

MATHEMATICS,
SCIENCE, AND
POSTCLASSICAL
THEORY

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Introduction: Networks and Symmetries,

Decidable and Undecidable

Barbara Herrnstein Smith

and Arkady Plotnitsky

THE aim of this volume is to indicate the scope, vitality, and general interest of recent work in and on mathematics and science, especially where it engages themes and issues that have also been central to contemporary cultural and literary theory and to a number of turns, recent and not so recent, in philosophy. While the term "postclassical theory" can be given a range of meanings in relation to more or less radical developments in all these fields, such as experimental and theoretical discoveries in quantum physics or significantly revisionary accounts of evolutionary dynamics in contemporary theoretical biology, its use here is intended primarily to evoke the various critical analyses and efforts at reconceptualization (again, more or less radical) that have emerged in the humanities and social sciences around a cluster of quite general but problematic concepts, notably, *knowledge, language, objectivity, truth, proof, reality, and representation*, and around such related issues as the dynamics of intellectual history, the project of foundationalist epistemology, and the distinctive (if they are distinctive) operations of mathematics and science.

Key figures here include, of course, Nietzsche, James, Peirce, Wittgenstein, Heidegger, Kuhn, Feyerabend, Foucault, Derrida, and Rorty, but also, as these essays indicate, Niels Bohr, Samuel Beckett . . . and Shakespeare. As they also indicate, a sense of the conceptual and practical (including technical) inadequacies of traditional formulations of such ideas is not confined to a handful of wayward Continental thinkers or local malcontents. More or less elaborately articulated critiques of all of them have emerged recurrently throughout the present century both from the diverse disciplines that study the operations of science, such as history, sociology, and philosophy, and from mathematics and the scientific disciplines themselves, including such new and hybrid fields

as ecology, robotics, and neuroscience. These critiques proceed from, among other things, the dissatisfaction of practitioners in such disciplines who have found that familiar or classic accounts of knowledge, proof, truth, reality, and so forth do not cohere with empirical descriptions or mathematical analyses, cannot capture the complex dynamic processes of organic development and individual cognition, and require increasingly questionable interpretations of intellectual and scientific history.

The prominence given here to mathematics reflects the initial occasion of a number of these essays in a colloquium on Mathematics and Postclassical Theory sponsored in fall 1993 by Duke University's Center for Interdisciplinary Studies in Science and Cultural Theory. Since the Center's initial year of operation had focused on *biology*, it seemed a good idea to follow with a topic that indicated clearly, even dramatically, the range of disciplines that its activities were designed to embrace; and, in relation to biology, *mathematics* is often seen as occupying a position at the opposite end of a number of quite vivid scales: of ethereality and materiality, for example, or of durability and mutability, or even, as in the lingo of the artificial-intelligence and artificial-life communities, of dryness (as in the new silicon-based versions of those attributes) and wetness (as in their more familiar carbon-based versions). Quaint or otherwise questionable as these scales and metaphors may be, they are not without some interest here, for they reflect conceptual dualisms and more or less overt hierarchies that are the legacy — with important theoretical as well as institutional consequences — of ancient oppositions considered in several of these essays.

A second and more significant reason for the initial coupling of postclassical theory with mathematics was precisely the fact that the latter is so often invoked as an exception, prohibitive limit, or clear counterinstance to the more radical reaches of such theory: to post-Nietzschean epistemology, for example, or to post-Kuhnian history and sociology of science. Thus it is argued that the (supposed) solipsism, social determinism, or cultural relativism of these projects and approaches, along with their evident and (it is thought) exaggerated concern with language and rhetoric, is refuted by the manifest objectivity of mathematical entities and the manifest transcultural, transhistorical validity of mathematical knowledge. It is also argued that, in challenging these latter notions (i.e., objectivity and transcultural or transhistorical validity), postclassical theory (under whatever name is employed for purposes of castigation — "postmodernism," "deconstruction," "irrationalism," etc.) threatens to undermine the public confidence and professional self-confidence that

secure the proper intellectual authority and technological benefits of mathematics and the sciences and ensure their continued pursuit. By contrast, although none of the essays here engages this popular “but $2 + 2$ still = 4” move directly, those dealing with mathematics suggest that the relations—both historical and conceptual—between mathematics and postclassical theory (in the sense indicated above) are on the whole quite cordial and that, even where those relations are complex, they do not involve any wholesale refutations or underminings in either direction.

This is not to say that there is no bite to these essays (meaning now the entire group, not only those focused on mathematics) or to the conceptual and methodological developments they report and exemplify. The more radical aspects of these developments in relation to the cluster of concepts mentioned above (knowledge, truth, proof, reality, etc.) are evident in the sense of scandal that in many quarters still attends any conjunction of science, including mathematics, with any “post” in advance of . . . well, the postlapsarian. The fact that radical *theoretical* challenges in any field are also likely to involve, sooner or later, challenges to its instituted structures and practices more generally is also evident in the frequent and not altogether inaccurate association of such conjunctions with threats to established order, academic and otherwise. Some implications of these theoretical and methodological developments for issues central to critical cultural studies (for example, the invocation of a monolithically and otherwise dubiously conceived “science” either to sustain entrenched traditional ideologies or to lend credibility to otherwise highly questionable social analyses and political programs) are suggested by a number of the essays here. The spelling out of such implications is not, however, the primary motive of any of them or, for better or worse, of the collection as such.

Nonspecialist readers glancing at these pages may find some of the idioms displayed—abstract, numerical, tabular, diagrammatical—initially formidable or alien. The degree of technical specificity here is, in fact, probably greater than that commonly met in publications on such topics addressed to a general readership. It is our belief, however, as it was the aim of those who contributed to and worked on this volume, that a substantive engagement with these essays does/should not require either a specialized knowledge of mathematics or extensive familiarity with any of the specific fields—physics, sociology, economics, biology, and so forth—they represent. On the contrary, readers should find that this collection offers a genial introduction to a range of important contemporary areas of study and related issues and approaches. They will

certainly find the contributors to be, for the most part, an unusually imaginative, witty, and chatty lot (and, *caveat lector*, not above a prank or two).

The general liveliness exhibited in these pieces as well as the ease with which individual contributors move from Frege to Beckett or from Darwin to Rube Goldberg should actually be no surprise. Although contemporary relations between the sciences and fields such as literary and cultural studies are vexed by a conceptual history of dualistic models and an institutional history of disciplinary segregation, the fundamental arbitrariness of all conceptual models and the instability and reconfigurability of all disciplinary divisions can be seen as both an implicit theme of these essays and a moral to be drawn from the achievements they report and embody. Only a very confined — fundamentally theological, perhaps — notion of the human would represent the humanities as standing in some essentially adversarial relation to mathematics or to the scientific disciplines more generally. And only a very confined — fundamentally metaphysical, it appears — notion of science would represent its domains and pursuits, including mathematics, as *other* than social, cultural, discursive, human, and, as Brian Rotman insists in the opening essay here, corporeal and therefore mortal.

Allusion was made above to common conceptions of the exemplary objectivity of mathematical knowledge. Of course, questions concerning the nature and reality of mathematical objects (numbers, geometrical figures, quaternions, Hilbert spaces, etc.), considered in a number of essays here from a largely postclassical perspective, have also been raised throughout the history of classical thought. Classical questioning, however, while not without significant theoretical and even, in a sense, postclassical implications, has been aimed for the most part (there are some exceptions) at solidifying or increasing rather than disturbing or diminishing the power of classical ideas and values. From Parmenides and Plato to Husserl and Heidegger and, via Kant and Hegel, beyond, whenever mathematical knowledge has been found wanting (as unable, for example, to address issues of ethics or morals), it is usually because mathematics is seen as incapable of reaching the kind of knowledge — that is, truth — thought to be available to philosophy and, in most cases, to philosophy alone. In other words, throughout the history of philosophy and in classical thought more generally, mathematics has been seen either as the example par excellence of the classical ideal of knowledge or as insufficient in just that respect.

It is clear, however, that—even leaving aside the ongoing debate opened by Gödel's theorem—many classical assumptions concerning mathematical knowledge and its historical, social, and cultural conditions have come under increasing scrutiny, sometimes by leading practitioners in the field. As early as 1830, Evariste Galois, considered by some the greatest mathematical genius who ever lived (even though and perhaps because he was killed in a duel at the age of twenty-one), offered what we would now consider striking insights into the psychological, social, and indeed political constitution and functioning of mathematics. But then Galois, one of the greatest mathematical revolutionaries ever, was also a political revolutionary, which fact may well have cost him and mathematics his life. In any case, it appears that mathematics and politics have more junctures than one would expect, given classical conceptions of either. Some of these junctures are familiar, others are strange, and still others are both, simultaneously. They are, in short, in a specific sense discussed below, postclassical.

Another point should, however, be stressed here. No matter how radical the critique of the foundations—especially the philosophical foundations—of mathematical knowledge undertaken by postclassical theory, it is never a simple dismissal of those aspects of mathematics that make it exemplary from a classical perspective. As remarked above, the relations between postclassical theory and mathematics, as represented in this collection, are on the whole quite cordial. This does not, however, diminish the force of contemporary critiques of the nature of mathematical knowledge, nor does it diminish the pressures that continue to evoke them. If anything, the opposite is the case. Thus, while a quite pointed questioning of the metaphysical appurtenance of infinitist mathematics—that is, all mathematics insofar as the concept of infinity figures in it—emerges in Brian Rotman's essay, the contributions by John Vignaux Smyth and Arkady Plotnitsky suggest that postclassical theory and mathematics, including infinitist mathematics, are not only compatible, but may even be necessary to each other in certain areas of their functioning—for example, in science and technology (as suggested by Plotnitsky's essay) or, sometimes interactively, in such fields as literature, the arts, or culture as a whole (as suggested by Smyth's).

The configuration just described may be seen as a key characteristic of postclassical theory: that is, where familiar metaphysical assumptions are challenged, it is not always or necessarily in order to deny their relevance but, rather, to indicate either the limits of that relevance or the simultaneous relevance of opposite assumptions. Alternatively, one

could say that such assumptions (or, strictly speaking, the propositions that articulate them), precisely in being metaphysical, are *undecidable*. The latter concept is crucial here and we return to it below.

While abstractness, in the sense of generality if not ethereality, could be seen as a defining attribute of theory, mathematics, and all scientific knowledge as such, several of the essays here are quite noticeably engaged by the sublunary and the concrete. For example, contemporary reconceptualizations of *materiality*, pursued along epistemological lines by Rotman and Plotnitsky, are addressed in what could be called socio-epistemological—or perhaps socio-antiepistemological—terms in the essays by Andrew Pickering, Michel Callon and John Law, and Malcolm Ashmore. One of the marks, in fact, of contemporary “social studies of science,” a revisionist field represented here primarily by the latter three contributions, is the general willingness of those who work in it to retain a focus on the mundane details of scientific culture: the local, the ephemeral, and even in a sense the domestic (e.g., the laboratory telephones and pencils that acquire a certain prominence in Callon and Law’s essay). What is significant here is that each of these three essays—and work in this field more generally—resists the tendency, characteristic of more classical accounts of science, to treat particular examples in such a way as to permit rapid ascent to an abstract, general, and thus presumptively transcendent level.

The reconceptualization of materiality reflected in the essays just mentioned may be seen as a logical extension of Bohr’s insistence on the fundamental role of measuring instruments in quantum mechanics, as discussed here by Plotnitsky. It is also related to the material technologies of “virtual reality” and of “writing” as understood by Derrida, both of which are considered in their varied and sometimes surprising connections with mathematics in Rotman’s essay (“Thinking Dia-Grams: Mathematics, Writing, and Virtual Reality”). Other significant aspects of materiality related to language emerge in Smyth’s essay, again along Derridian (and here also de Manian) lines. Clearly, there are many ways in which one could map the interconnections among these essays as well as their individual connections to various aspects of postclassical theory. While the possibility of a fully determinate or decidable map—whether geographical, historical, or other—is itself made questionable by postclassical theory, that does not eliminate the possibility or indeed the necessity (as here) of certain more or less localized mappings, determinations, and decisions.

Related, of course, to determination, the issue of *agency* is central

to a number of these essays. In Callon/Law's "Agency and the Hybrid *Collectif*," it is a matter of the taken-for-granted—but, as they point out, quite productively questioned—distinction between the human and the non-human. In Pickering's "Concepts and the Mangle of Practice: Constructing Quaternions," the issue is the relation between conceptual and material agency. The latter essay is a detailed analysis and reconstruction of the complex process by which a particular mathematical object was invented . . . or discovered . . . or constructed by the nineteenth-century mathematician William Rowan Hamilton. In view of the "but $2 + 2$ still = 4" challenge mentioned above, it should be noted that Pickering's account requires neither the classical view of mathematical objects as prior and autonomous nor the idea—sometimes seen as the only alternative—that the technical decisions of scientists, including mathematicians, can be readily explained by political ideology or, in a simplistic sense, social interests. Mathematical objects are certainly understood here as socially, culturally, and discursively constituted, but through processes considerably subtler and more complexly mediated than generally thought, claimed, or caricatured. The conceptual difficulties and rhetorical risks involved in attempts to articulate such processes—and, more generally, to develop alternative accounts of agency and causality—are indicated both in the exchange between Pickering and Owen Flanagan and in the mutually frustrating confrontations discussed by Barbara Herrnstein Smith in her essay ("Microdynamics of Incommensurability: Philosophy of Science Meets Science Studies").

Issues of determination and agency surface as well in the contribution by Susan Oyama ("The Accidental Chordate: Contingency in Developmental Systems"), but here in connection with what are commonly represented as the genetic determinants of individual development. In questioning such representations in contemporary biology, Oyama plays out some implications of Darwin's (still radical enough) theory of evolution—which, it will be recalled, crucially foregoes appeal to either specific design or directionality. As she indicates, metaphors of control as well as teleology that recur in descriptions of the functioning of genes go some distance toward making the latter into updated, secular counterparts of that "ghost in the machine" (spirit, consciousness, intentionality, etc.) which, in theological/metaphysical philosophy of action, is thought to distinguish human agency from (mere) mechanical effectivity. (The agency of the individual subject, as traditionally conceived, is not Oyama's concern on this occasion, but the questions she raises here obviously affect the terms of that issue as well.) Revisionary ideas of

human agency are also developed by Rotman, who redescribes mathematical activities as, in a rather more literal sense than usual, "thought experiments"—which, as such, involve a considerably expanded cast of subjective/"agential" characters, including "persons," "dreamers," and "imagoes," each with interesting relations to the others as well as highly differentiated roles in the relevant acts or scenes. Of course, from a quite traditional perspective it might be grumbled that agency, in this set of essays, is being intolerably fragmented or denied to everything or taken away from human beings uniquely and given to everything else—to pencils and assorted other lowly objects in Callon/Law's essay, to concepts and disciplinary discourses in Pickering's. It would be more accurate, however, to say that the idea of agency is evidently being, here (and in related work elsewhere), stretched, reconfigured, and transformed—or, in short, reconceptualized.

Allusions to *emergence*, emerging often, it appears, from biological models of temporal dynamics, recur in a number of these essays (and, it may be noticed, in this introduction as well). Their prominence seems to reflect the increasing need to address and describe, without implications of purposive agency or simple unilinear ("mechanical") causality, the ongoing effects of exceedingly complex interactions. Two points are worth stressing here.

First, postclassical theory has a distinctly Heraclitean flavor: these essays are dominated by images and models of flux—not simple mutability but complex and usually in(de)terminable dynamics, often involving significantly *reciprocal* interactions. Such images are evident not only in Oyama's piece, which is concerned with specifically biological systems and processes, but also in Pickering's "mangle" of mutually stabilizing interactive practices, in the interconnected lines-and-nodes of Callon/Law's "socio-technical networks," and in Smith's discussion of these and related theoretical developments. In all these cases, forces that are classically represented as distinct and opposed—for example, the genetic and the environmental or the natural and the social—are seen as reciprocally interactive and mutually constituting. This configuration of complex temporal dynamics and mutual constitution is also apparent in Roy Weintraub's account of the fortunes of a crucial theorem in mathematical economics ("Is 'Is a Precursor of' a Transitive Relation?"). As Weintraub indicates, what we take to be the events of intellectual history, including the history of science and mathematics, are not only continuously reinterpretable, but also, with respect to relations between causes and consequences, origins and effects, or "precursors" and "derivations," always potentially reversible.

Secondly, those always fundamentally unstable *constructs* and more or less radically contingent *constructings* or *interpretations*—which, here as elsewhere, replace the fixed entities-with-properties of traditional realism and the destined discovery-of-prior-facts of more traditional philosophy and history of science—seem to yield a universe where one can configure no reality *other* than virtual. Moreover, there appears to be no reason—the alleviation of cognitive dissonance aside—why there *should* be any other. That, at least, seems to have been the unscandalized attitude of Bohr, as discussed in Plotnitsky's contribution ("Complementarity, Idealization, and the Limits of Classical Conceptions of Reality"). If, as is often said, classical cosmology—as represented by post-Keplerian astronomy and Newton's mechanics—moved the human subject from a position of unique significance in the universe to that of a mere element in a machine which requires neither our participation nor even our existence to function, then postclassical physics can be said to restore the subject (so to speak) to significance, but in an epistemologically and otherwise disconcerting way. For the price of our apparently necessary participation in the constitution of the universe is the apparent dissolution of its *simple* existence—ourselves, of course, included. The price was, famously, too high for Einstein (among others) to be willing to pay. On the other hand, it could be thought that there are considerable—perhaps more than equal—conceptual and technical compensations to be gained from the exchange in question.

The concern with the agency of the non-human as well as the human in Callon/Law's essay, and with conceptual practices as well as material ones in Pickering's, reflects in both cases a commitment to *symmetry* that is an important feature of revisionist social studies of science and crucial to Malcolm Ashmore's essay ("Fraud by Numbers: Quantitative Rhetoric in the Piltdown Forgery Discovery"). As formulated especially by David Bloor and Barry Barnes, the so-called symmetry postulate of "the strong programme" in the sociology of science is not the (imagined) *epistemological* position that all truth-claims are equally (absolutely) valid, but the *methodological* position that, in accounting for the stabilization of knowledge, the sociologist (or historian) should not appeal to epistemically self-privileging or ("Whiggishly") present-privileging presumptions. Among such presumptions—the rejection of which would count as perverse skepticism from a classical perspective—are (a) that currently established knowledge reflects the uncovering of an always already determinate truth; (b) that the historical winners in scientific controversies are distinguished from the losers by the inherently better evidence they considered or the inherently better methods they used;

and (c) that genuine scientific knowledge can be distinguished from the products of bad science, pseudoscience, and fraudulent science on comparable evidential and/or methodological grounds *alone*. Thus Ashmore, in strict and scrupulous accordance with the symmetry postulate, subjects the analytic techniques by which the Piltdown forgery was exposed to the same detailed analysis that its self-declared "exposers" had used to undermine the claims made by the self-declared "discoverers" of certain contestably prehistoric bones. Like Weintraub and Pickering and in contrast to more traditional historians of science, Ashmore tells a pointedly non-Whiggish and non-teleological tale—and, in this case, also a pointedly non-edifying one.

From the perspective of a postclassical understanding of history, all the historical essays here "demonstrate" how scientific "facts" (such as those surrounding Piltdown Man) are produced by a continuous and quite complex play of forces, the traces of which are erased through the very process of the construction and appropriation of those facts *as such*—that is, without any quotation marks—by the relevant communities (scientists, engineers, historians, etc.). Thus, it could be said that Ashmore as *sociologist*, through his (deadpan) rigorously scientific analysis, demonstrates how the standards of individual scientists are sometimes less than rigorously scientific. But, applying the symmetry principle reflexively, Ashmore as *historian* could no more claim to have demonstrated (or "recovered") the *historical* facts of the Piltdown case than any of the scientists in question could claim to have demonstrated (or "discovered") the *scientific* facts. The point to be stressed is not that demonstrations, including rigorous ones, are impossible (a frequent misunderstanding), but that classical conceptions of what constitutes a demonstration—and, indeed, what constitutes rigor—cannot be taken for granted. What this means most significantly here is that no demonstration, whether unselfconsciously asymmetrical or rigorously symmetrical, can escape the multifarious play of forces, although these forces may, in each case, be played out quite differently and also constitute themselves quite differently to begin with.

Symmetries—exact and broken—are at the heart of the conceptual patterns, puzzles, and paradoxes that link the projects (or perhaps obsessions) of mathematical logic with the endless fascination which the joint instabilities of number and word, truth and lie, have held for a number of writers, ancient to postmodern. In addition to Shakespeare and Beckett, whose imaginative fertility and conceptual precision (and radi-
cality) in this respect Smyth delineates in his essay ("A Glance at SunSet: Numerical Fundamentals in Frege, Wittgenstein, Shakespeare, Beckett"),

one could also cite James Joyce, from whose *Finnegans Wake* the term "quark" was obtained, courtesy of the physicist Murray Gell-Mann. Like Beckett, Joyce was absorbed by the paradoxical strangeness of twentieth-century logic and science—just as Wittgenstein, Gell-Mann, and other key figures of modern philosophy and science were absorbed in turn by equally strange and paradoxical aspects of twentieth-century literature and art. Notice of such intellectual relations and individual ranges ("influences," "borrowings," "polymaths," etc.) is not unusual in literary and cultural studies. It is commonly confined, however, to particular cases and serves, often enough, to reinforce the very oppositional pairings—that is, art and philosophy, philosophy and science, science and literature, literature and logic, and so forth—that such cases might otherwise be thought to unsettle. In this respect and others, Smyth's essay, which considers the manifold of decidable and undecidable combinations, parallel situations, and trajectories among the constituents of all these classic pairs, demonstrates the impossibility of fixing any such sets of relations and offers a more aptly postclassical exploration.

Joining many of the recurrent themes and conceptual structures discussed above is the idea of *undecidability*. The latter term is borrowed from post-Gödelian mathematical logic where, in its most general and radical conception, it designates propositions that can be formulated within a given system but whose truth or falsity can never be established by means available in the system itself. Gödel proved that any formal system of axioms and rules, if it is large enough to contain arithmetic and, importantly, if it is free from contradiction, must contain some statements that are neither provable nor disprovable within the system. The truth of such statements is thus *undecidable* by standard procedures. (In fact, Gödel proved that the statement concerning the consistency of such a system is itself undecidable. It follows that such a system, although it can never be formally, mathematically proved to be consistent, could eventually be discovered to contain a contradiction; thus, there is no guarantee that the proposition " $2 + 2 = 5$ " could not one day be derived from a system of axioms containing arithmetic.)

Conceptual and metaphorical analogies with Gödel's undecidables have been effectively deployed by a number of postclassical theorists (notably, Derrida), and the idea resurfaces more or less explicitly in several contributions here. Callon and Law, for example, write as follows:

Debates about the status of agency are metaphysical. Are "humans" "like" "non-humans," or not? This is undecidable. Or perhaps it can

sometimes be decided, but only locally. So we can't in general *prove* that "humans" are like "non-humans." Or that some "non-humans" are agents. . . . All we can do is make stories which suggest that if you don't make such assumptions [i.e., that non-human agency is a "contradiction in terms"], then revealing things may happen, theoretically and empirically.

Here one might say, by analogy with Gödel, that the truth or falsity of metaphysical propositions about agency cannot be ascertained *in general*. Locally, however (i.e., in a particular situation), assuming the truth or falsity of a given proposition—with or without granting the corresponding metaphysical assumption—may have significant theoretical and practical consequences. This distinctively postclassical "logic" is applied by Derrida to a number of specific instances, such as the classic opposition between literature and philosophy (in his reading of Mallarmé in *Dissemination*), and also very generally to what he refers to as "all the pairs of opposites on which philosophy is constructed," which would include culture and nature, mind and matter, concepts and intuitions, and writing and speech. In accord with the "logic" just indicated, both the difference and the hierarchy between the constituents of each pair would be seen as generally, but not unconditionally, "undecidable." In the logic of most philosophical systems, however, both the difference and the hierarchy would be seen as absolute and decidable—for example, nature over culture, mind over matter, or intuitions over concepts—although, significantly enough, in different philosophical systems (and at different points in the same system) these hierarchies are produced in reverse, which in part enables Derrida to conclude that any such decidability can only be local or provisional.

An opposition of particular interest here is the one between philosophical and mathematical knowledge, considered briefly above. Are they fundamentally different? There are, as it happens, many classical answers, some of them mutually exclusive or conflicting, each claiming to decide the question once and for all, with many ensuing definitions of mathematics and philosophy and also the corresponding hierarchical relations between them (especially with respect to their proximity to some posited ultimate truth or knowledge, such as God's or that of a computer). Postclassical theory would see the question as, for many reasons—historical, theoretical, cultural, and other—undecidable *in general*, that is, unconditionally or once and for all, although decidable (and evidently decided) in specific situations. The same type of question can be asked of the relation between mathematical knowledge and

literature, or between science and art more generally, and answered in comparable ways. Smyth's essay demonstrates that the "logic" of numbers may itself follow many logics (some of which are illogical in classical terms); that mathematics can sometimes become literary and, conversely, that literature can and sometimes must be mathematical; and that all these relations can be decided differently under different circumstances. In the domains of either literature or mathematics, theater or life, the relation between mathematics and literature or (as Shakespeare famously told us) between theater and life cannot be established or decided once and for all. This is not to say that all differences or decisions between them are suspended as a result, but that any one of them (literature, life, art, mathematics, etc.) can be put into play in relation to the others in ways very different from those given by classical theory.

It appears, then, that all general metaphysical propositions, including those concerning the philosophical foundations of mathematics—or of physics or other sciences, or of literature or philosophy itself, or of the relationships between and among all these—are undecidable at best: that is, as Nietzsche was fond of pointing out, they can never be claimed true as general propositions, not even by any classical criterion of truth (a concept which can itself be defined, so to speak, only by means of undecidable propositions). This, again, does not eliminate locally significant differences between such propositions or the particular metaphysical assumptions correlative to them: such differences are often (though not always) decidable and sometimes also decisive. It remains the case, however, that some among such metaphysical assumptions may need to be abandoned altogether by a given postclassical theory. Nietzsche certainly abandoned a great many of them, but still far from all of them.

One implication of this general situation for the various projects of postclassical theory is the possibility, and sometimes the necessity, of utilizing mutually exclusive concepts (or concepts that appear to be "contradictions in terms") within the same framework, and without a classical (for example, Hegelian) synthesis. Niels Bohr's interpretation of quantum mechanics as what he called *complementarity*, discussed in some detail here by Plotnitsky, is precisely such an instance of necessity. Complementarity is not itself undecidability as conceived on the Gödelian model. (Nor, for that matter, is *indeterminacy* as represented by Heisenberg's uncertainty relations.) One can say, however, that complementarity is made possible by undecidability insofar as the latter concept applies to general metaphysical propositions and assumptions, as opposed to strictly mathematical ones, as in Gödel. Comple-

mentarity configurations of the former type—that is, arising from the undecidability of (or the impossibility of claiming general truth for) metaphysical assumptions—may be detected in several essays in this collection. For example, Callon/Law's "hybrid *collectif*" could be seen as an undecidable/complementary configuration of human and non-human participants in laboratory life, replacing classical definitions and related oppositional distinctions of agency. Analogous configurations are both implicit and explicit in Oyama's account of the interplay of chance and necessity, contingency and regularity, and predictability and unpredictability, both in evolutionary theory and in the development of individual organisms; such configurations are also evident in her account of the interplay among the different constituents of these classical oppositional pairs, which are not always equivalent to each other. As observed earlier, ideas of emergence and models of complex and often reciprocal processes dominate several essays in this collection, including the two just mentioned. It is worth adding that, in this respect, they differ interestingly and significantly from the more static configuration of the mathematical model of undecidability per se. But that confirms the point being made here, for in this respect these essays demonstrate the possible connections between, on the one side, undecidability or complementarity and, on the other, process, emergence, becoming, or history.

A final, reflexive point should be stressed here, namely, that the post-classical logic of undecidability may be applied to the very opposition between classical and postclassical. For this opposition, too, cannot be established once and for all, either theoretically or historically; nor can any hierarchy be established unconditionally between its constituents. Across the spectrum of the history or, speaking more postclassically, *histories* of modern mathematics, science, and theory—from Galois to Hamilton to Einstein to Bohr to Gödel; from classical algebra to quaternions to non-Euclidean geometry to Einsteinian relativity to quantum theory to chaos theory; from Adam Smith to the Arrow theorem and the complex mathematical models of modern economics; from Darwin to the neo-Darwinian synthesis to contemporary genetics to developmental systems theory; from the work of individual mathematicians and physicists, such as those mentioned above, to modern experimental science to postmodern big science and laboratory life; from Pascal's first calculating machine to modern computers to virtual reality, artificial intelligence, and artificial life; and from Hegel to Marx to Nietzsche to Wittgenstein to Feyerabend to Foucault to Derrida to the authors of the essays collected here: in all these fields and in the thinking of all the

figures involved, including our own interpretations of these events and histories, there is an immensely complex and sometimes undecidable interplay between that which is classical and that which is postclassical. For the moment, however, one might want to stress the local decidability and decisiveness of certain differences (often radical, though of course never absolute) between them, for example, the very logic of undecidability just delineated. This logic, which does not appear to be found in any classical theory, at least not in this form, appears to be decidably and decisively *postclassical*.

Recalling the dissatisfaction with classical conceptions of knowledge, language, truth, proof, reality, and representation (etc.) noted at the beginning, one could say that at stake in the *decision* here is a transformation of our understanding of the operations and significance of mathematics, science, and theory, classical and postclassical alike. In that respect, one might see the value of this collection as its demonstration that interest in the reconceptualizations that define postclassical theory from the era of Bohr and Wittgenstein to our own has moved from the question of intellectual legitimacy or philosophical scandal to the question of what, specifically, can be done with them, that is, to institutional practices. Once a theory, conceptualization, or reconceptualization begins to be played out in interesting, productive, and connectible ways in a number of domains of knowledge, such as biology, the history and sociology of science, literary theory, mathematics, and philosophy, then the question of its legitimacy has already been answered and so, too, one might say, has the question of its validity.

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