The SAGE Encyclopedia of

THEORY IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

James M. Matthews
Editor

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quodlibet does not hold in general. The division of those systems into distinct schools of paraconsistency, highlighting particular properties and motivations, can thus be understood solely as a pedagogical tool to introduce the rich and fruitful plurality of paraconsistent logics.

In addition to the cornerstone logic-philosophical debate, the study of paraconsistency from the perspective of finite models of arithmetic as well as the applications of paraconsistent logic in some computational areas have provided a new dimension to the ongoing debate. The fact is that since the first works in the area, paraconsistency has turned out to be a remarkably fertile research field that provides us with new ways to deal with contradictory yet nontrivial scenarios, including inconsistent theories, paradoxes, dialectics, ontology, belief dynamics, and many more.

Rafael R. Testa

See also Deduction; Logic, Formal and Informal; Paradoxes; Rationality; Reasoning

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Paradigm

The term *paradigm* comes from the Latin word *paradigma*, which, in turn, comes from the ancient Greek word *paradeigma* (παραδειγμα: "παρα," beside, near; "δειγμα," sample, what is shown). *Paradigm* and cognate expressions, such as "change of paradigm" or "paradigm shift," are used in different contexts, both scientific and academic, as well as in everyday life.

Until the appearance of Thomas S. Kuhn's work, the word *paradigm* was used primarily in two senses: (1) in rhetoric, as an example or case of something that serves as a model or pattern for other cases of the same that may be copied; as a very clear and typical example of something, as a type-example; (2) in grammar, as an example of a conjugation or declension showing a word in all its inflectional forms, creating a pattern of conjugating or declining, where other words of the same type conjugate or decline in an analogous way.

But it is only since Kuhn's work that the term *paradigm* and related expressions have acquired the diffusion and widespread use attained today. And although Kuhn introduces the term in the context of theoretical reflection on science, it is incorporated into colloquial language with an even more encompassing meaning, in the sense of a philosophical or theoretical framework of any kind, or in the more general sense of a perspective, a position, a view, a way of looking at something or regarding a situation or topic.

In fact, we are faced with a paradoxical situation: Although many people are familiar with the term *paradigm* and continue to use it in one sense

or another, Kuhn himself, owing to the term's ambiguity, had ceased to do so—although without renouncing the concepts that led him to its introduction. Moreover, such concepts continue to be of fundamental importance in understanding the nature, functioning, and development of science.

This entry focuses on these Kuhnian concepts of paradigm. After a brief introduction to Kuhn's paradigms, it will first place the Kuhnian conception in the context of 20th-century philosophy of science. Kuhn's concepts of paradigm will then be outlined. Next, it will be seen how these concepts explain the pattern or regularity that Kuhn identifies in the development of science. It will continue with the identification of some relations of Kuhn's proposal with classical philosophy of science. The entry concludes by pointing out some further developments of Kuhn's paradigms.

Introduction to Kuhn's Paradigms

Although the term *paradigm* is used by Kuhn for the first time in the 1959 text "The Essential Tension: Tradition and Innovation in Scientific Research," in the sense of what he would later call *exemplar*, it is with his 1962 work, *The Structure of Scientific Revolutions* (SSR), that it became customary in philosophical reflection and in historical analyses of science.

In this work, which seeks to promote a more authentically historical history of science, contra *presentism*, *whiggism*, or the *Whig interpretation of history*, Kuhn develops a theory of the history of science that opposes the received image of scientific development, which considers it to be cumulative, continuous, and linear.

This theory of the history of science has strong implications for the philosophy of science, where the philosophical importance of historiographical reform is manifested.

For, insofar as the philosophy of science is based on the history of science and forms its image of the practices and rationality of science from it, if the history of science is wrong, so will be the philosophy of science *modeled* on it.

Thus, SSR also promotes a revision of philosophers' image of science, in particular of scientific change, intending to bring philosophy of science in tune with what scientists really do, and have done, throughout history, thereby forcing us to rethink the concepts of rationality, progress, and scientific development.

In time, SSR ended up becoming a true best seller and has marked our conception of science ever since.

The Kuhnian Conception in the Context of 20th-Century Philosophy of Science

The prevalent image of philosophers of science by the mid-20th century was that of the so-called classical conception (or *received view*) of theories and some related ideas on science around topics such as concept formation, hypothesis testing, and scientific explanation. In its most general sense, the classical conception of theories can be characterized as explicating the concept of a scientific theory as a set of statements, sentences, or propositions deductively or axiomatically organized.

By contrast, in a more detailed formulation, such as that outlined by Rudolf Carnap, we can distinguish three general aspects in the explication of the concept of theory. The first one refers to the (more) *theoretical* (or *formal*) part that is constituted by the formal axiomatic system or *calculus* (symbolized by *T*)—which contain only descriptive theoretical terms. The second one corresponds to the (more) *empirical* or *testing* part that is given by pure observational statements—which contain only descriptive observational terms. The third one establishes the relationship between *theory* and *experience* through linguistic means, the so-called correspondence rules (symbolized by *C*)—which connect theoretical terms with observational terms. Thus, *the* theory, or interpreted calculus, consists of the conjunction of all the axioms and all the correspondence rules *T* and *C*.

Beginning in the 1950s, this view of scientific theories has been subject to criticism, of which there are mainly two kinds: (a) criticisms of certain aspects of the classical conception (e.g., of the distinction between theoretical and observational terms) and (b) a global criticism, which attacks mainly the bases of the conception, proposing an alternative view on science. The second kind of criticisms of the classical conception came mainly from people interested in the history of science, once referred to as *new philosophers*, giving rise to what would be called the *historical turn* in the

philosophy of science, of which Kuhn is its best-known representative. A new conception about the nature and the synchronic structure of scientific theories (without this being implied in a strict sense and without its being systematically developed) underlies the majority of diachronic studies and analyses, typical of this historicist phase, which is supposed to be closer to scientific practice, as history presents it to us.

According to the new conception, scientific theories, which the new philosophers refer to with different terms (paradigms or *disciplinary matrixes* for Kuhn, *research programs* for Imre Lakatos, *research traditions* for Larry Laudan), in order to avoid being confused with the classical conception, are not sentences or sentence sequences, and in a proper sense they cannot be described as true or false (although true or false empirical claims are certainly made with them), but they are highly complex and ductile entities, susceptible of evolving in time without losing their identity.

But Kuhn's proposal should also be placed within another of the *turns* that have taken place in analytic philosophy in general and philosophy of science in particular, namely the so-called *pragmatic turn*. This turn in philosophy of science arises from the rejection of what Wolfgang Stegmüller calls *the third dogma of empiricism*, namely the conviction that for the explication of all epistemologically relevant fundamental aspects of science the instruments of logic (syntactic and semantic tools) are sufficient.

This led to the acceptance that in the philosophical investigation of science, not only the syntactic and semantic aspects of language but also the pragmatic ones must be taken into consideration.

It is often said that the changes that occurred in the philosophy of science during the 1960s produced a real revolution in the field. If, however, we take into account the multiplicity and variety of positions held by philosophers of science in the first half of the 20th century, it would perhaps be better to characterize these changes as a recovery or deepening of the problems addressed and of the solutions previously advanced, for example, by logical empiricists such as Otto Neurath, Edgar Zilsel, Philip Frank, or even Rudolf Carnap, or by people outside this philosophical movement, in particular Ludwik Fleck.

Nevertheless, the incidence of the new philosophers was decisive in this resurgence in the 1960s: The consideration of the historical or historicist perspective that generally characterizes them definitely marks the development of later metascientific reflection.

Kuhn's Concept(s) of Paradigm

Since the appearance of the first edition of SSR in 1962, the notion of *paradigm*, central to Kuhn's conception of science, has been critiqued for its vagueness and ambiguity. One commentator went so far as to point out 21 different senses of this term, while acknowledging that not all of them are inconsistent with each other.

Kuhn took this criticism seriously. In 1969, he wrote three works—the book chapters "Second Thoughts on Paradigms," "Reflection on My Critics," and a postscript for the second edition of SSR—with the aim of clarifying some points of view developed in SSR, including his conception of paradigms. In them, he claims to have been using the term *paradigm* basically in two different senses: (1) as the global set of commitments shared by the members of a given scientific community and (2) as concrete solutions to problems.

To avoid misunderstandings, he proposes to replace the term *paradigm* by *disciplinary matrix* to refer to the first, *global* sense of the term, and by *exemplars* to refer to the second, *original* sense of the term. The following are the elements that constitute a disciplinary matrix:

1. *Symbolic generalizations*, which are law schemes not discussed by scientists, formalized or easily formalized, and which act partly as definitions and partly as genuine laws, establishing the most general relationships between the entities that populate the field under investigation (and corresponding to Kuhnian explication of the concept of fundamental law).
2. *Ontological* or *heuristic models*, which manifest the ontological or metaphysical convictions as to what there is and what its fundamental characteristics are, and which give the group its preferred or permissible analogies and metaphors and make it possible to visualize and make its behavior more comprehensible.

3. *Methodological values*, which may be shared with other disciplinary matrixes, such as accuracy—exact agreement, or not exceeding a certain margin of error, with the results of existing experiments and observations; consistency—internally and with other currently accepted theories; scope—extending far beyond the particular observations; simplicity—bringing order to phenomena that otherwise would be individually isolated and, as a set, confused; and fruitfulness—disclosing new phenomena or previously unnoted relationships among those already known.
4. *Shared examples* or *exemplars*, which Kuhn considers the most original and least understood aspect of his book, and which constitutes the original meaning of the term *paradigm*, as introduced in his (Kuhn, 1959) in analogy with its use in language teaching. They are concrete solutions that successfully solve problems posed by the paradigm-disciplinary matrix, adapting the symbolic generalizations and obtaining the specific symbolic forms required by particular problems; and which show scientists in a nondiscursive way what entities populate the universe of research, what questions can be asked, what are the admissible answers, and what are the methods for testing them. Shared examples or exemplars constitute sense 2 of *paradigm*, distinguished above.

The Development of Science

The nature and function of paradigms, both in the sense of disciplinary matrix and in the sense of exemplar, explain the pattern or regularity that Kuhn identifies in the development of the mature sciences, that is, the successive phases, stages or periods—after an initial one of preparadigm (prenormal or preconsensus) science—of normal science, crisis and extraordinary science, new normal science, new crisis and extraordinary science . . . (what constitutes "the structure of scientific development" in general), and the successive transition from one paradigm to another through a scientific revolution (what constitutes "the structure of scientific revolutions" in particular).

The preparadigm (or, perhaps better, prenormal or preconsensus) period is characterized by the existence of competing different schools and subschools working in different directions, without common commitments.

After a paradigm-disciplinary matrix achieves the consensus of the scientific community, a broad avenue for research opens up, in the form of closely related problem-solving or, insofar as they are supposed to have an assured solution within the accepted paradigm-disciplinary matrix, *puzzle*-solving, which scientists carry out under its guidance over a long period, called *normal science*. Scientists recognize the problems posed by the paradigm-disciplinary matrix as similar to the shared examples or exemplars and solve them in a manner similar to the shared examples. Through this practice, the paradigm-disciplinary matrix achieves greater precision and articulation within itself and with nature; that is, it also broadens its domain of application.

During this period of normal science, scientists work with the conviction that this or that problem will have a solution within the conceptual framework of the paradigm-disciplinary matrix, proposing, in a hypothetical manner, that a certain modification of the symbolic generalization—though not obtained by deduction (just) from it—will do the job. If the proposal of a specific symbolic form is successful, the applicability of the paradigm-disciplinary matrix to reality is extended, affirming it in its fertility. In the case of its refutation, the discredited one is, according to Kuhn, the scientist himself—who fails to propose the appropriate specific form of the symbolic generalization that would solve the problem posed, one that would satisfactorily fit the data obtained—and not the paradigm-disciplinary matrix.

Faced with a negative test, the symbolic generalization of the paradigm-disciplinary matrix is, or can be, always safeguarded by modifying the nonnuclear elements, in other words the specific form proposed by the scientist to solve the *puzzle* posed by the paradigm-disciplinary matrix and whose resolution would be assured.

However, when frustrations accumulate while trying to solve *problems* that should be solved, these go from being the driving force of the development of the paradigm-disciplinary matrix to being perceived as *anomalies* whose existence compromises the usefulness of the paradigm-disciplinary matrix for research. A period of *crisis* and *extraordinary science* begins. A small group of

researchers starts to work outside the accepted paradigm-disciplinary matrix from new perspectives that are incompatible with the previous ones, until a new paradigm-disciplinary matrix is established that succeeds in problem areas that the scientific community considers important, and promises to solve others, some of which were not even on the agenda of the previous one, and giving up others, which are now no longer considered legitimate. The bulk of the scientific community begins to abandon a paradigm-disciplinary matrix exhausted in its heuristics, to adopt the one that allows it to leave behind the feeling of futility of its own work, consummating a *scientific revolution* and giving rise to a new period of normal science.

The rupture present in the shift from the old paradigm-disciplinary matrix to the new one thus entails not only gain but also loss. Although incommensurable—meaning by this that there is no common or neutral basis with which to measure both paradigm-disciplinary matrixes or a common or neutral (observational) language that allows the intertranslatability of both paradigm-disciplinary matrixes without waste or loss—the process of abandoning one paradigm-disciplinary matrix and simultaneously accepting another is not irrational, as Kuhn's critics thought. The choice between paradigm-disciplinary matrixes is not resolved by the application of norms or rules based only on logic (internal coherence) or experiment (external coherence). This does not imply, however, that there are no good reasons guiding such a choice, rather only that these reasons (among which are the aforementioned simplicity, accuracy, coherence, scope, and the ability to generate fruitful research) function as values or criteria shared by scientists but are capable of being applied differently by different researchers—a rationality of another type (practical), different from the one traditionally proposed (logical or theoretical), but as far from arbitrariness as the latter: less precise, debatable, with risks in the choice that the scientific community diminishes by distributing the danger among its members, until time shows with its results the rightness of the bet.

Kuhn's emphasis that the scientific community is inseparable from the theoretical and empirical elements of the paradigm-disciplinary matrix clearly differentiates his conception of science from the traditional ones. He will go so far as to say—in a "circular, but not vicious" way—that a paradigm is what a scientific community shares, while a scientific community is one that shares a paradigm. There are several reasons for him to introduce this notion. On the one hand, the historian of science visualizes the changes in theories (paradigms-disciplinary matrixes) as a change in the beliefs of the only ones with the authority to decide them, the community of experts, in a context in which it was shown that there were no crucial facts that forced the discarding of one theory (paradigm-disciplinary matrix) and the adoption of another, nor a completely common language to guide the discussion. On the other hand, the existence of normal science means that the development of the paradigm-disciplinary matrix is not due to any isolated scientist but to the joint effort of a group of researchers that makes it advance when they solve under its guidance the innumerable problems it poses.

In addition, Kuhn proposes to abandon the *teleological notion of progress toward truth*, according to which changes in the paradigm-disciplinary matrix bring scientists ever closer to the truth, preferring instead to speak of a development—analogous to that proposed by the theory of evolution with respect to species—that can be defined *from* its previous stages, as opposed to a process of evolution *toward* something.

Kuhn's Relations With Classical Philosophy of Science

As regards his relations with classical philosophy of science, Kuhn—who expected to find in Popperians his best allies—tries to show how his ideas follow those of Karl Popper's, although in his own way.

The vehement rejection he suffered taught him that, although they coincided in some aspects, the Popperian community and Popper himself would not forgive him for the pragmatic, especially psychological and sociological, aspects of his proposal. From then on, he would be read as somebody who ascribes an irrational behavior to scientists instead of admitting the necessity (shown by his analyses) of modifying the concept of scientific rationality subscribed to until then.

The situation is equally paradoxical in relation to logical empiricism, which is supposed to be the adversary defeated by his work.

Apart from the stereotypes that turned it into the *straw man* everybody uses to revile it, this current in the philosophy of science presents a wide range of aspects and orientations which even justify the enthusiastic recommendation of Kuhn's SSR that Carnap wrote in his own hand on the back of the official letter of acceptance which he sent to Charles Morris.

There are clear affinities between Kuhn's proposal and that made by the logical empiricists Neurath and Zilsel, who carry out more *historical* and *sociological* analyses than the more *formalist* one represented by Carnap's work.

And there are affinities even with the latter, although Carnap did not consider the historical and social empirical studies of science as belonging to the philosophy of science, understood as the *logic* of science, but to the more inclusive category *theory* of science. Examples of such affinities include Carnap's acceptance of (1) the noncumulative conception of scientific development (positing a sort of incommensurability between different linguistic or conceptual frameworks), (2) the role of pragmatic considerations in the scientists' decision of using a linguistic framework, and (3) accepting or rejecting particular hypotheses (the latter also stressed by Neurath, Frank and Hempel's late work).

The fact that the *Postscript* to SSR written by Kuhn in 1969 was the last work published in the most ambitious publishing project coming from logical empiricism, the (*International*) *Encyclopedia of Unified Science*, constituted the perfect ending for an era, not because Kuhn finished with that tendency forever but because with him some interests that had begun in Vienna at the beginning of the century would find their way forward.

Further Developments

After the clarifying articles written in 1969, in which he replaces the term *paradigm* with the terms *disciplinary matrix* and *shared example* (or *exemplar*), Kuhn also stopped writing about disciplinary matrixes and instead wrote about *theories*. This doesn't mean, however, that Kuhn abandoned the *concept* of paradigm, in either of the two basic senses—the *original* sense of exemplar and the more overarching one of disciplinary matrix—but only the term.

Notwithstanding, that he uses the term *theory* doesn't mean that he accepted the classical concept of theory. According to his own explication of the concept of theory, it consists, among other things, of *symbolic generalizations*, in its (more) *theoretical* or *formal* part, *together with* examples of their function in use (*exemplars* or *paradigms* in the *original* sense), in its (more) *empirical* or *applicative* part. As for the link between the two parts, it is established by what Kuhn calls "special (or appropriate) versions" or "particular (or detailed) symbolic forms (or versions or expressions)," which acquire the symbolic generalizations in order to be applied to particular problems (situations, phenomena). And although Kuhn does not elaborate in detail what the relationship between symbolic generalizations and their particular forms is, he makes it very clear that this is not one of logical deduction.

Some historians and philosophers of biology have found the notion of *exemplar* fruitful for their analyses, either by holding that theories in the biological (and/or biomedical) sciences possess a particular structure distinct from that of physical theories as Darden (1991) and Schffner (1986) argue. or by considering that this is not the case, if analyzed within the framework of some version of the semantic conception of theories. Lorenzano (2007) and Schaffner (1993) provide such analyses.

In fact, Kuhn's concept of theory, which reformulates that of paradigm as a disciplinary matrix and contains the *original* sense of the former, finds an even more satisfactory explication in the framework of the semantic conception of theories, especially in that of the structuralist view, as Kuhn himself early recognized and continued to do so until the end of his days.

In the structuralist version of the semantic conception of theories that acknowledges the presence of irreducibly pragmatic and historically relative elements in the analysis of scientific theories as we see in Balzer et al. (1987), the Kuhnian notion of symbolic generalization is made more precise by means of the notion of *fundamental law/guiding principle*, that of exemplar through that of *paradigmatic application* and the relation between symbolic generalizations and the specific forms they adopt with the relation of *specialization*.

Whereas the overall synchronic structure of a theory is thus given by a *hierarchical (non-deductive) structure organized by the relation of specialization*

and the scientific development during the period of normal science is represented in it by the notion of *theory-evolution*.

And together with the *(usually partial) incommensurability* existing between theories separated by a scientific revolution, the structuralist view of theories also makes possible the representation of other inter-theoretical changes susceptible to be found in the history of science, such as the *emergence* of theories and the *reduction* between them.

Pablo Lorenzano

See also Abduction; Conceptual Analysis; Falsifiability; Hypothetico-Deductivism; Philosophy of Science; Received View of Theories; Scientific Revolutions

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Paradoxes

Typically when we reason, we start from premises that we believe, proceed through inferences based on principles of logic that we could not doubt, and arrive to a conclusion that we accept. *Paradox* is the name we give to situations in which this *doesn't* happen. Paradoxes arise when an argument seems to show that something has gone awry in our reasoning, when the argument itself seems airtight and yet the conclusion seems absurd. This is different from making a mistake on one's math homework where an error in a calculation might lead one to mistakenly deduce 0 = 1. But the difference is mainly one of degree; while it is usually straightforward to spot a dropped minus sign or division by 0 in math homework mistakes, paradoxes are not so easily resolved. Indeed, resolution of a paradox usually requires giving up a firmly held premise, adopting unfamiliar methods of reasoning, or accepting an intolerable conclusion. For this reason, the study of paradoxes has been