An invited book review, submitted to *The Philosophical Review,* at Cornell University, on September 15, 2011.

Paul Bartha, *By Parallel Reasoning: The Construction and Evaluation of Analogical Arguments.* Oxford: Oxford University Press, 2010. Pp. x, 356.

To the extent that the worth of scientific or philosophical efforts can be assessed by the number of productive research avenues they open up, this is definitely an important book. It deserves careful consideration by scientists, mathematicians, psychologists, and philosophers. Since it does not fit neatly into any usual category but rather stands athwart many research-areas, its reception may depend on precisely who attends to its bold claims. This book aims to answer two questions: "What criteria should we use to evaluate analogical arguments used in science?" and "How can we provide a philosophical justification for those criteria?" (ix)[1] Paul Bartha recognizes that analogies are widely used in all areas of human action – but claims: "We have no substantive normative theory of analogical arguments." He persuasively argues that none of the theoretical approaches to analogical argumentation that previously have been developed is *generally* applicable. But he holds that the uses of analogies in science and mathematics are "key or 'leading' special cases that provide an excellent basis for a general normative theory" of analogical reasoning (3). This book proposes a systematic theoretical treatment, and a set of evaluation criteria, that (Bartha claims) apply to all varieties of analogical reasoning – both in science and elsewhere. This assertion is not modest, but careful arguments support it well. The claim seems quite plausible.

Analogical arguments involve 'source' *(S)* and 'target' *(T)* domains that are similar to each other in certain respects. *Positive analogies* occur when property *P* and relation *R* pertain to domain *S* and corresponding property *P** and relation *R** pertain to *T.* If the target domain *T* has feature *A* but* the source domain *S* lacks that feature (so that ~*A* applies to *S*) this constitutes a *negative analogy*. The question at issue is: Under what conditions (and with what degree of confidence) would it be correct to infer that if *S* has a feature *Q* then *T* has a corresponding feature *Q**?

In favorable cases deductive reasoning may lead to conclusions that are considered correct with a high degree of certainty. In contrast, analogical reasoning at its best leads to results that are 'plausible' – that is "they have some degree of support" (15). Plausibility can be interpreted probabilistically, so that plausible statements are understood to have a rather high probability of being true and additional relevant evidence may increase that probability. In an alternative 'modal' interpretation, 'p is plausible' can be taken to mean:

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1 Page references are given in parentheses. Full quotes denote words taken from the work cited (normally Bartha). Not all initial upper-case letters shown in the quotes occur as such in the original text.

"there are sufficient grounds for taking p seriously." "To take a hypothesis seriously is to regard further investigation as reasonable, subject to feasibility and interest. It is to single out the hypothesis from an undifferentiated mass of logical possibilities." (16) Such *'prima facie* plausibility' either applies or does not apply – it does not pertain in variable degrees.

This book develops a normative theory of analogical argumentation – "The Articulation Model" (25) – which is based on two main principles. The first is "*The Requirement of Prior Association*: The description of the source domain must include an explicitly stated vertical relation which the analogy is supposed to extend in some way to the target domain." Two important classes of such 'vertical' relations are:

- *"Mathematical analogies* – *P* refers to a set of assumptions, while *Q* is a theorem about the source domain. The prior association is a proof that *P* (together with other assumptions) *entails Q.* The analogical argument is intended to make it plausible that that similar features *P** of the source domain entail a similar conclusion *Q** about the target domain."
- *"Explanatory analogies* – *Q* refers to a hypothesis and *P* to observed consequences*.* The prior association is that *Q explains P.* The analogical argument is meant to provide support for the idea that similar features *P** in the target domain are explained by a similar hypothesis *Q*.* Darwin's analogy[2] exhibits this pattern."

The second principle of The Articulation Model is: *The "Requirement of Potential for Generalization:* a good analogical argument is one where, at a minimum, there is no compelling reason to deny that the prior association that obtains in the source domain could be generalized in a way that extends to the target domain." In the cases of the two varieties of prior association just described this works out in the following ways.

- "In *mathematical analogies*, the features that play a central role in the prior association are the assumptions used in the proof of the theorem *Q*. The analogical argument stands or falls depending on whether the analogous assumptions are known to hold, or at least not known *not* to hold, in the target domain."
- "In *explanatory analogies*, any known observable consequence of the hypothesis *Q* counts as central to the prior association. The strength of the argument depends on the extent to which we know that these consequences have analogs in the target domain. This criterion directs us to

[2] The analogy is that between artificial selection as practiced by plant and animal breeders and the natural selection that Darwin postulated. (This note is not in the Bartha text.)

> search for such analogous consequences. If they are not found, then the argument is weakened or defeated." (26)

Various contemporary disciplines employ what seem to be different criteria for evaluation of analogical arguments: analogies that seemed quite appropriate in past historical periods no longer appear to be plausible. Hopefully, "such variation can be located primarily in the different forms of prior association that occur in analogical arguments," (28) both in present-day scientific fields and in earlier historical periods.

Providing philosophical justification for The Articulation Model of analogical argumentation faces two main problems: one is occasioned by the variety of types of reasoning that fall under the 'analogical argumentation' designation, and the other is raised by the modesty of the goals of such approaches – 'plausibility' is what is sought, rather than 'truth'. Two sorts of justification are proposed. One is based on the widely-accepted legal principle of *stare decisis,*[3] which enjoins adjudicators to decide present cases on the basis of the same reasoning that was used in similar cases in the past. This judicial custom rests on three ethical considerations: [A)] *Stare decisis* "provides a relatively stable basis on which people can predict the actions of the courts and make their plans; [B)]... It serves as a check on arbitrary decisions by an inexperienced or foolish judge;" and [C)] "… [It] allows for gradual evolution in the law. The doctrine thus allows a balance between conservative and progressive moral values." The author "argue[s] (analogously) that in scientific thinking, analogical arguments are justified for assessing the plausibility of hypotheses because they achieve an optimal balance between *conservative* epistemic values (such as consistency and coherence with existing theory) and *progressive* epistemic values (such as fruitfulness and theoretical unification). This is [a] top-down (goal-oriented) justification … ." (29) "A bottom-up (constraint-based) justification [is] founded on the principles of symmetry." (30) "Like problems demand a like solution. Symmetry acts as a constraint on our reasoning and lies at the heart of every analogical argument. … In a case of perfect symmetry, one has as much reason to treat the target hypothesis as worthy of investigation as one does the source hypothesis. In the case of an analogical argument that satisfies the requirements" of The Articulation Model "one has *adequate* reasons for doing so." (30) These two lines of justification of the theory are taken as "partial validation … relative to accepted norms of scientific practice." This is said to be: "the most that one can demand by way of justification for a general theory of analogical arguments."

Chapter 1 clarifies and develops the Articulation Model, and includes detailed discussion of many specific examples of analogical reasoning drawn from a variety of fields and historical periods. (Some of these

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3 This designation is taken from a Latin maxim: '*Stare decisis et non quieta movere.*' – Roughly translated as: 'Stand by decisions and do not disturb the undisturbed.' (This note is not in the text.)

examples are referred to repeatedly throughout the book.) Chapter 2 considers several prior philosophical approaches to the problem of justification of analogical reasoning, including those of Aristotle and of Mary Hesse. Prior philosophical treatments generally use simplified models that do not apply to all varieties of analogical reasoning. Some prior studies tend to "force all analogical reasoning into the mold of deduction or enumerative induction" and/or to "leave insufficient room" for assessment of what similarities are *relevant.* The Articulation Model does not merely list similarities and differences between source and target domains, but rather focuses on connections (The Prior Association) and on a criterion to assess relevance of positive and negative analogies (The Potential for Generalization). (57)

Chapter 3 deals with the large number of computer-based models of specific types of analogical reasoning that have recently been developed in cognitive science and artificial intelligence (AI) fields. Two types of models are considered: "On the structuralist approach, the relevance of a predicate or function is determined mainly by *systematicity*: the extent to which it enters into complex networks of relationships. … By comparison, CBR [case-based reasoning] programs are oriented around a set of indexes that includes every factor deemed to be relevant." The author finally asserts that: "No existing computation theory … provides a good, normative model of analogical arguments in science. … Both the structuralist and case-based approaches … encounter difficulties in identifying relevant similarities and differences, and both fail to provide adequate norms for analogical arguments. … Insofar as these studies incorporate any norm it is the systematicity principle. … Systematicity is at best statistically connected with plausibility. Nothing rules out deeply systematic analogical arguments that are implausible, or good analogies that depart from systematicity. By contrast ... case-based reasoning models are confined to well-understood problem domains with a rich history." (88) He also reports: "Despite these limitations, the work in cognitive science provides … four particularly important ideas that might never have emerged without the computational models. … [1] We must recognize the importance of focusing on the conventions governing how a domain is represented by the user. … [2] We need a clear idea of how the initial representation of the source and target domains should be *elaborated*, prior to determining correspondences and evaluating an analogical argument. [3] … There are a variety of ways to deal with multiple analogies: ... it is not necessarily the best strategy to pick a unique winner. [4] … Computational models provide a big clue as to how we should approach the problem of identifying relevant similarities and differences. Siding with the structuralists, we should do this dynamically, rather than working with a static list. Siding with case-based reasoners however, we should incorporate prior knowledge about relevance … and we should base our judgments … on the nature and strength of the vertical relations, rather than on their systematicity. … There is evidently much philosophical work to be done."(89)

Chapter 4 develops The Articulation Model in more detail, and applies it to additional cases of diverse sorts of analogical reasoning. Four logical types of analogical arguments are identified: 1) Predictive ($P \rightarrow Q$). 2)

Explanatory (Q → P). 3) Functional (P ↔ Q). 4) Correlative (P ↓ Q) (96-97). The two principles of The Articulation Model apply somewhat differently in each of these four cases. "To understand individual analogical arguments we should focus first … on clarifying the exact nature of the relations within the source domain that are to be transferred to the target domain … The most important objective is to define workable criteria for *prima facie* plausibility – demonstrable potential for generalizing the prior association." Support for The Articulation Model is weaker in the case of correlative analogies than in the other logical types because the prior association "becomes less precise and less informative" in this case.

Shifting from an emphasis on vertical (prior-association) relationships to an emphasis on horizontal ones (similarity), Chapter 5 considers a wealth of well-worked-out specific examples of the use of analogical reasoning in mathematics. In good analogical arguments in mathematics, "every assumption used in the proof in the source domain must correspond to something true, or not known to be false, in the target domain." The examples in this chapter show how this test may be usefully applied. "The murkiest part of the test is the notion of correspondence between the domains . … It is both feasible and valuable … to avoid three prevalent and misleading assumptions: (1) that relations of similarity can always be reduced to identity and difference, (2) that inter-domain relations can best be modeled by the notion of isomorphism, and (3) that similarity is an unanalyzable primitive relation. … We should move to a pluralistic approach that aims for a set of precise, but diverse, models of similarity. … We should not expect to eliminate entirely the role of good judgment in the evaluation of analogical argument. … These conclusions apply to nonmathematical as well as to mathematical analogies." (187)

The discussion of similarity continues in chapter 6 with yet more analyzed examples of analogical reasoning. The chapter begins with identification of three common types of similarity: feature matching, formal similarity, and parametric similarity. (195) Analogical arguments based on these three relationship-types tend to yield diverse sorts of generalization: extensions of kinds, common mathematical structure, uniform or invariant relationships, respectively. This chapter include discussion of several examples of analogical reasoning that have had major historical and scientific importance, such as arguments used by Maxwell and by Schrödinger in developing the great advances in physical understanding for which those scientists are famous. Some of these arguments appear to involve questionable 'Pythagorean' analogies – arguments that are based only on formal *mathematical* similarities between separate areas of science, in the absence of any valid indication of *physical* similarities underlying those (perhaps superficial) similarities. Bartha points out that, in each of the challenged cases, an accusation of Pythagoreanism is more readily made when considering *summary* versions of the argument rather than when dealing the *detailed* context in which that argument was originally made. "They appear Pythagorean only if we lift part of the reasoning free of the full argument." With this clarification, the cases discussed in this chapter give strong indication of the importance ‘indispensability’ might be a better word – of analogical reasoning to scientific understanding and its progress. As Rom Harré pointed out some time ago,[4] analogies (including ‘models’ of many sorts) are indispensible in theorizing that leads to “scientific discourse in which the referring expressions purport to denote object of possible experience.” (118) This kind of discourse is “always involved in the development of a science from one stage to the other” (119) – the Maxwell and Schrödinger examples discussed in this chapter illustrate this.

Chapters 7 and 8 provide further support for the two philosophical justifications for analogical reasoning that were sketched at the outset: the top-down argument based on *stare decisis*, and the bottom-up justification from symmetry. (The discussion of the latter case includes relevant Bayesian considerations.) The final chapter of the book explores the likely relevance of the proposed new theory of how analogical arguments work to science and to mathematics, and also to wider human concerns. To the extent that the thesis of this book, and The Articulation Model, become widely accepted, this book will have clearly made a major contribution to philosophy of science and also to science itself. This book also does a great service by bringing together careful discussions of analogical reasoning in many disparate fields: pure mathematics, physics, cognitive science, and the law, to name only a few of the areas touched upon.

One of the cases that this book considers in several chapters is the discovery of the painkilling properties of the chemical substance we now call ‘Demerol’. This important finding followed someone noticing that this material induced a peculiar S-shaped tail-curvature in mice – a deformity that was quite similar to one of the effects of morphine on similar laboratory animals. This is an example of use of analogical reasoning in what might be considered a ‘chemical’ context. Regrettably, the book does not deal extensively with the well-established and sophisticated sorts of analogical reasoning that are used in advanced chemical research on synthetic methods, structure-determination, and reaction-mechanism elucidation.[5] Chemists – and philosophers working in the currently-emerging discipline of philosophy of chemistry – should find this book to be especially interesting, and also suggestive of ideas for productive future research.

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4 Harre, R (1988). “Where models and analogies really count.” *International Studies in the Philosophy of Science, 2(2)*, 118-133.

5 A relevant book by a well-respected research chemist is briefly cited (ix-x): Brown, Theodore L. (2003). “*Making Truth: Metaphor in Science.”* Urbana: University of Illinois Press.