The Role of Themata in Science

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Abstract
Since the 1960s, thematic analysis has been introduced as a new tool for understanding the success or the failure of individual scientific research projects, particularly in their early stages. Specific examples are given, as well as indications of the prevalence of themata in areas beyond the natural sciences.

During the recent past, scholars concerned with the foundations and development of science have increasingly paid attention to aspects other than the logical/analytical/phenomenalistic ones. The latter have of course remained indispensable; but too often it is now forgotten that even in the heydays of logical empiricism such major contributors as Otto Neurath, Hans Hahn, Philipp Frank, and Edgar Zilsel insisted on including, for any full understanding of science, the lessons of contemporary scholarship in the history, psychology, and sociology of science.

A significant anecdote will illustrate why, without drawing on such elements, one would not understand the actual course of scientific discovery. In his classic book, *The Conceptual Development of Quantum Mechanics* (1966). Max Jammer recounts how two superb scientists, faced with essentially the same phenomena and the same tasks of ultimate explanation of them, adopted quite opposite positions about the proper ground of allowable explanation. It is worth quoting in full the most relevant passage for this book, well known to generations of students:

> "It is instructive to compare Schrödinger's wave mechanics with Heisenberg's matrix mechanics. It is hard to find in the history of physics two theories designed to cover the same range of experience, which differ more radically than these two. Heisenberg's was a mathematical calculus, involving noncommutative quantities and computation rules, rarely encountered before, which defied any pictorial interpretation: it was an *algebraic* approach which, proceeding from the observed discreteness or spectral lines, emphasized the element or *discontinuity*: in spite of its renunciation of classical description in space and time it was ultimately a theory whose basic conception was the *corpuscle*. Schrödinger's, in contrast, was based on the familiar apparatus of differential equations, akin to the classical mechanics of fluids and suggestive of an easily visualizable representation: it was an *analytical* approach which, proceeding from a generalization of the classical laws of motion, stressed the element of *continuity*: and, as its name indicates, it was a theory whose basic conception was the wave. Arguing that the use of multidimensional (>3) configuration spaces and the computation of the wave velocity from the mutual potential energy of particles is "a loan from the conceptions of the corpuscular theory," Heisenberg criticized Schrödinger's approach as "not leading to a consistent wave theory in de Broglie's sense." In a letter to Pauli he even wrote: "The more I ponder about the physical part of Schrödinger's theory, the more disgusting ['desto abscheulicher'] it appears to me." Schrödinger was not less outspoken about Heisenberg's theory when he said:"... I was discouraged ['abgeschreckt'], if not repelled ['abgestossen'], by what appeared to me a rather difficult method of transcendental algebra, defying any visualization ['Anschaulichkeit']."

What this story chiefly illustrates – and it stands for many confrontations of this sort, in all the sciences – is the powerful, motivating role of *basic thematic presuppositions* in the shaping of scientific advance. The purpose of this chapter is to examine in some detail this often-hidden mechanism which, together with the much better-known elements of scientific reasoning and speculation, has repeatedly fashioned the foundations of the sciences, and especially of physics. For this investigation, we shall furnish, as it were, a compact Reader's Guide to the thematic analysis of science, as developed over the past decades and presented through case studies in five books by this author. i.e., *Thematic Origins of Scientific Thought: Kepler to Einstein*; *The Scientific Imagination*; *The Advancement of Science and its Burdens: The Jefferson Lecture and Other Essays*; *Science and Anti-Science*; and *Einstein, History, and Other Passions*. To set the stage, we must consider that when scientists publish the results of their work in journals, textbooks, etc., they are submitted for acceptance into what could be called Public Science, in order to distinguish it from the prior stage of their effort, the scientist's individual activity during the nascent period, which deserves the term Private Science. The common error of using the word "science" without making this distinction can show up glaringly when the historian of science tries to understand the motivation of scientists for pursuing their research problems, the choice of their conceptual tools, or the treatment of their data. In all these cases, one is likely to discover that during the nascent, "private" period of work, some scientists, consciously or not, use highly motivating and very general presuppositions or hypotheses that are not directly derivable from the phenomena and are not provable or falsifiable. But when such work then is proposed for entry into the "public" phase of science, these motivating aids – which the author has termed *thematic presuppositions* or *thematic hypotheses* – tend to be suppressed, and disappear from view.

Even though such thematic notions arise from a deep conviction about nature, on which the initial proposal and eventual reception or rejection of one's best work is based, they are usually not explicitly acknowledged, they are not explicitly taught, and they are not listed in the research journals or textbooks. Instead, it is customary for scientists to express their results, or those of others, using only two types of meaningful statements. The first may be called *phenomenic propositions*; they concern empirical matters that ultimately boil down to protocol sentences about public phenomena such as meter readings. The second may be called *analytic propositions*; they deal with the logic and mathematics in the work, ultimately boiling down to tautologies consistent within the system of accepted axioms. (Einstein referred to these two components of public scientific knowledge respectively as the "empirical" and the "rational," calling them "inseparable" but also in "eternal antithesis.")

That neither of these two types of statements makes room for thematic propositions has certain advantages. Thus if, for mnemonic purposes, we consider the phenomenic and analytic aspects alone as two orthogonal (x and y) axes, they define a two-dimensional plane of discourse in which scientific discussion about results usually takes place. And this has been a functionally successful strategy for the scientific community insofar as it tends to steer away from the personal motivations and thematic preferences which energize the nascent phase, but on which there might be deep, unresolvable differences if allowed into the public phase; consensus is easier to reach if they are kept out of sight, and is also more suitable for the pedagogic presentation of science.

Some modern philosophies of science, particularly those tracing their roots to empiricism or positivism, go further and assign "meaning" to any scientific statement only insofar as the statement can be shown to have phenomenic and/or analytic components in this plane. And, to be sure, this policy has amputated from science innate properties, occult principles, and other tantalizing, "metaphysical" notions which cannot be resolved into components along the x and y axes, the two orthogonal axes. It was in part for the sake of this advantage that positivists and empiricists, from Hume to the Vienna Circle – movements that grew out of courageous opposition to speculative, ungrounded and metaphysical deadwood that was thought to infest the public science of their time – urged the activity "science" to be defined entirely in terms of sense observation and logical argument.

Nevertheless, this two-dimensional view of science also has had its costs. First, it is not true to the behavior and experience of the individuals engaged in research. It does nothing to explain why at any given time the choice of problems or the reception of theories may be strikingly different among individuals or like-minded groups who face the same corpus of data. Examples on this point are the early, quite different responses to relativity in Germany, England, France, and the United States of America. It also overlooks both the positive, motivating, and emancipatory potential of certain presuppositions, as well as the negative and enslaving role that sometimes has led promising scientists into disastrous error. For, again, Einstein and Niels Bohr were rather well matched in navigating the two-dimensional plane of science, as were Schrödinger and Heisenberg. Yet there were among them fundamental antagonies in terms of programs, tastes, and beliefs, with occasional passionate outbursts among the opponents. The thematic differences, which are at the core of such controversies, do sometimes break through – and they shatter the two-dimensional model.

Above all, as we noted, this limited view does not explain what a historian, looking at laboratory notebooks or drafts of a distinguished scientist, often sees with stark clarity: the willingness, particularly at the early stages, privately to cling, firmly, and sometimes at great risk, to what can only be called a suspension of disbelief about the possible falsification of their hypotheses, emerging from the data before them.

Thus while the planar view is satisfactory for the scientists intent on furthering advances in their field, it requires an amendment to help those trying to understand the sources and pathways of the creative process. This recognition of the disjunction forced itself on this author – who had been educated as an experimental physicist by teachers with an ecumenical but predominately positivistic attitude – when he became initially interested in comparing the scientific publications of Johannes Kepler and of Albert Einstein with their respective personal letters. (The resulting first publications are dated 1956 and 1960.) It led him to define a third component, represented by an axis rising orthogonally out of the phenomenic-analytic plane. Along that third (or z) dimension are located those fundamental presuppositions, held consciously or unconsciously, which show up in the motivations of the scientists' actual day-to-day work as well as in the end product.

Most of these presuppositions persist for long periods in the individual case as well as throughout long periods of history. Many are widely shared, and in a given science such as physics are surprisingly few in number. Since these presuppositions are not derivable from either observation or analytic ratiocination, they required a term of their own, and thus the author called them *themata* (singular, *thema*, from the Greek Θεμα: that which is laid down; proposition; primary word).

On this view – to elaborate the mnemonic device – a scientific statement is no longer, as it were, an element of area in the two-dimensional plane, but a volume-element, an entity in three-dimensional space, with components along each of the three orthogonal (phenomenic, analytic, and thematic) axes. The projection of the entity onto the two-dimensional plane continues to have the useful roles stressed earlier; but for the analysis of a given work it may be necessary to consider the line element projected onto the third axis, the dimension on which one may imagine the range of themata to be located, even though the particular scientist may be only vaguely aware of it. The statements of two scientists are therefore like two volume-elements that may not completely overlap and so may have differences in their projections.

Thematic analysis, then, can serve to identify the particular map of the various themata which, like fingerprints, can characterize an individual scientist or a part of the scientific community at a given time. In studying Johannes Kepler (book I on the list above, Chapter 2), the main finding was that Kepler was able to work simultaneously with three basic thematic ideas: the universe as a physical machine, the universe as a mathematical harmony, and the universe as central theological order. As he encountered the limitations of one of these – for example, owing to his still primitive physics – he took refuge in one of the others. This strategy explained the apparent complexity and disorder in his writings and commitments but also led to his successes.

For Einstein, who was unusually self-conscious about his fundamental presuppositions, one can discern them supporting his theory construction throughout most of his long scientific career (see especially book I, Chapters 6-9; book 3, Chapters 2-4; book 4, Chapter 3; and book 5, the second and fourth chapters): they include the primacy of formal (rather than materialistic or mechanistic) explanation; unity or unification; cosmological scale in the applicability of laws; logical parsimony and necessity; symmetry, as long as possible; simplicity; causality (in essentially the Newtonian sense); completeness and exhaustiveness; continuum; and, of course, constancy and invariance.

These themata, to which Einstein was obstinately devoted, explain why he would continue his work in a given direction even when the tests against experience were difficult or unavailable (as in General Theory of Relativity), or, conversely, why he refused to accept theories well supported by the phenomena, but, as in the case of Bohr's quantum mechanics, based on presuppositions opposite to his own, namely discontinuity, inherent probabilism, and the abandonment of completeness in the description of phenomena (see book 1, Chapters 4 and 12, and book 4, Chapter 3).

Among other major scientists discussed in the books noted in the list above, and whose work has lent itself to better understanding through thematic analysis, are Galileo (book 5, eighth chapter), Ernst Mach (book I, Chapter 7; book 4, Chapters I and 2), A. A. Michelson (book 1, Chapter 8), R. A. Millikan (book 2, Chapter 2), W. Heisenberg (book 3, Chapter 7), Erwin Schrödinger (book 1, Chapter 4), J. Robert Oppenheimer (book 3, Chapter 7), Max Planck (book 4, Chapter 3), P. W. Bridgman (book 5, eleventh chapter), Michael Polanyi (book 5, fourteenth chapter), and Steven Weinberg (book 2, Chapter I). Thematic analysis in teaching the history of science, discussed in the ninth chapter of book 5, is shown there to be one of nine conceptual tools needed for a full understanding of an event or a case in the history of science.

Themata often appear in opposing dyads, symbolized by $\Theta/\overline{\Theta}$. Examples are continuum (e.g., in field) versus discontinuum (e.g., in atomism); complexity/simplicity; reductionism/holism; unity/hierarchical levels; causality/probabilism; analysis/synthesis. There are also a few triads, such as evolution/steady state/devolution, or mechanistic/materialistic/mathematical models. While the author has studied primarily themata in physical science, the same findings appear to be applicable also to the other sciences. A list of those found so far can be constructed from the indexes of the books on the book list, under "thema" and "themata." All these become visible most strikingly during a conflict between individuals or groups that are committed to opposing themata, or within the developing work of a scientist holding on to a thematic concept before the data have given sufficient confidence in its value. It is impressive that research has led to the discovery that only a relatively small number of themata and thematic couples or triads – perhaps of the order of one hundred – have sufficed throughout modern science. This is one reason to avoid the word "theme" in place of *thema*, for as in music there is no limit to the number of possible themes, nor any overarching generality that can be drawn from them for science. We may distinguish between three uses of the notion of themata.

(1) A *thematic concept* is analogous to a line element in the three-dimensional representation space, having in addition to the x and y components also a strong projection on the z, or thematic axis. (An example is the concept of evolution.)
(2) A *thematic position* or *methodological thema* is a guiding preference, e.g., for seeking to express the laws of physics whenever possible in terms of constancies, or extrema (maxima or minima), or impotency ("it is impossible that ...").
(3) Between these two is the *thematic proposition* or *thematic hypothesis*, e.g., a statement or hypothesis with a predominant thematic content. (An example is the principle of constancy of the velocity of light in relativity theory, proposed as an axiom that initially seemed contrary to all the physics of the time.)

As noted, most themata are ancient and long-lived. The contrary themata of Heraclitus and Parmenides are still in use. Additions – such as the introduction of the thematic notion of complementarity in the 1920s – are rare. To be sure, a scientific concept such as "atom" has changed over and over again, from Democritus to this day. But what has not changed is the thematic concept of discreteness underlying atomism, which expresses itself in the same way in the ever-changing notion of "atom."

At the same time it also should be pointed out that some scientists function very well without allegiance to a set of thematic ideas (e.g., Enrico Fermi, book 2, Chapter 5), while others are led into error by holding fiercely to an inappropriate thematic idea (Mach, book 4, Chapter 2; and Felix Ehrenhaft, book 2, Chapter 2).

Of course, not all themata are meritorious. As Francis Bacon warned in discussing the four Idols that can trap the scientific mind, some have turned out to divert or slow the growth of science. Nor have all sciences benefited equally; the holistic viewpoint introduced at the start of the nineteenth century had advantages in physics, but was on the whole a handicap for biology. Similarly, it should not be necessary to stress that thematic analysis is not an ideology, a school of metaphysics, a plea for irrationality, an attack on the undoubted effectiveness of empirical data and experimentation, or a means for teaching scientists how to do their job better.

We can turn now to one of the puzzles facing every scientist and historian of science. If, as Einstein and others have claimed, the concepts of science are free inventions of the human mind, should that not allow an infinite set of possible axiom systems to which one's mind could leap or cleave? Virtually every one of these would ordinarily be useless for constructing a theory to encompass the phenomena being studied. How then could there be any hope of success except by chance? The answer must be that the license implied in the leap to an axiom system by the freely inventing mind is the freedom to make such a leap, but not the freedom to make any arbitrary leap whatever. The choices available are narrowly circumscribed by a scientist's particular set of themata that filters and constrains, and shapes the style, direction, and rate of advance on novel ground. (See book 2, Chapter 2.) And insofar as the individuals' sets of themata overlap, the progress of the scientific community as a group is similarly constrained or directed. Otherwise, the inherently anarchic connotations of "freedom" could indeed disperse the total effort.

Since science is ever unfinished, what is functional so far in a given field may turn out not to be so in the future, and hence there may be a flux of thematic allegiance by the community. Thematic analysis is descriptive, not prescriptive. It may turn out for example that the powerfully motivating quest for a general synthesis, so successful from Oersted to Maxwell and from Einstein to our day, could be a trap, as Isaiah Berlin warned in *Concepts and Categories*. Himself a dedicated pluralist, Berlin christened the drive toward a grand synthesis the "Ionian Fallacy," so designating the search, from Aristotle to Bertrand Russell to our own day, for the ultimate constituents of the world in some nonempirical sense.

Superficially, the seekers of unified physics, particularly in their monistic exhortations, may seem to have risked that trap – from Copernicus, who confessed that the chief point of his work was to perceive nothing less than "the form of the world and the certain commensurability of its parts," to Max Planck, who exclaimed in 1915 that "physical research cannot rest so long as mechanics and electrodynamics have not been welded together with thermodynamics and heat radiation," to today's theorists who seem to find the founding father of science among the ancient Greeks, Thales himself, in their insistence that one entity will explain all. But the scientific profession has been rescued over the years from becoming mired hopelessly in such traps, which devotion to a single thema might cause. In practice, there is at any time enough variety of commitments – for example. in this case, the existence of a group which in recent years is willing to settle for a pluralistic physics, as in a hierarchical set of levels.

Diversity in the spectrum of themata held by individuals at a given time, and overlap among these sets of themata (rather than "anything goes"): this formula answers the question why the preoccupation with the eventual achievement of, e.g., a unified world picture, did not lead science to a totalitarian disaster, as an Ionian Fallacy by itself could well have done, nor lead to an anarchic dispersal of the efforts of the community. At every step, each of the various world pictures in use is considered a preliminary version, a premonition of the Holy Grail. Moreover, each of these various hopeful but incomplete world pictures that guide scientists at a given time is not a seamless. unresolvable entity. Nor is it completely shared even within a given subgroup (in both respects unlike a "paradigm"). Each member of the group is apt to operate with a specific set of separable themata. Einstein and Bohr agreed far more than they differed, even though they had profound thematic incompatibilities. Moreover, most of the thematic currents at any one time are not newly minted. but adopted from predecessor versions of the world picture, just as many of them will later be incorporated in subsequent versions as they evolve from it. Einstein freely called his project a "Maxwellian program" in this sense.

On this model of the role which thematic components play in the advancement of science, we can understand why scientists need not hold substantially the same set of beliefs, either to communicate meaningfully with one another in agreement or disagreement, or to contribute to the cumulative, generally evolutionary improvement of the state of science. Scientists' beliefs have considerable fine structure; and within that structure there is room both for thematic overlap and agreement, which generally have a stabilizing effect, and for intellectual freedom, which may be expressed as thematic disagreements. Innovations emerging from the balance – even "far reaching changes," as Einstein termed the contributions of Faraday, Maxwell, and Hertz – very rarely require from the individual scientist or from the scientific community the kind of radical and sudden reorientation implied in such terms as revolution, Gestalt switch, discontinuity, incommensurability, conversion, etc. On the contrary, the innovations are coherent with a model of evolutionary scientific progress to which most scientists explicitly adhere, and which emerges also from the actual historical study of their work. Not being constrained to the two-dimensional plane alone, they engage in an enterprise whose saving pluralism resides in its many internal degrees of freedom. What does save science from falling victim to inappropriate presuppositions are the chastening roles both of the coordination with experiment and of the multiple cross-checks of any finding by other scientists who themselves may have started with quite different presuppositions. Thus we can understand why scientific progress is often disorderly, but not catastrophic; why there are many errors and delusions, but not one great fallacy; and how mere human beings, confronting the seemingly endless, interlocking puzzles of the universe, can advance at all.

Among the costs of the two-dimensional definition of "science" has long been a popular image of that pursuit which treats it as if it were a cold and lifeless imposition of an authoritarian, dogmatic excess of rationalism, one that left no room for the creative play of the intuition or personal preferences (see book 5, fifth and sixth chapters). But when one adds the role of the thematic dimension in actual research and in the acceptance and rejection of theories, this image is shown to be quite false. The corrected version also explains the exaltations and their opposites, the expressions of disgust and despair, which pepper the confessions of scientists, from Kepler's ecstasy to the response to Schrödinger's physics by those who shared his thematic propensity for continua ("a fulfillment of that long baffled and insuppressible desire," as K. K. Darrow put it). Conversely, as we saw, Werner Heisenberg, a master of discontinuum concepts, found this propensity "disgusting."

Here we touch also on the fact that the aesthetic and motivational value of themata in science shows that the role of such themata is not so different from the guiding presuppositions and framing worldviews expressed in other creative activities, from the arts to politics. More than that, some themata in a particular science are exemplifications of the same fundamental thema in other sciences, or even in cultural productions far from that of the sciences as such. Take Niels Bohr's complementarity principle as an example. As Bohr himself explicitly noted, he saw complementarity in physics as an expression of one general thema in that relatively small pool of themata from which the human imagination draws for all its endeavors. It is not the case that such an expression is in some way a pale reflection or vague analogy of a principle that is basic only in quantum physics; rather, the situation in quantum physics is only a reflection of an all-pervasive principle. Whatever the most prominent factors were which contributed to Bohr's original formulation of the complementarity point of view in physics – whether his physical research, or thoughts on psychology, or his reading in philosophical problems, or the controversy he witnessed between rival schools in biology, or the complementarity demands of love and justice in everyday dealings to which he often referred – it was the *universal* significance of the role of complementarity which Bohr came to emphasize.

Generalizing the case we may say that each special statement of a thema is an aspect of its more general conception; thus a general thema Θ would take on a specific form in physics that may be symbolized by Θ_{ϕ}, in psychological investigation by Θ_{φ}, in studies on mythology and folklore by Θ_{μ}, and so on. The general thema of discontinuity or discreteness, for example, thus appears in physics as the Θ_{ϕ} in discussions on atomism, whereas in psychological studies it appears as the thema Θ_{φ} of individualized identity. Similarly, the multiple appearances of Θ of evolution is evident, in different guises, in fields ranging from biology to cosmology, from embryology to economics. One may therefore express any given general Θ as the sum of its specific exemplifications.

On that point of view, it is reasonable to expect that thematic analysis, as described by the author in the publications cited in the book list, would be found useful also in a large variety of fields of study. And in fact this is what has been happening. The *Postscript* to the 1988 edition of book 1 cites some of the articles and books that have made explicit use of these concepts in various contexts. As specified there, among those authors are: for the history and philosophy of science, Yehuda Elkana, David Faust, Maurice A. Finocchiaro, Peter Galison, J. C. Jarvie, Helga Kragh, John Losee, Stephen Toulmin, Thaddeus Trenn, William Wallace; for the sociology of science, Robert K. Merton, Harriet Zuckerman, Joshua Lederberg, and Diana Crane; in physics itself, Charles W. Misner; in biology, E. 0. Wilson; in psychology, Erik Erikson, Jean Piaget, and Jerome Kagan; in sociology, Robert Nisbet and Michael Mulkay; Donald Fanger and Claudio Guillen in literary criticism; and Roman Jakobson in linguistics. Among these, the article by Robert K. Merton,"Thematic Analysis in Science: Notes on Holton's Concept," is particularly insightful.

For pedagogic purposes on a national level, the scientific content of curricula has been arranged largely along thematic lines in American Association for the Advancement of Science: Project 2061, *Benchmarks for Science Literacy*, and F. J. Rutherford and A. Ahlgren, *Science for All Americans*. Encyclopedia entries on thematic analysis include Allen Kent (ed.), *Encyclopedia of Library and Information Science* (Vol. 61, Supplement 6).

The wide range of these fields bears witness to the fact that there is a much greater commonalty of intellectual and motivational resources across areas than is generally acknowledged. The commonly assumed dichotomy between science and humanistic scholarship or productions, while real at many levels, is far less convincing if one looks carefully at the usefulness of the thematic materials in all of these.

Finally, a word about other concepts which occasionally are confused with thematic propositions. One is "metaphors and related notions such as mental models, frames, and schemata." The metaphoric imagination in science is a lively component of it, alongside others such as the visual and the thematic (see particularly book I, Chapter 9 and the eighth chapter in book 5). But metaphors, unlike themata, serve the traditional function of making conceptual connections between selected similarities; moreover, they are in principle infinite in number.

Another potential confusion with themata involves the concept of "paradigm." But the latter refers primarily to a social phenomenon in the scientific profession; the "paradigm" does not generally come fully into being until exemplified by the supposedly pervasive acceptance of a particular framework of thought. Sooner or later, however, its time is up, and another of a potentially infinite number of other paradigms holds sway, until in its turn it is removed in some discontinuous revolutionary development. By contrast, a thema is found in individual work, as part of a spectrum of themata that no one else may have accepted; also, themata are finite in number and generally of long duration, and so accentuate the longevity and evolutionary nature of scientific advance.

It may not be necessary to stress here that it is inappropriate to associate themata also with Platonic or Jungian archetypes. However, there may be a link between individual *research styles* and the embrace of a particular set of themata. Thus Kurt Lewin identified Aristotelian versus Galilean individual modes of thought, and showed their persistence in contemporary scientific work. A. C. Crombie's *Styles of Scientific Thinking in the European Tradition* has analogous, interesting case studies on six styles (postulational, experimental, hypothetical, taxonomic, probabilistic and statistical, and historical or genetic). Two recent books, based on extensive surveys and interviews, have identified differences in work styles and their effects on the scientific careers of men and women (Gerhard Sonnert and Gerald Holton, *Gender Differences in Science Careers: The Project Access Study*, and *Who Succeeds in Science? The Gender Dimension*).

Among the concepts that may be confused with themata, the most obvious is what Immanuel Kant, following Aristotle, called "Categories." Examples he gave in his *Critique of Pure Reason* involved unity/plurality/totality, and possibility/impossibility, existence/nonexistence, necessity/contingency. Apart from other obvious differences, Kant's "Categories" were, as he insisted, to be accepted as "pure concepts of the understanding which apply *a priori* to objects of intuition in general." Einstein agreed that the mind uses something that might be called categories or schemes of thought, in order "to find our way in the world of immediate sensations." He regarded them as necessary presuppositions for every kind of thinking about the physical world, and stated curtly "Thinking without the positing of categories and concepts in general would be as impossible as is breathing in a vacuum." But Einstein also insisted on an essential difference which shows that those categories are not Kant's concepts, but instead are quite close to thematic propositions: the selection of the categories is not unalterable *a priori*, conditioned by the very nature of our mind; rather they arise from and are subject to change by the unfettered imagination, and are "free conventions," justified only by their usefulness. Moreover, far from being frozen into position *a priori*, some scientists have changed their thematic allegiances dramatically. (For example, Planck turned from an early Machist to an opponent, and Ostwald first rejected and then accepted atomism.)

We end by noting an unsolved puzzle: what is the source of a person's particular set of thematic concepts and hypotheses? It is possible that the origin of themata in individual cases will someday be approached through studies concerned with the nature of perception and apperception, and particularly of the psychodynamics of the development of concepts in early life. For our part, the task continues to be the identification of additional recurring general themata among individual scientists and the profession as a whole.

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