

Philosophy of Science

An Introduction

Eighth Edition

Thomas J. Hickey

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Eighth Edition

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Abstract

This concise and accessible book is a synthesis of the basic principles of the contemporary realistic neopragmatist philosophy of science. It discusses the aim of basic science, the methods of scientific discovery, the criteria for scientific criticism, and the nature of scientific explanation. Included is a description of a newly emergent specialty called computational philosophy of science, in which computerized discovery systems create and test new scientific theories.

It also examines the essentials of the underlying realistic neopragmatist philosophy of language that has made philosophy of science a coherent and analytical discipline, and that has given new meaning to such key terms as "theory", "observation" and "explanation".

Preface

This book sets forth the elementary principles of the contemporary realistic neopragmatist philosophy of science including its underlying realistic neopragmatist philosophy of language, and it briefly describes the new and emerging area of computational philosophy of science. Many of the innovations in this book are made to accommodate computational philosophy of science. Computational philosophy of science is not something outside of philosophy of science; it is twenty-first century philosophy of science. However, for many staid academics it is a shocking "disenchantment" (to use Weber's phrase) of philosophy. Yet notwithstanding latter-day Luddite obstructionism artificial intelligence in philosophy of science is here to stay.

In his magisterial *Types of Economic Theory* (1967) Wesley Clair Mitchell (1874-1948), Columbia University American Institutionalist economist and founder of the prestigious National Bureau of Economic Research wrote that the process that constitutes the development of the social sciences is an incessant interaction between logically arranged ideas and chronologically arranged events. Since empirical science is an evolving cultural institution with a developmental history and a future, this memorable Institutionalist refrain can be adapted for philosophy of science: The process that constitutes the development of philosophy of basic science is an episodic interaction between logically arranged analyses in philosophy and chronologically arranged developments in science. Modern philosophy was forged in response to the historic Scientific Revolution commencing with Nicolaus Copernicus (1473-1543) and completed by Isaac Newton (1642-1727). <u>Modern-era philosophy of science is descended from Newton.</u>

With the demise of positivism, there has been an institutional change in philosophy of science. The institution-changing developmental episodes in science that produced the contemporary realistic neopragmatist philosophy of language are the scientific revolutions created by Albert Einstein (1879-1955) and especially by Werner Heisenberg (1901-1976). These revolutionaries produced an explosive chain reaction in philosophy as well as in physics. <u>Postmodern</u>-era philosophy of science is descended from Heisenberg.

The Harvard University realistic neopragmatist philosopher Willard van Quine (1908-2000) once said that there are two kinds of philosophers: Those who write philosophy and those who write history of philosophy. And worst of all there are those who are not authors, but are merely editors of anthologies and journals containing other writers' works. Most books on philosophy of science treat philosophy of science in an anecdotal historical perspective. Of course I am indebted to many earlier writers, whom I reference herein. But this book is not a history of philosophy; it is a work in systematic philosophy – a coherent and synthetic exposition of the contemporary ascendant realistic neopragmatist philosophy of science. Nor is this book a survey of the great variety of ideas that philosophers have advanced about science. Such a work would be an encyclopedia, and in most cases irrelevant to today's realistic neopragmatism.

Both during and before the modernist era the aim of philosophy of science was typically viewed in terms of justifying the claim to a superior epistemic status of empirical science. Today few philosophers of science perceive any imperative for such justification of science, and often dismiss such efforts as merely pedantic exercises. Now the aim of philosophy of science is seen to characterize the practices and criteria that have made the empirical sciences so unquestionably successful. As stated below in the first chapter of this book: "The aim of contemporary realistic neopragmatist philosophy of science is to discover principles that describe successful practices of basic-science research, in order to advance contemporary science by application of the principles" (See above, Section **1.01**).

I expect that the reader may have the same difficulty assimilating this introductory book that I have had in writing it. The contemporary realistic neopragmatist philosophy is an integrated system of inter-related concepts that are mutually defined by the context constituting the metatheory set forth herein. Its exposition therefore cannot simply be linear, because any beginning presupposes some exposition that follows. My attempt to cope with this circularity has been to approach the system in a sequence of levels of presentation. This treatment of circularity has occasioned repetition in the exposition and overlap among the chapters, in order to provide context and continuity for understanding. I have made the table of contents more detailed than the brief outline of levels shown below. **Chapter 1** is **definitional:** it sets forth several strategic concepts used throughout the book.

Chapter 2 is **historical:** it very briefly contrasts the basic features of contemporary realistic neopragmatism with comparable ideas in the two older twentieth-century romantic and positivist philosophies.

Chapter 3 is **essential:** it describes the new contemporary realistic neopragmatist philosophy of language that is central to and distinctive of the realistic neopragmatist philosophy of science.

Chapter 4 is **synthesizing:** it describes an architectonic of the subject in terms of the four functional topics that are characteristic of basic-research science and the realistic neopragmatist philosophy of language.

I was a graduate student both in the philosophy department and in the economics department of the University of Notre Dame in South Bend, Indiana. After receiving an M.A. degree in economics and having completed my graduate-level philosophy coursework I intended to develop an artificial-intelligence (AI) discovery system for my Ph.D. dissertation. The philosophy faculty including Edward Mainer and Michael Loux were under a Reverend Ernan McMullin, the Philosophy Department Chairman, who was personally hired by the University's President, the Reverend Theodore Hesburgh. Notre Dame is better at football than philosophy. Their philosophy school is still an intolerant academic ghetto. After initiating a denial that he wants "to play God", this Reverend McMullin questioned my seriousness, accused me of having a "bad attitude", threatened that if I persisted with my ideas I could never succeed with his philosophy faculty, and issued an ultimatum – get reformed or get out. I got out. I rejected this Reverend's Faustian bargain; I could never be this Reverend's recanting Galileo.

After leaving Notre Dame I enrolled as a nondegree student at San Jose City College in San Jose, CA, a two-year associate-arts degree community college, where I spent a year studying applied numerical methods in **FORTRAN** and then developing my **METAMODEL** AI system, which I had planned for my Ph.D. dissertation at Notre Dame. At San Jose I used my completed **METAMODEL** AI system to simulate the development of J.M. Keynes' revolutionary macroeconomic theory.

Using the **METAMODEL** discovery system I also created a <u>macro-sociometric</u> multi-equation-system model of the American national society with fifty years of historical data. My paper describing the macrosociological model and its findings was rejected for publication by four peer-reviewed sociological journals, because the macrosociometric model is not reducible to social psychology. The four journals are *Sociological Methods and Research* edited by George W. Bohrnstedt, the *American Journal of Sociology* edited by Edward O. Laumann, the *American Sociological Review* edited by William H. Form, and *Social Indicators Research* edited by Alex C. Michalos who also steadfastly refused even to disclose the one unwritten criticism he received of my paper.

Papers submitted for publication in peer-reviewed journals are ostensibly evaluated on the basis of their intrinsic merits. But neither these editors nor their chosen referees had the competence in either longitudinal multi-equation modeling or in AI systems to evaluate my paper. But instead of looking outside of academic sociology for competent referees, they remained faithful to their tribal loyalties and got two incompetent sociologists. This is by no means either the first time or the last time in the history of science that a new and consequential idea has been proposed by nonacademics and rejected by tradition-bound academicians. Mv rejoinders to the criticisms by the referees selected by these journal editors occasioned my cynical conclusion: academic sociologists want to suppress my work, in order to limit sociological theory to the social-psychological traditions accessible to their limited competence. Academic acceptance of my empirical macrosociometric theorizing, AI methodology and realistic neopragmatist philosophy of science would make the current sociologists, who are comfortably ensconced in their academic sinecures, disreputable and obsolete in their own time.

The Swedish Royal Academy awards its Nobel Prize to economists, but not to sociologists, because it recognizes that contemporary sociology has not yet matured into an empirical science. The criticisms attempted by the referees selected by the above mentioned editors are symptomatic of academic sociology's institutional retardation, and they also exhibit its Luddite mentality toward mechanized theory development by AI. Consider a few of the following comments appearing both in the sociology literature and in the popular press:

- In 1989 Joseph Berger reported in "Sociology's Long Decades in the Wilderness" in *The New York Times* that universities have disbanded their sociology departments and that the National Science Foundation has drastically cut back funding for sociological research. He reports that over the previous two decades the number of bachelor degrees awarded with majors in sociology has

declined by nearly eighty percent, the number of sociology masters degrees by sixty percent, and the number of sociology doctorate degrees by forty percent. Data that I have since obtained from the United States Department of Education, Office of Educational Research and Improvement, corroborate Berger's reporting.

- In 1993 University of Buffalo sociology professor Mark Gottdiener criticized sociological theory in his paper "Ideology, Foundationalism and Sociological Theory" in *Sociological Quarterly*. He reported that academic sociology is merely about power games among theorists seeking to construct "grandiose narratives" to sustain their status in an intellectual community.

- In 1998 University of Virginia sociologist Donald Black gave an address at the American Sociological Association's annual meeting. In his address published in *Contemporary Sociology* as "The Purification of Sociology", Black called for a revolution against classical sociology with its social-psychological reductionism.

- In 2012 in "Education for Unemployment" Margaret Wente reported in the *Globe and Mail* that there are three sociology applicants for every sociology job opening, and concluded that sociology students have been "sold a bill of goods". Later in 2015 she lamented that sociology professors are fooled into believing they might have a shot at the ever-shrinking tenure track, and that even if successful they are but "masters of pulp fiction".

- In 2013 Yale University sociologist and cognitive scientist Nicholas Christakis wrote a *New York Times* OP-ED article titled "Let's Shake Up the Social Sciences". Therein he maintained that while the natural sciences are evolving, the social sciences have stagnated thereby stifling creation of new knowledge, and that such inertia reflects insecurity and conservatism.

Writing this book has benefited greatly from my more than thirty years of practical research experience as an econometrician working in both business and government. This practical research has included application of my **METAMODEL** mechanized discovery system for nearly my entire career.

A reviewer of an earlier edition called this book a "manifesto". The book is explicitly addressed to academic philosophers and their students, and so it does indeed advocate both the contemporary realistic neopragmatist philosophy of science and the new specialty called computational philosophy of science. Thus this book is in fact a manifesto with an explicit agenda for philosophers of science. And the book furthermore proposes to instruct and enlighten many academics in the philosophically retarded social sciences.

My previous books include Introduction to Metascience: An Information Science Approach to Methodology of Scientific Research (1976), History of Twentieth-Century Philosophy of Science (1995), and the e-book Twentieth-Century Philosophy of Science: A History (2016).

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Contents

Abstract

Preface

Chapter 1. Overview

1.01 Aim of Philosophy of Science
1.02 Computational Philosophy of Science
1.03 Two Perspectives on Language
1.04 Dimensions of Language
1.05 Classification of Functional Topics
1.06 Classification of Modern Philosophies

Chapter 2. Modern Philosophies

2.01 Romanticism2.02 Positivism2.03 Contemporary Pragmatism

Chapter 3. Philosophy of Language

- 3.01 Synchronic and Diachronic Analysis
- 3.02 Object Language and Metalanguage
- 3.03 Dimensions of Language

3.04 Syntactical Dimension

- 3.05 Syntactical Rules
- 3.06 Mathematical Language
- 3.07 Logical Quantification in Mathematics
- 3.08 Semantical Dimension
- 3.09 Nominalist vs. Conceptualist Semantics
- 3.10 Naturalistic vs. Artifactual Semantics
- 3.11 Romantic Semantics
- 3.12 Positivist Semantics
- 3.13 Positivist Thesis of Meaning Invariance

- 3.14 Positivist Analytic-Synthetic Dichotomy
- 3.15 Positivist Observation-Theory Dichotomy
- 3.16 Contemporary Pragmatist Semantics
- 3.17 Pragmatist Semantics Illustrated
- 3.18 Rejection of the Observation-Theory Dichotomy
- 3.19 Rejection of Meaning Invariance
- 3.20 Rejection of the Analytic-Synthetic Dichotomy
- 3.21 Semantical Rules
- 3.22 Componential vs. Wholistic Semantics
- 3.23 Componential Artifactual Semantics Illustrated
- 3.24 Semantic Values
- 3.25 Univocal and Equivocal Terms
- 3.26 Signification and Supposition
- 3.27 Aside on Metaphor
- 3.28 Clear and Vague Meaning
- 3.29 Semantics of Mathematical Language
- 3.30 Semantical State Descriptions
- 3.31 Diachronic Comparative-Static Analysis
- 3.32 Diachronic Dynamic Analysis
- 3.33 Computational Philosophy of Science
- 3.34 An Interpretation Issue

3.35 Ontological Dimension

- 3.36 Metaphysical and Scientific Realism
- 3.37 Ontological Relativity Defined
- 3.38 Ontological Relativity Illustrated
- 3.39 Causality
- 3.40 Ontology of Mathematical Language

3.41 **Pragmatic Dimension**

- 3.42 Semantic Definitions of Theory Language
- 3.43 Pragmatic Definition of Theory Language
- 3.44 Pragmatic Definition of Test-Design Language
- 3.45 Pragmatic Definition of Observation Language
- 3.46 Observation and Test Execution
- 3.47 Scientific Professions
- 3.48 Semantic Individuation of Theories

Chapter 4. Four Functional Topics

4.01 Institutionalized Aim of Science

- 4.02 Positivist Aim
- 4.03 Romantic Aim
- 4.04 More Recent Ideas
- 4.05 Aim of Maximizing "Explanatory Coherence"
- 4.06 Contemporary Pragmatist Aim
- 4.07 Institutional Change
- 4.08 Philosophy's Cultural Lag
- 4.09 Cultural Lags among Sciences

4.10 Scientific Discovery

- 4.11 Discovery Systems
- 4.12 Types of Theory Development
- 4.13 Examples of Successful Discovery Systems

4.14 Scientific Criticism

- 4.15 Logic of Empirical Testing
- 4.16 Test Logic Illustrated
- 4.17 Semantics of Empirical Testing
- 4.18 Test Design Revision
- 4.19 Empirical Underdetermination
- 4.20 Scientific Pluralism
- 4.21 Scientific Truth
- 4.22 Nonempirical Criteria
- 4.23 The "Best Explanation" Criteria
- 4.24 Nonempirical Linguistic Constraints
- 4.25 Cognition Constraint
- 4.26 Communication Constraint
- 4.27 Scientific Explanation

Bibliography

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 book is a concise synthesis of the elementary principles of the contemporary realistic neopragmatist philosophy of science, the philosophy that the twentieth century has bequeathed to the twenty-first century. This chapter defines some basic concepts.

1.01 Aim of Philosophy of Science

Traditionally the purpose of philosophy of science was viewed in terms of justifying a superior epistemic status for empirical science. But on the contemporary realistic neopragmatist view today the aim of philosophy of science is to characterize the practices that have made the empirical sciences so unquestionably successful. Therefore:

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

The principles are set forth as a metatheory, which is sketched in this book. **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 medical 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.

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

In the "Introduction" to his *Models of Discovery* (1977) 1978 Nobel-laureate economist Herbert Simon (1916-2001), a founder of artificial intelligence, wrote that dense mists of romanticism and downright know-nothingism have always surrounded the subject of scientific discovery and creativity. The pragmatist philosophers Charles Sanders Peirce (1839-1914) and Norwood Russell Hanson (1924-1967) had described a **nonprocedural** analysis for developing theories. Peirce called this nonprocedural practice "abduction"; Hanson called it "retroduction". In the 1970's Hickey (1940) in his *Introduction to Metascience*: *An Information Science Approach to Methodology of Scientific Research* (1976) called the mechanized approach "metascience". In the 1980's philosopher of science Paul Thagard (1950) in his *Computational Philosophy of Science* (1988) named it "computational philosophy of science". Today in computational philosophy of science are coded into the design of what Simon called "discovery systems".

Thus, contemporary philosophy of science has taken the computational turn. Mechanized information processing for successful basic-research practices (a.k.a. "artificial intelligence") has permeated almost every science, and is now intruding into philosophy of science. Today computerized discovery systems facilitate investigations in both the sciences and in philosophy of science in a new specialty called "computational philosophy of science".

Mechanized reconstruction of successful developmental episodes in the history of science is typically used to test the plausibility of discovery-system designs. But the proof of the pudding is in the eating: application of computer systems at the frontier of a science, where prediction is also production in order to propose new empirically superior theories, further tests the systems. Now philosophers of science may be expected to practice what they preach by participating in basic-science research to produce empirically adequate contributions. Contemporary application of the 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 an organizing analytical framework that integrates contemporary philosophy of science. In philosophy of language philosophers have since Alfred Tarski (1902-1982) distinguished two perspectives called "object language" and "metalanguage".

Object language is discourse about nonlinguistic reality including domains that the particular sciences investigate as well as about the realities and experiences of ordinary everyday life.

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

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", all of which are pragmatic classifications of the uses of language. For example in the contemporary realistic neopragmatist philosophy a "**theory**" is a universally quantified hypothesis <u>proposed</u> for empirical testing. A "**test design**" is a universally quantified discourse <u>presumed</u> for the empirical testing of a theory in order to identify the subject of the theory independently of the theory and to describe the procedures for performing the test; it is viewed as unproblematic for the empirical 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 (1891-1970) called "dimensions" of language. The dimensions of interest to realistic neopragmatist philosophers are syntax, semantics, ontology, and pragmatics.

<u>Syntax</u> refers to the structure of language. Syntax is arrangements of symbols such as linguistic ink marks on paper, which display 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 out of terms, which are usually arranged by concatenation into strings or in some cases organized into matrices or arrays.

<u>Semantics</u> refers to the meanings associated with syntactical symbols. Syntax without semantics is literally meaningless. Associating meanings with the symbols makes the syntax "semantically interpreted". A stereotypic pedagogical sentence structure that philosophers employ to exemplify their discussions about language is the categorical form of statement, such as "Every X is Y", and that practice will be followed in the discourses in this book.

Semantical rules describe and analyze the meanings associated with elementary syntactical symbols, *i.e.* terms. For heuristic demonstration philosophers have traditionally found simple statements in categorical form to be useful. In the metalinguistic perspective belief in semantically interpreted universally quantified sentences such as the categorical affirmation "Every crow is black" enables sentences to function as semantical rules displaying the complex meanings of the sentences' component descriptive terms. Belief in the statement "Every crow is black" makes the phrase "black crow" redundant, thus displaying the meaning of "black" as a *component part* of the meaning of "crow". The lexical entries in a unilingual dictionary are an inventory of semantical rules for a language. This is not "rocket science", but there are academic philosophers who prefer obscurantism and refuse to acknowledge componential semantics.

<u>Ontology</u> refers to the aspects of reality described by the relativized perspectivist semantics of interpreted sentences believed to be true, especially belief due to experience or to 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, while ontology is **reality as known**, *i.e.* semantics is the perspectivist signification of reality, and ontology is the aspects of reality signified by semantics. Ontology is the aspects of mind-independent reality that is cognitively captured with a perspective revealed by a term's semantics.

Not all discourses are equally realistic; the semantics and ontologies of discourses are as realistic as the discourses are empirically adequate. 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. If all past falsified explanations were completely unrealistic, then so too are all currently accepted explanations and all future ones, because they are destined to be falsified eventually. Better to acknowledge in all explanations the limited degree of realism and truth that they have to offer. Scientists recognize that they investigate reality and are motivated to do so. Few would have taken up their basic-research careers had they thought they were merely constructing fictions and fantasies with their theories or fabricating semantically vacuous discourses.

<u>Pragmatics</u> in philosophy of science refers to how scientists use language, namely to create and to test theories, and thereby to develop scientific laws used in test designs and in scientific explanations. The pragmatic dimension includes both the semantic and syntactical dimensions.

1.05 Classification of Functional Topics

Basic-science research practices can be classified into four essential sequential functions performed in basic research. They are:

1. Aim of Basic Science

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

The institutionalized aim of basic science is the culturally shared aim that regulates development of explanations, which are the final products of basicscientific research. The institutionalized views and values of science have evolved considerably over the last several centuries, and will continue to evolve episodically in unforeseeable ways with future advances of science.

2. Discovery

Discovery is the construction of new and empirically more adequate theories. A scientific theory is a universally quantified statement <u>proposed</u> for testing. The semantics of newly constructed theories reveal new perspectives and ontologies.

A mechanized discovery system produces a transition from an inputlanguage state description containing currently available information to an output-language state description containing generated and tested new theories.

Contemporary realistic neopragmatism is consistent with computerized discovery systems, which aim to proceduralize and then to mechanize new theory construction, in order to advance contemporary science. The computerized discovery system is not a psychological theory; it is a constructional linguistic

metatheory. To borrow a phrase firstly used in philosophy by Carnap in his *Aufbau* (1928) but with a different meaning for computational philosophy of science, a discovery system is a dynamic diachronic linguistic constructional procedure called a "**rational reconstruction**", rational because it is procedural.

Both romantics and positivists define "theory" semantically, while contemporary realistic neopragmatists define "theory" pragmatically, i.e., by its function in basic-research science. Therefore for realistic neopragmatists "theory" is universally quantified language that is <u>proposed</u> for testing, and "test-design" is universally quantified language that is <u>presumed</u> for testing. And <u>scientific laws are former theories</u> that have been tested with nonfalsifying test outcomes.

3. Criticism

Criticism pertains to the criteria for the acceptance or rejection of theories. The <u>only</u> criterion for scientific criticism that is acknowledged by the contemporary realistic neopragmatist is the *empirical criterion, which is* operative in an empirical test.

On the realistic neopragmatist thesis of relativized semantics and ontological relativity, semantics and ontologies can never trump the empirical criterion for criticism, because acceptance of ontologies in science is based upon empirical adequacy of a theory especially as demonstrated by repeated nonfalsifying empirical test outcomes. Thus like the romantics, realistic neopragmatists permit description of intersubjective mental states in social-science theories and explanations, but unlike many romantic sociologists and economists realistic neopragmatists never require or employ such mentalistic description as a criterion for critical acceptance.

Syntactical transformations of the **surface structure** of theories produce the nontruth-functional hypothetical-conditional logical form that exhibits the **deep structure** of the theory language in a test thereby explicitly displaying the essential empirical contingency and the logic of falsification, while preserving the semantics of the surface structure. Given the variety and complexity of surface-structure forms the deep- structure form serves, as it were, as the essential common denominator for testing. The logic operative in the deep structure of an empirical test is a *modus tollens* deduction with the surface structure of the tested theory transformed into a nontruth-functional hypothetical-conditional statement. In

practice, however, the surface structure actually used by scientists may be more convenient for empirical tests.

Test-designs are universally quantified statements that are <u>presumed</u> for testing. Test designs characterize the subject of the test, and describe procedures for execution of the test. They also include universal statements that are semantical rules for the test-outcome statements, which are asserted with particular quantification, when the test design is executed and the test outcome is produced.

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

4. Explanation

An explanation is language that describes the occurrence of individual events and conditions that are caused by the occurrence of other described individual events and conditions according to universally quantified law statements.

The surface structure of a law for an explanation may be very complex mathematics. But syntactical transformations producing the nontruth-functional hypothetical-conditional logical argument form generate the **deep structure** underlying the surface structure. The logic operative in the deep structure of an explanation is a *modus ponens* deduction with the surface structure of the explaining law transformed into a nontruth-functional hypothetical-conditional statement displaying both the empirical conditionality in the constituent laws and the logic of explanation. Whenever possible the explanation is predictive of future events or for evidence of past events due to the universality claim of the explaining law. Scientific laws are not unconditional, nor are explanations historicist or prophesying.

In some cases laws may be said to be "explained" in the sense that a set of laws may be arranged into a deductive system with some laws derived from other laws. However, in a deductive system the choice of axioms is formally arbitrary.

1.06 Classification of Modern Philosophies

Twentieth-century philosophies of science may be segmented into three generic classes. They are **romanticism**, **positivism** and **pragmatism**. Romanticism is a philosophy for social and cultural sciences. Positivism is a philosophy for all sciences and it originated in reflection on Newtonian physics. Contemporary realistic neopragmatism is a philosophy for all sciences, and it originated in reflection on quantum physics.

Each generic 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 they are much more similar to each other than to those in either of the two other types. The relation between the philosophies and the four functional topics are cross-referenced in the next chapter.

Chapter 2. Modern Philosophies

This second chapter briefly sketches three generic types of twentiethcentury 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 more detailed discussion of the four functional topics in chapter 4.

2.01 Romanticism

Romanticism has 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 (1770-1831), a transitional figure between enlightenment and romantic eras, and especially Georg Hegel (1724-1804) with the latter's historicism and his emphasis on evolving ideas in social culture. Idealism is of purely antiquarian interest to philosophers today, and is irrelevant both to science and to philosophy of science.

Romantics have historically defaulted to the positivist philosophy for the natural sciences, but they reject using the positivist philosophy for the social sciences. Romantics maintain that there is a fundamental difference between sciences of nature and sciences of culture, *i.e.* 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 intersubjective mental states, *i.e.*, shared ideas and motives, views and values including the economists' maximizing behaviors as set forth in the rationality postulates, which are culturally shared by members of social groups.

This concept of the aim of science and of explanation is 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 culturally shared intersubjective social-psychological mental states.

Discovery

Romantics say "social theory" is language describing intersubjective mental states, notably culturally shared ideas and motivations, which are deemed the causes of "human action".

For romantics the creation of "theory" in social science may originate either:

(1) in the social scientist's introspective reflection on his own ideas and motivations originating in his actual or imaginary personal experiences, which ideas and motives are then imputed to the social members he is investigating, or

(2) in empirical survey research reporting social members' verbally expressed intersubjective ideas and motivations.

Some romantics call the imputed motives 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 thus oppose their view of the aim of science to that of the positivists' such as the sociologist George Lundberg (1895-1966) and the behavioristic psychologist B.F. Skinner (1904-1990). Romantics say that they explain consciously purposeful and motivated "human action", while behaviorists say they explain publicly observable "human behavior" with no reference to mental states.

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 nearly all romantics impose their mentalistic ontology as the criterion for criticism, while making empirical or statistical analyses at most optional or supplementary.

Furthermore, many romantic social scientists **require** as a criterion that a social theory must be recognizable in the particular investigator's own introspectively known intersubjective personal experience. In Max Weber's (1864-1920) terms this is called *verstehen*. It is the thesis that empathetic insight is a necessary and valuable tool in the study of human action, which is without counterpart in the natural sciences. It effectively makes all sociology what has been called "folk sociology".

Explanation

Romantics maintain that only "theory", *i.e.*, language describing intersubjective ideas and motives, can "explain" conscious purposeful human action.

Motives are the "mechanisms" referenced as "causal" explanations, which are also called "theoretical" explanations. Observed regularities are deemed incapable of "explaining", even if they enable correct predictions.

Some formerly romantic social scientists such as the institutionalist economist Wesley C. Mitchell (1874-1948) and the functionalist sociologist Robert K. Merton (1910-2003) have instead chosen to focus on objective outcomes rather than intersubjective motives. This focus would institutionalize testability and thus validate the scientific status of sociology. But the focus on objective outcomes still represents a minority view in academic social science. Although philosophically anachronistic Romanticism still prevails among social "scientists" in academia today, and its antiscientific orientation continues to have its residual effects in the social "sciences".

2.02 Positivism

Positivism was a reaction against the speculative metaphysics of the nineteenth century, and it carries forth many views of the preceding enlightenment era. Its origins are in the eighteenth-century British empiricist philosophers including John Locke (1632-1704) and most notably David Hume (1711-1776). But not until later in the nineteenth century did positivism get its name from the French philosopher Auguste Comte (1798-1857), who also founded positivist sociology.

The interwar "neopositivists" were the last incarnation of positivism. In 1936 Alfred J. Ayer (1910-1989) wrote a positivist manifesto titled *Language*, *Truth and Logic*, which dismissed all metaphysical discourse as literally nonsense, because metaphysical propositions are deemed empirically unverifiable. Therein he set forth the positivist verification principle of meaning that statements are semantically vacuous unless they are verifiable observationally.

Neopositivists also attempted to apply the symbolic logic fabricated by Bertrand Russell (1872-1970) and Alfred Whitehead (1861-1947) in their *Principia Mathematica* (1910-1913) early in the twentieth century. Neopositivists such as Carnap had fantasized that the Russellian truth-functional symbolic logic can serve philosophy, as mathematics has served physics. They are therefore also called "logical positivists". In the later twentieth century positivism was relegated to the dustbin of history.

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.

The positivists' ideas about all four of the functional topics in philosophy of science were greatly influenced by their reflections upon Newtonian physics.

Aim of science

For positivists the aim of science is to produce explanations having objectivity grounded in "observation language", which by its nature describes observed phenomena.

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. But not all positivists were foundationalists. Otto Neurath's (1882-1945) famous antifoundational boat metaphor compares scientists to sailors who must rebuild their ship on the open sea when they are unable to break it down in dry dock on *terra firma*. Neurath was a member of the Vienna Circle positivists.

Discovery

Positivists believed that empirical <u>laws</u> are inferentially discovered by inductive generalization based on repeated observations. They define empirical laws as universally quantified statements containing only "<u>observation terms</u>" describing observable entities or phenomena.

Early positivists such as Ernst Mach (1826-1916) recognized only empirical laws for valid scientific explanations. But after Einstein's achievements neopositivists such as 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 repeated singular observations.

Neopositivists believed that <u>theories</u> are discovered by creative imagination, but they left unexplained the creative process of developing theories. They define theories as universally quantified statements containing any "<u>theoretical terms</u>", *i.e.*, terms describing unobservable or never observed entities or phenomena.

Criticism

The early 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.

The later positivists or neopositivists maintain that theories are indirectly and tentatively warranted by observationally based empirical laws, when the valid laws can be logically derived from the theories.

Like Hume positivists deny that either laws or theories can be permanently validated empirically, but they require that the general laws be founded in observation language as a condition for the objectivity needed for valid science. And they maintain that particularly quantified observation statements describing singular events are incorrigible and beyond revision.

All 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

complain that subjective *verstehen* may easily involve erroneous imputation of the idiosyncrasies of the observer's experiences or fantasies to the subjects of inquiry.

Explanation

Positivists and specifically Carl Hempel (1905-1997) and Paul Oppenheim (1885-1977) in their "Logic of Explanation" in the journal *Philosophy of Science* (1948) advocate the "covering-law" schema for explanation.

According to the "covering-law" schema for explanation, statements describing observable individual events are explained if they are derived deductively from other 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".

The neopositivists also maintained that theories explain laws, when the theories are premises from which the empirical laws are deductively derived as theorems. The deduction is enabled by the mediation of "bridge principles". Bridge principles are sentences that relate the theoretical terms in an explaining theory to the observation terms in the explained empirical laws. The paradigmatic case is the deduction of Kepler's laws from Newton's theory.

2.03 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 is a new coherent master narrative appropriately called "contemporary realistic neopragmatism", which was occasioned by Heisenberg's reflections on his quantum theory, and is currently the ascendant philosophy in American academia. Contemporary realistic neopragmatism is a general philosophy for all empirical sciences, both social and natural sciences.

Neopragmatism has antecedent versions in the classical pragmatists, notably those of Charles Peirce, William James (1842-1910) and John Dewey (1859-1952). Some theses in classical pragmatism such as the importance of belief have been carried forward into the new. In contemporary realistic neopragmatism belief is

strategic, because it controls relativized semantics, which signifies and thus reveals a correspondingly relativized ontology that is realistic to the degree that the 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 realistic neopragmatist philosophy of science is 1932 Nobel-laureate physicist Werner Heisenberg's (1901-1976) reflections on the language in his revolutionary quantum theory 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 (1917-1992), **both** of the 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 in his *Physical Principles of the Quantum Theory* (1930), rather than two separate entities, as Bohm says.

1922 Nobel-laureate Niels Bohr (1885-1962), 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 are able to describe physical reality. Instrumentalism is the doctrine that scientific theories are not descriptions of reality, but are meaningless yet 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 of the electron's duality as both "wave" and "particle" is an empirically indispensable semantic antilogy that he called "complementarity".

Heisenberg, a colleague of Bohr at the Copenhagen Institute, proposed an alternative 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. Later Erwin Schrödinger (1887-1961) showed that Heisenberg's matrix mechanics and Schrödinger's wave mechanics are mathematically transformable into each other. Yale University's Norwood Russell Hanson, an advocate of the Copenhagen physics, said in his *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science* (1958) that Bohr maintained a "naïve epistemology".

Duality is a thesis in physics while complementarity is a thesis in philosophy of language. These two versions of the Copenhagen interpretation differ not in their physics, but 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 today called an "artifactual" 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 (1879-1955) had influenced Heisenberg's philosophy of language, which has later been incorporated into the contemporary realistic neopragmatist 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 to a wave or a particle by execution of a measurement operation. For Heisenberg indeterminacy is physically real.

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.

For more about Heisenberg and quantum theory the reader is referred to **BOOK II** and **BOOK IV** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science: A History*, which is available at Internet booksellers through hyperlinks in the web site.

The distinctive linguistic philosophy of Einstein and especially Heisenberg as incorporated into the contemporary realistic neopragmatist philosophy can be summarized in three theses, which may be taken as basic principles in contemporary realistic neopragmatist philosophy of language:

Thesis I: Relativized semantics

Relativized semantics is the perspectivist meanings defined by the linguistic context consisting of universally quantified statements believed to be true.

The seminal work is "Quantum Mechanics and a Talk with Einstein (1925-1926)" in Heisenberg's *Physics and Beyond* (1971). 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 Heisenberg 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**".

The event was historic. Einstein's aphorism about observation contradicts the fundamental positivist thesis that there is a natural 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, if indeed theory is meaningful at all.

In the next chapter titled "Fresh Fields (1926-1927)" in the same book Heisenberg reports that Einstein's 1925 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 (1869-1961) – and therefore 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. He 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 therefore 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 can be represented mathematically. He reports that he then developed a mathematical representation, which he called the "uncertainty relations", the historic contribution for which he received the Nobel Prize in 1932.

Later Hanson expressed Einstein's aphorism that the theory decides what the physicist can observe by saying observation is "theory-laden" and likewise Karl R. Popper (1902-1994) by saying it is "theory-impregnated". Thus for realistic neopragmatists the semantics of all descriptive terms is determined by the linguistic context consisting of universally quantified statements believed to be true.

In his Against Method (1975) Paul K. Feyerabend (1924-1994) also recognized employment of relativized semantics to create new observation language for discovery, and he called the practice "counterinduction". To understand counterinduction, it is necessary to understand the realistic neopragmatist concept of "theory": theories are universally quantified statements that are proposed for testing. Feyerabend found that Galileo (1564-1642) 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 from the apparently falsified heliocentric theory instead of the concepts from the prevailing geocentric theory. Likewise, Heisenberg had 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 that appeared to falsify quantum physics, and he then developed the indeterminacy relations.

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

Like Einstein, contemporary realistic neopragmatists say that the theory decides what the scientist can observe. Reality has its determinant character independently of human cognition. But realistic semantics is relativized in the sense that the meanings of descriptive terms used for reporting observations are not merely names or labels for such as Aristotelian forms, Kantian phenomena or positivist sensations, much less for nominalist entities in a cookie-cutter world, but rather are defined by the context in which they occur.

More specifically in "Five Milestones of Empiricism" in his *Theories and Things* (1981) Harvard's realistic neopragmatist 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.

The defining context consists of 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 their common test design. The change consists of replacement of some semantical component parts in the meanings of the terms in the old theory with some parts in the meanings of the terms in the new theory. 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 "particle", such that they are no longer mutually exclusive.

For more about Quine the reader is referred to **<u>BOOK III</u>** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: *A History*, which is available at Internet booksellers through hyperlinks in the site.

Thesis II: Empirical underdetermination

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

Measurement errors or inaccuracies and conceptual vagueness, which can be reduced indefinitely but never completely eliminated, exemplify the omnipresent and ever-present empirical underdetermination of descriptive language that occasions observational ambiguity and theoretical pluralism. Even concepts of quantized phenomena have vagueness. But no semantically interpreted syntax is completely underdetermined empirically such that it is utterly devoid of any ontological significance.

Einstein recognized that a plurality of alternative but empirically adequate theories could be consistent with the same observational description, a situation that 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* (1960) 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 contrary to positivists the types of terms are not qualitatively different. Quine also says that reference to ontology is "inscrutable"; reference to relativized ontology is as inscrutable as signification by semantics is empirically underdetermined.

Thesis III: Ontological relativity

Heisenberg imitated Einstein's practice of ontological relativity for making his version of the Copenhagen interpretation of quantum physics.

Heisenberg is a realist. In his *Physics and Philosophy*: *The Revolution in Modern Science* (1958) he says that the transition from the possible to the actual that takes place with the act of observation involves the interaction of the electron with the measuring device and applies to the physical and not to the psychological act of observation. Thus contrary to 1963 Nobel-laureate physicist Eugene Wigner (1902-1995) Heisenberg affirms that quantum theory does not contain "genuine subjective features" in the sense that it introduces the mind of the physicist as a part of the atomic event. Heisenberg also disliked Bohr's view that the equations of quantum theory must be viewed instrumentally, *i.e.*, that they do not describe reality. All such denials of realism are merely mystifications and are not physics.

Heisenberg practiced ontological relativity. In his discussions about Einstein's special theory of relativity in *Physics and Philosophy* and in *Across the Frontiers* (1974) he describes the "decisive step" in the development of special relativity. That step was Einstein's rejection of 1902 Nobel-laureate Hendrik Lorentz's (1853-1928) 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 theory characterize the physically real, i.e., physical ontology.

In "History of Quantum Theory" in his *Physics and Philosophy: The Revolution in Modern Science* Heisenberg describes his use of Einstein in his discovery experience for quantum theory. There he states that his development of the indeterminacy relations involved 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* (1977) 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 (1955) 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 realistic neopragmatist philosophers today 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* (1970) Quine called this thesis "ontological relativity", as it is known today.

Ontological relativity did not begin with Heisenberg much less with Quine. Copernicus (1473-1543) and Galileo practiced it when they both interpreted heliocentrism realistically thus accepting the ontology it describes – to the fateful chagrin of Pope Urban VIII (1568-1644), whose moral violence coerced Galileo to recant realism. Heisenberg's Copenhagen interpretation still prevails in physics today. The contemporary realistic neopragmatist concepts of the four functional topics may now be summarized as follows:

Aim of science

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

Wherever possible the explanation should enable prediction of either future events or evidence of past events, since laws make universal claims. And it is pragmatically beneficial furthermore for the explanation to enable control of explained nonlinguistic reality by applied science thus enabling applications such as new engineering technologies, new medical therapies and new social policies. **Discovery**

Discovery is the construction of new and empirically more adequate theories. The semantics of such newly constructed theories reveal new perspectives and new ontologies.

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

Contemporary realistic neopragmatism is consistent with computerized discovery systems, which aim to proceduralize and then to mechanize new theory construction, in order to advance contemporary science. The computerized discovery system is not a psychological theory, but rather is a generative grammar that is a dynamic diachronic linguistic procedure, a *rational* reconstruction, because it is procedural.

In the "Introduction" to his magisterial *Patterns of Discovery*, 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. 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 research science.

While both romantics and positivists define "theory" semantically, contemporary realistic neopragmatists define "theory" pragmatically, i.e., by its function in basic-research science. Contemporary realistic neopragmatists also define observation language pragmatically instead of semantically; the pragmatics of both theory and observation language in basic science is empirical testing.

For realistic neopragmatists "theory" is universally quantified language that is <u>proposed</u> for testing, and "test-design" is universally quantified language that is <u>presumed</u> for testing. For realistic neopragmatists <u>scientific</u> laws are former theories that have been tested with nonfalsifying test outcomes.

Realistic neopragmatists <u>identify theory language pragmatically</u> as universally quantified statements proposed for testing, but they <u>individuate</u> <u>theories semantically</u>. Two theory expressions are different theories either (1) if the expressions have different test designs so they address different subjects, or (2) if the expressions make contrary claims about the same subject as defined by the same test design.

Criticism

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

The <u>only</u> criterion for scientific criticism acknowledged by the contemporary realistic neopragmatist is the *empirical criterion* operative in an empirical test.

On the realistic neopragmatist theses of relativized semantics and ontological relativity, semantics and ontologies can never trump the empirical criterion for criticism, because acceptance of ontologies in science is based upon empirical adequacy of a theory especially as demonstrated by repeatable nonfalsifying empirical test outcomes. Thus like romantics, realistic neopragmatists permit description of intersubjective mental states in social-science theories and explanations, but unlike many sociologists and economists realistic neopragmatists never require or employ such description as a criterion for criticism. Syntactical transformations generating the nontruth-functional hypotheticalconditional logical form exhibit the **deep structure** of the language of the test. It explicitly displays its empirical contingency and the logic of its testing, while preserving the semantics of the surface structure. The deep structure of the language of an empirical test is a *modus tollens* logical deduction from a set of one or several logically related universally quantified theory statements expressible in a nontruth-functional hypothetical-conditional deep structure, together with a particularly quantified antecedent description of the initial test conditions as defined in a test design, that jointly conclude to a consequent particularly quantified description of a produced (predicted) test-outcome event that is compared with the observed test-outcome description. Unlike the logical positivists, realistic neopragmatists do not recognize the truth-functional conditional logic for scientific criticism, because the logic of empirical testing is not truth-functional.

Test-designs are universally quantified statements that are <u>presumed</u> for testing. Test designs characterize the subject of the test, and describe procedures for execution of the test. They are expressed as universal statements that are semantical rules for the test-outcome statements, which are asserted with particular quantification, when the test design is executed and the test outcome is produced and observed.

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

Unlike positivists, realistic neopragmatists 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. Unlike tests designs theories are not true by definition.

Explanation

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

Syntactical transformations of surface structures of explanations produce the nontruth-functional hypothetical-conditional logical argument form that exhibit the

deep structure of the language of the explanation thereby explicitly displaying the expression of empirical contingency in the constituent laws and the logic of the explanation, while preserving the semantics of the surface structure. The deep structure of a scientific explanation consists of a *modus ponens* logical deduction from a set of one or several universally quantified law statements expressible in a nontruth-functional hypothetical-conditional schema, together with a particularly quantified antecedent description of realized initial conditions that jointly conclude to a consequent particularly quantified description of the explained outcome.

In some cases laws may be said to be "explained" in the sense that a set of laws may be arranged into a deductive system with some laws derived from other laws.

Chapter 3. Philosophy of Language

Basic scientific research produces language such as theories, test designs, observation reports, laws and explanations. Therefore many and probably most of the central concepts and issues in philosophy of science involve philosophy of language. Accordingly the following selected elements of contemporary realistic neopragmatist philosophy of language are here discussed in relation to philosophy of science.

3.01 Synchronic and Diachronic Analyses

To borrow some terminology from Ferdinand de Saussure's (1857-1913) classic *Course in General Linguistics* (1959) language analyses may be either **synchronic** or **diachronic**.

The <u>synchronic</u> view is static, because it exhibits in a semantical state description the state of a language at a point in time like a photograph.

To borrow some terminology from Carnap's *Meaning and Necessity* (1947), the semantics of the language for a specific scientific problem is displayed synchronically for the believers in a theory in a "**semantical state description**". But Carnap's semantical state description contains the Russellian symbolic logic, which is of no use for either science or philosophy of science. However, the concept can be made serviceable for realistic neopragmatist computational philosophy of science, if the semantical state description consists of universally quantified statements including mathematical equations for both law language and theory language, which together function as a set of semantical rules describing the meanings of their constituent descriptive terms.

The <u>diachronic</u> view exhibits two chronologically successive state descriptions of the language for the same problem as defined by a single test design, and it 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 state descriptions is also described, as in the computer code for an artificial intelligence discovery system, then the diachronic view is dynamic like a motion picture film.

For more about Carnap the reader is referred to **BOOK III** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: *A History*, which is available at Internet booksellers through hyperlinks in the web site.

3.02 Object Language and Metalanguage

Following Tarski in his *Logic, Semantics, and Metamathematics (1956)* many philosophers of science such as Carnap in his *Logical Syntax of Language* (1937) distinguish two levels of language, **object language** and **metalanguage**.

<u>Object language</u> is used to describe the nonlinguistic real world.

<u>Metalanguage</u> is used to describe language, either object language or metalanguage.

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", "law" and "explanation" are examples of expressions in metalanguage.

3.03 Dimensions of Language

The metalinguistic perspective includes what Carnap called "dimensions" of language, which serve well as an organizing framework for philosophy of language. Four dimensions may be distinguished for realistic neopragmatist philosophy of language. They are A. syntax, B. semantics, C. ontology and D. pragmatics.

In summary syntax is the structure of language, semantics is the meanings associated with syntax, ontology is the real world as described by semantics, and pragmatics is the uses of semantically interpreted syntax.

Most philosophers of science ignore the linguists' phonetic and phonemic dimensions. And most linguists ignore the philosophers' ontological dimension.

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 said to be "semantically uninterpreted". And since much of the language of science is usually written, the syntax of interest consists of visible marks on paper or more recently linguistic source-code and discovery-system output displays on paper and computer monitor display screens. The syntax of expressions is also 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 rules". These rules are of two types: **formation rules** and **transformation rules**.

<u>Syntactical formation rules</u> are procedures described in metalanguage that regulate the construction of grammatical expressions out of more elementary symbols, usually terms.

A generative grammar applies formation rules to produce grammatical expressions from inputs consisting of terms.

A mechanized generative grammar is a computer system that implements a generative grammar.

A discovery system is a mechanized generative grammar that constructs and usually also empirically tests new scientific theories as its output.

Formation rules order such syntactical elements as mathematical variables and operator signs, descriptive (categorematic) and syncategorematic terms in logic, and the user-defined variable names and reserved words in computer source Expressions constructed from these symbols in compliance with the codes. formation rules for a language are called "grammatical" sentences or "well formed formulas" (or "wffs"), and include the computer instructions called "compileracceptable" 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". The mechanized generative-grammar computer programs input, process, and output object language, while the source-code instructions constituting the computer system are therefore metalinguistic expressions. When a mechanized generative grammar is used to produce new scientific theories in the object language of a science, the computer system is what Simon called a "discovery system". Typically the system also contains an empirical test criterion using measurement data to select for output a subset of the deluge of theories generated.

<u>Syntactical transformation rules</u> are procedures described in metalanguage that regulate the change of grammatical sentences into other grammatical sentences.

Syntactical transformation rules are used in logical and mathematical deductions. But logic and mathematical rules are intended not only to produce new grammatical expressions but also to guarantee truth transferability from one set of expressions to another to generate theorems, usually by the transformation rule of substitution that makes mathematics and logic extensional. In 1956 Simon developed a computer system named **LOGIC THEORIST**, which operated with his "heuristic-search" discovery system design. This system developed deductive proofs of theorems in Whitehead and Russell's *Principia Mathematica*. The symbolic-logic formulas are object language for this system. Simon correctly denies that the Russellian symbolic logic is an effective metalanguage for the design of discovery systems.

One use for syntactical transformation rules in philosophy of science is to exhibit the deep structure underlying the various surface structures in theories and laws. To borrow a concept from Noam Chomsky's (1928) *Syntactical Structures* (1957) the "**deep structure**" of a linguistic expression is a linguistic construct or a rational reconstruction that is produced by application of transformation rules that re-expresses linguistic structures called "surface structures" while preserving their semantics. The surface structures are the expressions that the scientist actually

uses to express a theory or law, and the deep structure is the nontruth-functional hypothetical-conditional expression that explicitly exhibits for the philosopher the contingency in the theory or law and its logic. The syntactical transformation rules that produce the deep structure vary with the syntax of the surface expression (including where applicable the type of mathematics). But the result is always the basically simple nontruth-functional hypothetical-conditional form of expression and its *modus ponens* logic of explanation and *modus tollens* logic of empirical testing.

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 functions as object language for which the syntax is supplied by the mathematical formalism. Often the object language of science is mathematical rather than colloquial, because measurement values for descriptive variables enable the scientist to quantify the error in his theory after estimates are made for the range of inevitable measurement error estimated where possible by repeated execution of the measurement procedure.

3.07 Logical Quantification in Mathematics

Mathematical expressions in science are universally quantified logically when descriptive variables have no associated numerical values, and are particularly quantified logically when numeric values are associated with 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 also contain mathematical descriptive 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, then 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 the individual empirical instance 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 known to be correct or accurate, but rather because the predicting theory makes an empirical claim that may be falsified by the empirical test. Falsification occurs when the predicted empirical instance falls outside the range of estimated measurement error in the individual measurement instance for the test-outcome value for the same variable.

B. SEMANTICS

3.08 Semantical Dimension

Semantics is the meanings associated with syntactical symbols.

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 realistic neopragmatism, but nominalism is the minority view. 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 semantical view terms symbolize universal meanings, which in turn signify such ontological 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 in perceived stimuli, which in turn are synthesized by the brain, and may then be registered in memory. The sense stimuli deliver information revealing similarities and differences in reality. The signified attributes have 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 as Quine says "inscrutable". The three-level view is often 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 as in simple supposition (See below, Section **3.26**). The intensions in turn signify attributes and thereby reference in personal supposition what Carnap called "extensions", which are the individual entities manifesting the signified attributes.

While the contemporary realistic neopragmatism emerged as a critique of neopositivism, some philosophers carried the positivists' nominalism into contemporary realistic neopragmatism. A few realistic neopragmatist philosophers such as Quine opted for nominalism. He rejected concepts, ideas, meanings, propositions and all other mentalistic views of knowledge due to his acceptance of the nominalist notational conventions of the Russellian first-order 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 a "universal", which he defined as a "repeatable event form".

Nominalism is by no means essential to or characteristic of contemporary realistic neopragmatism, and most contemporary realistic neopragmatist philosophers of science such as Hanson, Feyerabend and Thomas S. Kuhn (1922-1996), and most linguists except the behaviorists have opted for the three-level semantics, which is also assumed herein. Behaviorism is positivism in the behavioral sciences. 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, also reject both nominalism and behaviorism (See below, Section **3.34**).

Cognitive scientists 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* (1996) 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 terms are determined by their relation to their linguistic context consisting of universally quantified statements believed to be true.

The contemporary realistic neopragmatist philosophy of science is distinguished by a post-positivist philosophy of language, which has replaced the traditional naturalistic thesis with the artifactual thesis of semantics. The artifactual thesis implies that ontology, semantics and belief are mutually determining.

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

Thus on the naturalistic view descriptive terms function essentially as names or labels, a view that Quine ridicules with his phrases "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 formed by linguistic context consisting of a set of beliefs that by virtue of the set's belief status has a defining rôle for the semantics. When the beliefs that are laws function as test-design statements for a theory, the tests may occasion falsification of the proposed theory. The artifactual relativized semantical thesis together with the ontological relativity thesis revolutionized philosophy of science by relating 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 determining and thus reciprocally interdependent.

3.11 Romantic Semantics

For romantics the semantics for social sciences explaining human action *must* include description of the culturally shared intersubjective meanings and consequent motivations that human action have for the members of a social group.

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 sociocultural sciences. "Human action" considered in the romantic cultural sciences has intersubjective meaning for the members of a group or society, and it is purposeful and motivating for the members' social interactions.

Romantics call the resulting intersubjective semantics "interpretative understanding". The social member's voluntary actions are controlled by this interpretative understanding, *i.e.*, by the motivating views and values that are internalized and shared among the members of a social group by the social-psychological "mechanism" of socialization, and are reinforced by the social-psychological "mechanism" of social control.

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

3.12 Positivist Semantics

For positivists the semantics of observation language is causally determined by nature and acquired ostensively by perception. Positivists maintain the naturalistic philosophy of semantics, and the semantics for descriptive terms used for reporting observations are deemed primitive and simple. Typically positivists maintain a naturalistic philosophy of semantics. These meanings are variously called "sensations", "sense impressions", "sense perceptions", "sense data" or "phenomena" by different positivists. For these positivists sense perceptions are the object of knowledge rather than constituting knowledge thus making positivism solipsistic.

Positivists maintain three characteristic theses about semantics:

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

3.13 Positivist Thesis of Meaning Invariance

The positivists' naturalistic semantics thesis is that the semantics of a univocal descriptive term used to report observations is invariant through time and is independent of linguistic contexts in which the term may occur.

Positivists viewed meaning invariance as the foundation for objectivity in science.

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, such that the resulting observational semantics is primitive and simple. Different languages are conventional in their vocabulary symbols and in their syntactical structures and grammatical rules. But according to the naturalistic philosophy of semantics 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 explicit ostension.

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* (1690) by the British empiricist philosopher John Locke (1632-1704). 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 have independent meanings for their terms. The positivists view the analytic-synthetic distinction as a fundamental dichotomy between two types of statements. A similar distinction between "relations of ideas" and "matters of fact" can be found in *An Enquiry Concerning Human Understanding* (1748) by the British empiricist philosopher David Hume.

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 realistic neopragmatists such as Quine in his "Two Dogmas of Empiricism" (1952) reject the positivist thesis of a priori truth. Quine, who is a realistic neopragmatist, maintains that all sentences are actually empirical.

3.15 Positivist Observation-Theory Dichotomy

Positivists alleged the existence of "observation terms", which are terms that reference observable 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", if stated on the occasion of observing. For example the sentence "That crow is black" uttered while the speaker of the sentence is viewing a present crow, 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 universally quantified sentences containing any theoretical terms. Many positivists view the semantics of the meaningful theoretical term to be simple like the observation term even though its semantics is not acquired by observation but rather contextually. Carnap was a more sophisticated positivist. He said that the definition determines the whole meaning of a defined term, while the theory determines only part of the meaning of a theoretical term, such that the theoretical term can acquire more meaning as the science containing the theory is developed.

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 unobservable 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 literally meaningless, since tooth fairies are deemed mythical and thus never to have been observed. For nominalists theoretical terms in science receive their semantics by logical connection to observation language by "correspondence rules", a.k.a. "bridge principles", a connection that enables what positivists called "logical reduction to an observation-language reduction base". Without such connection the theory is deemed to be meaningless and objectionably "metaphysical".

Both the post-positivist Popper and later the formerly logical positivist Carl Hempel (1905-1997) 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 by the neopositivists as well as by contemporary scientists. This unsolvable problem made the positivists' observation/theory dichotomy futile.

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

Heisenberg's reflection on the development of quantum physics anticipated development of the contemporary realistic neopragmatist philosophy thus initiating realistic neopragmatism.

A fundamental postulate in the contemporary realistic neopragmatist philosophy of language is the rejection of the naturalistic thesis of the semantics of language and its replacement with the artifactual thesis that relativizes both semantics and ontology to linguistic context consisting of universally quantified beliefs.

The rejection of the naturalistic semantical thesis is not new in linguistics, but it is fundamentally opposed to the positivism that preceded contemporary realistic neopragmatism.

3.17 Pragmatist Semantics Illustrated

Consider the following analogy illustrating relativized semantics. Our linguistic system can be viewed as 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 **mathematically underdetermined** such that there is an indefinitely large number of possible numerical solution sets.

In pure mathematics, mathematical underdetermination can be eliminated and the system can be made uniquely determinate by adding related independent equations, until there are just as many equations as there are variables. Then there is a 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 are still an indefinitely large number of possible measurement values falling within even a narrow range of empirical underdetermination due to inevitable measurement errors.

When the simultaneous system of equations expresses an empirical theory in a test, and if its uniquely determined solution-set numerical values fall within the estimated range of measurement error in the corresponding measurement values produced in a test, then the theory is deemed not falsified. But if any of the uniquely determined 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 falsifying test design and its execution.

Our descriptive language system is like a mathematically underdetermined system of equations having an indefinitely 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 but not unique to 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 universally quantified beliefs that have contextually definitional force. But the semantics conceptualizing sense stimuli always contains residual vagueness. Due to this vagueness the linguistic system is empirically underdetermined and admits to an indefinitely large number of relativized semantical solution sets for the system. Unlike pure mathematics there never exists a uniquely determinate belief system.

This vagueness does not routinely manifest itself or cause communication problems and is deceptively obscured, so long as we encounter expected or familiar experiences for which our conventionalized beliefs are prepared. But the language user may on occasion encounter a new situation, 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 his existing beliefs, and then add some new clarifying beliefs, if the decision about applicability is not simply *ad hoc*. This is true even of terms describing quantized objects.

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 semantical 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 the beliefs. Our access to mind-independent

reality is by language-dependent relativized semantics, which signifies a corresponding ontology. Ontology is the cognitively apprehended aspects or facets of the fathomless plenitude that is mind-independent reality as described by the relativized perspectivist semantics. Thus there are no referentially absolute or fixed terms. Instead descriptive terms are always referentially fuzzy, or as Quine says "inscrutable", because their semantics is always empirically underdetermined.

For the realistic neopragmatist there are three noteworthy consequences of the artifactual thesis of relativized semantics: -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 per Quine what the positivists called "theoretical terms" are simply descriptive terms that are more empirically underdetermined than what the positivists called "observation terms".

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' 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 Einstein told Heisenberg that the theory decides what the physicist can observe, and after Heisenberg said he could observe the electron in the cloud chamber, philosophers of science began to reconsider the concept of observation, a concept that had previously seemed inherently obvious. On the contemporary realistic neopragmatist 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 small 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 realistic neopragmatists.

All descriptive terms lie on a spectrum of greater or lesser empirical underdetermination. Contemporary realistic neopragmatists view the positivist problem of the reduction of theoretical terms to observation terms as a pseudo problem, or what Heisenberg called a "false question", and they view both observation terms and theoretical terms as positivist fabrications.

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 logically quantified statements believed to be true, such that a change in any of those contextual beliefs changes some component parts of the terms' meanings.

In science the linguistic context consisting of universally quantified statements believed to be true may include both theories undergoing or awaiting empirical testing and law statements used in test designs, which jointly contribute to the semantics of their shared 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 for the believer 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 categorical 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 their 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 crow is black" requires an empirical investigation of the crow-bird population and then a generalizing inference.

On the alternative realistic neopragmatist view the semantics of all descriptive terms are contextually determined, such that all universally quantified categorical 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 <u>empirically true</u>, the sentence can then be <u>used analytically</u> as a semantical rule, 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 crow is black" is as analytic as "Every bachelor is unmarried", so long as both statements are believed to be true. The meaning of "bachelor" includes the idea of being unmarried and makes the phrase "unmarried bachelor" pleonastic. Similarly so long as one believes that all crows are black, then the meaning of "crow" includes the idea of being black and makes the phrase "black crow" pleonastic. The only difference between the beliefs is the degree of conventionality in usage, such that the phrase "married bachelor" seems more antilogous than the phrase "white crow".

In science the most important reason for belief is empirical adequacy demonstrated by reproducible and repeated nonfalsifying empirical test outcomes. Thus it may be said that while the Kantians conjured the *synthetic a priori* to fabricate fictitious eternal verities for science, the realistic neopragmatists on the contrary recognize the *analytic a posteriori* to justify decisive empirical criticism for science.

3.21 Semantical Rules

A semantical rule is a universally logically quantified statement or equation 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 <u>component parts</u> 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 Carnap and Alonzo Church (1903-1995) but with a different meaning in the realistic neopragmatist philosophy. In the contemporary realistic neopragmatist 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 (See below, Section **3.26**).

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 unreflectively. Thus if a fluent speaker of English were asked about crows, his answer would likely be in ontological terms such as the real creature's black color rather than as a reflection on the componential semantics of the term "crow" with its semantical component of black. Reflective semantical analysis is needed to appreciate the componential nature of the meanings of descriptive terms.

3.22 Componential vs. Wholistic Semantics

On the realistic neopragmatist view when there is a transition due to a falsifying test outcome from an old theory to a new theory having the same test design, for the advocates of the falsified old theory who consequently reconsider, there occurs a semantical change in the descriptive terms shared by the old and new theories, due to the replacement of some of the meaning parts of the old theory with meaning parts from the tested and nonfalsified new theory. But the meaning parts contributed by the common test-design language remain unaffected.

Semantical change had vexed the early post-modern 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 lexical meaning.

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".

The philosopher of science Feyerabend tenaciously maintained wholism, but attempted to explain it by his own interpretation of an ambiguity he found in Benjamin Lee Whorf's (1897-1941) thesis of linguistic relativity also known as the "Sapir-Whorf hypothesis" formulated jointly by Whorf and Edward Sapir (1884-1931), a Yale University Linguist. In his "Explanation, Reduction and Empiricism", in *Minnesota Studies in the Philosophy of Science* (1962) 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 classical to quantum physics as an example of such semantic incommensurability.

The thesis of semantic incommensurability was also advocated by Kuhn, who later proposed "incommensurability with comparability". But incommensurability with comparability is inconsistent as Hilary Putnam (1926-2016) observed in his *Reason, Truth and History* (1981), because comparison presupposes that there are some commensurabilities. Kuhn then revised the idea to admit "partial" incommensurability that he believed enables incommensurability with comparability but without explaining how incommensurability can be partial.

Semantic incommensurability can only occur in language describing phenomena that have never previously been observed, *i.e.*, an observation for which the current state of the language has no **semantic values** (See below, Section **3.24**). But it is very seldom that a new observation is indescribable with the stock of existing descriptive terms in the language. The scientist may be able to resort to what Hanson called "phenomenal seeing". Furthermore incommensurability does not occur in scientific revolution understood as theory revision, which is a reorganization of pre-existing articulate descriptive language.

thesis including wholistic semantical notably the semantic A incommensurability thesis creates a pseudo problem for the decidability of empirical testing in science, as the transition to a new theory implies complete replacement of the semantics of the descriptive terms used for test design and observation. 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 an empirically more adequate one. Such 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 a contemporary aerodynamic analysis proving that bees cannot fly. But 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 Hanson, Kuhn and Feyerabend. Philosophers of science have overlooked componential semantics, but linguists have long recognized componential analysis in semantics, as may be found for example in George L. Dillon's (1944) *Introduction to Contemporary Linguistic Semantics* (1977). Some other linguists use the phrase "lexical decomposition". With the componential semantics much less any incommensurable discontinuity in language in episodes of theory development.

The expression of the componential aspect of semantics most familiar to philosophers of language is the analytic statement. But the realistic neopragmatists' 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. 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. Thus on the realistic neopragmatist view when there is a transition from an old theory to a new theory having the same test design, for the former advocates of the falsified 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 from the old theory with meaning parts from the tested and nonfalsified new theory, while the shared meaning parts contributed by the common test-design language remain unaffected.

For empirical testing in science the component meaning parts that remain unaffected by the change from one theory to a later alternative one consist of those parts contributed by the statements of test design shared by the alternative theories. Therein is found the semantical continuity that enables empirical testing of alternative theories to be decidable between them.

Thus a revolutionary change in scientific theory, such as for example 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 (1882-1942) could test both Newton's and Einstein's theories of gravitation simultaneously by describing the celestial photographic observations in his 1919-eclipse test. There is no semantic incommensurability here.

For more about the philosophies of Kuhn, Feyerabend, and Eddington's 1919-eclipse test readers are referred to **BOOK VI** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: *A History*, which is available at Internet booksellers through hyperlinks in the site.

3.23 Componential Artifactual Semantics Illustrated

The set of affirmations believed to be true and predicating characteristics universally and univocally of the term "crow" such as "Every crow is black" are semantical rules describing component parts of the complex meaning of "crow". But if a field ornithologist captures a white bird specimen that exhibits all the characteristics of a crow except its black color, he must make a semantical decision. He must decide whether he will continue to believe "Every crow is black" and that he holds in his birdcage some kind of white noncrow bird, or whether he will no longer believe "Every crow is black" and that the white *rara avis* in his birdcage is a white crow, such as perhaps an albino crow. 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 crow 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 minddependent linguistic characterizations of mind-independent reality and thus the ontologies, i.e., the signified aspects of reality that the changed semantics reveals. This is due to the perspectivist nature of relativized semantics and thus of relativized ontology.

3.24 Semantic Values

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

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

Different languages have different semantics and therefore display different ontologies. Where the semantics of one language displays some semantic values not contained in the semantics of another language, the two languages may be said to be semantically incommensurable to one another. Translation is therefore made inexact, as has long been recognized by the old refrain, "*traduttore, traditore*".

A science at different times in its history may also have semantically incommensurable language, when a later theory contains semantic values not contained in the earlier law or theory with even the same test design. But incommensurability does not occur in scientific revolutions understood as theory revisions, because the revision is a reorganization of pre-existing articulate information. When incommensurability occurs, it occurs at times of discovery that occasion articulation of new semantic values due to new observations, even though the new observations may occasion a later theory revision.

3.25 Univocal and Equivocal Terms

A descriptive term's use is univocal, if no universally quantified <u>negative</u> categorical statement accepted as true can relate any of the predicates in the several universal categorical affirmations functioning as semantical rules for the same subject term. Otherwise the term is equivocal.

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".

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 (and for deconstructionist escapades). 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 unilingual dictionary, or otherwise recognized by members of some trade or clique as part of their argot.

A definition, *i.e.*, a lexical entry 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 seldom the whole description. Univocal terms routinely have many semantical rules, when many characteristics can be predicated of a given subject in universally quantified beliefs. Thus there are multiple predicates that universally characterize crows, characteristics known to the ornithologist, and which may fill a paragraph or more in his ornithological reference book.

Descriptive terms can become 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 a newer one due to a test outcome, while the test design for both theories remains the same. A term common to old and new theory may on occasion remain univocal only with respect to the parts contributed by the testdesign 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 immediately above in Section **3.25.** The signification of a univocal term has different suppositions, when it describes its 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 entities, while the predicate term is said to be in "simple" or "formal" supposition, because the predicate signifies attributes without referencing any individual entities manifesting the attributes. For this reason unlike the subject term the predicate term in the categorical proposition is not logically quantified with any syncategorematic quantifiers such as "every" or "some". For example in "Every crow is black" the subject term "crow" is in personal supposition, while the predicate "black" is in simple supposition; so too for "No crow is black".

The <u>subject-term</u> rôle in a sentence in object language has personal supposition, because it references entities.

The <u>predicate-term</u> rôle in a sentence in object language has simple or formal supposition, because it signifies attributes <u>without</u> referencing the entities manifesting the attributes.

Both personal and simple suppositions are types of "**real**" **supposition**, because they are different ways of talking about extramental nonlinguistic reality. They operate in expressions in object language and thus describe ontologies as either attributes or the referenced individuals characterized by the signified attributes.

In logical supposition the meaning of a term is considered specifically as a meaning.

Real supposition is contrasted with "logical" supposition, in which the meaning of the term is considered in the metalinguistic perspective exclusively as a meaning, *i.e.*, only semantics is considered and not extramental ontology. For example in "Black is a component part of the meaning of crow", the terms "crow" and "black" in this statement are in logical supposition. Similarly to say in explicit metalanguage "Every crow is black' is a semantical rule" to express "Black is a component part of the meaning of crow", and "black" in logical supposition.

Furthermore just to use "Every crow 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 a greater context revealing the intention of the writer or speaker. Whenever a universally quantified categorical 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. An example is "Crow' is a four-letter word". In this example "crow" does not refer either to the individual real bird or to its characteristics as in real supposition or to the universal concept of the creature 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 modern philosophers have used other vocabularies for recognizing this equivocation, such as Stanislaw Lesńiewski's (1886-1939) "use" (semantics) vs. "mention" (syntax) and Carnap's "material 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 predicate's meaning complex that would conventionally 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 realistic neopragmatists. In his "Posits and Reality" (1954) in his *Ways of Paradox* (1961) 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 realistic neopragmatists 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 cloud chamber. While contemporary realistic neopragmatist 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 (unconventionally) true and (conventionally) false. In a speaker or writer's conventional or so-called "literal" linguistic usage the entire conventional meaning complex associated with a univocal predicate term of a universal categorical 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 tacitly 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 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 categorical affirmations intended to be true of that subject and that set forth just those parts of the predicate's meaning that the issuer of the metaphor intends to be applicable.

The explanation may be further elaborated by listing separately the categorical 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 eventually become conventional.

There is an alternative "interactionist" concept of metaphor that was proposed by Max Black (1909-1988), a Cambrian positivist philosopher, in his *Models and Metaphors* (1962). On Black's interactionist view both the subject and predicate terms change their meanings in the metaphorical statement due to a semantical "interaction" between them. Black does not describe the process of interaction. Curiously he claims for example that the metaphorical statement "Man is a wolf" allegedly makes wolves seem more human and men seem more lupine. This is merely obscurantism; it is not logical, because the statement "Every man is a wolf" in not universally convertible; recall the ancient square of opposition in logic: "Every man is a wolf" does not imply logically "Every wolf is a man". The metaphorical use of "wolf" in "Every man is a wolf" therefore does not make the subject term "man" a metaphor. "Man" becomes a metaphor only if there is an independent acceptance of "Every wolf is a man", where "man" occurs as a predicate.

3.28 Clear and Vague Meaning

Vagueness is empirical underdetermination, and can never be eliminated completely, since our concepts can never grasp reality exhaustively.

Meanings are more or less clear and vague, such that the greater the clarity, the less the vagueness. In "Verifiability" in *Logic and Language* (1952) Friedrich Waismann (1896-1954) called this inexhaustible residual vagueness the "open texture" of concepts.

Vagueness in the semantics of a univocal descriptive term is reduced and clarity is increased by the addition of universal categorical 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.

Additional semantical rules increase clarity. The clarification is supplied by the semantics of the predicates in the added universal categorical affirmations and/or negations. 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 amending the meaning of "X".

Clarity is also increased by adding semantical rules that relate any of the univocal predicates in the list of semantical rules for the same subject thus increasing coherence.

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 expanded list can be logically derived from the others by a syllogism. Awareness of the deductive relationship and the consequent display of structure in the meaning complex associated with the term "X" clarifies the complex meaning of "X", because the deductive relation makes the semantics more integrated. Clarity is thus added by exhibiting semantic structure in a deductive system. The resulting coherence also supplies psychological satisfaction, because people prefer to live in a coherent world. However "Every A is B" and "Every B is A" are also empirical statements that may be falsified, and if not falsified when tested they offer more than psychological satisfaction, because they are what Ernest Nagel (1901-1985) calls "correspondence rules", when the new laws occur in what he calls "heterogeneous reductions".

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 thus added by the negation.

3.29 Semantics of Mathematical Language

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

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 wholly or in part by mathematical expressions, such that the structure of their meaning complexes is partly mathematical. The semanticsdetermining 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 suggest what 1946 Nobel-laureate physicist Percy Bridgman (1882-1961) in his Logic of Modern Physics (1927) calls "operational definitions", because the statements describing the measurement procedures and apparatus contribute meaning to the descriptive term that occurs in a test design. Bridgman says that a concept is a set of operations. But contrary to Bridgman and as even the positivist Carnap recognized in his Philosophical Foundations of Physics (1966), each of several operational definitions for the same term does not constitute a separate definition for the term's concept of the measured subject thereby making the term equivocal. Likewise realistic neopragmatists say that descriptions of different measurement procedures contribute different parts to the meaning of the univocal descriptive term, unless the different procedures produce different measurement values, where the differences are greater than the estimated measurement errors in the overlapping ranges of measurement. Also contrary to Bridgman operational definitions have no special status; they are just one of many possible types of statement often found in a test design. Furthermore the semantics is not the real measurement procedures as a nominalist would maintain, but rather the semantics is the concept of the measurement procedures. Realistic neopragmatists need not accept Bridgman's nominalism; the operational definition contributes to the concept that is the semantics for the test design.

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 several 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 semantical state description in his philosophy of semantical systems. Similarly in computational philosophy of science a state description is a semantical description but different from Carnap's, which he illustrates with the Russellian symbolic logic. The statements and/or equations in the realistic neopragmatist semantical state description supplying the terms for a discovery system's input and the statements and/or equations constituting the output semantical state description are all semantical rules expressed in the surface structure of the language of the science. Each alternative theory or law in a state description has its distinctive semantics for its constituent descriptive terms, because a term shared by several alternative theories or laws is partly equivocal. But the term is also partly univocal due at least to the common test-design statements and/or equations that are also semantical rules, which are operative in state descriptions.

In computational philosophy of science the state description is a synchronic and thus a static semantical display. The state description contains vocabulary **actually used in the surface structure** of a science both in an **initial state description** supplying object-language terms inputted to a discovery system, and in a **terminal state description** containing new object-language statements or equations output generated by a computerized discovery-system's execution. No transformation into a deep structure is needed. The initial state description represents the current frontier of research for the specific problem. Both input and output state descriptions for a discovery-system execution address only one problem identified by the common test design, and thus for computational philosophers of science they represent only one scientific "profession" (See below, Section **3.47**). For semantical analysis a state description consists of universally quantified statements and/or equations. These statements and/or equations including theories and the test design from which the inputted terms were extracted, are included in the state description although not for discovery system input, because these statements and/or equations would prejudice the output. Statements and/or equations function as semantical rules in the generated output only. Thus for discovery-system input, the language input is a set of descriptive terms found in the input state description and extracted from the statements and/or equations of the several currently untested theories addressing the same unsolved problem as defined by a common test design at a given point in time.

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

3.31 Diachronic Comparative-Static Analysis

A diachronic comparative-static display consists of two chronologically successive state descriptions containing theory statements for the same problem defined by the same test design and therefore addressed by the same scientific profession.

In computational philosophy of science comparative-static comparison is typically a comparison of a discovery system's originating input and generated output state descriptions of theory statements for purposes of contrast.

State descriptions contain statements and equations that operate as semantical rules displaying the meanings of the constituent descriptive terms and variables. Comparison of the statements and equations in two chronologically separated state descriptions containing the same test design for the same profession exhibits semantical changes resulting from the transition.

3.32 Diachronic Dynamic Analysis

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 describes a <u>process</u> of linguistic change between the two successive state descriptions.

Such transitions in science are the result of two pragmatic functions in basic research, namely **theory development** and **theory testing.** A change of state description into a new one is produced whenever a new theory is constructed 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 mechanized discovery systems that can explicitly proceduralize and thus mechanize a transition applied to language in the current state description of a science, in order to develop a new state description containing new and empirically adequate theories.

The discovery systems created by the computational philosopher of science represent diachronic dynamic metalinguistic analyses. The systems proceduralize developmental transitions explicitly with a mechanized system design, in order to accelerate the advancement of a contemporary state of a science. Their various **procedural** system designs are metalinguistic logics for **rational reconstructions** of a scientific discovery process. The discovery systems produce surface-structure theories as may actually be found in the object language of the applicable science.

A discovery-system in computational philosophy of science is a mechanized finite-state generative grammar that produces sentences or equations from inputted descriptive terms or variables. As a grammar it is creative in Noam Chomsky's sense in his *Syntactical Structures*, because when encoded in a computer language and executed, the system produces new theories that have never previously been considered in the particular scientific profession. A mechanized discovery system is Feyerabend's principle of theory proliferation applied with mindless abandon. Nevertheless it is a finite-state generative grammar, in which control of the size and quality of the generated output is accomplished by empirical testing of the generated theories. Empirical testing is enabled by associating measurement data with the inputted variables. Thus the system designs often employ one or another

type of applied numerical methods. In an execution run a system usually rejects most of the generated theories.

Presently few philosophy professors have the needed competencies for this new and emerging area in philosophy of science, with the result that few curricula in academic philosophy departments will expose students to discovery systems, much less actually enable them to develop complex AI systems. Among today's academic philosophers the mediocrities will simply ignore this new area, while latter-day Luddites will shrilly reject it. Lethargic and/or reactionary academics that dismiss it are fated to spend their careers denying its merits and evading it, as they are inevitably marginalized, destined to die in obscurity.

The exponentially growing capacities of computer hardware and the proliferation of computer-systems designs have already been enhancing the mechanized practices of basic-scientific research in many sciences. Thus in his *Extending Ourselves* (2004) University of Virginia philosopher of science and cognitive scientist Paul Humphreys reports that computational science for scientific analysis has already far outstripped natural human capabilities, and that it currently plays a central rôle in the development of many physical and life sciences. Neither philosophy of science nor the retarded social sciences can escape such developments much longer.

In the "Introduction" to their *Empirical Model Discovery and Theory Evaluation: Automatic Selection Methods in Econometrics* (2014) David F. Hendry and Jurgen A. Doornik of Oxford University's "Program for Economic Modeling at their Institute for New Economic Thinking" write that automatic modeling has "come of age". Hendry was head of Oxford's Economics Department at Oxford University, England, from 2001 to 2007, and at this writing is Director of the Economic Modeling Program at Oxford University's Martin School. These authors have developed a mechanized general-search algorithm that they call **AUTOMETRICS** for determining the equation specifications for econometric models.

Artificial intelligence today is producing an institutional change in both the sciences and the humanities. In "MIT Creates a College for Artificial Intelligence, Backed by \$1 Billion" *The New York Times* (16 October 2018) reported that the Massachusetts Institute of Technology (MIT) will create a new college with fifty new faculty positions and many fellowships for graduate students, in order to integrate artificial intelligence systems into both its humanities and its science curricula. The article quoted L. Rafael Reif, president of MIT as stating that he

wanted artificial intelligence to make a university-wide impact and to be used by everyone in every discipline [presumably including philosophy of science]. And the article also quoted Melissa Nobles, dean of MIT's School of Humanities and Sciences, as stating that the new college will enable the humanities to survive, not by running from the future, but by embracing it.

Computational philosophy of science 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", "computational philosophy of science" or "artificial intelligence". Our twenty-first century perspective shows that computational philosophy of science has indeed "come of age", as Hendry and Doornik report. So, there is hope that the next generation of academic journal editors and their favorite referees – whose peer-reviewed publications now operate as havens for mediocrities, reactionaries, parasites, Luddites and group-thinking hacks – will stop running from the future and belatedly acknowledge the power and productivity of artificial intelligence.

3.34 An Interpretation Issue

In "A Split in Thinking among Keepers of Artificial Intelligence" *The New York Times* (18 July 1993) reported that scientists attending the annual meeting of the American Association of Artificial Intelligence expressed disagreement about the goals of artificial intelligence. Some maintained the traditional view that artificial-intelligence systems should be designed to simulate intuitive human intelligence, while others maintained that the phrase "artificial intelligence" is merely a metaphor that has become an impediment, and that AI systems should be designed to exceed the limitations of intuitive intelligence – a pragmatic goal.

There is also 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 identified by a test design. Like the diverse members of a profession, the system produces a diversity of new theories. But no psychological claims are made about intuitive thinking processes.

Computer discovery systems are generative grammars that generate and test theories.

On the linguistic analysis interpretation, the computer discovery systems are mechanized generative grammars that construct and test theories. The AI system inputs and outputs are both surface-structure object-language state descriptions. The instructional code of the computer system is in the metalinguistic perspective, and exhibits diachronic dynamic procedures for theory development. The various procedural discovery system designs are rational reconstructions of the discovery process. As such the linguistic analysis interpretation is neither a separate philosophy of science nor a psychologistic agenda. It is compatible with the contemporary realistic neopragmatism and its use of generative grammars makes it closely related to computational linguistics.

On the cognitive-psychology interpretation the state description represents a scientist's cognitive state consisting of mental representations and the discovery system represents the scientist's cognitive processes.

Computer discovery systems are psychological hypotheses about intuitive human problem-solving processes.

Contemporary views in cognitive psychology are illustrated in *Cognitive Psychology: An Overview for Cognitive Scientists* (1992) by Lawrence W. Barsalou of the University of Chicago, who writes that cognitive psychology has used internal psychological constructs (internal constructs that are rejected altogether by the behaviorist school). He says that these constructs almost always describe information-processing mechanisms, and that their plausibility rests primarily on their ability to explain behavioral data. He notes that internal psychological constructs are analogous to a computer's information flows: neurological mechanisms and cognitive constructs in the brain are analogous to electronics and information processing in computers respectively (P. 10).

The originator of the cognitive-psychology interpretation is Simon. In his *Scientific Discovery: Computational Explorations of the Creative Processes* (1987) and earlier 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 those processes. There he states that an empirical test of the systems as psychological theories of intuitive 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 the systems performed the rediscoveries.

The academic philosopher Thagard, who follows Simon's cognitive psychology interpretation, originated the name "computational philosophy of science" in his *Computational Philosophy of Science* (1988). Hickey admits that it is more descriptive than the name "metascience" that he had proposed in his *Introduction to Metascience* over a decade earlier. Thagard defines computational philosophy of science as "normative cognitive psychology". His 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 proposed any new contributions to the current state of any science.

In their "Processes and Constraints in Explanatory Scientific Discovery" in *Proceedings of the Thirteenth Annual Meeting of the Cognitive Science Society* (2008) Pat Langley and Will Bridewell, who advocate Simon's cognitive-psychology interpretation, appear to depart from the cognitive-psychology interpretation or at least to redefine it. 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 relation between the psychological and the linguistic perspectives can be illustrated by way of analogy with man's experience with flying. Since primitive man first saw a bird spread its wings and escape the hunter by flight, mankind has been envious of birds' ability to fly. This envy is illustrated in ancient Greek mythology by the character Icarus, who escaped from the labyrinth of Crete with wings that he made of wax. But Icarus flew too close to the hot sun, so that he fell from the sky as the wax melted, and he then drowned in the Aegean Sea. Icarus' fatally flawed choice of materials notwithstanding, his basic design concept was a plausible one in imitation of the evidently successful flight capability of birds. Call Icarus' design concept the "wing-flapping" technology. In fact in the 1930's there was a company called Gray Goose Airways, which claimed to have developed a wing-flapping aircraft they called an "ornithopter". But pity the investor who holds equity shares in Gray Goose Airways today, because his common-stock certificates are good only for folded-paper toy-glider airplanes. A contemporary development of the wing-flapping technology might serve well for an ornithological investigation of how birds fly, but it is not the fixed-wing technology used for modern flight, which evolved quite pragmatically.

When proposed imitation of nature fails, pragmatic innovation prevails, in order to achieve the practical *aim*. Therefore when asking how a computational philosophy of science should be conceived, it is necessary firstly to ask about the aim of basic science, and then to ask whether or not computational philosophy of science is adequately characterized as "normative cognitive psychology", as Thagard would have it. Contemporary realistic neopragmatist philosophy of science views the aim of basic science as the production of a linguistic artifact having the status of an "explanation", which includes law language that had earlier been a proposed theory and has not been falsified when tested empirically. The aim of a computational philosophy of science in turn is derivative from the aim of science: to enhance scientists' research practices by developing and employing mechanized procedures capable of achieving the aim of basic science. The computational philosopher of science should feel at liberty to employ any technology that achieves this aim with or without any reliance upon psychology.

So, is artificial intelligence computerized psychology or computerized linguistics? There is as yet no unanimity. To date the phrase "computational philosophy of science" need 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 that produce contributions to an empirical science, the psychologistic interpretation will prevail. If the philosophers take it up successfully, their linguistic-analysis interpretation will prevail. It is an issue of credentialed tribalism.

For more about Simon, Langley, and Thagard and about discovery systems and computational philosophy of science readers are referred to **BOOK VIII** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: A *History, w*hich is available at Internet booksellers through hyperlinks in the web site.

C. ONTOLOGY

3.35 Ontological Dimension

Semantics is description of reality; ontology is reality as described and thus revealed by semantics.

Ontology is the aspects of mind-independent reality that are signified and thus revealed by relativized perspectivist semantics.

Ontology is the metalinguistic dimension after syntax and semantics, and it presumes both of them. It is the reality that is signified by semantics. Semantically interpreted syntax describes ontology most realistically, when a statement is warranted empirically by independently repeated nonfalsifying test outcomes. Thus in science ontology is more adequately realistic, 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.

Scientists believe prejudicially that their explanations describe reality, and their prejudice is neither wrong nor stupid; indeed it is typically integral to their motivation to practice basic research. Nonrealism (or "antirealism") is an indulgence of frivolous academic philosophers. Such philosophers have spilt much wasted ink arguing over realism and its alternatives.

The thesis of metaphysical realism is the recognition that there exists determinate mind-independent reality responsible both for falsifying scientific theories in empirical tests and for producing everyday surprises. For example by our empirical testing it informs us that microphysical reality is as the falsifiable indeterminacy relations of quantum theory say it is, and not arbitrarily otherwise.

The phrase "metaphysical realism" does <u>not</u> mean a characterization of reality as some super ontology that can be described with some all-encompassing "God's-eye view". The phrase "metaphysical realism" refers to all reality, but it is

not a descriptive phrase; the thesis is transcendental to all ontologies and signifies none. Thus it cannot be relative, because there is nothing to which it can relate, and to say "everything is relative" is to issue a well known self-contradictory paradox.

In the section titled "Is There Any Justification for External Realism" in his *Mind, Language and Society: Philosophy in the Real World* (1995) University of California realistic philosopher John R. Searle (1932) 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.

Searle denies that external 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 presupposes that there is a way that things are. He also affirms the picture of science as giving us knowledge of independently existing reality, knowledge that is taken for granted in the sciences.

Similarly in "Scope and Language of Science" in *Ways of Paradox* (1976) Harvard University realistic philosopher 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 prosaically 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 simply affirmations.

And Martin Heidegger (1889-1970) too recognized that the problem of the reality of the external world is a pseudo problem. He notes that while for Kant the scandal of philosophy is that no proof has yet been given of the existence of things outside of us, for Heidegger the scandal is not that this proof has yet to be given, but that any such proof is attempted and that it is even expected.

Hickey joins these realistic philosophers. He maintains that metaphysical realism, the thesis that there exists self-evident mind-independent reality accessible to and accessed by cognition, is the "primal prejudice" that cannot be proved or disproved but can only be affirmed or denied. Mind-independent reality is not

Kant's ineffable reality, but rather is the very effable reality revealed by our perspectivist semantics as ontologies. And he affirms that the primal prejudice 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. Its self-evident character makes it antecedent to any such discursive movements by the mind, and it is therefore fundamentally prejudicial. Hickey regards misguided pedantics who say otherwise as "closet Cartesians", because they never admit that The imposing, intruding, recalcitrant, obdurate they are academic atavisms. otherness of mind-independent reality is immediately self-evident at the dawn of a person's consciousness; it is the most rudimentary experience. Bats, cats, gnats, rats, and all other sentient creatures that have survived Darwinian predatory reality are infra-articulate and nonreflective realists in their apprehensions of their environmental realities. To dispute realism is to step through the looking glass into Alice's labyrinth of logomanchy, of metaphysical jabberwocky where as Schopenhauer believed the world is but a dream. It is to indulge in the academic philosophers' hallucinatory escapist narcotic.

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 says realism is the robust state of mind of the scientist, who has never felt any qualms beyond the negotiable uncertainties internal to his science.

Scientific realism is the thesis that a tested and currently nonfalsified theory is the most empirically adequate, truest and thus most realistic description of ontology known at the current time.

N.B. 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 perspectivist semantics, the result is ontological relativity.

Ontological relativity in science is the thesis that the relativized and thus perspectivist semantics of a theory or law and its descriptive terms reveal aspects of mind-independent reality.

The ontology of any 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 ontological decisions 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 for example, when we distinguish logical and real suppositions respectively in statements. We describe mind-independent reality with our relativized perspectivist semantics, and ontology is reality as it is thus revealed empirically more or less adequately by our semantics. All semantics has ontological significance and is objective. The ancient opposition of appearances and reality is a pernicious philosophical fallacy; appearances are revelations of reality and they display ontologies. Our semantics and ontologies cannot be exhaustive. Ontologies are more or less adequately realistic, as the semantics describing them are demonstrated to be more or less adequately empirical. In institutionally well-functioning basic science, scientific laws and explanations yield the most adequately empirical perspectives available at the time.

Prior to the evolution of contemporary realistic neopragmatism 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 Bohm's "hidden variable" interpretation of quantum theory. Such too is the error in Popper's proposal for his propensity interpretation of quantum theory and Schrödinger's pilot wave interpretation. Similarly contrary to Einstein's EPR thesis of a single uniform ontology for physics, Aspect, Dalibard and Roger's findings from their 1982 nonlocality experiments empirically demonstrated entanglement and thus validated 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. 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 plenum of existence from the ontologies revealed by the perspectivist semantics of more or less empirically adequate beliefs. Ontological relativity enables admitting change of ontology without lapsing into instrumentalism, idealism, phenomenalism, 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-<u>dependent</u> ontologies that are defined in constructed laws and theories, while at the same time acknowledging the regulative discipline of mind-<u>independent</u> reality operative in the empirical constraint in tests with their possibly falsifying outcomes.

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

3.38 Ontological Relativity Illustrated

There is no semantically interpreted syntax that does not reveal some more or less realistic ontology. Since all semantics is relativized, is part of the linguistic system, and ultimately comes from sense stimuli, no semantically interpreted syntax – not even the description of a hallucination – is utterly devoid of ontological significance.

To illustrate ontological relativity consider the semantical decision about white crows mentioned in the above discussion about componential artifactual semantics (See above, Section 3.23). The decision is ontological as well as semantical. For the bird watcher who found a white but otherwise crow-looking bird and decides to reject the belief "Every crow is black", the phrase "white crow" becomes a description for a type of existing birds. Once that semantical decision is made, white crows 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 crow is black", then there are no white crows in existence, because whatever kind of creature the bird watcher found and that Darwinian Mother Nature had long ago evolved, the white bird is not a crow. The bird watcher caught something, and his characterization of what it is in reality is a product of his semantical and ontological decisions. The availability of the choice illustrates the artifactuality of the relativized perspectivist semantics of language and of the consequently relativized ontology that the relativized perspectivist semantics reveals about mind-independent reality.

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 the postulate of mischievous elves jinxing magically with evil eyes enabled predicting the collapse of a market-price bubble on Wall Street more accurately and reliably than the postulate of euphoric humans gambling greedily with borrowed money, then we would decide that the ontology of mischievous elves is as adequately realistic as it was found to be adequately empirical, and we would busy ourselves investigating elves, as we do with elephants and electrons for successful predictions about elephants and electrons. On the other hand were our price-collapse predictions to fail, as they nearly always do, then those failures would inform us that our belief in the mischievous elves of Wall Street is as empirically inadequate as the discredited belief in the legendary gnomes of Zürich that are reputed to manipulate currency valuations ruinous to the wealth of nations, and we would decide that the ontology of mischievous elves is as inadequately realistic, as it is 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 evolved greatly since the days of the ancient philosophers Leucippus (480-420 BCE) and Democritus (460-370 BCE). The semantics of "atom" has since been revised repeatedly under the regulation of empirical research in physics, as when George J. Stony (1826-1911) concluded that the atom is not simple as the ancients had thought and 1906 Nobel-laureate J.J. Thomson (1892-1975) discovered that the atom has an internal structure. 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 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. 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 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 those of ancient medical beliefs. And 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 disease-causing demon's willful malevolence.

This thesis can be found in Quine's "Two Dogmas of Empiricism" (1952) in his *Logical Point of View* (1953) even before he came to call it "ontological relativity" sixteen years later. 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. And Quine the realistic might have added explicitly that experience is experience <u>of</u> 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, an invisible tooth-fairy person having large butterfly wings will exchange the tooth for a coin as they sleep. The boy who does so and routinely finds a coin the next morning, has an empirically warranted belief in the semantics describing an invisible 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. The boy's situation is complicated, because the concept of tooth fairy is not altogether unrealistic; no semantically interpreted syntax is utterly devoid of ontological significance. In this case the boy has previously seen insects with butterfly wings, and there was definitely someone who swapped coins for lost teeth on previous nights. Yet the tooth fairy's recent nondelivery of a coin has given him reason to be suspicious about the degree of realism in the tooth fairy ontology.

Thus like the bird watcher with a white crow-looking bird, the boy 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 to explain midnight coin-for-tooth swapping. Or like the ancient 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 likely be encouraged to revise this semantics of "tooth fairy" again, and to accept the more conventional semantics and ontology that excludes tooth fairies, as modern physicians exclude willfully malevolent demons. This sociology of knowledge and ontology has been insightfully examined by the sociologists of knowledge Peter Berger (1929-2017) and Thomas Luckmann (1927-2016) in *The Social Construction of Reality* (1966).

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 (See above, Section **3.27**). For

fictional literature the reader views as true the parts of the text that he finds reveals reality adequately, and the reader excludes as untrue the parts that he views critically and finds to be inadequately realistic. For example readers know that Huckelbery Finn is a fictitious creation of Samuel Clemens (1835-1910), a.k.a. Mark Twain, but they also know that white teenagers with Huck's racist views existed in early nineteenth-century antebellum Southern United States. Sympathetic readers, who believe Twain's portrayal of the slavery ontology, recognize an ontology that is realistic about the injustices of the racist antebellum South. And initially unsympathetic readers who upon reading Twain's portrayal of Huck's dawning awareness of fugitive black slave Jim's humanity notwithstanding Huck's racist upbringing, may thus be led to accept the more realistic ontology of black persons that is without the dehumanizing fallacies of racism. Ontological relativity enables recognition that such reconceptualization can reveal a more realistic ontology not only in science but 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 (See above, Section **3.22**). That historic astronomical test is often said to have "falsified" Newton's theory. Yet today the engineers of the U.S. National Aeronautics and Space Administration (a.k.a. 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 unrealistic, or else neither NASA nor anyone else could ever have used it. Therefore the Newtonian ontology must be realistic, but it is now known to be less realistic, *i.e.*, more empirically underdetermined than the Einsteinian ontology, because the former has been demonstrated to be less empirically adequate.

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-functional hypotheticalconditional law statement describing a causal dependency is expressible as a logically universally quantified empirical statement indicated by observed empirical correlation, and is therefore always vulnerable to future falsification. Ontological relativity implies that a statement's demonstrated empirical adequacy warrants belief in its ontological claim of causality, even when the relation is stochastic. Nonfalsification does not merely make the statement affirm a Humean constant psychological conjunction. Correlation is often distinguished from causality, as when two correlated variables are caused by a third correlated variable. The third and causal factor is detected by empirical testing in which falsification is a breakdown in the correlation in the initially observed correlated pair.

Causality is often wrongly conceived as necessarily a unidirectional influence. But reciprocal causality is revealed by correlations, which are routinely displayed by simultaneous-equation systems and by recursive longitudinal models with negative or positive feedback relations.

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 real entities and their semantically signified real attributes constitute the ontology described by the categorical proposition that is believed to be true due to its experimentally or otherwise observationally demonstrated empirical adequacy. These existential conditions are expressed explicitly in the categorical proposition by the copula term "is" as in "Every crow <u>is</u> 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 empirical mathematical expression are also instances of individual measurement results that are magnitudes determined by comparison with some standard, which are acquired by executing measurement procedures yielding 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 chosen metric, the measurement procedures, and any employed apparatus, all of which are included in a test design.

Also calculated and predicted values for descriptive variables describing effects in equations with measurement values for other variables describing causal factors, make ontological claims that are tested empirically. Untested theories make relatively more hypothetical quantitative causal claims. Tested and nonfalsified empirical equations are quantitative causal laws, unless and until they are eventually falsified.

D. PRAGMATICS

3.41 Pragmatic Dimension

Pragmatics is the uses or functions of language. The pragmatics of basic research in science is theory construction and empirical testing, in order to produce laws for test designs 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 theories, which are deemed laws when not falsified by the currently most critically empirical test. Explanations and laws are accomplished science, while theories and tests 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" referred to universally quantified sentences containing "theoretical terms" that reference unobserved phenomena or entities.

The nineteenth-century early positivists such as the physicist Ernst Mach rejected theory, especially the atomic theory of matter in physics, because atoms were deemed unobservable. These early positivist philosophers' idea of discovery consisted of induction, which yields empirical generalizations containing only observation terms rather than theories containing theoretical terms.

Later the twentieth-century neopositivists, who were nominalists, believed that they could validate the meaningfulness of theoretical terms referencing unobserved microphysical particles such as electrons, and thus admit theories as valid science. For discovery of theories they invoked human creativity but offered no description of the processes of theory creation.

These neopositivists also 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 can be derived deductively as theorems from Newton's inverse-square principle. For the atavistic romantic philosophers and the anachronistic romantic social scientists "theory" means language describing intersubjectively experienced mental states such as ideas and motivations that are deemed to be "causes" of "human actions".

Many romantics still portray the theory-creation process as consisting firstly of introspection by the theorist upon his own personal intersubjective experiences or his imagination. Then secondly it consists of the theorist imputing his introspectively experienced ideas and motives to the social members under investigation. The sociologist Max Weber (1864-1920) called this process *verstehen*. When the social scientist can recognize or at least imagine the imputed ideas and motives, then the ideas and motives expressed by his theory are "convincing" to him, even if his theory is empirically inadequate.

3.43 Pragmatic Definition of Theory Language

Scientific theories are universally quantified language that can be expressed as nontruth-functional hypothetical-conditional statements including mathematical expressions (a.k.a. "models") <u>that are proposed for empirical testing</u>.

Unlike positivists and romantics **realistic neopragmatists define theory language pragmatically**, *i.e.*, **by its function in basic research**, instead of syntactically as an axiomatic system or semantically by some distinctive content. The realistic neopragmatist definition contains the traditional idea that theories are hypotheses, but the reason for their hypothetical status is not due either to the positivist observation-theory dichotomy or to the romantics' requirement of referencing intersubjective mental states. On the realistic neopragmatist philosophy theory language is hypothetical because interested scientists agree that in the event of falsification, it is the theory language that is deemed falsified instead of the test-design language. Sometimes theories are deemed to be more hypothetical, because their semantics is believed to be more empirically underdetermined than the test-design language.

Contrary to positivists and romantics the realistic neopragmatist view theory as a special function of language – empirical testing – rather than a special type of language.

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

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.

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 can design new and additional empirical tests. Designing empirical tests can tax the ingenuity of the most brilliant scientist, and theories may have lives lasting many years due to difficult problems in 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.

Romantic social scientists adamantly distinguish theory from "models". Many alternative supplemental and fanciful speculations about motives, which romantics call "theory", can be appended to an empirical model that has been tested. But it is the model that is empirically tested statistically and/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.

Sometime 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 been accepted as scientific law, it was tested in 1919 in the historic Eddington eclipse test of Einstein's alternative relativity theory. Thus for a time early in the twentieth century Newton's theory was pragmatically speaking a theory again.

On the pragmatic definition "theory" identifies the transient status of language that is proposed for testing.

On the archival definition "theory" identifies a permanent status of accepted language as in a historical archive.

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 occasionally done herein). The archival meaning is what in his *Patterns of Discovery* Hanson calls "completed science" or

"catalogue science" as opposed to "research science". Nevertheless the archival sense has long-standing usage and will be in circulation for a long time to come.

But the archival sense is history and is not the meaning needed to understand the research practices and historical progress of basic science. Research scientists seeking to advance their science using theory in the archival sense instead of the functional concept are misdirected away from advancement of science. They resemble archivists and antiquarians, who do not produce the documents and artifacts they merely collect.

Philosophers of science today recognize the pragmatic meaning of "theory", which describes it as a transitional phase in the history of science. Pragmatically 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 and lesser truth.

3.44 Pragmatic Definition of Test-Design Language

Pragmatically theory in research science is universally quantified language that is <u>proposed</u> for testing, and test-design language is universally quantified language that is <u>presumed</u> for testing.

Accepting or rejecting the hypothesis that there are white crows presumes a prior agreement about the semantics needed to identify a bird's species. The testdesign language defines the semantics that identifies the subject of the tested theory and the procedures for executing the test. Its semantics also includes and 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 theory's initial conditions. The semantics for the independent characterization of the observed outcome resulting after the test execution is also included in the test design language. If the test outcome is nonfalsifying, the universally quantified test-design statements then 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 test 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. However during the test only the test-design statements have definitional force, so that the test has contingency. Theories are not true by definition.

Often test-design concepts describing the subject of a theory are either not yet formulated or are too vaguely described 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. Such is the condition of string theory in physics today. 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 test decision supplies the additional clarifying semantics that reduces the disabling empirical underdetermination.

3.45 Pragmatic Definition of Observation Language

In an empirical test observation language in science is test-design sentences that are given particular logical quantification for describing the subject of the individual test event, the test procedure and its execution including notably 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 otherwise observationally 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, realistic neopragmatists 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 it contributes semantical components to the complex meanings associated with the descriptive terms shared with the universally quantified test-design sentences. And the nonfalsified tested theory, *i.e.*, law, when given particular quantification is also used for observational reporting. As Einstein told Heisenberg, the theory decides what the physicist can observe.

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 any of the test-design sentences from the theory sentences. But after the nonfalsifying test outcome, where such derivation is possible, coherence is increased and vagueness is thereby further reduced. Furthermore due to such a derivation test-outcome measurement values in mathematically expressed theories may be changed to numerical values that still fall within the range of measurement error, and the accuracy of the measurement values may be judged improved.

3.46 Observation and Test Execution

Before the test the semantics for all the language needed to realize a theory's initial conditions together with the test-outcome statements have their semantics defined by the universal statements in the test design, since particularly quantified language does not define semantics.

During the individual test event all the antecedent test design statements describing the subject of the theory and the test protocols have their logical quantification change to particular quantification together with the test outcome statements. Then the particularly quantified conditional theory statements are used to produce the consequent prediction in the test.

After the test is executed the particularly quantified statements that are the test outcome statements in the test design report the observed test outcome, and these are compared with the particularly quantified prediction statements. If the consequent prediction statements and the test outcome statements state the same thing, then the test is nonfalsifying. The prediction statements are not as such observation statements unless the test outcome is nonfalsifying. If the test is falsifying, the falsified theory and its erroneous predictions are merely rejected language.

For a mathematically expressed theory particular logical quantification is accomplished by assigning values by measurement to implement the theory's initial conditions needed to calculate the theory's one or several prediction variables and then by calculating the predicted numerical values. A nonfalsifying test outcome is a predicted magnitude that deviates from the measurement magnitude for the same variable by an amount that is within the estimated range of measurement errors, 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 has falsified the theory, and the prediction values are simply rejected as erroneous.

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 a 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 and is furthermore not limited to academicians.

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 are different theories with different subjects.

Secondly different expressions are different theories, because each makes contrary claims about a common subject. The test-design language defines the common subject. This is equivalent to Popper's individuating theories.

A problem related to individuation of theories is the **linguistic boundary of an individual theory,** a problem ignored by philosophers who take a wholistic view of theories. The extent of the language of an individual theory is determined by what is necessary to solve the problem defined by the test design, *i.e.*, necessary to make an empirically adequate explanation and make empirically accurate predictions. If the theory is falsified in a test, then an innovative scientist may decide to incorporate more language that he believes is strategic to a nonfalsifying test, thereby performing the discovery practice of theory elaboration. Or he may call upon the other discovery practices of theory extension or theory revision.

Chapter 4. Functional Topics

The preceding chapters have offered generic sketches of the principal twentieth-century philosophies of science, namely romanticism, positivism and neopragmatism. And they have discussed selected elements of the contemporary realistic neopragmatist 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 the philosophy of language into the four sequential functional topics, namely (1) the institutionalized aim of basic science, (2) scientific discovery, (3) scientific criticism, and (4) scientific explanation.

4.01 Institutionalized Aim of Science

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

During the last approximately three hundred years empirical science has evolved into an institution with its own distinctive and autonomous professional subculture of shared naturalistic views and values.

Idiosyncratic motivations of individual scientists are historically noteworthy, but are largely of anecdotal interest for philosophers of science, except when such idiosyncrasies have episodically produced results that initiated 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

Early positivists aimed to create explanations having objective basis in observations and to make empirical generalizations summarizing the individual observations. They rejected all theories as speculative and therefore as unscientific. The positivists proposed a foundational agenda based on their naturalistic philosophy of language. Early positivists such as Mach proposed that science should aim for firm objective foundations by relying exclusively on observation, and should seek only empirical generalizations that summarize the individual observations. They deemed theories to be at best temporary expedients and too speculative to be considered appropriate for science. However, the early positivist Pierre Duhem (1861-1916) admitted that mathematical physical theories are integral to science, and he maintained that their function is to summarize laws as Mach said laws summarize observations, although Duhem denied that theories have either a realistic or a phenomenalist semantics thus avoiding the later neopositivists' problems with theoretical terms.

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

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

Positivists alleged the existence of "observation terms", which are terms that reference only observable entities or phenomena. Observation terms are deemed to have simple, elementary and primitive semantics and to receive their semantics ostensively and passively in perception. Positivists furthermore called the particularly quantified sentences containing only such terms "observation sentences", if issued on the occasion of observing. For example the sentence "That crow is black" uttered while the speaker of the sentence is viewing a present crow, is an observation sentence.

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

These neopositivists were self-deluded, because in fact a truth-functional logic cannot capture the hypothetical-conditional 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 expressing the theory is defined as true no matter whether the consequent is true or false. But in the practice of science a false antecedent statement means that execution of a test did not comply with the definition of initial conditions in the test design thus invalidating the test, and is therefore irrelevant to the truth-value of the conditional statement that is the tested theory. Consequently the aim of these neopositivist philosophers was not relevant to the aim of practicing research scientists or to contemporary realistic neopragmatist philosophy of science. The truth-functional logic is not seriously considered by post-positivist philosophers of science much less by practicing research scientists, and 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 disconnect between the positivists' philosophical agenda and the actual practices and values of research scientists.

For more about positivism readers are referred to **BOOK II** and **BOOK III** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: *A History* available in the web site at Internet booksellers.

4.03 Romantic Aim

The aim of the *social sciences* is to develop explanations describing social-psychological intersubjective 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 enforced by many social scientists. Thus both romantic philosophers and romantic social scientists maintain that the sciences of culture differ in their aim from the sciences of nature.

Some romantics call their 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. Some romantics advocate "hermeneutics", which originated with the theologian Frederich Scheiermacher (1768-1834). The concept is often associated with literary criticism. It discloses purportedly hidden meaning in a text accessed by vicariously re-experiencing the intersubjective experience of the text's author.

Examples of romantic social scientists are sociologists like Talcott Parsons (1902-1979), an influential American sociologist who taught at Harvard University. In his *Structure of Social Action* (1937) he advocated a variation on the philosophy of the sociologist Max Weber, in which vicarious understanding that Weber called "*verstehen*" is a criterion for criticism that the romantics believe trumps empirical evidence. *Verstehen* sociology is also known as "folk sociology" or "pop sociology". Enforcing this "social action" 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.

An example of an economist whose philosophy of science is paradigmatically romantic is Ludwig von Mises (1881-1973), an Austrian School economist. In his *Human Action: A Treatise on Economics* (1949) Mises proposes a general theory of human action that he calls "praxeology" that employs the "method of imaginary constructions", which suggests Weber's ideal types. He finds praxeology exemplified in both economics and politics. Mises maintains that praxeology is deductive and a priori like geometry, and is therefore unlike natural science. Praxeological theorems cannot be falsified, because they are certain. All that is needed for deduction of praxeology's theorems is knowledge of the "essence" of human action, which is known introspectively. On his view experience merely directs the investigator's interest to problems.

The 1989 Nobel-laureate econometrician Trygve Haavelmo (1911-1999) in his "Probability Approach in Econometrics" in *Econometrica* (July supplement, 1944) supplies the romantic agenda ostensibly used by most econometricians today. Econometricians do not reject the aim of prediction, simulation, optimization and policy formulation using statistical econometric models; with their econometric modeling agenda they enable it. But they subordinate the selection of explanatory variables in their models to factors that are derived from economists' heroically imputed maximizing rationality theses, which identify the motivating factors explaining the decisions of economic agents such as buyers and sellers in a market. As Mary S. Morgan (1921-2004) laments in her *History of Econometric Ideas* (1990) the econometricians following Haavelmo exclude econometrics from discovery and limit its function to testing theory. In his *Philosophy of Social Science* (1995) Alexander Rosenberg (1946) describes the economists' theory of "rational choice", *i.e.*, the use of the maximizing rationality theses, as "folk psychology formalized".

However the "theoretical" economist's rationality postulates have been relegated to the status of a fatuous *cliché*, because in practice the econometrician almost never derives his equation specification deductively from the rationality postulates expressed as preference schedules. Instead he will select variables to produce statistically acceptable models that produce accurate predictions regardless of the rationality postulates. In fact in Haavelmo's seminal paper he wrote that the economist may "jump over the middle link" of the preference schedules, although he rejected determining equation specifications by statistics.

For more about the romantics including Parsons, Weber, Haavelmo and others readers are referred to **BOOK VIII** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: A *History*, which is available through hyperlinks in the web site to Internet booksellers.

4.04 More Recent Ideas

Most of the twentieth-century philosophers' 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. For example:

Einstein: Reflection on his relativity theory influenced Albert Einstein's concept of the aim of science, which he set forth as his "programmatic aim of all physics" stated in his "Reply to Criticisms" in *Albert Einstein: Philosopher-Scientist* (1949). 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 certainly did not reject empiricism, but he included an explicit coherence agenda in his aim of science. His thesis implies a uniform ontology for physics, and he accordingly found statistical quantum theory to be "incomplete" according to his aim. His is a minority view among physicists today.

Popper: Karl R. Popper was an early post-positivist philosopher of science and was also critical of the romantics. Reflecting on Arthur Eddington's (1882-1944) historic 1919 solar eclipse test of Einstein's relativity theory in physics Popper proposed in his *Logic of Scientific Discovery* (1934) that the aim of science is to produce tested and nonfalsified theories having greater universality and more information content than any predecessor theories addressing the same subject. Unlike the positivists' view his concept of the aim of science thus focuses on the growth of scientific knowledge. And in his *Realism and the Aim of Science* (1983) 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* (1958) and in *Perception and Discovery*: *An Introduction to Scientific Inquiry* (1969) that the aim of 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 ideas into more elegant formal axiomatic patterns. He follows Peirce who called hypothesis formation "abduction". Today mechanized discovery systems typically 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* (1957) maintained in his popular *Structure of Scientific Revolutions* (1962) 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". And he said that scientists neither desire nor aim consciously to produce revolutionary new theories, which he called "extraordinary science". This concept of the aim of science is thus a conformist agenda; Kuhn therefore defined scientific revolutions as institutional changes in science, which he excludes from the institutionalized aim of science.

Feyerabend: Paul K. Feyerabend reflecting on the development of quantum theory in his *Against Method* (1975) proposed that each scientist has his own aim,

and that contrary to Kuhn anything institutional is a conformist impediment to the advancement of science. He said that historically successful scientists 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, Feyerabend advocates "revolution in permanence".

For more about the philosophies of Popper, Kuhn, Hanson and Feyerabend readers are referred to <u>BOOK V, BOOK VI</u> and <u>BOOK VII</u> at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: A *History* available at Internet booksellers through hyperlinks in the web site.

4.05 Aim of Maximizing "Explanatory Coherence"

Thagard: Computational philosopher of science Thagard proposes that the aim of science is "best explanation". This thesis refers to an explanation that aims to maximize the explanatory coherence of one's overall set of beliefs. The 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. His computer system described in his *Conceptual Revolutions* (1992) simulated the realization of the aim of maximizing "explanatory coherence" by replicating various episodes of theory choice in the history of science. In his system "explanation" is an undefined primitive term. He applied his system **ECHO** to replicate theory choices in several 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. It is surprising that these developments are described as maximized coherence with overall beliefs.

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 three criteria yields the "best explanation".

"Explanationism", maximizing the explanatory coherence of one's overall set of beliefs, is inherently conservative. The **ECHO** system appears to document the historical fact that the coherence aim is psychologically satisfying and occasions strong, and for some scientists nearly compelling motivation for accepting coherent theories, while theories describing reality as incoherent with established beliefs are psychologically disturbing, and are often rejected when first proposed. But progress in science does not consist in maximizing the scientist's psychological contentment. Empiricism eventually overrides coherence when there is a conflict due to 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 general relativity theory, do not conform to **ECHO**'s maximizing-explanatory-coherence criterion.

For more about the philosophy of Thagard readers are referred to **BOOK <u>VIII</u>** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: A *History*, which is available at Internet booksellers through hyperlinks in the web site.

4.06 Contemporary Pragmatist Aim

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

The principles of contemporary realistic neopragmatism including its philosophy of language have evolved through the twentieth century beginning with the autobiographical writings of 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: (1) relativized semantics, (2) empirical underdetermination and (3) ontological relativity, which are not repeated here.

For more about the philosophy of Heisenberg readers are referred to **BOOK II** and **BOOK IV** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: A *History*, which is available at Internet booksellers through hyperlinks in the web site.

The institutionally regulated practices of research scientists may be described succinctly in the realistic neopragmatist statement of the aim of science.

The contemporary research scientist seeking success in his research may consciously employ this aim as what some social scientists call a "rationality postulate". The institutionalized aim of science can be expressed as such a realistic neopragmatist rationality postulate as follows:

The institutionalized aim of science is to construct explanations by developing theories that satisfy critically empirical tests, which theories are thereby made scientific laws that can function in scientific explanations and test designs.

Pragmatically rationality is not some incorrigible principle or intuitive preconception. The contemporary realistic neopragmatist statement of the aim of science is a postulate in the sense of an empirical hypothesis about what has been and will be responsible for the historical advancement of basic-research science. Therefore like any hypothesis 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 by philosophers and scientists as misconceptions and perhaps even superstitions, as are the romantic and positivist beliefs today. The aim of science is more elaborately explained in terms of all four of the 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 and even irrelevant. Thus the contemporary realistic neopragmatist statement of the aim of science may instead be phrased as follows in terms of a successful **outcome** instead of a conscious aim imputed to scientists:

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

The empirical criterion is the <u>only</u> criterion acknowledged by the contemporary realistic neopragmatist, because it is the only criterion that accounts for the advancement of science. Historically there have been other proposed criteria, but whenever there has been a conflict, eventually it is demonstrably superior empirical adequacy often exhibited in practicality that has enabled a new theory to prevail. This is true even if the superior 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 (who lived in the third century BCE).

4.07 Institutional Change

Change <u>within</u> the institution of science is change made under the regulation of the institutionalized aim of science, and may consist of new theories, new test designs, new laws and/or new explanations.

Change <u>of</u> the institution of science, *i.e.*, institutional change, on the other hand is the historical evolution of scientific practices involving revision of the aim of science, which may be due to revision of its criteria for criticism, its discovery practices, or its concept of explanation.

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 often 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. The emergence of artificial intelligence in the sciences may exemplify an institutional change in progress today.

In the history of science institutionally deviate practices that yielded successful results were 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 became conventionalized. And that is clearly true of the quantum theory. By the time they are deemed acceptable to the peer-reviewed literature, reference manuals, encyclopedias, student textbooks, academic mediocrities and hacks, and desperate plagiarizing academics, the institutional change is complete and has become the received 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.

Newton's contemporaries, Gottfried Leibniz (1646-1716) and Christian Huygens (1629-1695) had criticized Newton's gravitational theory for admitting action at a distance. Both of these contemporaries of Newton were convinced that all physical change must occur through direct physical contact like colliding billiard balls, as René Descartes (1596-1650) had believed. Leibniz therefore described Newton's concept of gravity as an "occult quantity" and called Newton's theory unintelligible. But eventually Newtonian mathematical physics became institutionalized and paradigmatic of explanation in physics. For example by the later nineteenth century the physicist Hermann von Helmholtz (1821-1894) said that to understand a phenomenon in physics means to reduce it to Newtonian laws.

In his *Concept of the Positron* (1963) Hanson proposes three stages in the process of the evolution of a new concept of explanation; he calls them the blackbox, the gray-box, and the glass-box stages. In the initial black-box stage, there is an algorithmic novelty, a new formalism, which is able to account for all the phenomena for which an existing formalism can account. Scientists use this technique, but they then attempt to translate its results into the more familiar terms of the prevailing orthodoxy, in order to provide "understanding". In the second stage, the gray-box stage, the new formalism makes superior predictions in comparison to older alternatives, but it is still viewed as offering no "understanding". Nonetheless it is suspected as having some structure that is in common with the reality it predicts. In the final glass-box stage the success of the new theory will have so permeated the operation and techniques of the body of the science that its structure will also appear as the proper pattern of scientific inquiry.

Einstein was never able to accept the Copenhagen statistical interpretation in quantum mechanics and a few physicists today still reject it. Writing in 1962 Hanson said that quantum theory is in the gray-box stage, because scientists have not yet ceased to distinguish between the theory's structure and that of the phenomena themselves. This amounts to saying that they did not practice ontological relativity. But since Aspect, Dalibard, and Roger's findings from their 1982 nonlocality experiments demonstrated empirically the Copenhagen interpretation's semantics and ontology, the quantum theory-based evolution of the concept of explanation in physics has become institutionalized.

4.08 Philosophy's Cultural Lag

There often exists a time lag between an evolution in the institution of science and developments in philosophy of science, since the latter depend on the realization of the former.

And there are also retarding sociological impediments. Approximately a quarter of a century passed between Heisenberg's philosophical reflections on the language of his indeterminacy relations in quantum physics and the emergence of the contemporary realistic neopragmatist philosophy of science in academic Heisenberg is not just one of the twentieth century's greatest philosophy. physicists, he is also one of its greatest philosophers of language. But even today academic philosophers are still mute about Heisenberg's philosophical writings; they treat him as a mere layman in philosophy who is unworthy of reference by serious academic philosophers. These tribal academics cling to their positivist thesis of operational definitions, use only textbooks written by other academic philosophers, publish only journal articles written by other academic philosophers, and reference only books written by other academic philosophers - all while ignoring works having superior intrinsic merit that are written by nonacademics such as Heisenberg. With the incestuous institutional values of a mediaeval occupational guild academic philosophers stake out their turf, construct their territorial defenses, barricade themselves in their silos and enforce their monopoly status in 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 of the received wisdom. As Planck (1858-1947) grimly wrote in his *Scientific Autobiography* (1949), a new truth does not triumph by convincing its opponents, but rather succeeds because its opponents have died off; or as he also said, science progresses "funeral by funeral".

The younger social and behavioral sciences have remained institutionally retarded. Naïve sociologists and even economists today 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 counterproductive. The result has been the emergence and survival of philosophical superstitions in these retarded social sciences, especially to the extent that they have looked to their own less successful histories to formulate their ersatz and erroneous philosophies of science.

Thus currently most sociologists and economists still enforce a romantic philosophy of science, because they erroneously 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. These sciences are institutionally retarded, because they erroneously impose preconceived semantical and ontological commitments as criteria for scientific criticism. Realistic neopragmatists can agree with Popper, who in his critique of Kuhn in "Normal Science and its Dangers" in *Criticism and the Growth of Knowledge* (1970) said that science is "subjectless" meaning that valid science is not defined by any particular semantics or ontology. Realistic neopragmatists tolerate any semantics or ontology that romantics or positivists may include in their scientific explanations, theories and laws, but realistic neopragmatists recognize *only* the empirical criterion for criticism.

4.10 Scientific Discovery

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

Discovery is the first step toward realizing the aim of science. The problem of scientific discovery for contemporary realistic neopragmatist philosophers of science is to proceduralize and then to mechanize the development of universally quantified statements for empirical testing with nonfalsifying test outcomes, thereby making laws for use in explanations and test designs. **Contemporary realistic neopragmatism is consistent with the use of computerized discovery systems.**

4.11 Discovery Systems

A mechanized discovery system produces a transition from an inputlanguage state description containing currently available language to an output-language state description containing generated and tested new theories. 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 realistic neopragmatist philosophy of science thus carries forward the classical pragmatist Dewey's emphasis on participation. Unfortunately few academic philosophers have the requisite computer skills to write AI systems much less the needed working knowledge of an empirical science for participation in basic research. Hopefully that will change in future Ph.D. dissertations in philosophy of science, which are very likely to be interdisciplinary endeavors.

Every useful discovery system to date has contained procedures both for constructional theory creation and for critical theory evaluation for quality control of the generated output and for quantity control 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 in empirical tests eliminates language from the current state description to produce a new state description. Thus theory development and theory testing together enable a discovery system to be a specific and productive diachronic dynamic procedure for linguistic change to advance 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* (1971) to produce a proliferation of theories. But while many are made by these systems, mercifully few are chosen thanks to the empirical testing routines in the systems to control for both quality and quantity of the outputted equations.

4.12 Types of Theory Development

In his *Introduction to Metascience* Hickey distinguishes three types of theory development, which he calls **theory extension**, **theory elaboration** and **theory revision**. This classification is vague and may be overlapping in some cases, but it suggests three alternative types of discovery strategies and therefore implies different discovery-system designs.

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 a new problem at hand. **Analogy is a special case of theory extension.** When physicists speak of "models", they are referring to analogies. In his *Computational Philosophy of Science* (1988) Thagard describes this strategy for mechanized theory development, which consists in the patterning of a proposed solution to a new problem by analogy with a successful explanation originally developed for a different subject. Using his system design based on this strategy his discovery system called **PI** (an acronym for "Process of Induction") produced a rational reconstruction of the theory of sound waves by analogy with the description of water waves. The system was his Ph.D. dissertation in philosophy of science at the University of Toronto, Canada.

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 explain. 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 also a "leap", because analogic is not conclusive like deduction.

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 affected profession may experience the communication constraint to the high degree that is usually associated with a theory revision. The communication constraint is discussed below (See 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 (and also perhaps removing some) that correct the falsified universally quantified statements and erroneous predictions of the old falsified theory.

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 reflection on the basis for individuating theories reveals that in fact it creates a new one (See above, Section **3.48**).

For example the introduction of a variable for the volume quantity and the development of a constant coefficient for the particular gas could elaborate Gay-Lussac's (1778-1850) law for gasses into Boyle's law. Similarly 1976 Nobel-laureate Milton Friedman's (1912-2006) macroeconomic quantity theory might be elaborated into a Keynesian hyperbolic liquidity-preference function by the introduction of an interest rate both to account for the cyclicality manifest in an annual time series describing the calculated velocity parameter and to display the liquidity trap phenomenon, which actually occurred in the Great Depression of 1929-1933, in the Great Recession of 2007-2009 and in the recession due to the coronavirus epidemic beginning in 2020.

Pat Langley's **BACON** discovery system exemplifies mechanized 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 given 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 many variables, **BACON** searches for functional relations among the variables. **BACON** has produced rational reconstructions that 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 the reorganization of currently available information to create a new theory.

The results of theory revision may be radically different from any current theory address in the same subject, and may thus be said to occasion a "paradigm change". It might be undertaken after repeated attempts at both theory extension and theory elaborations have failed. The source for the input state description for mechanized theory revision presumably consists of the descriptive vocabulary from the currently untested theories addressing the problem defined by a test design. But 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. In fact even terms and variables from tested and nonfalsified theories could also be included, just to see what new proposals come out; empirical underdetermination permits scientific pluralism, and reality is full of surprises. Hickey notes that a mechanized discovery system's newly outputted 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 due to the transition.

Theory revision, the reorganization of currently existing information to create a new theory, is evident in the history of science. The central thesis of Cambrian historian of science Herbert Butterfield's (1900-1979) Origins of Modern Science: 1300-1800 (1958, P. 1) is that the type of transition known as a "scientific revolution" was not brought about by new observations or additional evidence, but rather by transpositions in the minds of the scientists. Specifically he maintains that the type of mental activity that produced the historic scientific revolutions is the "art" of placing a known bundle of data in a new system of relations. Hickey found this "art" in the history of economics: 1980 Nobellaureate econometrician Lawrence Klein (1920-2013) wrote in his Keynesian Revolution (1949, Pp. 13 & 124) that all the important parts of Keynes theory can be found in the works of one or another of his predecessors. In other words Keynes put a known bundle of information into a new system of relations, relations such as his aggregate consumption function and his money-demand function with its speculative-demand component and the liquidity trap. Thus Hickey saw that his theory-revising METAMODEL discovery system could simulate the development of Keynes' revolutionary general theory.

Therefore using his **METAMODEL** discovery system in 1972 Hickey produced a rational reconstruction of the development of 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 input information consisted of variables found in the published literature of macroeconomics up to 1935 and the corresponding statistical data are published in the U.S. Department of Commerce releases titled *Historical Statistics of the United States*: *Colonial Times to 1970* and *Statistical Abstract of the United States*. Hickey's **METAMODEL** discovery system described in his *Introduction*

to Metascience is a mechanized generative grammar with combinatorial transition rules for producing longitudinal econometric models. His mechanized grammar is a combinatorial finite-state generative grammar that satisfies the collinearity restraint for the regression-estimated equations and for the formal requirements for executable multi-equation predictive models. The system tests for statistical significance (Student t-statistics), for serial correlation (Durbin Watson statistic), for goodness-of-fit and for accurate out-of-sample retrodictions.

He also used his **METAMODEL** system in 1976 to develop a **postclassical macro<u>sociometric</u> neofunctionalist** model of the American national society with fifty years of historical time-series data. The generated sociological model disclosed an *intergenerational negative feedback* that sociologists would call a "macrosocial integrative mechanism", in which an increase in social disorder indicated by a rising homicide rate calls forth a delayed intergenerational stabilizing reaction by the **socializing institution** indicated by the high school completion rate, which in turn restores order by reinforcing compliance with criminal law. The paper is reprinted as "Appendix I" to <u>BOOK VIII</u> at the free web site <u>www.philsci.com</u> and in the e-book *Twentieth-Century Philosophy of Science: A History*.

This macrosociometric model was not just a simulation of a past episode. It is an example of contemporary AI-developed theory revision, an excursion into new territory that is still both unfamiliar and intimidating to academic sociologists, because it is beyond their competence and threatens their dogmas.

Consequently Hickey incurred the rejection often encountered by such pioneering excursions. To the shock, chagrin and dismay of complacent academic sociologists the model is not a social-psychological theory, and the paper panicked the editors of four peer-reviewed sociological journals, to which he submitted his paper. The referee criticisms and Hickey's rejoinders are given in **"Appendix II"**, and his consequent critique of the retarded condition of academic sociology is given in **"Appendix III"**. Both appendices are in **BOOK VIII** at the free web site www.philsci.com and in the e-book *Twentieth-Century Philosophy of Science: A History*, which is available at Internet booksellers through hyperlinks in the web site. Hickey fully expects that some desperate and mediocre academic sociologist will plagiarize his ideas without referencing his books or his web site.

The scientific revolution in sociology against "classical" sociology demanded by University of Virginia sociologist Donald Black's address at the American Sociological Association's annual meeting, published in *Contemporary Sociology* as "The Purification of Sociology", requires recognition of the distinctive characteristics of <u>macrosociology</u>. Contrary to the reductionist conventional wisdom of current sociologists, distinctively macrosocial outcomes are not disclosed by multiplying social-psychological (*i.e.* microsociological) behaviors *n* times. Hickey calls romantic sociology with its social-psychological reductionism "classical", because his macrosociological quantitative functionalist theory supersedes the prevailing social-psychological reductionism, and manifests a basic difference between macro and micro levels of sociological explanation, which resembles the difference is to commit the fallacy of composition, as 1970 Nobel-laureate economist Paul Samuelson (1915-2009) explains in his ubiquitous undergraduate textbook *Economics*. Hickey's macrosociometric model with its intergenerational negative feedback is such a distinctively macrotheory.

Hickey calls academic sociologists "classical" with the same meaning as Black, who said that "purifying" sociology of its "classical" tradition is a necessary condition for its needed revolutionary advance. Black expects that this new purified sociology will differ so fundamentally from the prevailing classical sociology, that most sociologists will undoubtedly resist it for the rest of their days, declaring it "incomplete, incompetent and impossible". And he adds that sociology has never had a revolution in its short history, that classical sociology is all that sociologists have ever known, and that sociologists "worship dead gods of the past" while viewing disrespect as heresy. Hickey believes that instead of "purify" he might have said "purge".

Simon called the combinatorial system design for theory revision (like the design of Hickey's **METAMODEL**) a "generate-and-test" design. In the 1980's Simon proposed his "heuristic-search" design, because he believed that combinatorial procedures consume excessive computational resources for present-day electronic computers. But Hickey's generate-and-test system was small enough to operate in IBM 370 and IBM RS 6000 computers. Gordon E. Moore formulated a famous "law" appropriately known as "Moore's Law", which states that the number of transistors that can be placed on a CPU chip doubles every year. This is an annually compounded exponential growth rate in computing power. Furthermore developments in quantum computing promise to overcome computational constraints, where such capacity constraints are currently encountered. The increase in throughput that will be enabled by the quantum computer is extraordinary relative to the conventional electronic computer including the electronic supercomputer. The availability of practical quantum

computing seems only a matter of time. *The New York Times* (24 October 2019) reported that Google's Research Lab in Santa Barbara, CA, announced in the scientific journal *Nature* that its computer scientists have achieved "quantum supremacy". The article also quoted John Martinis, project leader for Google's "quantum supremacy experiment" as saying that his group is now at the stage of trying to make use of this enhanced computing power.

4.13 Examples of Successful Discovery Systems

There are several examples of successful discovery systems in 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 before Laumann and his romantics, who would likely have rejected it, had taken over the University of Chicago sociology department. Sonquist described the system in his *Multivariate Model Building: Validation of a Search Strategy* (1970). The system has long been used at the Survey Research Center, Institute for Social Research, University of Michigan, Ann Arbor, MI. Now modified as the **CHAID** system using chi-squared (χ^2) Sonquist's discovery system is widely available commercially in both the SAS and SPSS software packages. Its principal commercial application has been for list-processing scoring models for commercial market analysis and for creating credit-risk scores as well as for academic investigations in social science. It is not only the oldest mechanized discovery system, but is also the most widely used in practical applications to date.

Robert Litterman developed his **BVAR** (Bayesian Vector Autoregression) 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 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.

Hickey originally developed his **METAMODEL** discovery system to simulate the development of J. M. Keynes' general theory. For the next thirty years he used his discovery system occupationally as a research econometrician in both business and government. While he was Deputy Director and Senior Economist for the Indiana Department of Commerce in the mid-1980's, he integrated his macro<u>sociometric</u> model of the American national society into a Keynesian macroeconometric model and produced an institutionalist macroeconometric model of the American national economy. He described the model and its findings in "The Indiana Economic Growth Model" in *Perspectives on the Indiana Economy* (March, 1985). The model showed that increased funding for public education improves the economy by increasing labor productivity, and that a consequent increase in high school graduation rates improves social stability by mitigating crime rates. A report of the findings was read to the Indiana Legislative Assembly by the Speaker of the House in support of Governor Orr's successful "A-plus program" legislative initiative for an increase of \$300 million in State-government spending for K-12 primary and secondary public education.

Hickey also used his METAMODEL system for market analysis and for risk analysis for various 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 the TransUnion LLC credit bureau. In 2004 TransUnion purchased a perpetual license for his system to analyze their proprietary TrenData aggregated quarterly time series extracted from their national database of consumer credit files. While in TransUnion's Analytical Services Department Hickey used the models he generated with his discovery system to forecast payment delinquency rates, bankruptcy filings, average balances and other consumer borrower characteristics indicating risk exposure for lenders. He also used his system for Quaker Oats, Kraft Foods and Brown & Williamson Companies to analyze the sociology, economics and demographics responsible for the secular market dynamics of their processed food products and other nondurable consumer goods. Findings from this METAMODEL discovery system earned Hickey promotions and substantial bonuses from several of his employers.

In 2007 Michael Schmidt, a Ph.D. student in computational biology at Cornell University, and his dissertation director, Hod Lipson, developed their system **EUREQA** at Cornell University's Artificial Intelligence Lab. The discovery system automatically develops predictive analytical models from data using a strategy they call an "evolutionary search" to find invariant relationships, which converges on the simplest and most accurate equations fitting the inputted data. They report that the system has been used by many business corporations, universities and government agencies including Alcoa, California Institute of Technology, Cargill, Corning, Dow Chemical, General Electric Corporation, Amazon, Shell Corporation and NASA.

For more about discovery systems and computational philosophy of science readers are referred to **BOOK VIII** at the free web site <u>www.philsci.com</u> or in the

e-book *Twentieth-Century Philosophy of Science*: A *History*, which is available at Internet booksellers through hyperlinks in the web site.

4.14 Scientific Criticism

Criticism pertains to the criterion for the acceptance or rejection of theories. The <u>only</u> criterion for scientific criticism that is acknowledged by the contemporary realistic neopragmatist is the *empirical criterion*.

The philosophical literature on scientific criticism has little to say about the specifics of experimental design, as might be found in various college-level science laboratory manuals. Most often philosophical discussion of criticism pertains to the criteria for acceptance or rejection of theories and more recently to the effective decidability of empirical testing that has been called into question due to the wholistic semantical thesis.

In earlier times when the natural sciences were called "natural philosophy" and social sciences were called "moral philosophy", nonempirical considerations 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 theories including preconceptions about causality or specific causal factors. Such semantical and ontological preconceptions have misled them to reject new empirically superior theories.

What historically has separated the empirical sciences from their origins in natural and moral philosophy is the empirical criterion. This criterion 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. Contemporary realistic neopragmatists accept relativized semantics, scientific realism, and ontological relativity, and they therefore reject all prior semantical or ontological criteria for scientific criticism including the romantics' mentalistic ontology requiring social-psychological or any other reductionism.

4.15 Logic of Empirical Testing

Different sciences often have different surface structures, which may involve complex mathematics. But the syntactical transformation of the surface structure of a theory into the nontruth-functional hypothetical-conditional logical form is the philosopher's heuristic enabling a rational reconstruction that produces the **deep structure** of the theory and explicitly displays the contingency of the empirical test and its logic.

The deep structure of the language of an empirical test exhibits:

(1) an effective decision procedure that can be expressed as a *modus tollens* logical deduction from a set of one or several universally quantified theory statements expressed in a nontruth-functional hypothetical-conditional form

(2) together with a particularly quantified antecedent description of the test protocols and the initial test conditions as defined in the test design

(3) that jointly conclude to a consequent particularly quantified description of a produced (predicted) test-outcome event

(4) 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 syntactically transformed into a nontruth-functional hypothetical-conditional deep structure, *i.e.*, as a statement with the logical form "For every A if A, then C."

This nontruth-functional hypothetical-conditional schema "For every A if A, then C" represents a system of one or several universally quantified and typically interdependent theory statements or equations that describe a dependency of the occurrence of events described by "C" upon the occurrence of events described by "A". In some cases the dependency is expressed as a bounded stochastic density function for the values of predicted probabilities. For advocates who believe in the theory, the nontruth-functional hypothetical-conditional schema is the theory-language context that contributes meaning parts to the complex semantics of the theory and test design. But the theory's semantical contribution cannot be operative in a test for the test to be independent of the theory, since the test outcome is not true by definition; it is empirically contingent and the test-design terms must remain vague with respect to 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 including the protocol statements describing the measurement and setup procedures needed for their realization. These statements constituting "A" are always presumed to be true or the test design is rejected as invalid, as is any test made with it. The test-design statements are semantical rules that 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 execution of the test 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 from universal to particular quantification to describe the realized initial conditions in the individual test execution. And the particular quantification of "A" makes the nontruth-functional hypothetical-conditional statement also particularly quantified, to make a prediction or to describe a produced effect. When the universally quantified test-design and test-outcome statements have their logical quantification changed to particular quantification, the belief status and thus the definitional rôle of the universally quantified test-design confer upon their particularly quantified versions the status of "<u>fact</u>" for all who decided to accept the test design. Nietzsche (1844-1900) said that there are no facts; there are only interpretations. Hickey says that due to relativized semantics with its empirical underdetermination and due to its ontological relativity with its consequent referential inscrutability, *all facts are interpretations of reality*. Failure to recognize the interpreted character of facts is to indulge in what Wilfred Sellars (1912-1989) in his *Science, Perception and Reality* (1963) called "the myth of the given", a phrase earlier used by Dewey.

The theory statement need only say "For every A if A, then C". The nontruth-functional hypothetical-conditional statement expressing a theory need not say "For every A and for every C if A, then C, (or "For every A if and only if A, then C" or "For every A, iff A, then C") unless the nontruth-functional hypothetical-conditional statement is convertible, *i.e.*, a biconditional statement, also saying "For every C if C, then A". The uniconditional "For every A if A, then C" is definitive of functional relations in mathematically expressed theories. In other words the nontruth-functional hypothetical-condition for the correct prediction made in C upon realization of the test conditions described in "A", and not a necessary condition. This may occur when scientific pluralism (See below, Section **4.20**) occasions multiple theories proposing alternative causal factors for the same outcome predicted correctly in "C". Or when there are equivalent measurement procedures

or instruments described in "A" that produce alternative measurements with each having values falling within the range of the others' measurement errors.

The theory statements in the nontruth-functional hypothetical-conditional deep structure are also given particular quantification for the 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 and in the test procedure. In a multi-equation system whether recursively structured or simultaneous, all the exogenous variables are assigned values by measurement, and are included in "A". In longitudinal models with dated variables 'A' must also include 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.

The consequent "C" represents the set of universally quantified statements of the theory that predict the outcome of every correct execution of a test design. The nontruth-functional hypothetical-conditional's logical quantification is changed from universal to particular quantification to describe the predicted outcome for the individual test execution. In a mathematically expressed singleequation theory the dependent variable of the theory's equation is in "C". When no value is assigned to any variable, the equation is universally quantified. When the predicted value of a dependent variable is calculated from the measurement values of the independent variables, the equation has been particularly quantified. In a multi-equation theory, whether recursively structured or a simultaneousequation system, the solution values for all the endogenous variables are included in "C". In longitudinal models with dated variables "C" includes the current-dated values of endogenous variables for each iteration of the model, which are calculated by solving the model through successive iterations.

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 in "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 and vague about the theory's content and claims. In an individual test execution "O" represents observations and/or measurements made and measurement values assigned apart from the prediction in "C", and it too has particular logical

quantification to describe the observed outcome resulting from the individual execution of the test. There are then three possible 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 the agreed protocols in the 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 logic is therefore not applicable to testing in empirical science, because in science a false antecedent, "A", does not make the nontruth-functional 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 nontruth-functional hypothetical-conditional "For every A if A, then C" is false by logic. Falsification occurs when the prediction statements in "C" and the observation reports in "O" are not accepted as describing the same thing within the range of vagueness and/or measurement error that are manifestations of empirical underdetermination. The falsifying logic of the test is the modus tollens argument form, according to which the nontruth-functional hypotheticalconditional deep structure expressing the theory is falsified, when one affirms the antecedent clause and denies the consequent clause. This is the falsificationist philosophy of scientific criticism initially advanced by Peirce, the founder of classical pragmatism, and later advocated by Popper, who was a post-positivist but not a pragmatist. For more on Popper readers are referred to **BOOK V** at the free web site www.philsci.com or in the e-book Twentieth-Century Philosophy of Science: A History, which is available in the web site through hyperlinks in the web site to Internet booksellers.

The response to a conclusive falsification may or may not be attempts to develop a new theory. Responsible scientists will not deny a falsifying outcome of a test, so long as they accept its test design and test execution. Characterization of falsifying anomalous cases is informative, because it may contribute to articulation of a new problem that a new and more empirically adequate theory must solve. But 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. Such a response is simply a disengagement from attempts to solve the problem that the falsified theory had addressed. 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.

For more on Kuhn readers are referred to **<u>BOOK VI</u>** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: *A History* available at Internet booksellers through hyperlinks in the web site.

Scenario III: If "A" and "C" are both true, then the nontruth-functional hypothetical-conditional deep structure expressing the tested theory is validly accepted as asserting a causal dependency between the phenomena described by the antecedent and consequent clauses, even if the nontruth-functional hypothetical-conditional statement was merely an assumption. But the acceptance is not a logically necessary conclusion, because to say that it is logically necessary is to commit the fallacy of affirming the consequent. The acceptance is of an empirical and thus falsifiable statement. Yet the nontruth-functional hypotheticalconditional statement does not merely assert a Humean psychological 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 nontruth-functional hypothetical-conditional represents a mathematical function.

But if the test design is afterwards modified such that it changes the characterization of the subject of the theory, then a previous 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 new test outcome is not falsification, then the new information is merely new parts added to the meaning of the univocal terms common to the old and new test-design descriptions. Such would be the case for example for a new and additional way to measure temperature for extreme values that cannot be measured by the old measurement procedure, but which yields the same temperature values within the range of measurement errors, where the alternative procedures produce overlapping measurement results.

On the contemporary realistic neopragmatist 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 the theory has been falsified, it is merely rejected language unless the falsified theory is still useful for the lesser truth it contains. 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 later tested again and falsified. The law is still hypothetical because it is empirical, but it is less hypothetical than it had previously 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 and it is known to function successfully, the science in that engineering is not what is tested when the particle accelerator is operated for the microphysical experiments, but rather the employed science is presumed true and contributes to the test design semantics for experiments performed with the accelerator.

4.16 Test Logic Illustrated

For theories using a mathematical grammar for their surface structures, the mathematical grammar in the object language is typically the most efficient and convenient way to express the theory and to test it. But philosophers of science may transform the mathematical forms of expression representing the surface structures into the deep-structure heuristic consisting of a nontruth-functional hypothetical-conditional schema that exhibits explicitly the empirical contingency expressed by the theory and its logic.

Consider the simple heuristic case of Gay-Lussac's law for a fixed amount of gas in an enclosed container as a theory proposed for testing, a case in which the surface structure is the mathematical equation, which can be transformed into the deep structure expressed as a nontruth-functional hypothetical-conditional sentence. The container's volume is constant throughout the experimental test, and therefore is not represented by a variable. The mathematical equation that is the surface structure of the theory is $\mathbf{T'/T} = \mathbf{P'/P}$, which can be transformed to $(\mathbf{T'/T})^*\mathbf{P} = \mathbf{P'}$, where the variable \mathbf{P} means gas pressure, the variable \mathbf{T} means the gas temperature, and the variables $\mathbf{T'}$ and $\mathbf{P'}$ are incremented values for \mathbf{T} and \mathbf{P} in a controlled experimental test, where $\mathbf{T'} = \mathbf{T} \pm \Delta \mathbf{T}$, and $\mathbf{P'}$ is the predicted outcome that is produced by execution of the test design. The statement of the theory may be schematized in the nontruth-functional hypothetical-conditional form "For every A if A, then C", where "A" includes $(\mathbf{T'/T})^*\mathbf{P}$, 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 easily exhibited in this case, because the equation is monotonic, such that each variable can be expressed as a mathematical function of all the others by simple algebraic transformations.

"A" also includes the universally quantified 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. 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** = 300°K and **P** = 1.0 atmospheres. Let the incremented measurement value be recorded as Δ **T** = 15°K, so that the measurement value for **T'** is made to be 315°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. But 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 the resulting observed 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 measurement error propagated into **P'** by calculation. 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 can summarize the dispersion of measurement errors about the means.

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 equivalent within their estimated ranges of measurement error, *i.e.*, are sufficiently close to 1.050 atmospheres as to be within the measurement errors, then the theory is 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 called today.

4.17 Semantics of Empirical Testing

The ordinary semantics of empirical testing is as follows: In all scientific experiments including microphysical experiments, the relevant set of universal statements is dichotomously divided into a subset of universal statements that is presumed for testing and the remainder subset of universal statements that is proposed for testing. The division is pragmatic. The former subset is called testdesign statements and the latter subset is called theory statements. The test-design statements are presumed true for the test. Consider a descriptive term that is a subject term in any one of the universal statements, and that is common to both the test-design statements and the theory statements in the divided list. The dual analytic-synthetic nature of all of the universal statements makes that common subject term have part of its semantics supplied by the concepts that are predicated of it in the test-design statements. This part of the common subject term's semantics remains unchanged through the test, so long as the division between theory and test-design statements remains unchanged. The proponents and advocates of the theory presumably believe that the theory statements are true with enough conviction to warrant empirical testing, but their belief does not carry the same high degree of conviction that they have in the test-design statements.

Before the execution of a test of the theory, all interested scientists agree that the universally quantified test-design statements and also the particularly quantified language that will describe the test-outcome with semantics defined in the universally quantified test-design statements are true independently of the theory. If the test outcome shows an inconsistency between the characterization supplied by the test-outcome statements and the characterization made by theory's prediction statements, the interested scientists agree than it is the theory that is to be viewed as falsified and not the universally quantified test-design statements.

This independence of test-design and test-outcome statements is required for the test to be contingent, and it precludes the test-design statements from either implying or denying the theory to be tested or any alternative theory that addresses the same problem. Therefore for the cognizant scientific profession the semantical parts defined by the test-design statements before test execution make their terms effectively vague relative to the theory, because test-design statements are silent with respect to any of the theory's claims. The originating proposer and supporting advocates of the theory may have such high confidence in their theory, that for them the theory may supply part of the semantics for its constituent terms even before testing, but they have nonetheless agreed that in the event of a falsifying test outcome the test-design language trumps the theory does not define any part of the semantics of its constituent terms that are common to the test design. Or in other words the test-design statements assumed the vague semantical status that Heisenberg called the physicist's "everyday" concepts.

After the test is executed in accordance with its test design, the particularly quantified test-outcome statements and the theory's particularly quantified prediction statements are either consistent or inconsistent with one another (after discounting empirical underdetermination not attributable to failure to execute the test in accordance with the agreed test design). In other words they either characterize the same observed or measurement instances or they do not. If the test outcome is an inconsistency between the test-outcome description and the theory's prediction, then the theory is falsified. And since the theory is therefore no longer believed to be true, it cannot contribute to the semantics of any of its constituent descriptive terms even for the proposer and advocates of the theory. But if the test outcome is not a falsifying inconsistency between the theory's prediction and the test-outcome description, then they identify the same instances, and for each term common to the theory and test design the semantics contributed by the both universally quantified test-design and theory statements are component parts of the univocal meaning complex of each shared descriptive term. The additional characterization supplied by the semantics of the tested and nonfalsified theory statements resolves the vagueness that the meaning of the common descriptive terms had before the test, especially for those who did not share the conviction had by the theory's proposers and advocates.

In some sciences such as physics a theory's domain may include the testdesign domain for the theory. As stated above, *before* the test execution of such a theory and *before* the test outcome is known, the test-design language must be vague about the tested theory's domain, in order for the test to be independent of the theory's description. But if *after* the test the outcome is known to be nonfalsification of the tested theory, then the nonfalsified theory has become a law, and the domain of the test-design language may be describable with the language of the new law, possibly by logical derivation of the test-design laws from the tested and nonfalsified theory. This application of the test-design statements by still theory to its test domain changes the semantics of the test-design statements by still further resolving the vagueness in the test-design language.

In 1925 when rejecting positivism Einstein told Heisenberg that he must assume that the test design domain can be described by the theory. Einstein argued that it is in principle impossible to base any theory on observable magnitudes alone, because *it is the theory that decides what the physicist can observe*. Einstein argued that when the physicist claims to have observed something new, he is actually saying that while he is about to formulate a new theory that does not agree with the old one, he nevertheless must assume that the new theory functions in a sufficiently adequate way that he can rely upon it and can speak of observations. The claim to have introduced nothing but observable magnitudes is actually to have made an assumption about a property of the theory that the physicist is trying to formulate.

Einstein's conversation with Heisenberg in 1925 about observation influenced Heisenberg's views on quantum mechanics. Before the test outcome is known it is sufficient to use a vaguer or less precise vocabulary that Heisenberg calls "everyday" words used by physicists, in order to describe the experimental set up, which is a macrophysical phenomenon. The meanings of these "everyday" concepts are vague, because they are silent about the fundamental constitution of After the test outcome is known, the tested and nonfalsified quantum matter. theory is recognized as empirically adequate, and the vagueness in these everyday concepts is resolved by the equations constituting the quantum theory. The quantum mechanics became a semantical rule contributing meaning parts to the complex meanings of the univocal terms used to describe the experimental set up and observation. This effectively makes the meanings quantum concepts, whether or not quantum effects are empirically detectable or operative in the description of the macroscopic features of the experimental set up. It is sufficient merely that the scientist realize that the nonfalsifying test outcome has made quantum mechanics and not classical mechanics an empirically warranted microphysical theory for the quantum semantic values to be included in the univocal meaning complexes associated with the observation description. Thus Newtonian concepts were never included, because the macrophysical description never affirmed a Newtonian microphysical theory.

4.18 Test Design Revision

On the realistic neopragmatist philosophy all universally quantified statements are hypothetical, but theory statements are relatively more hypothetical than test-design statements, 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.

Consequently 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 also accept both the test design and the test-execution outcomes produced with the accepted test design.

Therefore contrary to positivists and romantics 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 agreement by the cognizant scientists, and that these basic statements are subject to reconsideration.

A dissenting scientist who does not accept a falsifying test outcome of a theory has either rejected the report of the observed test outcome or reconsidered the test design. If he has rejected 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 protocols. Independent repetition of the test with conscientious 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, he has thereby changed the semantics involved in the test in a fundamental way. Such reconsideration amounts to rejecting the design as if it was falsified, and letting the theory define the subject of the test and the problem under investigation – a rôle reversal in the pragmatics of testdesign language and theory language that makes the original test design and the falsifying test execution irrelevant.

In his "Truth, Rationality, and the Growth of Knowledge" (1961) reprinted in Conjectures and Refutations (1963) 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 B. Conant (1873-1978) recognized to his dismay in his On Understanding Science: An Historical Approach (1947) the history of science has shown that 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 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 that had been contributed by the rejected test-design statements are the parts that are excluded from the semantics of one or several of the descriptive terms common to the theory and test-design statements. Such a semantical outcome can indeed be said to be "content-decreasing", as Popper said.

But a scientist's prejudiced or "tenacious" (per Feyerabend) rejection of an apparently falsifying test outcome may have a contributing function in the development of science. It may function as what Feyerabend called a "**detecting device**", a practice he called "**counterinduction**", which is a 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 the apparently falsifying observational description. As Feyerabend showed, 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 aphorism that the theory decides what the physicist can observe, and Heisenberg reports that as a result he then developed his indeterminacy relations using his matrix-mechanics quantum concepts.

Another historic example of using an apparently falsified theory as a detecting device involves 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 (1767-1843) developed calculations locating the positions of the planet Uranus using Newton's celestial mechanics. But observations of Uranus showed significant deviations from the calculated positions.

A <u>first</u> possible response would have been to dismiss the deviations as measurement errors and preserve belief in Newton's celestial mechanics. But the astronomical measurements were at that time repeatable, and the deviations were large enough that they were not dismissed as observational errors. The deviations were recognized to have presented a new problem.

A <u>second</u> possible response would have been to give Newton's celestial mechanics the hypothetical status of a theory, to view Newton's law of gravitation as falsified by the anomalous observations of Uranus, and then to 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 yet been proposed. Therefore there was great reluctance to reject Newtonian physics.

A <u>third</u> possible response, which was historically taken, was to preserve belief in the Newtonian celestial mechanics, to modify the test-design language by proposing a new auxiliary hypothesis of a gravitationally disturbing planet, and then to reinterpret the observations by supplementing the description of the deviations using the auxiliary hypothesis. 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; it added new semantic values and structure to the semantics of the test design.

In 1845 both John Couch Adams (1819-1892) in England and Urbain Le Verrier (1811-1877) in France independently using apparently falsified Newtonian physics as what Feyerabend called 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 by telescope. On 23 September 1846 using Le Verrier's calculations Johann Galle (1812-1910) observed the postulated planet with the telescope of the Royal Observatory in Berlin.

Theory is language proposed for testing, and test design is language presumed for testing. But here the pragmatics 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 modified test-design language was given the relatively more hypothetical status of theory by the auxiliary hypothesis of the postulated planet thus newly 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 was named Neptune. Generalizing on this discovery offers an example of the theory-elaboration discovery technique with the modified version of the original test design functioning as a new theory.

But counterinduction is after all just a strategy, and it is more an exceptional practice than the routine one. Le Verrier's counterinduction strategy 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. In 1843 Le Verrier presumed to postulate a gravitationally disturbing planet that he named Vulcan and predicted its orbital positions. However unlike Le Verrier, Einstein had given Newton's celestial mechanics the more hypothetical status of theory language, and he viewed Newton's law of gravitation as having been falsified by the anomalous perihelion precession. He had initially attempted a revision of Newtonian celestial mechanics by generalizing on his special theory of relativity. This first such attempt is known as his *Entwurf* version, which he developed in 1913 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 per century instead of the actual 43 seconds.

In 1915 he finally abandoned the *Entwurf* version, and under prodding from the mathematician David Hilbert (1862-1943) he turned to mathematics exclusively to produce his general theory of relativity. He then developed his general theory, and announced his correct prediction of the deviations in Mercury's orbit to the Prussian Academy of Sciences on 18 November 1915. 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 further vindicated by Arthur Eddington's (1888-1944) historic eclipse test of 1919. Some astronomers reported that they had 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. MIT professor Thomas Levenson (1958) relates the history of the futile search for Vulcan in his *The Hunt for Vulcan* (2015).

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 rôles 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 Newtonian theory statements were more likely to be productively revised than the test-design statements, and he took the anomalous orbital observations of Mercury to falsify Newton's physics, thus indicating that theory 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.

For more about Feyerabend on counterinduction readers are referred to **BOOK VI** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: A *History*, which is available at Internet booksellers through hyperlinks in the web site.

There are also more routine cases of test design revision that do not occasion counterinduction. In such cases there is no rôle reversal in the pragmatics of theory and test design, but there may be an equivocating revision in the test-design semantics depending on the test outcome due to a new observational technique or instrumentality, which may have originated in what Feyerabend called "auxiliary sciences", *e.g.*, development of a superior microscope or telescope. If retesting a previously nonfalsified theory with the new test design with the new observational technique or instrumentality does not produce a falsifying outcome, then the result is merely a refinement that has reduced the empirical underdetermination manifest as vagueness in the semantics of the test-design language (See below, Section **4.19**). But if the newly accepted test design occasions a falsification, then it has produced a semantical equivocation between the statements of the old and new test-designs, and has thereby technically redefined the subject of the tested theory.

4.19 Empirical Underdetermination

Conceptual vagueness and measurement error are manifestations of empirical underdetermination, which may occasion scientific pluralism.

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. This is even true of concepts of quantized objects. Mathematically expressed theories use measurement data that always contain measurement inaccuracy that can be reduced indefinitely but never eliminated completely. The empirical underdetermination of language may make an empirical test design incapable of producing a decisive theory-testing outcome.

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 range of measurement error. But in research using historical time-series data such as in econometrics, repetition is not typically possible.

4.20 Scientific Pluralism

Scientific pluralism is recognition of the co-existence of multiple empirically adequate alternative explanations due to undecidability resulting from the empirical underdetermination in a test-design.

All language is always empirically underdetermined by reality. Empirical underdetermination explains how two or more semantically alternative empirically adequate explanations can have the same test-design. This means that there are several theories having alternative explanatory factors and 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 the test design. In such cases empirical underdetermination in 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 often large in comparison to those incurred in laboratory sciences. In such cases each social-science model has different equation specifications, i.e., different causal variables in the equations of the model, and makes different predictions 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 explanations for output. They produce what Einstein called "an embarrassment of riches". Logically this multiplicity of alternative explanations means that there may be alternative empirically warranted nontruth-functional hypothetical-conditional deep structure in the form "For all A if A, then C" having alternative causal 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 (1591-1630), a heliocentrist, used the measurement observations of Mars that had been collected by Tycho Brahe (1546-1601), 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. Kepler used Brahe's astronomical measurement data. There was empirical underdetermination in these measurement data, as in all measurement data.

Kepler was a convinced Copernican placing the sun at the center of the universe. His 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 more complicated combined geocentric-heliocentric cosmology's semantical contribution. The manner in which Brahe and Kepler could have different observations is discussed by Hanson in his chapter "Observation" in his *Patterns of Discovery*. Hanson states that even if both the geocentric and heliocentric astronomers saw the same dawn, they nonetheless saw differently. Thus Brahe *sees that* the sun is beginning its journey from horizon to horizon, while Kepler *sees that* the earth's horizon is dipping away from our fixed local star. Einstein said that the theory decides what the physicist can observe; Hanson similarly said that observation is "theory laden".

explanations Alternative empirically adequate due to empirical underdetermination are all more or less true. An answer as to which explanation is truer must await further development of additional observational information or more accurate measurements that reduce the empirical underdetermination in the test-design concepts. But there is never any ideal test design with "complete" information, *i.e.*, without vagueness or measurement error. Recognition of possible undecidability among alternative empirically adequate scientific explanations due to empirical underdetermination occasions what realistic neopragmatists call "scientific pluralism".

4.21 Scientific Truth

Truth and falsehood are spectrum properties of statements, such that the greater the truth, the lesser the error.

Tested and nonfalsified statements are more empirically adequate, have more realistic ontologies, and are truer than falsified statements.

Falsified statements have recognized error, and may simply be rejected, unless they are found still to be useful for their lesser realism and truth.

The degree of truth in untested statements is unknown until tested.

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

As Jarrett Leplin (1944) maintains in his *Defense of Scientific Realism* (1997), 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. Belief and truth are not identical. Belief is acceptance of a statement as predominantly true. Therefore one may wrongly believe that a predominantly false statement is predominantly true, or wrongly believe that a predominantly true statement is predominantly false. Belief controls the semantics of the descriptive terms in a universally quantified statement, while truth is the relation of a statement's semantics together with the ontology it describes to mind-independent nonlinguistic reality.

Test-design language is presumed true with definitional force for its semantics, in order to characterize the subject and procedures of a 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 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, are predominantly false, and may be rejected unless they are found still to be 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 still uses Newton's laws to navigate interplanetary rocket flights such as the *Voyager* and *New Horizon* missions. Thus Newton's "falsified" theory is not completely false or totally unrealistic, or it could never have been used before or after Einstein. Popper said that science does not attain truth. But contemporary realistic neopragmatists believe that such an absolutist idea of truth beyond the reach of basic science 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 semantically interpreted syntax utterly devoid of ontological significance and thus no discourse utterly devoid of truth. Therefore Hickey adds that the more empirically adequate explanation goes farther – is truer and more realistic – than its less empirically adequate falsified alternatives.

In the latter half of the twentieth century there was a melodramatic melee among academic philosophers of science called the "Science Wars". The phrase "Science Wars" appeared in the journal Social Text published by Duke University in 1996. The issue contained a bogus article by a New York University physicist Alan Sokal. In a New York Times article (18 May 1996) Sokal disclosed that his purpose was to flatter the editors' ideological preconceptions, which were social Sokal's paper was intended to be a debunking exposé of constructionist. postmodernism. But since the article was written as a parody instead of a serious scholarly article, it was basically an embarrassment for the editors. The "Science Wars" conflict involved sociology of science due to the influence of Thomas Kuhn's Structure of Scientific Revolutions. On the one side of the conflict were the postmodernists who advocated semantical relativism and constructivism. On the other side were traditionalist philosophers who defended scientific realism and objectivism. The postmodernists questioned the decidability of scientific criticism, while the traditionalists defended it in the name of reason in the practice of science.

The "Science Wars" pseudo conflict is resolved by the introduction of the ideas of relativized componential semantics and ontological relativity, which are both realistic and constructivist, and are also decidable by empirical criticism. Relativized semantics is perspectivist and it relativizes ontology that is revealed reality. Empirical underdetermination limits the decidability of criticism and occasionally admits scientific pluralism within empirically set limits. But perspectivist relativized semantics and constructivist discovery do not abrogate decidability in scientific criticism or preclude scientific progress; it does not deliver science to social capriciousness or to any inherent irrationality.

As discovery and empirical criticism increase empirical adequacy in science, they thereby increase realism and truth.

4.22 Nonempirical Criteria

Confronted with irresolvable scientific pluralism – having several alternative explanations that are tested and not falsified due to empirical underdetermination in the test-design language – philosophers and scientists have proposed various nonempirical criteria that they believe have been operative historically in explanation choice. Furthermore a plurality of untested and therefore unfalsified theories may also exist before any testing, so that different scientists may have their preferences for testing one theory over others based on nonempirical criteria.

Philosophers have proposed a great variety of such nonempirical criteria. Popper advanced a criterion that he says enables the scientist to know in advance of any empirical test, whether or not a new theory would be an improvement over existing theories, were the new theory able to pass crucial tests in which its performance is comparable to the older alternative existing alternatives. He calls this criterion the "potential satisfactoriness" of the theory, and it is measured by the amount of "information content" in the theory. This criterion follows from his concept of the aim of science, the thesis that the theory that tells us more is preferable to one that tells us less with the more informative theory having more "potential falsifiers".

But the amount of information in a theory is not static; it will likely evolve as the tested and nonfalsified theory is extended by the cognizant scientific profession over time. And a theory with greater potential satisfactoriness may be empirically inferior, when tested with an improved test design. Test designs may be improved by developing more accurate measurement procedures and/or by adding clarifying descriptive information that reduces the vagueness in the characterization of the subject for testing. Such test-design improvements refine the characterization of the problematic phenomenon addressed by the theories, and thus reduce empirical underdetermination and improve the decidability of testing.

When empirical underdetermination makes testing undecidable among alternative theories, different scientists may have personal reasons for preferring one or another alternative as an explanation. In such circumstances selection may

be due to an ego involvement for the scientist rather than an investigative decision. Or 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 helps an author getting his paper published. In the January 1978 issue of the Journal of the American Society of Information Science (JASIS) the editor wrote that referees often 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.*, competitive careerists attempt censorship of ideas contrary to their own. Furthermore editors are not typically entrepreneurial; as "gate guards" they are academia's riskaversive rearguard rather than the risk-taking avant-garde. They select the established "authorities" with reputation-based vested interests in their personal preferences or in the prevailing traditional views. These so-called "authorities" cynically suborn the peer-review process by using their personal preferences or conventional views as criteria for criticism and rejection for publication instead of using empirical criteria. Such cynical reviewers and editors are hacks that represent the status quo demanding trite papers rather than new, original and empirically superior ideas. Thus acceptance in the peer-reviewed literature is a sign of banal conventionality instead of empirical adequacy. When this cynicism becomes sufficiently pervasive as to be normative, the science has become institutionally corrupted and is destined to exhibit the degenerate sterility of an intellectually incestuous monoculture.

In contemporary academic sociology the existing degenerate sterility of an intellectually incestuous monoculture is accentuated by the social-control mechanisms described in sociological theory, and which are operative in science as described by sociologist Warren O. Hagstrom in his The Scientific Community (1965). Furthermore among sociologists the corrupting conformism is reinforced by sociologists' enthusiastic embrace of Kuhn's conformist sociological thesis of For example shortly after Kuhn's Structure of Scientific "normal science". Revolutions there appeared a new sociological journal, Sociological Methods and Research edited by George W. Bohrnstedt of Indiana University. In a statement of policy reprinted in issues for many years the editor states that the journal is devoted to sociology as a "cumulative" empirical science, and he describes the journal as one that is highly focused on the assessment of the scientific status of sociology. One of the distinctive characteristics of conformist "normal" science in Kuhn's theory is that it is cumulative, such that it can demonstrate progress. In other words research that does not conform to Kuhnian "normal science is not Such corrupting intellectual incest has thus become more progress. institutionalized and more retarding in academic sociology than in the more mature sciences.

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. He reports that fundamental concepts in the pre-Copernican astronomy had become strands for a much larger fabric of thought, and that 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, consequences that would lead his contemporaries of less restricted vision to reject his innovation as absurd.

Citing Kuhn some sociologists of knowledge including notably those advocating the "strong program" maintain that cultural, social and political forces that influence society at large also inevitably influence the content of scientific beliefs. For example the Nazis and Stalinists made their political ideologies dictate biology. Sociologists who believe that this means empiricism does not control acceptance of scientific beliefs in the long term are mistaken, because it is pragmatic empiricism that in the competitive world enables wartime victories, peacetime prosperity – and in all times business profits – as reactionary politics, delusional ideologies and utopian fantasies cannot.

Even today persons with different political philosophies, partisan ideologies, and personal interests defend and attack economic ideas and policies by using nonempirical criteria. Political views are like any other in that people believe what they want to believe. For example in the United States more than eighty years after Keynes, Republican politicians still attack Keynesian economics while Democrat politicians defend it. Many Republicans are motivated by the right-wing political ideology such as may be found in 1974 Nobel-laureate Frederich von Hayek's (1899-1992) *Road to Serfdom* or in the heroic romantic novels by the author Ayn Rand (1905-1982). The prevailing political philosophy among Republicans opposes government intervention in the private sector of the national economy. But as Federal Reserve Board of Governors Chairman Ben Bernanke (1953), New York Federal Reserve Bank President Timothy Geithner (1961) and U.S. Treasury Secretary Henry Paulson (1946) maintain in their *Firefighting: The Financial Crisis and Its Lessons* (2019), Adam Smith's invisible hand of

capitalism cannot stop a full blown financial collapse; only the visible hand of government can do that (P. 5).

The post-World War II era offered no opportunity to witness a liquidity trap, but that changed in the 2007-2009 Great Recession, which thus offered added resolution of the previous empirical underdetermination to improve decidability. In his *After the Music Stopped* (2013) Alan S. Blinder (1948), Princeton University economist and former Vice Chairman of the Federal Reserve Board of Governors, reports that "ultraconservative" Republican President George W. Bush (1946) "let pragmatism trump ideology" (P. 213), when he signed the Economic Stimulus Act of 2008, a distinctively Keynesian fiscal policy of tax cuts, which added \$150 billion to the U.S. Federal debt notwithstanding Republicans' visceral abhorrence of the Federal debt.

In contrast Democrat President Barak Obama (1961) without reluctance and with Democrat-party control of both houses of Congress signed the American Reinvestment and Recovery Act in 2009, a stimulus package that added \$787 billion to the Federal debt. In "How the Great Recession was Stopped" in Moody's Analytics (2010) Blinder reports that simulations with the Moody Analytics large macroeconometric model showed that the effect of President Obama's 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). Pragmatic Republicans in Congress were not willing to permit doctrinaire conservative noninterventionism produce another Great Depression with its 25% unemployment rates as in 1933, although it would have made the Great Recession more empirically decidable about the effectiveness of Federal fiscal stimulus policy. Yet Chairman Bernanke wrote in his memoir The Courage to Act (2013), that President Obama's 2009 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 instead actually concluded that the recovery was needlessly slow, because the Obama Federal fiscal stimulus program was disproportionately small for the size of the U.S. national macroeconomy.

As it happens Chairman Bernanke discovered at the time of the Great Recession that expansionary Keynesian fiscal policy could be supplemented with a new monetary policy. Keynesian deficit spending was needed to force money into the economy, because traditional monetary policy merely increases bank reserves. But increasing bank reserves in the economy's liquidity trap condition produces negligible increased lending by banks for private-sector investment spending, since short-term interest rates are at or near zero and cannot be lowered. But Bernanke's Federal Reserve Board supplemented the Obama fiscal stimulus by introducing a new monetary stimulus policy called "quantitative easing", which consisted of purchasing mortgages and long-term U.S. Treasury bonds. These actions occurred in three stages called "QE1" in 2009, "QE2" in 2011 and "QE3" in 2012, which altogether injected \$4.5 trillion into the economy and reduced long-term interest rates. The conservative Cassandras in the U.S. Congress warned of a resulting hyperinflation, but inflation in the decade that followed has been negligible.

Now at this writing during the COV-19 pandemic, long-term interest rates are also near zero (the 10-year Treasury notes are now 0.5% and falling), so quantitative easing is no longer an effective option to stimulate the economy. Thus political pragmatism dictates much more deficit spending. The recent Federal deficit due to the pandemic depression has already dwarfed the deficit incurred during the 2007-9 Great Recession. The Wall Street Journal (14 July 2020) reported that the Federal deficit for the calendar year ending 30 June 2020 amounted to \$3 trillion, reaching a record-level 14% of the GDP, and that the Congressional Budget Office estimates that the deficit for the Federal fiscal year ending 30 September 2020 will be \$3.7 trillion. And the pandemic is still ongoing with no end in sight until some day a vaccine is developed. The only option left for the Federal Reserve is to continue to purchase U.S. Treasury securities, so the U.S. Treasury Department has more money to spend. Thus with both short-term and long-term interest rates in a liquidity trap more Federal super deficits are likely over the next several Federal fiscal years, because Republicans like all political animals understand the pragmatic *real politick* of political economy, especially in election years. Their options now are Keynesianism, socialism, or an historic depression that exceeds the 1930's Great Depression by orders of magnitude.

There are many other examples of nonempirical criteria that have operated in scientific criticism. Another example is 1933 Nobel-laureate physicist Paul Dirac (1902-1984) who relied on the aesthetics he found in mathematics for his development of his operator calculus for quantum physics and for his prediction of the positron. Nonetheless all nonempirical criteria are presumptuous. To make such anticipatory choices is like betting on a horse before it runs the race.

No nonempirical criterion enables a scientist to predict reliably which among alternative either untested theories or nonfalsified explanations will survive empirical testing, when in due course the degree of empirical underdetermination is reduced by a new and improved test design that enables decidable testing.

4.23 The "Best Explanation" Criteria

As previously noted (See above, Section 4.05) Thagard's cognitivepsychology system ECHO developed specifically for theory selection has identified three nonempirical criteria to maximize achievement of 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 "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 deemed to be less empirically adequate.

Contemporary realistic neopragmatists acknowledge <u>only</u> 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 as evidence for progress. 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 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 and who reject the paper due to its unconventionality. Such editors make marketing-based instead of evidence-based publication decisions, and they corrupt the institution of science. But nonempirical criteria are often 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 lengthy 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 constraint imposed upon theorizing by empirical test outcomes is the empirical constraint, the criterion of superior empirical adequacy. It is the 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.

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

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. But the artifactual thesis of language implies that semantics and belief are mutually determining.

Therefore given the conventional meaning for a descriptive term, certain beliefs that determine the meaning of the term are implied. And these beliefs are furthermore reinforced by habitual linguistic fluency with the result that the meaning's conventionality constrains change in those defining beliefs. The conventionalized meanings for descriptive terms produce the cognition constraint, the linguistic impediment that inhibits construction of new theories, which is manifested as lack of imagination, creativity or ingenuity.

In his *Concept of the Positron* Hanson identified this impediment to discovery and called it the "conceptual constraint". He reports that physicists' identification of the concept of the subatomic 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* Hickey referred to this conceptual constraint as 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 explicit rules; they are also strong linguistic habits with subconscious roots that enable prereflective competence and fluency in both thought and speech. Six-year-old children need not reference explicit grammatical and semantical rules in order to speak competently and fluently. And these subconscious habits make meaning a synthetic psychological experience.

Given a conventionalized belief or firm conviction expressible as a universally quantified affirmative categorical statement, the predicate in that categorical affirmation contributes meaning parts to the meaning complex of the statement's subject term. The conventionalized status of meanings makes development of new theories difficult, because new theory construction requires greater or lesser semantical dissolution and restructuring of the complex semantics of conventional terms. Accordingly the more extensive the revision of beliefs, the more constraining are both the semantical restructuring and the psychological conditioning on the creativity of the scientist who would develop a new theory. Revolutionary theory development requires both relatively more extensive semantical dissolution and restructuring and thus greater psychological adjustment in linguistic habits.

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.

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 (1941) principle of linguistic relativity set forth in his "Science and Linguistics" (1940) reprinted in *Language, Thought and Reality* (1956). But contrary to Whorf it is not the grammatical system that determines semantics, but rather it is what Quine called the "web of belief", *i.e.*, the shared belief system as found in a unilingual dictionary.

For more about the linguistic theory of Whorf readers are referred to in **<u>BOOK VI</u>** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science*: A *History*, which is available at Internet booksellers through hyperlinks in the web site.

4.26 Communication Constraint

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

The communication constraint has the same origins as the cognition constraint. This impediment is also 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 is familiar with and to the theory that is new to him. And this learning involves overcoming psychological habit that enables linguistic fluency that 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. That is why dictionaries are presumed not to contain falsehoods. 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.

But if the differences between the old and new theories are so great as perhaps to be called revolutionary, then 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 semantic dissolution and consequent psychological disorientation. 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 relevant concepts in the web of belief. The communication constraint and its effects on scientists have been insightfully described by Heisenberg, who personally witnessed the phenomenon when his quantum theory was firstly advanced. In his *Physics and Philosophy*: *The Revolution in Modern Science* Heisenberg defines a "revolution" in science as a change in thought pattern, which is to say a semantical change, and he states that a change in thought pattern becomes apparent, when words acquire meanings that are different from those they had formerly. The central question that Heisenberg brings to the phenomenon of revolution in science understood as a change in thought pattern with semantical change is how the revolution is able to come about. The occurrence of a scientific revolution is problematic due to resistance to the change in thought pattern presented to the cognizant profession.

Heisenberg notes that as a rule the progress of science proceeds without much resistance or dispute, because the scientist has by training been put in readiness to fill his mind with new ideas. But he says the case is altered when new phenomena compel changes in the pattern of thought. Here even the most eminent of physicists find immense difficulties, because a demand for change in thought pattern may create the perception that the ground has been pulled from under one's feet. He says that a researcher having achieved great success in his science with a pattern of thinking he has accepted from his young days, cannot be ready to change this pattern simply on the basis of a few novel experiments. Heisenberg states that once one has observed the desperation with which clever and conciliatory men of science react to the demand for a change in the pattern of thought, one can only be amazed that such revolutions in science have actually been possible at all.

It might be added that since the prevailing conventional view has usually had time to be developed into a more extensive system of ideas, those unable to cope with the semantic dissolution produced by the newly emergent ideas often take refuge in the psychological comforts of coherence and familiarity provided by the more extensive conventional wisdom, which assumes the nature of a dogma and for some scientists an occupational ideology.

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 Samuelson offers a documented example: He wrote in "Lord Keynes and the General Theory" in *Econometrica* (1946) that he considers it a priceless advantage to have been an economist before 1936, the publication year of Keynes' *General Theory*, and to have received a thorough grounding in classical

economics, because his rebellion against Keynes' *General Theory's* pretensions would have been complete save for his uneasy realization that he did not at all understand what it is about. And he adds that no one else in Cambridge, Massachusetts really knew what it is about for some twelve to eighteen months after its publication. Years later he 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 the rearguard that was immune. Samuelson was a member of the Keynesian vanguard.

Note also that contrary to Kuhn and especially to Feyerabend the transition however great 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 American economists in the 1930's the semantics for the test-design language was defined for both the Keynesian and pre-Keynesian macroeconomic theories by the relevant Federal agencies. For example the unemployment rate was collected and defined by the Bureau of Labor Statistics, U.S. Department of Labor, and the interest rates and money stocks were collected and defined by the nation's central bank, the Federal Reserve Board of Governors. And in his *General Theory* Keynes explicitly footnoted the National Income and Product Accounts, which include the gross national product, developed by 1971 Nobel-laureate Simon Kuznets (1901-1985) and published by the National Bureau of Economic Research (NBER) in 1935.

The semantic incommensurability muddle is resolved by recognition of componential semantics. 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. It may furthermore 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 theories developed by a fellow human scientist.

Fortunately today the Internet and e-book media enable dissemination of new ideas that circumvent obstructionism by the conventionally-minded peerreviewed literature. These new media function as a latter day *Salon des Refusés* for both scientists and philosophers of science, who can now easily afford the now inexpensive self publishing with world-wide distribution through Internet booksellers. For Hickey's communications with sociology journal editors and referees exemplifying the retarding effects of the communication constraint in the current academic sociology literature, see **Appendix II** to **BOOK VIII** at the free web site <u>www.philsci.com</u> or in the e-book *Twentieth-Century Philosophy of Science: A History*, which is available at Internet booksellers through hyperlinks in the site.

The communication constraint is a general linguistic phenomenon that is not limited to the language of science. It applies to philosophy as well. Many philosophers of science who received much if not all of their philosophy education before the intellectually eventful 1960's or whose philosophy education was for whatever reason retarded, are unsympathetic to the reconceptualization of familiar terms such as "theory" and "law" that are central to contemporary realistic neopragmatism. They are dismayed by the semantic dissolution resulting from the rejection of the positivist or romantic beliefs.

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 determine the meaning of the term, which beliefs are furthermore reinforced by subconscious psychological habit that enables linguistic fluency. The result is that the meaning's conventionality impedes change in those defining beliefs.

4.27 Scientific Explanation

Different sciences have different surface structures, which may involve complex mathematics. But the syntactical transformation of the surface structure of the laws into nontruth-functional hypothetical-conditional logical form is the philosopher's heuristic enabling a rational reconstruction that produces the deep structure of the explanation, which clearly and explicitly displays the essential contingency of the universally quantified law language and the logic of explanation. Scientific laws are neither historicist nor prophesying nor otherwise unconditional.

The deep structure of a scientific explanation exhibits:

(1) a discourse that can be expressed as a *modus ponens* logical deduction from a set of one or several universally quantified law statements expressible in a nontruth-functional hypothetical-conditional form

(2) together with a particularly quantified antecedent description of the production protocols and the realized initial conditions

(3) that jointly conclude to a consequent particularly quantified description of the explained event.

Explanation is the ultimate aim of basic science. There are nonscientific types such as 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 explanation as in basic science, unless there is an unexpected failure in spite of correct, conscientious and competent implementation of the relevant applied laws.

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 transformed into a deep structure containing 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 nontruth-functional 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 and/or exogenous conditions and the nontruth-functional hypothetical-conditional statements or equations 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 logical form of an explanation is "For every A if A, then C" is true. "A" is true. Therefore "C" is true (and explained). The nontruth-functional hypothetical-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". When the individual explanation is given, "A" is the set of one or several particularly quantified statements describing the realized initial and exogenous conditions that cause the occurrence of the explained phenomenon as in a test. The particular quantification of "A" makes the nontruth-functional hypothetical-conditional statement also particularly quantified, to make the explanation of the specific event. And "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 scientific explanation the statements in the nontruth-functional 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 and exogenous conditions in the explanation constitute the explaining language that Popper calls the "*explicans*". And he calls the logically consequent language, which describes the explained phenomenon, the "*explicandum*". Hempel used the terms "*explanans*" and "*explanandum*" respectively. Furthermore it has been said that theories "explain" laws. Falsified theories do not occur in a scientific explanation. Scientific explanations consist of laws, which are formerly theories that have been tested with nonfalsifying test outcomes. Explanations that employ untested assumed general statements are not scientific explanations.

The "explaining" of laws means that a system of logically related laws in the surface-structure language forms a deductive system dichotomously partitioned into subsets of explaining antecedent axioms and explained consequent theorems. Logically 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. Logical reductionism was integral to the positivist Vienna Circle's unity-of-science agenda. Hanson calls this "catalogue science" as opposed to "research science". The logical axiomatizing reductionist fascination is not validated by the history of science. Great developmental episodes in the history of science such as the development of quantum physics have had the opposite effect of fragmenting science, *i.e.*, classical physics cannot be made a logical extension of quantum mechanics. Attempts to resolve this fragmentation in physics had exercised both Popper and Bohm. But while fragmentation has occasioned the communication constraint and thus provoked opposition to a discovery, attempts to resolve it have delayed but not halted the empirical advancement of science in its history. The only criterion for scientific

criticism that is acknowledged by the contemporary realistic neopragmatist is the *empirical criterion*. Eventually realistic empirical pragmatism prevails.

However, physical reductionism as opposed to mere axiomatic logical reductionism represents discoveries in science and does more than just add semantical coherence. Simon and his associates developed discovery systems that produced physical reductions in chemistry. Three such systems named, **STAHL**, **DALTON** and **GLAUBER** are described in Simon's *Scientific Discovery*. System **STAHL** named after the German chemist Georg Ernst Stahl (1659-1734) was developed by Jan Zytkow. It creates a type of qualitative law that Simon calls "componential", because it describes the hidden components of substances. **STAHL** replicated the development of both the phlogiston and the oxygen theories of combustion. System **DALTON**, named after John Dalton (1766-1668) the chemist creates structural laws in contrast to **STAHL**, which creates componential laws. Like the historical Dalton the **DALTON** system does not invent the atomic theory of matter. It employs a representation that embodies the hypothesis and incorporates the distinction between atoms and molecules invented earlier by Amadeo Avogadro (1776-1856).

System **GLAUBER** was developed by Pat Langley in 1983. It is named after the eighteenth century chemist Johann Rudolph Glauber (1604-1668) who contributed to the development of the acid-base theory. Note that the componential description does not invalidate the higher-order description. Thus the housewife who combines baking soda and vinegar and then observes a reaction yielding a salt residue may validly and realistically describe the vinegar and soda (acid and base) and their observed reaction in the colloquial terms she uses in her kitchen. The colloquial description is not invalidated by her inability to describe the reaction in terms of the chemical theory of acids and bases. Both descriptions are semantically significant and both semantic components together realistically describe an ontology.

The difference between logical and physical reductions is illustrated by the neopositivist Ernest Nagel in his distinction between "homogeneous" and "heterogeneous" reductions in his *Structure of Science* (1961). The homogeneous reduction illustrates what Hanson called "catalogue science", which is merely a logical reduction that contributes semantical coherence, while the heterogeneous reduction illustrates what Hanson called "research science", which involves discovery and new empirical laws, which Nagel calls "correspondence rules", that relate theoretical terms to observation terms. In the case of the homogeneous reduction, which is merely a logical reduction with some of the laws operating as a

set of axioms and the other as a set of conclusions, the semantical effect is merely an exhibition of semantical structure and a decrease in vagueness to increase coherence. This can be illustrated by the reduction of Kepler's laws describing the orbital motions of the planet Mars to Newton's law of gravitation.

But in the case of the heterogeneous reduction there is not only an increase in coherence and a reduction of vagueness, but also the addition of correspondence rules that are universally quantified falsifiable empirical statements relating descriptive terms in the two laws to one another. Nagel maintains that the correspondence rules are initially hypotheses that assign additional meaning, but which later become tested and nonfalsified empirical statements. Nagel illustrates this heterogeneous type by the reduction of thermodynamics to statistical mechanics, in which a temperature measurement value is equated to a measured value of the mean of molecular kinetic energy by a correspondence rule. Then further development of the test design makes it possible to calculate the temperature of the gas in some indirect fashion from experimental data other than the temperature value obtained by actually measuring the temperature of the gas. Thus the molecular kinetic energy laws empirically explain the thermodynamic laws. But contrary to Nagel's positivism the correspondence rules do not relate theoretical terms to observation terms and do not give statistical mechanics any needed observational status, because statistical mechanics is already observational. As Einstein said, "the theory decides what the physicist can observe".

In his "Explanation, Reduction and Empiricism" in *Minnesota Studies in the Philosophy of Science* (1962) Feyerabend with his wholistic view of the semantics of language altogether dismissed Nagel's analysis of reductionism. Feyerabend maintained that the reduction is actually a complete replacement of one theory together with its observational consequences with another theory with its distinctive observational consequences. But the contemporary realistic neopragmatist can analyze the language of reductions by means of the componential semantics thesis applied to both theories and to their shared and consistent test designs.

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