the theory due to the falsifying test outcome.

4.18 Test Design Revision

Empirical tests are conclusive decision procedures only for scientists who agree on which language is proposed theory and which language is presumed test design, and who furthermore accept both the test design and the test-execution outcomes produced with the accepted test design.

The decidability of empirical testing is not absolute. Popper had recognized that the statements reporting the observed test outcome, which he called "basic statements", require prior agreement by the cognizant

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scientists, and that those basic statements are subject to future reconsideration.

Theory language is relatively more hypothetical than test-design language, because the interested scientists agree that in the event of a falsifying test outcome, revision of the theory will likely be more productive than revision of the test-design language.

For the scientist who does not accept a falsifying test outcome of a theory, a different semantical change is produced than if he had accepted the test outcome as a falsification. Such a dissenting scientist has either rejected the report of the observed test outcome or reconsidered the test design. If he rejects the outcome of the individual test execution, he has merely questioned whether or not the test was executed in compliance with its agreed test design. Repetition of the test with greater fidelity to the design may answer such a challenge to the test's validity one way or the other.

But if in response to a falsifying test outcome the dissenting scientist has reconsidered the test design itself, then he has thereby changed the semantics involved in the test in a fundamental way. Reconsideration of the test design amounts to rejecting the test design as if it were falsified, and letting the theory define the subject of the test and the problem under investigation – a rôle reversal in the pragmatics of test-design language and theory language. Then the theory's semantics characterizes the problem for the dissenter, and the test design is effectively falsified, because it is deemed inadequate thus making the test design and the test execution irrelevant.

If a scientist rejects a test design in response to a falsifying test outcome, he has made the theory's semantics define the subject of the test and the problem under investigation.

Popper rejects such a dissenting response to a test, calling it a "content-decreasing stratagem". He admonishes that the fundamental maxim of every critical discussion is that one should "stick to the problem". But as James Conant recognized to his dismay in his *On Understanding Science: An Historical Approach* the history of science is replete with such prejudicial responses to scientific evidence that have nevertheless been productive and strategic to the advancement of basic science in historically important episodes. The prejudicially dissenting scientists may decide that the design for the falsifying test supplied an inadequate description of the problem that the tested theory is intended to solve, often if he developed the

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theory himself and did not develop the test design. The semantical change produced for such a recalcitrant believer in the theory affects the meanings of the terms common to the theory and test-design statements. The parts of the meaning complex contributed by the test-design statements are then the parts excluded from the semantics of one or several of the descriptive terms common to the theory and test-design statements. Such a semantical outcome for a tested theory can indeed be said to be “content-decreasing”, as Popper said.

But a scientist’s prejudiced or tenacious rejection of an apparently falsifying test outcome may have a contributing function in the development of science. It may function as what Paul Feyerabend called a “detecting device”, a practice he called “**counterinduction**”, which is a discovery strategy that he illustrated in his examination of Galileo’s arguments for the Copernican cosmology. Galileo used the apparently falsified heliocentric theory as a “detecting device” by letting his prejudicial belief in the heliocentric theory control the semantics of observational description. This enabled Galileo to reinterpret observations previously described with the equally prejudiced alternative semantics built into the Aristotelian geocentric cosmology. Counterinduction was also the strategy used by Heisenberg, when he reinterpreted the observational description of the electron track in the Wilson cloud chamber using Einstein’s thesis that the theory decides what the physicist can observe, and he then developed his indeterminacy relations using quantum concepts.

Another historic example of using an apparently falsified theory as a detecting device is the discovery of the planet Neptune. In 1821, when Uranus happened to pass Neptune in its orbit – an alignment that had not occurred since 1649 and was not to occur again until 1993 – Alexis Bouvard developed calculations predicting future positions of the planet Uranus using Newton’s celestial mechanics. But observations of Uranus showed significant deviations from the predicted positions.

A first possible response would have been to dismiss the deviations as measurement errors and preserve belief in Newton’s celestial mechanics. But astronomical measurements are repeatable, and the deviations were large enough that they were not dismissed as observational errors. They were recognized to be a new problem.

A second possible response would have been to give Newton’s celestial mechanics the hypothetical status of a theory, to view Newton’s law

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of gravitation as falsified by the anomalous observations of Uranus, and then attempt to revise Newtonian celestial mechanics. But by then confidence in Newtonian celestial mechanics was very high, and no alternative to Newton's physics had been proposed. Therefore there was great reluctance to reject Newtonian physics.

A third possible response, which was historically taken, was to preserve belief in the Newtonian celestial mechanics, propose a new auxiliary hypothesis of a gravitationally disturbing phenomenon, and then reinterpret the observations by supplementing the description of the deviations using the auxiliary hypothesis of the disturbing phenomenon. Disturbing phenomena can "contaminate" even supposedly controlled laboratory experiments. The auxiliary hypothesis changed the semantics of the test-design description with respect to what was observed. In 1845 both John Couch Adams in England and Urbain Le Verrier in France independently using apparently falsified Newtonian physics as a **detecting device** made calculations of the positions of a disturbing postulated planet to guide future observations in order **to detect** the postulated disturbing body. In September 1846 using Le Verrier's calculations Johann Galle observed the postulated planet with the telescope at the Berlin Observatory.

Theory is language proposed for testing, and test design is language presumed for testing. But here the status of the discourses was reversed. In this third response the Newtonian gravitation law was not deemed a tested and falsified theory, but rather was presumed to be true and used for a new test design. The new test-design language was actually given the relatively more hypothetical status of theory by supplementing it with the auxiliary hypothesis of the postulated planet characterizing the observed deviations in the positions of Uranus. The nonfalsifying test outcome of this new hypothesis was Galle's observational **detection** of the postulated planet, which Le Verrier named Neptune.

But counterinduction is after all just a discovery **strategy**, and Le Verrier's counterinduction effort failed to explain a deviant motion of the planet Mercury when its orbit comes closest to the sun, a deviation known as its perihelion precession. He presumed to postulate a gravitationally disturbing planet that he named Vulcan and predicted its orbital positions in 1843. But unlike Le Verrier and most physicists at the time, Einstein had given Newton's celestial mechanics the hypothetical status of theory language, and he viewed Newton's law of gravitation as falsified by the anomalous perihelion precession. He had initially attempted a revision of

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Newtonian celestial mechanics by generalizing on his special theory of relativity. This first attempt is known as his *Entwurf* version, which he developed in 1913 in collaboration with his mathematician friend Marcel Grossman. But working in collaboration with his friend Michele Besso he found that the *Entwurf* version had clearly failed to account accurately for Mercury's orbital deviations; it showed only 18 seconds of arc each century instead of the actual 43 seconds.

In 1915 he finally abandoned the *Entwurf* version with its intuitive physical ideas carried over from Newton's theory, and under prodding from the mathematician David Hilbert turned to mathematics exclusively to produce his general theory of relativity. He then developed his general theory, and in November 1915 he correctly predicted the deviations in Mercury's orbit. He received a congratulating letter from Hilbert on "conquering" the perihelion motion of Mercury. After years of delay due to World War I his general theory was vindicated by Arthur Eddington's famous eclipse test of 1919. Some astronomers reported that they observed a transit of a planet across the sun's disk, but these claims were found to be spurious when larger telescopes were used, and Le Verrier's postulated planet Vulcan has never been observed.

Le Verrier's response to Uranus' deviant orbital observations was the opposite to Einstein's response to the deviant orbital observations of Mercury. Le Verrier reversed the roles of theory and test-design language by preserving his belief in Newton's physics and using it to revise the test-design language with his postulate of a disturbing planet. Einstein viewed Newton's celestial mechanics to be hypothetical, because he believed that the theory statements were more likely to be productively revised than the test-design statements, and he took the deviant orbital observations of Mercury to be falsifying, thus indicating that revision was needed. Empirical tests are conclusive decision procedures only for scientists who agree on which language is proposed theory and which is presumed test design, and who furthermore accept both the test design and the test-execution outcomes produced with the accepted test design.

Finally **there can be cases of test design revision other than those that occasion counterinduction.** A new observational technique or instrumentality due to developments in what Feyerabend called "auxiliary sciences" may occasion a falsifying test outcome of a theory due to a reduction in empirical underdetermination (See below Sec. 4.19) in the new test design, *e.g.*, development of a superior microscope or telescope. In such

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a case the newly falsified theory had previously been a law due to earlier empirical testing that had a nonfalsifying outcome. In such a case there is no role reversal between theory and test design. Rather a law simply reverts to its earlier more hypothetical status as a theory due to the new test design.

4.19 Empirical Underdetermination

Vagueness and measurement error are manifestations of empirical underdetermination that permit scientific pluralism.

Empirical underdetermination can be reduced indefinitely but never completely eliminated.

Empirical tests are conclusive only when empirical underdetermination is small relative to the effect predicted in a test.

The empirical underdetermination of language may make empirical criteria incapable of producing decisive theory-testing outcomes. Two manifestations of empirical underdetermination are conceptual vagueness and measurement error. All concepts have vagueness that can be reduced indefinitely but can never be eliminated completely. Mathematically expressed theories use measurement data that always contain measurement inaccuracy. Measurement error can be reduced indefinitely but never eliminated completely.

Scientists prefer measurements and mathematically expressed theories, because they can measure the amount of prediction error in the theory, when the theory is tested. But separating measurement error from a theory's prediction error can be problematic. Repeated careful execution of the measurement procedure, if the test is repeatable, enables statistical estimation of the degree or range of measurement error. A test is conclusive to the extent that the estimated measurement error is manifestly small relative to the produced effect in the test. But as in economics, repeated measurement is not always possible.

4.20 Scientific Pluralism

Scientific pluralism is recognition of the coexistence of empirically adequate alternative explanations due to undecidability permitted by the empirical undetermination in test-design language.

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All language is always empirically underdetermined by reality. Empirical underdetermination explains how two or more semantically alternative empirically adequate theories can have the same test-design language. This means that there are several theories yielding accurate predictions that are alternatives to one another, while having differences that are small enough to be within the range of the estimated measurement error. In such cases empirical underdetermination due to the current test design imposes undecidability on the choice among the alternative explanations.

Econometricians are accustomed to alternative empirically adequate econometric models. This occurs because measurement errors in aggregate social statistics are large in comparison to those in natural sciences. Each such model has different equation specifications, i.e., different causal variables, and makes different forecasts for some of the same prediction variables that are accurate within the relatively large range of estimated measurement error. And discovery systems with empirical test procedures routinely proliferate empirically adequate alternative theories for output. They produce what Einstein called “an embarrassment of riches”. Logically this multiplicity of alternative theories means that there may be alternative empirically warranted nontruth-functional hypothetical conditional statements in the form “For all A if A, then C” having alternative antecedents “A” and making different but empirically adequate predictions that are the empirically indistinguishable consequents “C”.

Empirical underdetermination is also manifested as conceptual vagueness. For example to develop his three laws of planetary motion Johannes Kepler, a heliocentrist, used the measurement observations of Mars that had been collected by Tycho Brahe, a type of geocentrist. Brahe had an awkward geocentric-heliocentric cosmology, in which the fixed earth is the center of the universe, the stars and the sun revolve around the earth, and the other planets revolve around the sun. But Kepler used Brahe’s astronomical measurement data, so measurement error was not the operative underdetermination permitting the alternative cosmologies. But Kepler was a convinced Copernican placing the sun at the center of the universe.

Kepler’s belief in the Copernican heliocentric cosmology made the semantic parts contributed by that heliocentric cosmology become for him component parts of the semantics of the language used for celestial observation, thus displacing Brahe’s complicated combined geocentric-heliocentric cosmology’s semantical contribution. Then hypothesizing with the simpler Copernican heliocentrism’s clarifying contributions to the

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observational celestial semantics, he developed his three laws after deciding that the orbit is elliptical.

Alternative empirically adequate theories due to empirical underdetermination are all more or less true. An answer as to which theory is truer must await further development of additional observational information or measurements that clarify the empirically inadequate test-design concepts. But there is never any ideal test design with “complete” information, i.e., with no vagueness or no measurement error. Pragmatist recognition of possible undecidability among alternative empirically adequate scientific explanations due to unavoidable empirical underdetermination is called the thesis of “scientific pluralism”.

4.21 Scientific Truth

Truth and falsehood are properties of statements, and admit to more or less.

Tested and nonfalsified statements are more empirically adequate, have more realistic ontologies, and have more truth than falsified ones. Falsified statements have recognized error, and may simply be rejected unless they are still useful for their lesser realism and lesser truth.

What is truth! Truth is a property of descriptive language with its relativized semantics and ontology. It is not merely a subjective expression of approval.

Belief and truth are not identical. Belief is acceptance of a statement as true. But one may wrongly believe that a false statement is true, or wrongly believe that a true statement is false. Belief controls the semantics of the descriptive terms in universally quantified statements. Truth is the relation of a statement’s semantics to nonlinguistic reality. Furthermore as Jarrett Leplin maintains in his *Defense of Scientific Realism*, truth and falsehood are properties of statements that admit to **more or less**; they are not simply dichotomous, as they are represented in two-valued formal logic.

Test-design language is presumed true with definitional force for the semantics of the test-design language, in order to identify the subject of the test. Theory language in an empirical test may be believed true by the developer and advocates of the theory, but the theory is not true simply by

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virtue of their belief. Belief in an untested theory is speculation about a future test outcome. A nonfalsifying test outcome will warrant belief that the tested theory is as true as the theory's demonstrated empirical adequacy. Empirically falsified theories have recognized error, and may be rejected unless they are still useful for their lesser realism and lesser truth. Tested and nonfalsified statements are more empirically adequate, have ontologies that are more realistic, and thus are truer than empirically falsified statements.

Popper said that Eddington's historic eclipse test of Einstein's theory of gravitation in 1919 "falsified" Newton's theory and thus "corroborated" Einstein's theory. Yet the U.S. National Aeronautics and Space Administration (NASA) today uses Newton's laws to navigate interplanetary rocket flights such as the *Voyager* missions. Thus Newton's "falsified" theory is not completely false or it could never have been used before or after Einstein. Popper said that science does not attain truth. But contemporary pragmatists believe that such an absolutist idea of truth is misconceived. Advancement in empirical adequacy is advancement in realism and in truth. Feyerabend said, "Anything goes". Regarding ontology Hickey says, "Everything goes", because while not all discourses are equally valid, there is no semantics utterly devoid of ontological significance. Therefore he adds that the more empirically adequate tested theory goes farther – is truer and more realistic – than its less empirically adequate falsified alternatives. Empirical science progresses in truth and in realism.

4.22 Nonempirical Criteria

Given the fact of scientific pluralism – of having several alternative explanations that are tested and not falsified due to empirical underdetermination in the test-design language – **philosophers have proposed various nonempirical criteria they believe have been operative historically in explanation choice.** And a plurality of untested and therefore unfalsified theories may also exist before any testing, so that scientists may have preferences for testing one theory over another based on nonempirical criteria. **But no nonempirical criterion enables a scientist to predict reliably which alternative nonfalsified explanation will survive empirical testing, when in due course the degree of empirical underdetermination is reduced by a new or improved test design that enables decidable testing.** To make such an anticipatory choice is like betting on a horse before it runs the race.

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Test designs are improved by developing more accurate measurement procedures and/or by adding new descriptive information that reduces the vagueness in the characterization of the subject for testing. Such test-design improvements refine the characterization of the problem addressed by the theories, and thus reduce empirical underdetermination to make testing decisive.

When empirical underdetermination makes testing undecidable among alternative theories, different scientists may have personal reasons for preferring one alternative as an explanation. In such circumstances selection may be an investment decision for the career scientist rather than an investigative decision. The choice may be influenced by such circumstances as the cynical realpolitik of peer-reviewed journals. Knowing what editors and their favorite referees currently want in submissions greatly helps an author getting his paper published. Publication is an academic status symbol with the more prestigious journals yielding more brownie points for accumulating academic tenure, status and salary.

In the January 1978 issue of the *Journal of the American Society of Information Science* (JASIS) the editor wrote that referees sometimes use the peer review process as a means to attack a point of view and to suppress the content of a submitted paper, *i.e.*, they attempt censorship. Furthermore editors are not typically entrepreneurial; they are the risk-avoiding rearguard rather than the risk-taking avant-garde. They select the established “authorities” with reputation-based vested interests in the prevailing traditional views, and these “authorities” suborn the peer-review process by using their personal views as criteria for criticism and thus acceptance for publication.

External sociocultural factors have also influenced theory choice. In his *Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (1957) Kuhn wrote that the astronomer in the time of Copernicus could not upset the two-sphere universe without overturning physics and religion as well. Fundamental concepts in the pre-Copernican astronomy had become strands for a much larger fabric of thought, and the nonastronomical strands in turn bound the thinking of the astronomers. The Copernican revolution occurred because Copernicus was a dedicated specialist, who valued mathematical and celestial detail more than the values reinforced by the nonastronomical views that were dependent on the prevailing two-sphere theory. This purely technical focus of Copernicus enabled him to ignore the nonastronomical consequences of his innovation,

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consequences that would lead his contemporaries of less restricted vision to reject his innovation as absurd.

Later in discussing modern science in his famous *Structure of Scientific Revolutions* Kuhn does not make the consequences to the nonspecialist an aspect of his general theory of scientific revolutions. Instead he maintains, as part of his thesis of “normal” science that a scientist may willfully choose to ignore a falsifying outcome of a decisive test execution. This choice is not due to the scientist’s specific criticism of either the test design or the test execution, but rather is due to the expectation that the falsified theory will later be improved and corrected. However any such “correcting” alteration made to a falsified theory amounts to theory elaboration, which produces a new and different theory.

Similarly sociology and politics operate as criteria today in the social sciences, where defenders and attackers of different economic views are in fact defending and attacking certain social/political philosophies, ideologies, interests and policies. For example in the United States Republican politicians attack Keynesian economics, while Democrat politicians defend it. But pragmatism has prevailed over ideology, when expediency dictates, as during the 2007-2009 Great Recession crisis. Thus in his *After the Music Stopped* Alan S. Blinder, Princeton University economist and former Vice Chairman of the Federal Reserve Board of Governors, reports that ultraconservative Republican President Bush “let pragmatism trump ideology” (P. 213), when he signed the Economic Stimulus Act of 2008, a distinctively Keynesian fiscal policy, which added \$150 billions to the U.S. Federal debt.

In contrast Democrat President Obama without reluctance and with a Democrat-controlled Congress signed the American Reinvestment and Recovery Act in 2009, a stimulus package that added \$787 billions to the Federal debt. Blinder reports that simulations with the Moody Analytics large macroeconomic model showed that the effect of the stimulus in contrast to a no-stimulus simulation scenario was a GDP that was 6 per cent higher with the stimulus than without it, an unemployment rate 3 percentage points lower, and 4.8 million additional Americans employed (P. 209). Nonetheless as former Federal Reserve Board Chairman Ben Bernanke wrote in his memoir *The Courage to Act*, the stimulus was small in comparison with its objective of helping to arrest the deepest recession in seventy years in a \$15 trillion national economy (P. 388). Thus Bernanke, a conservative Republican, did not reject Keynesianism, but concluded that

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the recovery was needlessly slow and protracted, because the stimulus program was too small.

Citing Kuhn some sociologists of knowledge including those advocating the “strong program” maintain that the social and political forces that influence society at large also influence scientific beliefs. This is truer in the social sciences, but sociologists who believe that this means that empiricism does not control acceptance of scientific beliefs in the long term are mistaken, because it is pragmatic empiricism that enables wartime victories, peacetime prosperity – and in all times business profits, as reactionary policies, delusional ideologies and utopian fantasies cannot.

4.23 The “Best Explanation” Criteria

As noted above Thagard’s cognitive-psychology system **ECHO** developed specifically for theory selection has identified three nonempirical criteria to maximize the coherence aim. **His simulations of past episodes in the history of science indicate that the most important criterion is breadth of explanation, followed by simplicity of explanation, and finally analogy with previously accepted theories.** Thagard considers these nonempirical selection criteria as productive of a “best explanation”.

The breadth-of-explanation criterion also suggests Popper’s aim of maximizing information content. In any case there have been successful theories in the history of science, such as Heisenberg’s matrix mechanics and uncertainty relations, for which none of these three characteristics were operative in the acceptance as explanations. And as Feyerabend noted in *Against Method* in criticizing Popper’s view, Aristotelian dynamics is a general theory of change comprising locomotion, qualitative change, generation and corruption, while Galileo and his successors’ dynamics pertains exclusively to locomotion. Aristotle’s explanations therefore may be said to have greater breadth, but his physics is now known to be less empirically adequate.

Contemporary pragmatists acknowledge **only** the empirical criterion, the criterion of superior empirical adequacy. They exclude all nonempirical criteria from the aim of science, because while relevant to persuasion to make theories appear “convincing”, they are irrelevant to evidence. Nonempirical criteria are like the psychological criteria that trial lawyers use to select and persuade juries in order to win lawsuits in a court of law, but which are irrelevant to courtroom evidence rules for determining the facts of

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a case. Such prosecutorial lawyers are like the editors and referees of the peer-reviewed academic literature (sometimes called the “court of science”) who ignore the empirical evidence described in a paper submitted for publication.

But nonempirical criteria are routinely operative in the selection of **problems** to be addressed and explained. For example the American Economic Association’s *Index of Economic Journals* indicates that in the years of the Great Depression the number of journal articles concerning the trade cycle fluctuated in close correlation with the national average unemployment rate with a lag of two years.

4.24 Nonempirical Linguistic Constraints

The empirical constraint is the institutionalized value that regulates theory acceptance or rejection.

The constraint imposed upon theorizing by empirical test outcomes is the empirical constraint, the criterion of superior empirical adequacy. **It is a regulating institutionalized cultural value definitive of modern empirical science that is not viewed as an obstacle to be overcome, but rather as a condition to be respected for the advancement of science toward its aim.**

There are other kinds of constraints that are nonempirical and are retarding impediments that must be overcome for the advancement of science, and that are internal to science in the sense that they are inherent in the nature of language. They are the **cognition** and **communication** constraints.

4.25 Cognition Constraint

The semantics of every descriptive term is determined by its linguistic context consisting of universally quantified statements believed to be true.

Conversely given the conventionalized meaning for a descriptive term, certain beliefs determining the meaning of the term are reinforced by habitual linguistic fluency with the result that the meaning’s conventionality constrains change in those defining beliefs.

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The conventionalized meanings for descriptive terms thus produce the cognition constraint, which inhibits construction of new theories, and is manifested as lack of imagination, creativity or ingenuity.

In his *Course in General Linguistics* (1916) Ferdinand de Saussure, the founder of semiology, maintained that spoken language is an institution, and that of all social institutions it is the least amenable to initiative. He called one of the several sources of resistance to linguistic change the “collective inertia toward innovation”.

In his *Concept of the Positron* (1963) Hanson similarly identified this impediment to discovery and called it the “conceptual constraint”. He reports that physicists’ erroneous identification of the concept of the particle with the concept of its charge was an impediment to recognizing the positron. The electron was identified with a negative charge and the much more massive proton was identified with a positive charge, so that the positron as a particle with the mass of an electron and a positive charge was not recognized without difficulty and delay.

In his *Introduction to Metascience* (1976) Hickey referred to what he called the “cognition constraint”. The cognition constraint inhibits construction of new theories, and is manifested as lack of imagination, creativity or ingenuity. Semantical rules are not just rules. They are also strong linguistic habits with subconscious roots that enable prereflective competence and fluency in both thought and speech, and that make meaning a synthetic psychological experience. Given a conventionalized belief or firm conviction expressible as a universally quantified affirmative statement, the predicate in that affirmation contributes meaning part(s) to the meaning complex of the statement’s subject term. Not only does the conventionalized status of meanings make development of new theories difficult, but also any new theory construction requires greater or lesser semantical dissolution and restructuring.

The cognition-constraint thesis is opposed to the neutral-language thesis that language is merely a passive instrument for expressing thought. Language is not merely passive but rather has a formative influence on thought. The formative influence of language as the “shaper of meaning” has been recognized as the Sapir-Whorf hypothesis and specifically by Benjamin Lee Whorf’s principle of linguistic relativity set forth in his “Science and Linguistics” (1940) reprinted in *Language, Thought and*

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Reality. But contrary to Whorf it is not just the grammatical system that determines semantics, but rather what Quine called the “web of belief”, the shared belief system as found in a dictionary.

Accordingly the more revolutionary the revision of beliefs, the more constraining are both the semantical structure and psychological conditioning on the creativity of the scientist who would develop a new theory, because revolutionary theory development requires relatively more extensive semantical dissolution and restructuring. However, use of computerized discovery systems circumvents the cognition constraint, because the machines have no linguistic-psychological habits. Their mindless electronic execution of mechanized procedures is one of their virtues.

Readers wishing to know more about the linguistic theory of Whorf are referred to **BOOK VI** in www.philsci.com.

4.26 Communication Constraint

The communication constraint is the impediment to understanding a theory that is new relative to those currently conventional.

The communication constraint has the same origins as the cognition constraint. It is the semantical impediment to understanding a new theory relative to those currently accepted and thus currently conventional. This impediment is both cognitive and psychological. The scientist must cognitively learn the new theory well enough to restructure the composite meaning complexes associated with the descriptive terms common both to the old theory that he knows and to the new theory to which he has just been exposed. And this involves overcoming existing psychological habit that enables linguistic fluency, which reinforces existing beliefs.

This learning process suggests the conversion experience described by Kuhn in revolutionary transitional episodes, because the new theory must firstly be accepted as true however provisionally for its semantics to be understood, since only statements believed to be true can operate as semantical rules that convey understanding. If testing demonstrates the new theory’s superior empirical adequacy, then the new theory’s pragmatic acceptance should eventually make it the established conventional wisdom.

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But if the differences between the old and new theories are very great, some members of the affected scientific profession may not accomplish the required learning adjustment. People usually prefer to live in an orderly world, but innovation creates disorder. In reaction the slow learners and nonlearners become a rearguard that clings to the received conventional wisdom, which is being challenged by the new theory at the frontier of research, where there is much conflict that produces confusion due to semantic dissolution and consequent restructuring of the web of belief.

Since the conventional view has had time to be developed into a more elaborate system of ideas, those unable to cope with the semantic dissolution produced by the newly emergent ideas take refuge in the psychological comfort of coherence provided by the more elaborate conventional wisdom, which assumes the nature of an ideology if not a theology. In the meanwhile the developers of the new ideas together with the more opportunistic and typically younger advocates of the new theory, who have been motivated to master the new theory's language in order to exploit its perceived career promise, assume the avant-garde rôle and become a vanguard.

1970 Nobel-laureate economist Paul Samuelson wrote in his *Keynes General Theory: Reports of Three Decades* (1964) that Keynes' theory had caught most economists under the age of thirty-five with the unexpected virulence of a disease first attacking and then decimating an isolated tribe of South Sea islanders, while older economists were immune.

Note that contrary to Kuhn and especially to Feyerabend the transition does not involve a complete semantic discontinuity much less any semantic incommensurability. And it is unnecessary to learn the new theory as though it were a completely foreign language. For the terms common to the new and old theories, the component parts contributed by the new theory replace those from the old theory, while the parts contributed by the test-design statements remain unaffected. Thus the test-design language component parts shared by both theories enable characterization of the subject of both theories independently of the distinctive claims of either, and thereby enable decisive testing. The shared semantics in the test-design language also facilitates learning and understanding the new theory, however radical the new theory may be.

It may also be noted that the **scientist viewing the computerized discovery system output experiences the same communication impediment with the machine output that he would were the outputted**

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theories developed by a fellow human scientist. New theories developed mechanically are grist for Luddites' mindless rejection mills.

In summary both the cognition constraint and the communication constraint are based on the reciprocal relation between semantics and belief, such that given the conventionalized meaning for a descriptive term, certain beliefs determining the meaning of the term are reinforced by psychological habit that enables linguistic fluency. The result is that the meaning's conventionality impedes change in those defining beliefs.

The communication constraint is a general linguistic phenomenon and not limited to the language of science. It applies to philosophy as well. Thus many philosophers of science who received their education before 1970 or whose education was otherwise retarded are unsympathetic to the reconceptualization of familiar terms such as "theory" and "law" that are carried forward into contemporary pragmatism. They are dismayed by the semantic dissolution resulting from the rejection of the old positivist beliefs. For example Hickey remembers hearing a Notre Dame University professor tell his philosophy-of-science class when contemporary pragmatism was emerging in the 1960's, "Now everything is messy." That culturally retarded professor advocated positivist operational definitions to the end of his teaching career.

4.27 Scientific Explanation

A scientific explanation is a discourse consisting of a set of one or several related universally quantified law statements expressible jointly in a nontruth-functional hypothetical-conditional schema together with particularly quantified antecedent description of realized initial conditions, which together conclude by *modus ponens* deduction to a particularly quantified description of the consequent occurrence of the explained event.

Explanation is the ultimate aim of basic science. There are other types such as the historical explanation, but history is not a science, although it may use science, as in economic history. But only explanation in basic science is of interest in philosophy of science. When some course of action is taken in response to an explanation such as a social policy, a medical therapy or an engineered product or structure, the explanation is used as applied science. Applied science does not occasion a change in an

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explanation like basic science, unless there is a failure in spite of conscientious and competent implementation of the relevant laws.

Since a theory in an empirical test is proposed for an explanation, the logical form of the explanation in basic science is the same as that of the empirical test. The universally quantified statements constituting a system of one or several related scientific laws in an explanation can be schematized as a nontruth-functional hypothetical-conditional statement in the logical form “For every A if A, then C”. But while the logical form is the same for both testing and explanation, the deductive argument is not the same.

The deductive argument of the explanation is the *modus ponens* argument instead of the *modus tollens* logic used for testing. In the *modus tollens* argument the hypothetical-conditional statement expressing the proposed theory is falsified, when the antecedent clause is true and the consequent clause is false. On the other hand in the *modus ponens* argument for explanation both the antecedent clause describing initial conditions and the hypothetical-conditional statement having law status are accepted as true, such that affirmation of the antecedent clause validly concludes to affirmation of the consequent clause describing the explained phenomenon.

Thus the schematic form of an explanation is “For every A if A, then C” is true. “A” is true. Therefore “C” is true (and explained). The conditional statement “For every A if A, then C” represents a set of one or several related universally quantified law statements applying to all instances of “A” and to all consequent instances of “C”. “A” is the set of one or several particularly quantified statements describing the realized initial conditions that cause the occurrence of the explained phenomenon as in a test. “C” is the set of one or several particularly quantified statements describing the explained individual consequent effect, which whenever possible is a prediction.

In the explanation the statements in the hypothetical-conditional schema express scientific laws accepted as true due to their empirical adequacy as demonstrated by nonfalsifying test outcomes. These together with the antecedent statements describing the initial conditions in the explanation constitute the explaining language some call the *explanans*. And they call the logically consequent language, which describes the explained consequent phenomenon, the *explanandum*.

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It has also been said that theories “explain” laws. Neither untested nor falsified theories occur in a scientific explanation. Explanations consist of laws, which are formerly theories that have been tested with nonfalsifying outcomes. Proposed explanations are merely untested theories. Since all the universally quantified statements in the nontruth-functional hypothetical-conditional schema of an explanation are laws, the “explaining” of laws means that a system of logically related laws forms a deductive system partitioned into dichotomous subsets of explaining antecedent axioms and explained consequent theorems.

Integrating laws into axiomatic systems confers psychological satisfaction by contributing semantical coherence. Influenced by Newton’s physics many positivists had believed that producing reductionist axiomatic systems is part of the aim of science. The belief is integral to the Vienna Circle’s unity-of-science agenda. But the reductionist preconception is not validated by the history of science. Great developmental episodes in the history of science have had the opposite effect of fragmenting science. And while the fragmentation has incurred the communication constraint and occasioned opposition to the new discoveries, it has delayed but did not halt the advancement of science in its history. Eventually pragmatic empiricism prevails.

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