# *The Poetics of Modeling: Duhem, Harré, Lem*

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[This is an articled-up version of a talk delivered at the Conference on The Nature of Evidence: Rhetoric, Literature, Science, at the University of Iowa in 1990. It appears that I never sent it out for publication, though it was an important inspiration for *The Seven Beauties of Science Fiction*.]

It is a given in literary criticism that a linguistic text models things other than itself, though these things too may be treated as texts. Any more or less allegorical discussion of literary fictions presupposes that they mediate knowledge of human reality much like a theoretical model in science mediates knowledge of physical phenomena. A literary fiction is, to the professional literary scholar, rationally and systematically interpretable, even if it cannot be verified or falsified.

It is also well known that a scientific model requires a particular kind of suspension of disbelief, similar to the way we read literary fictions. A model is used to fill gaps in theoretical knowledge, to provide a "theoretical image" of what we do not yet know (Harré). It is an analogical extension of a more familiar theory's language onto a new "field of application" (Black) and, as an analogy, it is necessarily an approximation, presenting certain phenomena in strictly defined circumstances, with the purpose of testing or illuminating a certain aspect of a general theory. Because its

context is necessarily limited, a model implies that alternatives to it may exist for illuminating different aspects of the relevant theory (in contrast with a theory's claim to general relevance and truth) (Achinstein). A model is a theoretical explanation of a specific phenomenon, in contrast with theory's claim to provide a general explanation. And finally, since a model's purpose is to illuminate or generate hypotheses, a model is known to be tentative, and indeed false with respect to reality -- in a word it is a *fiction*. It is sometimes asserted that a model is at most a *heuristic* fiction that changes nothing in a theory, simply making it more accessible; but it is also asserted that models can act through the scientific imagination to reveal new theoretical possibilities, that is, they can be *generative* fictions that have profound effects on the thinking, and ultimately the actions, of the people who read and use them (Black; Hesse).

In this paper I wish to identify some of the forms that I believe the rhetorical analysis of discursive scientific modeling might take. I call it the poetics of modeling, since it is concerned with the literary qualities that give models both their persuasive and aesthetic pleasure. I cannot speak to the considerations of cognitive adequacy--the subject of most of the works in the philosophy of science devoted to the subject of modeling. I should note that for many writers, a scientific model must necessarily be a matter of equations, and consequently the discursive explanation is merely a translation

of the model into a more accessible, but fatally imprecise language. But modeling equations, since they are mathematical sentences, may well prove open to discursive analysis by observers who are equally versed in mathematics and rhetoric. The commonplace that certain mathematical expressions can induce greater aesthetic pleasure than others points to a rhetorical, indeed a poetic, dimension to mathematical language. But I do not have the requisite knowledge for that. Here I wish only to discuss discursive articulations of scientific models. Even if they are only second-generation and imprecise translations of the "true" scientific models, the role of these discursive articulations within the scientific culture at large, and in constructing the value of science in the general culture, justify our study of them as legitimate scientific models. I will discuss three aspects, which, for want of more precise terms, I call the stylistics, the analogics, and the fantastics of modeling.

By stylistics I mean the part of rhetoric that studies the manner in which arguments and proofs are made; specifically, the ways in which verbal texture, the choice of words and figures of speech, syntax, forms of allusion, kinds of verbal economy, construct the appeal for intellectual assent, over and above the presentation of the facts. By analogics I mean the study of the forms of analogies in which model-concepts are constructed and embedded in arguments, and give form to those

arguments. The only completely new term here is fantastics. I mean by it the study of the manner in which concepts and theories are shown to be embedded in a world of cultural assent, or "cognitive estrangement" (Suvin). This would normally be called "fictive" I suppose, and it is the sort of perspective that treats the rhetorical role of tropes like the sudden vivid fictions and thought-experiments that philosophers and scientists often insert in close arguments, such as Plato's divine horses, Descartes's or Maxwell's demons, Kierkegaard's Don Juan, Wittgenstein's speculation about measurements on a planet where all bodies are plastic, etc. I use the word fantastics in this case because extended fictive interventions into science's extremely strict construction of reality usually have the flavor of drastic implausibility.

In the pages that follow I will elaborate some examples. To illustrate the stylistics of modeling I will discuss Pierre Duhem's chapter, "Abstract Theories and Mechanical Models" in *The Aim and Structure of Physical Theory* (1905); to illustrate the analogics of modeling, H. Rom Harré's taxonomy of models in his *The Principles of Scientific Thinking* (1970); and to illustrate the fantastics of modeling, Stanislaw Lem's ideas on 20th century literary strategies as forms of fantastic modeling.

*Styles of Modeling: Pierre Duhem*

Questions about the styles of scientific discourse generally have to do with science as a social institution, since the stylistic devices of exposition reflect and construct the audience to which the exposition is directed. Thus, for example, Paul Feyerabend excoriates contemporary science by comparing the prose style of Masters and Johnson to Galileo's and Newton's; while the latter could describe even their astronomical and optical researches in terms of personal intellectual adventure, the former write about human sexuality as if they were speaking about the calibration of machine parts (96-98).

The *locus classicus* of the evaluation of theory-construction, and of modeling in particular, on the basis of style in a chapter of Pierre Duhem's *The Aim and Structure of Physical Theory*, entitled "Abstract Theories and Mechanical Models." Duhem's goal in *ASPT* is to demonstrate that physical theory is a form of explanation and classification whose value depends on the metaphysical system that one adopts. Most interesting in this context is that in the middle of his book Duhem takes an apparent detour in order to explore the differences between the style of model-construction favored by many 19th century English physicists, that of elaborating mechanical analogies for abstract phenomena, and the style of thought Duhem felt characterized continental theorists,

pure logical deduction from initial axioms. The former Duhem considers works of "imagination," the latter works of "abstraction."

Throughout the chapter, Duhem maintains a rigorous polarity between the two kinds of theory-construction. At first, they appear to be granted equal value. Theories are constructed by two types of minds: using terms from Pascal, he considers "imagination" characteristic of *l'esprit géometrique*, "reason" of *l'esprit de finesse*. The former is "ample," "geometrical," visual, able to perceive a collection of disparate concrete elements at once, but lacking the power to organize and classify them according to abstract principles. Gradually, this sort of mind acquires in Duhem's discussion recurring pejorative epithets: it is the "broad-and-weak," the "ample-but-shallow." By contrast, there are the "strong-and-narrow" and ultimately the "strong-and-accurate" and "deep" minds of the pure physicists who avoid visual representations of abstract entities.

Duhem skews the polarity subtly, but his prose often barely contains itself from open lampooning. Like most arguments against certain styles, Duhem's depends on his own style of exposition. Consequently, it is worth quoting him at some length to give the flavor of the tone.

> The French or German physicist conceives, in the space separating two conductors, abstract lines of force having no real thickness or real existence; the English physicist materializes these lines and thickens them to the dimensions of a tube which he will fill with vulcanized rubber. In the place of a family of lines of ideal forces, conceivable only by reason, he will have a bundle of elastic strings visible and tangible, firmly glued at both ends to the surfaces of the two conductors, and, when stretched, trying to contract and to expand. When the two conductors approach each other, he sees the elastic strings drawing closer together; then he sees each of them bunch up and grow large. Such is the familiar model of electrostatic action imagined by Faraday and admired as a work of genius by Maxwell and the whole English school....
>
> The employment of similar mechanical models, recalling by certain more or less rough analogies the particular feature of the theory being expounded, is a regular feature of the English treatises on physics. Here is a book [Oliver Lodge's *Modern Theories of Electricity* (1890)] intended to expound the modern theories of electricity and to expound a new theory. In it there are nothing but strings which move around pulleys, which rolls around drums, which go through pearl beds, which carry weights; and tubes which pump water while others swell and contract; toothed wheels which are geared to one another and engage hooks. We thought we were entering the tranquil and neatly ordered abode of reason but we find ourselves in a factory. (70-71)

Such mechanical models have, for Duhem, one essential flaw. Their visual analogies must be understood before the validity of their analogies can be evaluated. And since the analogies are not required by their authors to fit perfectly into a consistent, all-embracing system, the reader is likely to become confused by the images which were intended to make the abstract qualities accessible.

Duhem's obvious antagonists are the overtly mechanical modelers, like Lodge and Kelvin, who can claim, as Kelvin did, "I can never satisfy myself until I can make a model of a thing. If I make a mechanical model, I understand it" (71). Of much greater concern is Maxwell, whose style of algebraic modeling had a greater role in determining the method of physical theory. And indeed algebra itself is, in Duhem's eyes, only an abstract surrogate for mechanical analogy. While granting Maxwell credit for making the electromagnetic theory of light possible, Duhem cannot accept what appears to him to be a disregard for theoretical consistency, an attitude he considers inherent in the use of models.

> Maxwell's *Treatise on Electricity and Magnetism* was in vain attired in a mathematical form. It is no more of a logical system than Thomson's *Lectures on Molecular Dynamics*. Like these *Lectures*, it consists of a succession of models, each representing a group of laws without concern for the other models representing other laws, and at times representing these very same laws or some of them; except that these models, instead of being constructed out of gyrostats, spiral springs, and glycerine, are an apparatus of algebraic signs. These different partial theories, each developed in isolation, indifferent to the previous one but at times covering part of the field covered by its predecessor, are less properly addressed to our reason than to our imagination. They are paintings, and the artist, in composing each of them, has selected with complete freedom the objects he would represent and the order in which he would group them. It matters little whether one of his clients has already posed in a different attitude for another portrait. The logician would be out of place being shocked by this; a gallery of paintings is not a chain of syllogisms. (86)

The English predilection for holding in mind "a complicated collection of disparate objects...with each detail clearly perceived in its place and relative importance" (56) Duhem finds already in Newton. The limitation of this powerful sense of concrete relationships is precisely its concreteness. It is limited by *sensory experience*:

> ...objects to which it is directed must be those falling within the purview of the senses, they must be tangible and visible. The minds possessing this power need the help of sensuous memory in order to have conceptions; the abstract idea stripped of everything to which this memory can give shape seems to vanish like an impalpable mist. A general judgment sounds to them like a hollow formula void of meaning; a long and rigorous deduction seems to them to be the long and monotonous breathing of as windmill whose parts turn constantly, but crush only the wind. (56)

An adept rhetorician, Duhem shows that he, too, can deploy the metaphorical style to depict the essence of the metaphorical English mind. The striking image of a deduction as a windmill is unexpected in the context of abstract classifications in which it appears, and it has the feel of intellectual stress. By *crushing* "only the wind," the windmill/deductive proof seems an inappropriate mechanism. Without elaborating it into a full-fledged conceit, Duhem evokes certain rich associations: the windmill as a pastoral machine, an icon of pre-industrial technology; its violent imaginary behavior, which seems to call forth a Don Quixote to tilt against it (subtly underscoring the link between the English physicists and "the imagination"); and the ironic knowledge that the windmill is in fact crushing grain, not only wind, just as deduction creates the

intellectual flour from which new theories can be baked. It is in fact in literature that Duhem finds his strongest, most familiar examples of the English and French minds, establishing an isomorphism between literary and scientific discourse that we are now making ourselves. Duhem identifies the characteristic of the English novel, for example, as the reliance on lengthy, minute descriptions, which make each object picturesque, but blur the whole.

> The numerous images that the author has evoked for [the French reader] flow confusedly into one another, while new images pour in constantly only to increase this disorder; before you are a quarter of the way through the description. you have forgotten the beginning of it, and you turn the pages without reading them, fleeing from this nightmarish series of concrete things. What this deep but narrow sort of French mind wants are the descriptions of [Pierre] Loti, abstracting and condensing in three lines the essential idea, of the soul of the whole landscape. The Englishman has no such requirements. All those visible, palpable, tangible things that the novelist enumerates and describes minutely are seen by his compatriots, without any trouble, as a whole: each English reader sees a charming picture where we French perceive nothing but a chaos importuning us. (64)

Whatever its applicability to the novel, the Duhemian distinction is most familiar in comparisons of English and French classical drama, the Corneille-Shakespeare contrast. Duhem takes up this line explicitly. Corneille's heroes take the floor like "lawyers before the bar expounding in perfectly finished briefs their reasons why they will win their case, and when the reasons on both sides have been clearly expounded, the will of man puts an end to the debate through a precise decision, resembling a

judicial decree, or a conclusion in geometry" (*Ibid.*) On the other side are Shakespeare's heroes, "the Lady Macbeth or Hamlet:"

> What a mess of confused, imperfect thoughts, with vague, incoherent outlines, dominating and being dominated at the same time! The French spectator raised by our classical theater tries in vain to *understand* such characters; that is, to deduce clearly from a definite setting that multitude of attitudes and of inexact and contradictory words. The English spectator does not assume this undertaking; he does not seek to understand these characters, to classify and arrange their gestures in order; he is content to *see* them in their living complexity. (65)

The classicism of Duhem's policy is evident throughout his polemic. He associates the English penchant for making models with bondage to experience, considered as the sensuous consciousness of tangible things. At best, a model is like a Metaphysical conceit, in which the vehicle's concreteness and vividness usurps the authority of the more abstract tenor it was putatively intended to illustrate. At worst, it is a form of violence against abstract reasoning, an intellectual terror-device distracting attention from the necessity of understanding the rational universe with purely local and utilitarian considerations. Thus Locke, Bentham, the two Mills "proceed not so much by a consecutive flow of reasoning as by a piling up of examples. Instead of linking up syllogisms, they accumulate facts. Darwin and Spencer did not engage their adversaries in the learned fencing of discussion; they crushed them by throwing rocks"

(67). The windmill of deduction crushes wind, at worst, and grain, at best; the rocks of imaginative modeling crush only bones.

It must be clear already from the examples I have quoted that Duhem's critique of the English style involves very strongly held ideological prejudices. The chauvinism should not be surprising, given the year of Duhem's book (1905) and the general climate of rivalry between England and France. It is also telling that Duhem makes subtle associations between the "ample and weak" minds of English physicists and the minds of women — e.g., the "picturesque" descriptions of any "young authoress aspiring to literary fame" in England (64). Even more telling is the odd choice of heroes Duhem makes for comparing Corneille and Shakespeare. Corneille's masculine clarity is represented by Auguste and Rodrigue, archetypes of the aristocratic hero. Shakespeare's confusion is represented by *Lady* Macbeth and Hamlet. The point seems to be that the imaginative, picturesque, example-mongering, fact-gathering, model-constructing, experience-bound consciousness is characteristic of women and dithering men — characters "ample and weak."

A more explicit association relates to class. Duhem's ideal, like the aristocratic abstraction of neoclassical theater, is ultimately a matter of correct style, deportment in action and language appropriate for an elite educated in the disinterested

contemplation of the truth. The enemy of this elite of the mind is the class concerned with immediate practice and profits.

"Let us substitute Descartes and Bacon for Corneille and Shakespeare" (65). In contrast with Descartes's project, the purpose of Bacon's *Novum Organum* is "quite practical, I should go so far as to say industrial" (66). While Descartes is concerned to find principles that will reduce the appearances of nature to an intellectually manipulable system, Duhem detects in Bacon a concern only for *using* nature. "We must see what instructions or directions," he quotes Bacon, "we may especially desire in order to produce or create in a given body some new property, and explain it in as simple terms as possible" *(Ibid.*). The examples of Lodge's and Kelvin's mechanical models, with their tubes filled with vulcanized rubber and spiral springs, also tie models to factory production; and in this light the witty comment "we thought we were entering the tranquil and neatly ordered abode of reason, but we find ourselves in a factory" (71) loses most of its wit. It is not an insouciant image, but an allusion to a model that mediates between scientific exposition and class-consciousness. The English style is to good science as factory-production and engineering is to elite theoretical contemplation.

Indeed, in the final analysis this appears to be the motivation for the whole chapter on mechanical modeling. Grudgingly granting Maxwell his due, Duhem sees in

his influence a threat to the purity of French science. He detects a fashion in France of imitating the English style, ultimately motivated by "industrial needs" (91).

> The industrialist has very often an ample mind; the need to combine machinery, to deal with business matters, and to handle men has early accustomed him to see clearly and rapidly complicated assemblages of concrete facts. On the other hand, his is nearly always a very shallow mind. His daily occupation keeps him removed from abstract ideas and general principles. Gradually, the faculties constituting strength of intellect have atrophied in him, as happens with organs no longer functioning. The English model cannot, therefore, fail to appear to him the most appropriate to his intellectual aptitudes [...]
>
> Naturally, he desires to have physics expounded in that form for those who will have to direct workshops and factories. Besides, the future engineer requires instruction in a short time; he is in a hurry to make money with his knowledge, and he cannot waste time, which for his is money [...] Those who are commissioned to teach engineering are therefore eager to adopt the English methods and teach this sort of physics, which sees even in mathematical formulas nothing but models. (92).

The political terms are as familiar in French cultural history as the literary ones: on the one hand, aristocratic legitimacy, based in disinterest and principle; on the other, the industrialists, the grande bourgeoisie, who have usurped the social power of the intellectual elite by converting all values into considerations of profit. Undermining the clean and noble, if not particularly efficient, world of the windmill-deduction, the industrialist-engineer-imaginative physicists have corrupted the good sense of society.

Despite his antipathy to imaginative modeling, at the conclusion of "Abstract Theories and Mechanical Models" Duhem admits the value of restricted analogies in scientific theory. Indeed, we learn that precise analogy is the "most fruitful method of all procedures in the construction of physical theory" (96). A Duhemian analogy is what contemporary philosophers of science refer to as a nomic isomorphism: the mapping of the operations of a more familiar system onto a less familiar one. Thus an analogy can establish homologies between two theories that are essentially heterogeneous in terms of the laws they co-ordinate. Because of their abstract, primarily algebraic nature, these analogies escape the irrational imaginative pitfalls of overly concrete models.

Hempel notes that the difference between analogy and model in this formulation is one of degree, not of kind (438), and Duhem's description of an analogy is similar to more recent definitions of theoretical models. The stylistic problem then is not whether analogical links are permissible in physics, but whether they are logically rigorous and systematic; and whether other sciences can — and should — achieve such analogical purity.

Duhem maintained that only such strict analogies are fruitful methods of discovery; pictorial models are merely tools for exposition. As DeBroglie notes, Duhem was unaware of the significance of contemporary developments in atomic physics, most

particularly the Lorentz theory of electrons. This blindness is caused, according to DeBroglie, precisely by the refusal to recognize that the contributions of theoreticians using "pictorial methods" to the progress of physics "has undoubtedly been greater than has been that of theoreticians solely preoccupied with the axiomatization and perfectly rigorous logical deduction" (xi). I would propose that this refusal is bound up with certain ideological prejudices regarding national, gender and class hierarchy and the purity of science. Duhem wished to draw a clear distinction between "English" and "continental" scientific mentalities, a penchant illustrated in his preference for Helmholtz's now largely discarded account of electromagnetism as opposed to Maxwell's (DeBroglie). Ironically, the year Duhem's *ASPT* was published was the year of Einstein's epochal paper on relativity, which made ample use of visual and mechanical imagery. Indeed, Duhem appears to have been unaware of the whole question of what Hertz called "mental imagery" (*das Scheinbild*) in German science — a quality essential to Boltzmann's work, as well as the basis of the debate that evolved between Schrödinger and Bohr on the one hand, and Heisenberg on the other, on the question of visualizability in quantum physics.[1]

***Analogics: H. Rom Harré***

The stylistics of modeling is concerned primarily with the kinds of expressive language used to persuade and delight the reader of the discursive model. It is not a matter of ornamentation overlaid on a substantive argument. The category of style includes such "substantive" matters as the choice of analogies and the elaboration of the connecting web of associations. These choices are, as the example of Duhem demonstrates, closely bound to the language and imagery of the audience to which the model is addressed, and thus involve the prejudices and predilections of given social constructions of gender, ethnicity and class.

Where the stylistic aspects of modeling are seen on the level of sentences, the analogics of modeling occurs on the level of logical paragraphs, the connections among sentences. Models are essentially forms of analogy, one of the most privileged tropes in the rhetorical tradition. As analogies, models take part in the fundamental ambiguities of metaphorical expressions — i.e., the aporetic gap between the tenor and the vehicle, which can never be completely contained by the contextual purpose of the discourse. They are essentially forms of ellipsis. What makes a model distinctive is that it consists of an analogy of structures. But whether every analogy involves the same kind of ellipsis is difficult to determine. Most studies of scientific modeling have concentrated on the analogical aspect of the model (Black; Hesse; Hacking). They have for the most

part accepted as a *modus vivendi* the indeterminacy of the relationship between the original tenor structure and the vehicle structure. Perlman and Olbrechts-Tyteca state explicitly that modeling analogies in science are of the nature of "invention," not "proof" (396). There is no imputation that a connection existed between the respective terms of the tenor (or *theme*) and vehicle (or *phoros*) before the analogy was constructed. As a result, the model is invented in order to generate hypotheses.

In most cases, we do not perceive the social-ideological elements in the language of a model until we have gained enough historical perspective to see as epoch-bound language what contemporaries viewed as self-evident. The analogics of scientific models studies the formal properties of the model tropes to see them as much as possible as mental forms rather than historically mutable linguistic constructs. One of the most interesting recent attempts as such a formal analysis is found in H. Rom Harré's taxonomy of models in his *Principle of Scientific Thinking.*

In contrast with Duhem, Harré argues that some form of visual modeling within a "statement-picture complex" is central to theorizing in science. For Harré theory is not merely a classification and systematization of laws, but an attempt to get to the bottom of things, an attempt to answer the question "why is it that the patterns of phenomena are the way they are?" (35). To become global, theories must try to account for things we

do not know about "the structure and constitution of things," which they do by conceiving models for as yet unknown mechanisms of nature.

> A theory cannot [...] be a single deductive structure. It consists [...] of at least three sets of sentences, the successful deductive organization of any of which is quite fortuitous. There will be one for the description of the phenomena for which the theory is devised. There will be another for the central model, and one or more describing the material on which the central model is based. These sets of sentences are tied together by various relations of analogy, that is by further sets of sentences whose extent cannot be discovered *a priori*. (*Ibid.*)

Translated into the terminology of poetics, the model will involve a tenor (in Harré's terminology a "subject"), a vehicle (for Harré a "source"), and a more or less extended elaboration of the vehicle motivating its use in the analogy. The heuristic and creative function of the model lies in this motivation: to provide an imaginary "hypothetical mechanism" to explain an unknown process, based on an analogy with a known one. "Whatever is in the black box, one might say, is like this" (39).

Harré offers a classificatory scheme of models in terms of the relations between their sources and subjects, vehicles and tenors.

The first overarching class is that of *homeomorphs*, models whose source and subject are identical. These include scale-models, "teleiomorphs" whose sources are in some respects improvements on their subjects (i.e., idealizations and abstractions), and "metriomorphs," the average family, whose source and subject are always a class.

Homeomorphic models are primarily heuristic and explanatory, since the relationship of subject and source is putatively transparent, and the process to be explained by the model is generally well understood.

More interesting for Harré is the class of *paramorphs*, models whose mode of operation is drawn from a source different from the subject. Such models are useful when the equipment of a given science is very cumbersome (as, for example, the analogy of an electrical network to a hydraulic system); when the process under study is complex (e.g., heat transfer across phase boundaries); or when it is not clear what is actually going on in a process. Paramorphic models may take the form of partial paramorphic analogues, in which the initial and final states of two processes may be exactly alike but their processes are different. (Harré gives as an example the computer's simulation of human arithmetical calculation.) Or the initial and final states may be only similar (as in the case of the electrical simulation of hydraulic networks). One of the most striking cases of partial paramorphic analogue is the Bohr atom; its input and output are the same as the "real radiating atom," but it contains no time loss or gain in the electrons' movement. Harré also mentions the possibility of a paramorphic homologue, in which the source and subject work in an identical manner,

but their inputs and outputs differ. Harré's example is a computer built from living nerve cells.

The richest class of modeling-analogy for theory construction in Harré's view is that of partial paramorphic analogues. These analogies involve relationships between source and subject domains that cannot be contained within transparent homologies; the imaginary connections suggest as yet obscure relationships that must be explored to be understood. Harré distinguishes three forms of these models: singly connected, multiply connected, and semi-connected paramorphs. A singly connected paramorph has a single vehicle, its source is a single science. Thus in the corpuscular theory of gases the principles of a single science, mechanics, supply the definitions of the entities and laws of the processes that make up the model. A multiply connected paramorphic model draws from two or more independent sources. The Bohr atom derives from both mechanics and electromagnetism, which are not explicable in terms of each other. Darwin also constructed his model of natural selection by drawing on two different sources, via a homeomorphic analogy with domestic selection (animal breeding), and a paramorphic analogy with the Malthusian population model (itself a teleiomorphic abstraction). Semi-connected paramorphs construct the subject by using analogies with some aspects of a science, but mixed with principles not known to any science. The

Freudian mind model, with its economy of "psychic energy," involves some analogies with physics (energetics), but also processes considered completely "unscientific."

In general, it appears that the scientific project most favors multiply connected paramorphs. "Electronic radiation, viruses, quasars, electrons, the benzene ring, infant sexuality each began as multiply connected paramorphs" (49). Of the paramorphic models, the semi-connected are the closest to literary fictions, in that the scientific laws and definitions of the source/vehicle are motivated, at least in part, by nonscientific (or perhaps as yet scientifically unproven) vehicles with which they coexist in the model. Such models are generally suspect, and can easily be seen as pseudo-scientific. But for Harré "sometimes semi-connected paramorphs are just what give us a new scientific development, by suggesting the idea of a new kind of entity, or process" (45).

The purpose of this taxonomy is not to set up some new system of cubbyholes. Harré requires a definition of the way paramorphic models work in order to underpin his broader philosophical point: that scientific theory develops by endowing the heuristic fiction of the model with "hypothetical existence" in order to explain the underlying causes of phenomena. Paramorphic models, especially multiply connected ones, create the need to imagine the world in novel ways. Thus, Harré writes, every paramorphic model involves some metaphysical doctrine about what are essential and

what are secondary properties of things. Once it is imagined to be a description of a hypothetical mechanism, a multiply connected paramorphic model demands that earlier conceptions of what can and cannot exist be modified (49).

Thus, in sharp contrast with Duhem, it is precisely the possible analogical *excess* in modeling that Harré finds valuable — the excess of undefined and unspecified implications which require a reform of the scientific conception of the material world. Where Duhem's notion of analogy (vs. models) ultimately implies the underlying accessibility of phenomena to logic and reason, Harré's notion of the model implies what we might call a poetic universe, in which relationships among the parts are constantly being discovered and redrawn as a consequence of the imaginative work of modeling.

There is a danger that this sort of study of modeling-analogics may become an overly formalistic project, in which pragmatic strategies are hypostasized as formal types, a danger it shares with other forms of figural and tropical analysis. Harré's point, however, despite the vocabulary of static classification, is to map out a hierarchy of analogogenic operations, a psychology of modeling, that favors the less interpreted, more adventurous approaches to theory-construction — and beyond, to an ontological imagination. Whether Harré's classification scheme can aid this project might be

questioned, and the question would be one of modeling style. For Harré's taxonomy is itself a form of modeling — of a mental activity of analogy-generation in terms of a quasi-morphological (hence quasi-biological) rhetorical system.

The study of modeling-analogics need not follow Harré's taxonomy. But any exploration of analogical connections will necessarily have to study both world-pictures and motivations— questions about the aptness of the domains from which, and the motives for which, the analogy is chosen. Such explorations might lead to interesting questions about the relationships of domains, as for instance, the question of the relationship between Aristotle's biological field research and his other classificatory projects, including rhetoric. They might also lead to more urgent questions, regarding the ideological dimension of model-analogy construction — as raised, for example, by Evelyn Fox Keller's discussion of the politics of modeling cellular differentiation in the slime mold in *Reflections on Gender and Science*. For, as Keller has shown, the decision to work from a "master molecule model" rather than a self-organization model has far-reaching implications not only in terms of the formal results of research, but in terms of the organization of the actual research work itself.

***Fantastics: Stanislaw Lem***

The terms of an analogy are not determined by any internal necessity. If they were, it would not be *ana*-logical. Much of the problematic attraction to, and suspicion of, models comes from the quasi-fictive status of the analogical link. Harré speaks of the necessity for some kind of "plausibility control" (48). But such controls become increasingly difficult the less defined the elements, the more global the application, and the less predictive the consequences of the model are. The further a theoretical model moves from nomic isomorphism into archetype or complexly connected paramorphism, the more *as if* it becomes. The Bohr-Rutherford atom, or Schrödinger's wave-mechanics model of a single electrically charged electron surrounding the nucleus, could hardly have been considered plausible explanations of atomic behavior, since they were predicated on drastic violations of "normal" plausibility. Yet they were generally far more acceptable to contemporary scientists than Heisenberg's even less plausible claim that the physical entities being studied could only be perceived via a mathematical transformation of perception. The question of plausibility is a question of context, and it becomes increasingly vexed as the context becomes increasingly uncontrollable — culminating in the completely irreproduceable context of history.

The greater the sense of *as if* associated with the model, the more it can call into question whether the phenomenon the model was called upon to illuminate was indeed

*prestructured*, and hence not necessarily distinct from the structure used to interpret it, but rather possessing some motivated family resemblance of shared prestructuring. Thus the study of modeling from a sufficiently abstract distance can detect a modeling of the experimental data on which the legitimacy of a model is based (Suppes).

Harré could perhaps argue that the purpose of the model is precisely to indicate such prestructurings, since they are clues to underlying or overarching regularities we do not yet understand. Yet clearly this presents problems for scientists, who must avoid the needless proliferation of such concepts if they are to arrive at anything approaching positive knowledge. From the literary-theoretical point of view, it is more interesting to observe that, from a sufficiently abstract remove, the distance between the cultural interests of scientists and the phenomena of "extracultural" nature they study does not appear so great. Saving the phenomena becomes more difficult when the evidence for their existence and behavior appears to be part of a deeper cultural project.

The fantastics of modeling begins by posing counterfactual examples of the link between cultural interests and values (even biological ones, culturally conceived), on the one hand, and scientific consciousness, on the other. As the theorist of science fiction Darko Suvin puts it, science fiction is concerned with "cognitive estrangement," presenting fantastic models of human cognition that, through implicit contrast with

society's received wisdom, reveal the unconscious ideological and cultural assumptions that delimit its rationality.

The essence of such fantastic modeling is given in a phrase by the Polish science-fiction writer and philosopher of science, Stanislaw Lem. Writing on Jorge Luis Borges, Lem says: "As soon as nobody assents to it, a philosophy becomes automatically fantastic literature" ("Unitas Oppositorum" 237 n.3). Obviously, a writer of scientific fantasy can secure assent for models that could never pass the plausibility controls of "serious" science. For in literary fictions, the "normal" order of modeling relations is reversed. The plausibility of the phenomena of the model is a consequence of the language of the model; the analogy constitutes the domain of relevance, since, in the fiction, it is the equivalent of the real. Where the theoretical model must more or less suppress its own discursive preconditions— its figural and stylistic nature — , the fantastic model creates an equivalence between language and the exposition of the object it articulates. By depriving the object of its extradiscursive authority, it transforms it into another "phase" of articulation.

Plausibility is gained in fantastic modeling by imitating the language of scientific modeling, and, absent an extratextual reality to appeal to, bringing the persuasive and imaginative qualities of modeling into the foreground. By a sleight of hand, the model

becomes a grand cultural trope that reveals the consciousness of its maker more than the physical qualities of its object. Fantastic modeling treats models as if they were all we could know of nature.

Such fantastics are as yet rare in literature. They are properly the domain of science fiction, but with few exceptions writers in the genre are not interested in playing games with the whole historical project of science. Writers of "hard" science fiction regularly present sketches of fantastic models, but these are usually plot devices embedded in the traditional adventure romance. They do not usually reflect on their own activity, and as a result they "re-enchant" what they cursorily estranged. Some writers, however, have made this reflective play the basis of their writing. Lem, Calvino, Borges and Pynchon come immediately to mind.

Lem in particular makes the question of modeling the central problem in his fictions, and his mature work can be read as a project to invent as many grotesquely ironic potential combinations as possible. I will mention just two. In the story "Professor A. Donda," Lem narrates the history of the discovery of the "Donda Barrier," the threshold of information density beyond which information reaches critical mass, and is transformed into energy — the verification of which is the day when all recorded information on Earth disappears to form a "cosmicle," a tiny new universe whose

energy is our information that was. In Lem's magnum opus, *Solaris*, scientists have been frustrated for a hundred years studying the ocean of the planet Solaris, which appears to be a sentient being, but cannot be comprehended in the available categories of human science. In what amounts to a Swiftian cavalcade of flummoxed models (which can be read as an ironic version of Kuhn's *Structure of Scientific Revolutions*), we are told of a long-repudiated, eccentric work by a dilettante Solarist, who claimed to have discovered anthropomorphisms in the theory of relativity and the equations of field theory. In both these cases, the fantastic models give form (in ironic style) to the uncertainties inherent in the culture/nature difference upon which positive science in the West has been traditionally based.

In his major critical work, *Science Fiction and Futurology*, Lem provides four examples of writers working at the level of "fantasy of the abstract": Olaf Stapledon, Borges, Robbe-Grillet, and Kafka. Stapledon, the English author of visionary works of science fiction in the 30s and 40s, offers Lem the least problematic example. In Lem's view, Stapledon was the first writer to understand that science fiction is a visionary branch of philosophy; that its proper subject is the transformations of human culture and the problems encountered in the dialogue with Nature; and that its proper method is to model the process of modeling itself, to place in an imaginative and contrafactual

metaphysical frame the process of constructing models of reality for the whole human species. Stapledon's work acquires tragic grandeur in the way he depicts these models being tested constantly by Nature on the existence of every sentient species, who nonetheless continue to create cosmic-scale models (cultures) in an effort to understand the universe and to communicate with all other forms of consciousness.

Stapledon referred to his futuristic-historical epic, *Last and First Men*, as "an essay in myth-creation." Lem translates this into terms consonant with the scientific imagination:

> I would use another word, and speak of a modeling intention, which starts from the extremely modest state of existing knowledge and strives to grasp the gigantic, unfamiliar mass of the future's facts through approximation. Stapledon did not really set out to predict the future. [...] Rather, the book is a form of fantasy-construct which takes into account everything that is already known, at least facultatively, and strives to grasp the structure, the breadth, and the informational richness of the unknown original: i.e., the future history of the human species. ("On Stapledon's *Last and First Men*" 72)

Lem considers Stapledonian fantastic modeling close to the actual historical experience of science. For example, midway through Stapledon's epic, an early evolutionary incarnation of humankind discovers that the Moon is exhibiting certain inexplicable new perturbations which will, in the far future, threaten the survival of human beings on Earth. With this knowledge they can begin work on migrating to

another planet. In a later, far more advanced evolutionary stage, on another planet, humanity discovers that there is a connection between the level of civilizational complexity of a planet and the orbital regularity of its satellites.

> Now, whether or not there may be some real correlation between psychozoic and gravitational phenomena is not important. Most likely there isn't any. But the statement is completely unprovable from the standpoint of our present knowledge. It goes beyond the boldest hypotheses of science and philosophy, and so it leads us to wonder. It is precisely its extraordinariness that gives it value as a model. In our own time we have seen bridges rise up between fields that were previously isolated from one another: like the bridge between thermodynamics and logic built by information theory. We should certainly expect other, similar discoveries, especially in the far distant future — probably not like the connection of gravitation and information, but on the same scale. [...]
>
> We may or may not approve of this idea of Stapledon's. A contemporary physicist might consider it nonsense. But if we treat any of these ideas as intelligible hypotheses, if we could accept them without any resistance, they would not have the modeling value that Stapledon wanted them to have. On this level of the work, phenomena must appear that are absurd from the viewpoint of contemporary science. In this they will correspond to the absurdity that a logician of the 18th century would have felt vis a vis the idea of a logic without the principle of the excluded middle, or a classical physicist vis a vis the conceptual foundations of quantum mechanics. The main point is that the future will certainly be unbelievably rich in different kinds of phenomena and facts, and with a richness we would never accept without resistance, even if a marvelous visitor from the 30th or 70th century were to appear and tell us nothing but the unvarnished truth about the shape of things to come. (72-73)

Other forms of fantastic modeling have also been tried, not all of them realistic. Lem mentions Borges's rigorous, quasi-algebraic collapse of fundamental cultural

oppositions, demonstrating the arbitrariness of the "natural selection" of historical value categories. There is Robbe-Grillet's method of inviting randomness into the intentional text, through cutups and related techniques of "damaging" the text with noise ("Metafantasia" 189). But perhaps the epitome of fantastic modeling for Lem is that of Kafka. Kafka's work is not the least bit mimetic, either of nature or of science. It deals rather with the *arché* of science, Law, and its relation to Meaning, on the one hand, and to consciousness, on the other. Kafka devised a technique for modeling "the Secret" of the meaning of the cosmos, and the condition in which it is impossible to determine whether the object of the scientific quest is meaning or emptiness, metaphor or mirror, just as it is impossible to decide whether the search for knowledge of the origin of the Law is the transcendental drive for freedom and an inescapable wild goose chase. Only the Secret and its narrative model remain.[2]

Although the domain of fantastic modeling has been primarily literary, separated from more sober cognitive approaches to modeling by the genre boundaries of science fiction, the situation appears to be changing in the postmodern era. The collapse of boundaries of authority and hierarchy between cultural texts has extended to the heretofore fundamental difference between fiction and scientific and philosophical reflections of nature. In the works of certain radical cultural philosophers,

like Jean Baudrillard and Donna Haraway, fantastic models occupy a central position, incorporating scientific methods and models into critical meta-models. Baudrillard's various fantastic models and Haraway's concept of the cyborg differ from earlier periods' pseudo-scientific mythologies in that they are both overtly ironic and meticulously critical of actual scientific work. Arguably, the late 20th century has witnessed so many different scientific paradigms, both in Western history and in non-Western cultures, that critical theorists are being drawn naturally to models that reflect the inherent plurality of paradigms, and the undecideability of their future evolution.

*Conclusion*

The stylistics, analogics, and fantastics I have been discussing in these pages are not hard and fast categories. Indeed, once theoretical modeling and literary fiction appear to be family relations, there are few imaginable ways to study them without becoming part of the family. Even as distinct categories each form of commentary on modeling is inextricably entwined with the others. The analogical logic of models can no more be detached from the style of their exposition than a vocabulary can be detached from grammar and syntax. And viewed in terms of the history of science, so rich in unpredictable *nova*, every theoretical model reveals as much about the prestructuring and preselection of data of its culture as it does about the possibilities of

positive knowledge of the world. And this revelation necessarily leads to entertaining other theoretical possibilities, whose main sin is that they are not the case, and hence fantastic comments on the tentativeness, and the fictiveness, of the real.

NOTES

1.) On the problem of visualizability in quantum physics, see Miller, Arthur I. *Imagery in Scientific Thought.* Cambridge, MA: MIT Press, 1986. Chapter 4.

2.) My article, "Kafka and Science Fiction" (*Newsletter of the Kafka Society of America* June, 1983) elaborates this argument.

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