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# Toulmin and the Mathematicians: A Radical Extension of the Agenda

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**ABSTRACT:** Toulmin is famously seen as the progenitor of informal logic and the related theory of argument and is first among many who seek to move the study of argument away from its roots in formal, especially mathematical, logic. Toulmin's efforts, however, have been substantively criticized by Harvey Siegel, among others, for failing to offer the sort of foundation that, according to Siegel, even Toulmin sees to be required lest the theory of inquiry fall to impotent relativism. What I will attempt to indicate in this paper is, that although Toulmin is correct in rejecting mathematical logic as standardly construed as an adequate theory of argument, and logical empiricist constructions as an adequate basis for the philosophical understanding of science, there is a significant role for metamathematics in the new logic. In particular, I will show how a formal model based on mature physical science rather than arithmetic furnishes crucial support to Toulmin, furnishing philosophical metaphors that afford the foundational support required for normativity and the clarification of key logical concepts required for a robust normative theory of argument in the context of inquiry.

**KEY WORDS:** Toulmin, metamathematics, truth, argument, epistemology, entailment, philosophy of science, inquiry, formal logic

Stephen Toulmin begins the *Uses of Argument* by distinguishing his project from traditional logical theory which, following Aristotle, maintains that 'logic should become a formal science—an *episteme*' (Toulmin, 1969, p. 3). His project, the 'practical assessment of argument' leads to the alternative 'jurisprudential model' that is the hallmark of his contribution. This reflects a policy found throughout his contribution. In *Human Understanding* Toulmin draws a rich and complex description of the epistemological foundations of disciplined knowledge barely mentioning the then dominant tradition in Philosophy of Science that draws upon first-order models of key scientific concepts such as explanation and reduction. The position is already apparent in his iconoclastic, *The Philosophy of Science: An Introduction*, proscribed reading in the logical-empiricist doctoral program in which I was trained. Similarly, there is little extended discussion of the mathematical basis of the physical inquiry that he and June Goodfield illuminate in their splendid volumes on the history of science.

Toulmin's work, however, has been substantively criticized by Harvey Siegel (1987) among others, for failing to offer the sort of foundation that, according to Siegel, even Toulmin sees to be required lest the theory of inquiry fall to impotent relativism. What I will attempt to indicate in this paper is, that although Toulmin is correct in rejecting mathematical logic as standardly construed as an adequate theory of argument, and logical empiricist constructions as an adequate basis for the philosophical understanding of science, there is a significant role for metamathematics in the new logic. In particular, I will show how a model of truth and entailment, based on mature physical science rather than arithmetic, furnishes crucial support to Toulmin viz. a viz. Siegel's trenchant criticisms, furnishing philosophical metaphors that afford the foundational support required for normativity and the clarification of key logical concepts

required for a robust normative theory of argument. In this paper I will indicate a radical extension of Toulmin's agenda, one that, hopefully, will move the agenda forward. I will argue that the key redefinition of central logical terms required to develop Toulmin's notion of warrant calls for a technical treatment that draws upon the very metamathematical tradition that Toulmin is most often seen to reject.

Toulmin's discussion is more complex than the focus on the familiar model of warrant, grounds and backings might indicate. Toulmin introduces the model in the first chapter of *The Uses of Argument*, 'Fields of Argument and Modals', and although the issues of fields, among the more discussed aspects of Toulmin in the literature, warrants significant discussion, much of the chapter is focused on the modalities, an issue less common in discussions of Toulmin's work. But both concerns are essential, and as the structure of the chapter indicates, they shed light on each other. Concern with the modalities with which claims are put forward and the complexity of the context that underlie the modal qualification is essential to understanding the deep issues of arguments being embedded in fields—that is to say, the strength of the warrants, and the standards of rigor and method characteristic of the backing. Toulmin's discussion is rich and includes issues of probability addressed in a detailed and technical manner, offering arguments against the then standard views of Carnap and Kneale. But from our point of view the main contribution of his alternative view is the general requirement that 'to keep clear about knowledge and probability, we must remember to take into account the occasion on which a claim is to be judged' (Toulmin, 1969, p. 57). Sensitivity to the occasion is required by the embeddedness of the argument in a context of prevailing assumptions: the field from which the argument is drawn and the purposes for which the argument is being advanced (e.g. Toulmin distinguishes between 'warrant-using and warrant-establishing' arguments, p. 118.).

Toulmin's main concern reflects the preponderance of arguments that essentially include guarded assertions such as estimations of likelihood of the evidence as a condition for the strength with which the claim is put forward, a myriad of mitigating factors drawn from the level of commitment of the argument in light of limitations and counter-arguments, open-questions that although unaddressed may impinge on the argument once included and the like. Toulmin rejects both the standard model for categorical assertions, what he calls 'analytic arguments', as well as any account of inductive reasoning that requires a definitive estimation of the likelihood of the evidence to be required for the estimation of probabilities. 'The fundamental mistake is to suppose that the evidence in the light of which we estimate the likelihood of some view must be written into the estimate we make, instead of being kept in the background and alluded to only implicitly' (op. cit., p. 75). The reason for this is the ever changing context of knowledge, of commitment shifting under the pressure of argument, that points all arguments towards the 'occasion on which claims are to be judged' and where 'a statement will have to be attributed as many truths as there are possible bodies of evidence bearing on it' (ibid.). This creates the essential challenge for a theory of argument adequate to Toulmin's agenda. For issues of likelihoods and the support of claims at particular levels of analysis and argumentation require that definitions of and distinctions among levels and kinds of support be adumbrated with sufficient transparency and cogency that philosophical intuitions can be applied in response to the underlying logical and epistemological issues. And for this, I would argue, there is no substitute for the richness and transparency of meta-mathematics.

Toulmin, in his rejection of formal logic and the analytic entailments that determine its practical applications as well as its metatheory, contrasts 'technical logic' to what he refers to as 'practical assessment of arguments' (op. cit., p. 2). Distancing himself from the tradition that sought to develop a 'science of logic' he explores the relation of the key concepts found in logical theory in terms of another perspective on argumentation that 'has throughout its history

tended to develop in a direction leading away from...the way that practical questions about the manner in which we have occasion to handle and criticize arguments in different fields' (ibid.). It is in the practice of practical argument or alternatively the practical application of arguments that the jurisprudential model has its sway. But is that the right place to draw the line? For there is an equally fundamental distinction, that between practical arguments engaged in within political and ordinary affairs, and argumentation within specialized fields of inquiry. There is little reason to think that such disparate domains of argumentation will share logical structures, except when they are seen as in contrast to technical logic of the sort that Toulmin's agenda was constructed to question. Although there is reason to think that much of the 'field-invariant' apparatus envisioned by Toulmin (op. cit., p. 33) and other informal logicians might be usefully applied with appropriate modification to both sorts of argumentative context, I will argue, perhaps paradoxically, that deep concepts in logical theory are better derived from the specialized argumentation of the most effective modes of disciplined inquiry, and that an adequate conception of such argument permits a significant meta-mathematical treatment, showing how the central notion of entailment tied to a radical revision of the set-theoretic model of truth yields a dialectically effective yet foundationally compelling fragment of logical theory that can offer an epistemological foundation for Toulmin's much contested notion of warrant, and more importantly show a direction for the advance of his truncated project in *Human Understanding*. For both the logical project and the epistemological concerns that give logic its point require a rethinking of fundamental concepts, in particular, truth, entailment and relevance.

As should be apparent, the notion of truth available from the study of mathematics within standard formal languages suffers from its inapplicability to situations that do not share three essential aspects of mathematics as logically represented: clarity of model relations, the underlying identification of truth as within a chosen model (e.g. arithmetic), and necessity as truth in all possible models. Without substantive argument to the contrary, it seems obvious that the concepts used in real argument are not readily reconstructed to fit the mathematical ideal, without significant distortion. Concepts are not extensional, criteria for membership are not defined for the most part, there are overlaps and 'bushes' in the tree structures that represent conceptual relations within a language, membership cannot be decided in any finitary way, etc.

The inadequacy of mathematical construals of truth is already clear in Toulmin (1969). Argumentative support requires more than the truth of premises and abstract rules of inference. Among the premises we need to distinguish the grounds, that is, a relevant basis in fact or other information to support the claim at the appropriate level of abstraction, from the warrants, that is statements or rules sufficiently general in respect of the ground and claim that support the inference, and most crucially, from the backing, that is to say, a context of interpretation and understanding that sets standards for the degree of rigor of acceptable model relations (the semantics of the warrant, claim, ground relation), a domain of primary application, and a relevantly restricted notion of necessity, for example, physical necessity construed as truth in a selected range of physically possible models.

That is to say, the mathematical notion of truth is irrelevant to most situations that require human beings to determine the facts of the matter. Traditionally this has been construed as the distinction between deductive and inductive logic. But, given the central role of deduction in science and other empirical procedures (Magnani, 2001), that line must be drawn elsewhere. But where? Without the anchor of a priori necessity exemplified by the well-understood domain of arithmetic, from where will we draw an alternative paradigm? Toulmin's concern with disciplined inquiry points the way away from the domination of the arithmetic paradigm to the broader concerns of human understanding. Surprisingly, the concern with disciplined knowledge might not support Toulmin's rejection of 'scientific logic'. For short of a disciplinary based

relativism of the sort that Siegel (1987) has shown to be inadequate for significant normative understanding, the disciplines require the same sort of foundational grounding that was traditionally sought in the foundations of arithmetic. That is, from a logical point of view, an understanding of the normative foundation of disciplined knowledge requires that some account of the essential logical triad, truth, entailment and relevance be attempted.

I would argue that it was the traditional concern with foundation of arithmetic that renders formal logic problematic in many contexts of argumentation, not the scientific nature of the meta-logical inquiries. That is, it was the image of arithmetic in the underlying logic and especially in the theory of truth associated with Tarski, rather than the metamathematical turn, that creates many of the problems that Toulmin sees so clearly. That is not to deny the essential contribution to logic that the focus on argumentation, 'the uses of argument', affords. Nor is it to question the enormous value of Toulmin's concern with 'evolution of concepts' as exemplified in scientific inquiry. And I especially include the historical work with June Goodfield. It is rather to assert that description, no matter how compelling, needs to be grounded in a normative philosophical enterprise that attempts the traditional task of understanding the central logical concepts as used.

The connection between the two is my conjecture that metamathematical structures representing models of such key logical concepts can be drawn from, in particular, the practice of physical chemistry, as the prototype for disciplined inquiry that yields knowledge at the highest level of epistemological warrant consistent with its a posteriori nature. If the model is noetically compelling the task is to see whether it may serve as a foundation for analogous images of, in this instance, truth and entailment in less epistemologically demanding domains. This then could serve as the basis for the general theory of truth in argument and a consequent theory of entailment.

In the case envisioned, as in much of inquiry, what is required is an account of the subtle dynamic of propositions as interconnected by various relationships of support that both reflect and afford estimates of likelihoods, estimations of vulnerability to challenge in light of competing positions, degree of relevance to the issues of hand as a function of consequences across the field of commitments and so on. Logic adequate to inquiry must be sensitive enough to take practical and theoretic account of such a range considerations. It is among Toulmin's most salient contributions to epistemology, especially in *Human Understanding*, that he sees this as the essential philosophical project.

Toulmin has a lot to say about how disciplinary practice grounds the epistemic enterprise, both in *Human Understanding* where he offers insights into the underlying epistemological structures in rather abstract philosophical terms and in the deeply indicative volumes in the history of science with telling historical and methodological detail. Although the historical texts have been overlooked in the discussion, even by Toulmin (there is a bare mention of his work with Goodfield in *Human Understanding*), they characterize the richness of the dialectic in disciplined discourse in a manner that permits the arguments to stand out. Using the frames of large areas of science (physical chemistry, astronomy and time-bound disciplines such as history and evolutionary biology) he is able to reconstruct a plausible account of how the problem situation is constructed and resolved through theoretic and practical advance. This is the sort of data that a theory of inquiry can be built from. *Human Understanding* attempts this while arguing for the centrality of the description of practice to an adequate philosophical account of inquiry-based understanding as against alternative philosophical models.

This sets the task. For participants in the discipline the level and kind of support are more or less apparent in the claims made and challenges refuted. Students of a subject matter acquire the sense of familiarity that supports such complex judgments as the result of long study and

assimilation into a community of argument. It is for the student of the logic of argument to make the underlying structure of these complexes transparent both in their functioning and in their noetic plausibility. And this transcends description. It requires a normative account that captures what the description contributes in a noetically transparent manner. This seems to me to require metamathematical precision and reach. It also seems to me to require changes in the logical foundation.

Toulmin's study of argument in science makes the emergent notion of truth evident, for truth is an essential outcome of inquiry and other critical dialogues, when viewed from an epistemological perspective. But the role that truth plays in such essential dialogical activities requires normative stability, in that, as Harvey Siegel (1987) reminds us, relative truth is no truth at all. An immediate problem for an emergent theory of truth is to offer an account of stability sufficient to meet the test of non-relativism while admitting the evolutionary nature of truth.

The standard account of truth presupposes that a model exists against which adequacy is to be assessed. In fact, given the Lowenheim-Skolem theorem an arithmetic model is guaranteed. But as Putnam (1983) has taught us an arithmetic (denumerable) model, although always available, may be far from an adequate model of the subject matter about which truth is to be determined. The problem then is to develop an account of truth that has the robustness typical of the standard account, while permitting an image of truth far different from that envisioned by Tarski. In the standard account the model, as in arithmetic, is available independent of the inquiry. If we take physical science as the paradigm, the model against which truth is to be ascertained emerges from inquiry (Weinstein, 2002). The scientist must wait upon science to see if his conjecture is true.

In addition and in contrast to the mathematical, truth based on the paradigm of mature physical science requires ambiguity in evolving model relations. Truth, in the final analysis, is identified with the progressive appearance of a model that deserves to be chosen (so both the intuitions of correspondence and coherence are saved) but the model, not unlike in Pierce, evolves as inquiry persists. It is the substance of how judgments of epistemic adequacy are made antecedent to the truth predicate being defined that is the main contribution of the construction here. Finally, in place of strict implication contrasted with induction in its various senses, the construction permits degrees of necessity reflective of the extent of model relations, that is, it permits inferences within models (that are relatively strict) to be reassessed in terms of the depth and breadth of the field of reducing theories from which models are obtained. That is to say, the theory of truth yields a theory of entailment that permits of degree.

But why metamathematics? Whatever the failings of mathematical logic as an object language, that is, computers aside, a language in which arguments are plausibly couched, mathematical logic has excelled as a meta-language—that is, as a language in which the exploration of complex systems such as arithmetic is both possible and useful. This shows up as a serious ambiguity in Toulmin's demarcation of scientific from practical logic. Scientific, that is formal, logic has been applied both as a practical tool for argument and as the basis of the meta-structure that yielded the wealth of knowledge of logical systems hard won over the past century. It enabled the foundation of arithmetic to be displayed, and as essentially, mathematical logic as a meta-language developed and sustained the highest standards of noetic clarity and systematicity. That is, metamathematical arguments appealed to the deepest philosophical intuitions while permitting the well-regulated development that enabled deep results about logic to be conjectured, proved and rejected. The latter is a great deal to give up in logical theory in the name of the former. That is, the weakness of formal logic as a vehicle for the construction and evaluation of arguments has little apparent consequence for formal logic as a framework for the

theory of argument, a role that it played in the deepening understanding of arithmetic in the last century.

Of essential importance, the metamathematical tradition gives us direction as to how to proceed. Entailment has been at the core of a number of elaborations and extensions in attempts to offer images of aspects of human thought, from the epistemological to the ethical. Such attempts give a synoptic image that connects with the procedures developed within meta-theory. That is, through transparent definitions and regularized rules of procedures, metamathematical formulations permit of reasoned assessment that is at the highest levels of rigor in human thought. To write a metamathematical construct is to invite such scrutiny. This in itself is enormous dialectical yield. But rigor without purpose is mere show. A metamathematical image must show persuasive structural elements that give a noetically satisfying account of logical properties. It must be adequate to the phenomena that it attempts to portray and indicative of deep philosophical clarifications. The latter, rigor, has been more often achieved in metamathematics than the former, that is relevance for understanding the nature of argument. But that is, I maintain, because the two distinguishable roles of traditional metamathematics have been confused—that is, first, as a vehicle for logical clarity in theory, and second, as a contributor towards determining the standards for logical rigor reflective of its intended domain of application, arithmetic. Traditional metamathematics, drawing from concern with its domain of application, arithmetic, was stymied in its ability to afford useful analyses of actual argument by limiting its purview to arguments that satisfied the criterion of adequacy natural to arithmetic but patently inadequate for most arguments elsewhere, that is, necessity. For mathematical systems, in so far as they are a priori, require necessity, as do arguments based on analytic principles, such as the categorical arguments that are characteristic of syllogistic. But in the overwhelming majority of the topics for which argumentation is central, necessity is too high a demand. This is clear to Toulmin, who sees argument against the penumbra of often ‘cloudy’ warrants supported by equally gauzy traditions serving as backing. But the principle, not yet forgotten, that clarity where possible is a virtue calls for at least an attempt to elaborate core logical concepts with as much clarity as the subject permits and the meta-language affords. Again the key notions are truth, entailment and relevance, shorn of the arithmetic associations that determine the traditional meta-theoretical account, e.g. necessity, monotonicity, categoricity, etc.

As in many non-standard analyses, the formal model of truth and entailment indicated here is sensitive to the preponderance of evidence and changes in the evidence. Relevance is a complex function of the other two. As in all formal models, its contribution is one of systematicity and transparency. Whatever the difficulty of initial understanding, the model, once understood, wears its virtues and vices on its face. In particular the model’s contribution lies in adding to the understanding of the evaluation of claims in context a systematic way to organize, articulate and evaluate changes in the field of theories in terms of which the evidence for a claim is to be interpreted and explained. To participate in a dialogue in respect of such a claim is, for the most part, to have been initiated into a linguistic community where the appreciation of information through accepted principles of inference and strategies for estimating the weight of evidence are an essential part of professional training and competence. To understand the normative structures that such a dialogue inhabits, that is, to do logic and applied epistemology, requires an account which is rich enough to capture the phenomena but transparent enough that its noetic power can be debated.

The model indicated in the Technical Appendix has at its core the specification of two different sorts of functions. First, fairly standard functions map from a theory (construed as a coherent and explanatory set of sentences) onto models, that is, interpretations of theories in a

domain. Second, a much more powerful set of functions map from other theories onto the theory, thereby enormously enriching the evidentiary base and furnishing a reinterpretation now construed in relation to a broader domain. This is the insight that reflects the choice of physical science as the governing paradigm. Mature physical science is characterized by deeply theoretical reconstructions of experimental evidence, laws and theories in light of higher order theories as they are seen to unify heretofore independent domains of physical inquiry. These unifications, or 'reductions', offer a massive reevaluation of evidentiary strength and theoretic likelihood. It is the weight of such reconstructions in identifying the ontology that grounds the truth predicate that the construction attempts to capture. And in so far as the formalism captures what is salient in physical theory it affords a vision of emerging truth that may have significant implications for the computation of epistemic adequacy in systems that include a rich and theoretically structured data-base as in medical diagnostic systems.

Mature physical science is also characterized by the open textures of its models and the approximations within which surrogates for deductions occur (in the standard account idealizations and other simplifications). The construction here attempts to make sense of the need for approximations and other divergences among models at different levels of analysis and articulation by offering intuitive criteria for assessing the epistemic function of the approximation in light of emerging data and the theoretic surround. Obviously for the student of the field this is found in the details of warrant and backing. For the logician what is required is an account of how, in principle, such a practice can be seen as normatively compelling in light of core logical intuitions.

The key contribution of the construction is that it enables us to construe epistemic adequacy as a function of theoretic depth and the increase of explanatory adequacy as inquiry progresses, rather than, as in standard accounts, as conformity to pre-existing models or predicted outcomes. This changes the logical structure of truth and entailment as compared to the arithmetic ideal and to the positivist accounts that take, for example, models of data as fulfilling an analogous role to models in arithmetic in the standard account. That is, both serve as a template against which a claim is evaluated. As in the once standard account of scientific inquiry, the model that yields confirmation is available prior to the inquiry; the relation between theory and data is a function mapping expectations onto outcomes. But, as Toulmin shows us, epistemic adequacy requires something more. It requires concern with the epistemic surround. This construction here adds an essential function that maps from a deep explanatory base onto the theories upon which expectations are based. This allows us to, among other things, choose between alternative theories even where expectations converge, and grounds the assignment of prior probabilities and other estimations of likelihood. But most important it shows how decisions are made in light of a relatively stable but often changing structure of fact and theoretic adjudication. As always in the formal tradition, what is offered, although an idealization, is a precise root metaphor. The test is to see whether the root metaphor once articulated has essential consequences in the elaborated structure that it generates and most pertinently, whether the elaborated structure offers a philosophical compelling image of the fundamental concepts it encapsulates. That is, the model should be articulatable so that it makes sense of actual practices while affording a noetically available normative account of the logic of that practice.

## TECHNICAL APPENDIX

A preliminary version of the model is available in Weinstein (2002). The following is a brief indicator of the essential elements.

The basis for the construction is a scientific structure defined as an ordered triple,  $TT = \langle T, FF, RR \rangle$ , where:

- a)  $T$  is the syntax of  $TT$ , that is, a set of sentences that are the linguistic statement of  $TT$ . The set  $T$  is closed under some appropriate consequence relation,  $Con$ , where  $Con(T) = \{s: T \vdash s\}$ .
- b)  $FF$  is a field of sets,  $F$ , such that for all  $F$  in  $FF$ , and  $f$  in  $F$ ,  $f(T) = m$  for some model,  $m$ , where either:
  - i)  $m \models T$ , or
  - ii)  $m$  is a near isomorph of some model,  $n$ , and  $n \models T$ .
  - iii)  $FF$  is closed under set theoretic union: if sets  $X$  and  $Y$  are in  $FF$ , so is  $X \cup Y$ .
- c)  $RR$  is a field of sets of functions,  $R$ , such that for all  $R$  in  $RR$  and every  $r$  in  $R$ , there is some theory  $T^*$  and  $r$  represents  $T$  in  $T^*$ , in respect of some subset of  $T$ ,  $k(T)$ . We close  $RR$  under set-theoretic union as well.

This enables us to define key notions, articulating the history of  $T$  under the functions in  $F$  and  $R$  of  $FF$  and  $RR$  respectively. An example is the basic notion of model chain. The intuition of a model chain permits us to formalize the intuition that a progressive theory expands its domain of application by furnishing theoretic interpretations to an increasingly wide range of phenomena. The basic interpretation is the intended model. Thus, theories have epistemic virtue when all models are substantially interpretable in terms of the intended model, or are getting closer to the intended model over time.

A related, but distinguishable notion, a theory being model progressive begins with the intuition that theories transcend their domain of applications as they begin as conjectures. This notion defines a sequence of models that capture increasingly many aspects of the theory.

The intuition should be clear. A theory's models in the sense of the sets of phenomena to which it is applied must confront the logical expectations the theory provides. That is to say, as the range of application of a theory moves forward in time and across a range of phenomena, the fit between the actual models and the ideal theoretic model defined by the intended model is getting better or is as good as it can get in terms of its articulation.

These constructs, reflecting the model history of a theory  $T$ , enable us to evaluate the theory as it stands. By examining the  $T$  under  $RR$  we add the dimension of theoretic reduction. Similar constructions offer a precise sense of progressiveness under  $RR$ . The key intuition here is that, under  $RR$ , models are donated from higher-order theories<sup>1</sup> becoming models (or near models) of  $T$  while being differentiated from models of  $T$  under  $FF$  by their derivational history and by the particulars of the  $RR$  relation. This enables us to offer essential definitions resulting in a principled ontological commitment in terms of the history of the theory and its relations to other essential theories with which it comports.

The construction enables us to distinguish particular models and their history across the field, giving us criteria for preference among them. It is this ex post facto selection from among the intended models in light of their history that affords ontological commitment and the related notions of reference and truth. The main contribution of the formal model is how it elucidates the criteria for model choice in terms of the history of the scientific structure,  $TT$ , within which a theory sits. That is, we define plausible desiderata, not only upon the theory and its consequences (its models under functions in  $FF$ ), but also in terms of the history of related theories that donate models to the theory under appropriately selected reduction relations (functions in  $RR$ ). It is the structure of the field under these reduction relations, and in particular the breadth and depth of

<sup>1</sup> Since reduction is irreflexive, asymmetric and transitive, 'higher order' is easily defined in terms of a linear ordering.

the model chains donated by interlocking reducing theories, that determine the epistemic force and ultimately the ontology of the theory.

The intuition should be clear. A theory, whatever its intended models, takes its ontological commitment in light of how the theory fares in relationship to other theories whose models it incorporates under reduction. That is, we fix reference in light of the facts of the matter, the relevant facts being how the theory is redefined in light of its place in inquiry as inquiry progresses.

It is the awareness on the part of inquirers of the history of success of scientific structures that enables participants in the inquiry to rationally set standards for model choice in terms of plausible criteria, based on successful practice. Crucially, the formal model enables us to look at the history of approximations, and most essentially at goodness-of-fit relations between models donated from above (from reducing theories) and the original interpretations of the theory. Finally, it permits a natural definition of truth internal to the scientific structure. Truth is defined in an ideal outcome. Truthlikeness becomes a quantifiable metric as the theories in the structure move towards truth, that is, as the intended model of strong reducing theories substitutes for intended models for reduced theories.

The intuition is fairly standard: true theories ramify. The force of the construction is in its logical clarity, and what that permits. The construction displays what one can mean by 'ramify' and indicates how a metric might be defined. The structure could be modeled with any finitary assignment, and consequences drawn. It offers an adequate metaphor for truthlikeness as the outcome of inquiry of the sort found in physical chemistry, a putative candidate for a naturalist ontology. A model of this sort, whatever its intuitive appeal, stands or falls on the clarity with which it exposes the actual structure of informational structures of which scientific theories are the paradigmatic example. But this requires that actual exemplifications be constructed and their adequacy to the phenomena determined. My intuition is that this could be exhibited through a computer construction that relied on the architecture sketched here. It could then be determined whether such a model affords insights that might begin to offer a rational reconstruction of the historical details, thus beginning to explore that role of computer-realized mathematical models in the theory of argument.

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