

Selection and the Extent of Explanatory Unification

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According to Philip Kitcher, scientific unification is achieved via the derivation of numerous scientific statements from economies of argument schemata. I demonstrate that the unification of selection phenomena across the domains in which it is claimed to occur, evolutionary biology, immunology and, speculatively, neurobiology, is unattainable on Kitcher's view. I then introduce an alternative method for rendering the desired unification based on the concept of a mechanism schema which can be integrated with Wesley Salmon's causal-mechanical model of explanation. I conclude that the gain in unification provided by the alternative account suggests that Kitcher's view is defective.

1. Introduction. The view that scientific explanation is achieved via unification was formally introduced by Michael Friedman (1974) and modified and extended by Philip Kitcher (1976, 1981, 1989, 1993). The essence of the unification view is that science increases our understanding of the world by extending our unified picture of it (Friedman 1974, 15). Kitcher's view is that we extend unification and, so, increase scientific understanding, by reducing the number of types of facts, brute facts, that scientists must accept in articulating their world view (1976, 212; 1981, 529; 1989, 432). The reduction of brute facts is achieved by deriving a *maximum* number of statements about scientific phenomena from a *minimum* number of schematic arguments, or argument patterns which bring together under one or a few schemata statements about a class of phenomena (Kitcher 1981, 512; 1989, 432).

Among the unificatory schemata Kitcher has provided, he has shown that a certain economy of them unifies, and so explains, natural selection phenomena, or selection phenomena in the domain of evolutionary biology.³ But there are two, perhaps three, scientific domains in which selection phenomena is said to occur (i.e., evolutionary biology, immunology and, speculatively, neurobiology), and Kitcher has not attempted to show how his patterns, or modified versions of one or more of them, might be used to unify the phenomena in these three domains. After a brief summary of the technical details of Kitcher's view, I show that such a unification is *unrealizable* on the model. I go on to argue that since the selection mechanism governs selection phenomena in each domain, its *mechanism schema* combined with Wesley Salmon's (1984, 1994, 1997) causal-mechanical view of scientific explanation can be used to yield the desired unification. The evidence I provide that unification can be extended beyond what can be achieved on Kitcher's view suggests that his view is defective because it fails to embody fully its essential thesis.⁴

2. Extending Scientific Unification. Kitcher (1981, 1989) sets out his view of explanation as unification as the problem of determining, for the set of accepted sentences in science, *K*, the

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^{2‡} I am grateful to Lindley Darden for helpful discussion on earlier drafts of this essay.

³ 'Domain' is to be understood in Shapere's (1977) sense.

⁴ Kitcher's view has seen considerable attention. Critical work has been done by Barnes (1992a, b), Dupré (1993), Humphreys (1993), Koertge (1990), Morrison (1992), Rosenberg (1994), Salmon (1984). The view has been defended and clarified by Jones (1995a, b, 1997).

explanatory store over K , or $E(K)$. Sentences that comprise K are unified by theories when theories provide some small number of patterns of argument from which large numbers of members of K can be derived. The explanatory store, $E(K)$, is the set of argument patterns that result in such unification. Science is thus viewed as progressing by giving patterns, and showing that those patterns, which minimize the ultimate number of types of facts or types of laws that must be accepted, can be used over and over again in derivations of phenomena. Argument patterns perform the crucial work. Argument patterns are strictly constructed sets of schematic sentences, or *types* of premise. A schematic sentence is arrived at by replacing some of the non-logical expressions in the sentence with variable names in similar fashion to that of the logician. Argument patterns are accompanied by instructions that guide the filling in of variable names and the inferential character of the group of schematic sentences. Argument patterns are explanatory if they belong to the explanatory store and if they are stringent, which means, essentially, that they must not be too narrow, or too broad in their unificatory powers. This very basic summary will be extended in further discussion and application.

3. Limits to the Extent of Explanatory Unification. Scientific unification is defined by the relation between the number of argument patterns provided for by theories and the number of statements that can be derived from them. What the unificationist wants is to *minimize* the number of argument patterns and *maximize* the number of derivations *insofar as is possible*. Kitcher claims that one or a few (derivationally) related argument patterns are to be expected for the derivation of a class of phenomena. He illustrates this in his discussion of a number of cases drawn from specific domains of science (Kitcher 1981, 1989, 1993). In what follows, I demonstrate that a unification of selection phenomena is impossible on Kitcher's view. Kitcher's core pattern unifies only statements about selection phenomena in evolutionary biology; a modified version of Kitcher's core pattern fails to yield the desired unification as well. There is no reason to expect Kitcher's related patterns to fair any better due to their fundamental similarities.

Kitcher has developed an economy of argument patterns for the unification of selection phenomena constructed out of the history of Darwinism. The central pattern, in Figure 1, is called **Simple Selection**.

Why do (virtually) all members of G have P ?

Answer:

- (1) The organisms in G are descendants of the members of an ancestral population G^* who inhabited an environment E .
- (2) Among the members of G^* there was variation with respect to T : some members of G^* had P , others had $P\#$, $P\#\#$,....
- (3) Having P enables an organism in E to obtain a complex of benefits and disadvantages C , making an expected contribution to its reproductive success $w(C)$; having $P\#$ enables an organism to obtain a complex of benefits and disadvantages $C\#$, making an expected contribution to its reproductive success $w(C\#)$; ... {continued for $P\#\#$ and all other variant forms of T present in G^* }. $w(C) > w(C\#)$, $w(C) > w(C\#\#)$, etc.
- (4) For any properties P_1, P_2 , if $w(P_1) > w(P_2)$ then the average number of offspring of organisms with P_1 that survive to maturity is greater than the average number of offspring of organisms P_2 with that survive to maturity.
- (5) All the properties $P, P\#, P\#\#, \dots$ are heritable.
- (6) No new variants of T arise in the lineage leading from G^* to G (i.e., the only variation with respect to T comprises the properties $P, P\#, P\#\#, \dots$ already present in G^*). All the organisms in this lineage live in E .

(7) In each generation of the lineage leading from G^* to G the relative frequency of organisms with P increases.

(8) The number of generations in the lineage leading from G^* to G is sufficiently large for the increases in the relative frequency of P to accumulate a total relative frequency of 1.

(9) All members of G have P .

Filling instructions: ‘ T ’ is to be replaced by the name of some determinable trait; ‘ P ’, ‘ $P\#$ ’, ‘ $P\#\#$ ’, ‘...’ are to be replaced with the names of determinate forms of the trait; ‘ G^* ’ is replaced by the name of some ancestral species [‘ G ’ with a group under scrutiny]; ‘ E ’ is replaced by some environment for ‘ G^* ’ [and ‘ G ’]; ‘ C ’, ‘ $C\#$ ’, and so forth are replaced by specifications of sets of traits; and ‘ $w(C)$ ’ and ‘ $w(C\#)$ ’ are replaced with non-negative numbers.

Classification: (1)-(6), (8) are premises; (7) is derived from (1)-(6); (9) is derived from (7) and (8).

Fig. 1. **Simple Selection**, Kitcher (1989, 444).

According to Kitcher, **Simple Selection** explains the adaptation of organisms to their environments; it answers the explanation seeking question, “Why do all organisms in a group have a particular property or trait?” The process of adaptation in natural populations of organisms can be briefly characterized in the following way. In natural populations there exist organisms that vary according to certain properties (statements 1 and 2 in Figure 1). Organisms interact with their environments and that interaction can be affected by the properties the organisms possess. Properties contribute a constellation of effects on organisms’ chances for reproduction, and these chances are measured in relation to the contribution of the effects of other properties on other members of the population (statement 3). Assuming the properties, or traits, are heritable, those organisms whose chances at reproduction have been positively influenced by their interaction with their environments have a tendency to leave more offspring with the same or similar properties in future generations. The opposite is true for organisms who have had the reproductive chances decreased by their interactions with their environments (statements 4-6). Over time, the properties with a positive influence on the increase in reproductive chances for their possessors are prevalent in the population (statements 7-8). It follows that the vast majority of G s in E have P (statement 9).

Recent history and philosophy of science indicates *three domains* in which statements about selection phenomena can be said to occur (Darden and Cain 1989). The domains of selection phenomena are the purviews of the fields of evolutionary biology, immunology and, speculatively, neurobiology. Kitcher has considered *only* phenomena in the domain under study in evolutionary biology. Using terminology compatible with Kitcher’s, let K_{EB} , K_I and K_{NB} be the sets of sentences in K that partition the respective domains of selection phenomena studied in evolutionary biology, immunology and neurobiology. Notice that there is no domain K_S of which K_{EB} , K_I and K_{NB} can be said to be members. The domain K_S would presume the existence of a scientific field, e.g., selection science, complete with a theory or set of theories that deal(s) with the domain of selection phenomena as a whole. There is no such field of selection science, no such domain that is its purview and no indication of the future existence of such a domain despite the existence of selection phenomena in disparate domains.

Simple Selection does not unify selection phenomena in immunology (K_I) or neurobiology (K_{NB}) and, so, does not unify the three domains of selection together, K_{EB} with K_I and K_{NB} . Such unification is not achieved because the selection sentences in K_I and K_{NB} cannot be derived from **Simple Selection** and that is because the relationship between items across the

three domains is not strong enough to be subsumed under the pattern(s) used for selection in evolutionary biology. The selection process in immunology governs the proliferation of variant lymphocyte cells in the bloodstream; the theory is due to Burnet (1957). Lymphocyte cells in the blood stream vary according to the arrangement of reactive sites on their surfaces. These cells interact with invading antigens, and the arrangement of the reactive sites on the surfaces of lymphocyte cells affects that interaction in such a way as to cause the activation of lymphocytes with particular site arrangements. Activated cells proliferate in clones, producing more lymphocytes with the same pattern of reaction sites. These cloned cells release free antibodies of the appropriate type to attack the invading antigen. After the invaders have been eliminated, lymphocytes with the same reactive site pattern are prevalent relative to other patterns, adapting the immune system to invaders of the previous type. **Simple Selection** cannot be instantiated for clonal selection of antibodies because there is no way to fill in the pattern: There are, strictly, no organisms (statements 1, 3, 5, 7), there are no descendant populations, properly speaking (statements 1-2), and cloning is a limiting case of reproduction, inadequately represented by **Simple Selection** (statements 3, 4, 7, 8). In other words, some of the non-variable, non-logical terms in Kitcher's **Simple Selection**, such as 'organism,' make it inapplicable in a domain of selection where the entities undergoing the process are cells.

Similar conclusions can be drawn for the domain of neurobiology (K_{NB}). The selection process in neurobiology governs the reinforcement of the set of variant neuronal groups in the brain (see, e.g., Edelman 1987). According to Edelman's speculative theory, a set of neuronal groups exist in the brain, varying according to the patterns of their connections. The intrinsic connections between neurons enable the group to be more or less excitable by stimuli. Neuronal groups that are more easily excited have a marked tendency to be reinforced relative to those that are less easily excited. Over time, easily excitable groups are reinforced while groups that are less so are inhibited. There is a selection process governing the reinforcement of neuronal groups by virtue of their intrinsic patterns. But **Simple Selection** cannot be instantiated for neuronal group selection because there is no way to fill in the pattern. Indeed, virtually every statement in **Simple Selection** is in some way violated: There are no organisms (statements 1, 3, 5, 7), no descendant populations (1-2), no reproduction (3, 4, 7, 8), no heritable traits between the neuronal groups and no lineages (5-8).

To unify the selection statements in evolutionary biology, neurobiology and immunology on Kitcher's model, the phenomena would have to be related appropriately so as to result in a single domain, K_S , the domain of selection science. From this domain an argument pattern could be constructed from the theory governing K_S , thereby unifying statements about all known selection phenomena. But as I pointed out previously, there is no domain of selection science. To yield the domain K_S , the theory of selection science would have to provide concepts that tied together the disparate concepts of the three domains of selection phenomena. Kitcher, I take it, would have to show that the argument patterns for selection between the domains are derivationally related. In the evolutionary biology case, Kitcher shows that **Simple Selection** is not capable of generating all natural selection statements. Other patterns, such as **Directional Selection** and **Correlated Selection** are required and, according to Kitcher, these patterns can be derived from parts of **Simple Selection** (Kitcher 1989, 445). Perhaps the same is true of **Simple Selection** and its unconstructed counterparts **Clonal Selection** and **Neuronal Group Selection**, that is, that schematic statements of the latter two can be shown to be derived from schematic statements of **Simple Selection**. The response to this claim is that the theories of clonal and neuronal group selection are *not* derivable from the theory, or parts of the theory, of evolution by natural selection. Rather, they were constructed by *analogy* guided by the fact that the selection mechanism operates in each domain (Darden and Cain 1989).

Although Kitcher does not, it is possible to construct an argument pattern that bridges domains, one that can be instantiated in each domain of selection phenomena without being specifically tied to any particular one. What is called for in the construction of an argument pattern

that is domain independent is one that is sufficiently *abstract* to capture the kinds of entities that undergo selection, their properties and their effects. That is, we must abstract away from the evolutionary domain according to which selection phenomena is to be explained with a pattern that makes reference to descendent populations, organisms, reproduction, etc. to one that has the *capacity* to reference cells, neuronal groups, reinforcement, etc. My schema, **General Selection**, is detailed in Figure 2, and is based upon Kitcher's **Simple Selection** pattern as well as other work on selection schemata (see especially Darden and Cain 1989).

Why do Gs with P (tend to) prevail in E?

Answer:

1. There is a set of Gs in an environment E.
2. Gs vary according to T: some have P others have P#, P##,
3. Having P enables Gs with P in E to obtain a complex of benefits and disadvantages that contributes to their PRODUCTIVITY {similarly for P#...}. The measurement of PRODUCTIVITY of Gs with P is greater than the measurement of PRODUCTIVITY of Gs with P#
4. For any properties P_1, P_2 , if P_1 increases the contribution to PRODUCTIVITY, then the average PRODUCTIVITY of Gs with P_1 will be greater than the average PRODUCTIVITY of Gs with P_1, P_2 .
5. No new variants of T arise in the set of Gs. All Gs are in E.
6. Over time, PRODUCTIVITY of Gs with P increases to a maximum and Gs with P#... to a relative minimum.
7. Gs with P prevail in E.

Filling instructions: 'G' is the name of an individual; 'E' is the description of an environment; 'T' is the name of a discernible trait; P (P#, P##, ...) is the name of a variation of T; PRODUCTIVITY is the description of the effect of the complex of benefits and disadvantages obtained by Gs with variations of T. The measurement of PRODUCTIVITY [whatever way that is to be quantified] is replaced by a non-negative number.

Classification: (1-5) are premises; (6) is derived from (1-5); (7) is derived from (6).

Fig. 2. **General Selection** argument pattern.

In **General Selection**, the statements in **Simple Selection** that caused problems in the instantiations for selection in immunology and neurobiology have either been eliminated or relaxed just enough to accommodate selection phenomena in the three selection domains. Because of the nature of selection in immunology and neurobiology, statements making reference to organisms, lineages, reproduction and heritability had to be modified. Thus, statement 5 of **Simple Selection** has been eliminated, statements 7 and 8 have been combined and modified, and statements 1-4 and 9 have been substantially rewritten. Most of the work in **General Selection** is being done by the abstract term *PRODUCTIVITY*. *PRODUCTIVITY* is the name for which the effects of selection, such as reproduction of heritable traits in natural selection and stimulation and reinforcement in neuronal group selection, can be substituted depending on the domain of instantiation. Notice further that the explanation seeking question asked and the concluding statement of the schema have been changed due to the demands of the general schema.

One might suppose that Kitcher could accept **General Selection** as an explanatory pattern, but I will argue that he cannot. The *main* problem with **General Selection** is that it is not a *stringent* argument pattern and, so, is not explanatory. The stringency requirement for schemata specifies that argument patterns must be similar in logical structure and number of non-logical terms (Kitcher 1989, 433). Kitcher is vague about the details of the stringency requirement, but it seems fairly clear what he wants out of it having established its boundaries. Argument patterns are too stringent if they do not unify at all, and they are not stringent enough if they admit of spurious unifications (Kitcher 1981, 518; 1989, 433). The reason Kitcher cannot accept **General Selection** as an explanatory pattern is that it admits of spurious unifications. On **General Selection**, it is possible to unify *any* phenomena with even the *weakest* positive analogical relation to selection. Such unification broadens the limits of patterns that are intended to explain, and that limit is scientific phenomena, or phenomena within the statement set defined by *K*, the accepted sentences in science. *Surely*, patterns that unify beyond *K*, or patterns that unify sentences that are in *K* with sentences that do not belong in *K*, in such a way are unifying spuriously.

The reason that **General Selection** unifies seemingly all ‘selection’ statements is because, as it was constructed here, it lacks a domain according to which unifications are to be made. Without an attachment to an established domain, **General Selection** has the capacity to unify anything that is *something like* selection (e.g., the prevalence of classic jazz CDs in my music collection, the prevalence of students with high GRE scores in the graduate philosophy program at Princeton University, the prevalence of the West Coast style offense in the National Football League, etc.). Attachment to some domain, such as the domain of selection science, would render **General Selection** explanatory because the domains would indicate the boundaries of allowable unifications on the pattern. Or at least that *seems* to be what Kitcher would require to make **General Selection** explanatory. It is hard to see how to limit what is to be unified on a general pattern such as **General Selection**. At any rate, as I have already made clear, there is no domain of selection science and no indications of the genesis of one. Indeed, I suggested that the likelihood of such a domain was exceedingly low given the weak relationship between selection phenomena in evolutionary biology, immunology and neurobiology: An analogical relationship between phenomena is not enough to establish a domain, not in Shapere’s (1977) sense, and not with Kitcher’s derivational tool-kit.

To sum up, I have argued that explanatory unification does not supply what is necessary to unify and, so, explain selection phenomena, where that includes the phenomena in immunology and neurobiology. I have shown that **Simple Selection** in evolutionary biology does not unify similar phenomena in immunology or neurobiology because of the inextricable ties **Simple Selection** has to the evolutionary domain, and that **General Selection**, an argument pattern that accommodates the phenomena across its domains, is unexplanatory because it violates Kitcher’s stringency requirement. In the next section of the paper, I provide an alternative means to unifying and explaining selection phenomena not limited in the way I have shown Kitcher’s is.

4. Pervasive Mechanisms, Broadening Unification and Explanation. I have claimed that the domains of evolutionary biology, immunology and, if the selection theory is correct, neurobiology are connected by virtue of their sharing similar phenomena, selection phenomena. I further claimed that those phenomena were similar because their theories are selection theories, their construction based on the fact that the *selection mechanism* is claimed to govern the phenomena in each of the domains. Since the selection mechanism is what is central to each domain, a schema that integrates it across domains is crucial to the unification of the phenomena. A mechanism schema, in which the selection mechanism is laid bare, is a plausible means of providing the necessary unification. I provide such a schema in Figure 3.⁵

⁵ See also Brandon (1980), Darden and Cain (1989), Hull (1988).

Structure:

A. Initial Conditions

1. A set of Ys exist.
2. Ys vary according to property P .
3. Ys are in environment E with critical factor F .

B. Interaction

1. Ys , in virtue of possessing or not possessing property P , can interact differently with environment E .
2. Critical factor F can affect that interaction so that

C. Short-range Effects

1. the possession of P has the propensity to confer upon Ys with P_1 *C-BENEFITS* and Ys with P_2 *C-DISADVANTAGES*.

D. Long-range Effects

1. C may be followed by *D-BENEFITS* or *D-DISADVANTAGES*.

E. Longer-range Effects

1. D may be followed by *E-BENEFITS* or *E-DISADVANTAGES*.

Filling Instructions:

Y is the name of an individual

P is the name and description of a property of Y

P_1 is the name of the property that has a positive causal influence on Y

P_2 is the name of the property that has a negative causal influence on Y

E is the name and description of an environment in which Ys exist

F is the name of a critical factor in E

BENEFIT/DISADVANTAGE: are theoretical metaphors that function as place-holders for descriptions of differential causal influences on Ys due to Y 's interaction with E due to P and F .

C-BENEFITS/DISADVANTAGES: description of short-range effects of B interaction

D-BENEFITS/DISADVANTAGES: description of long-range effects of B interaction

E-BENEFITS/DISADVANTAGES: description of longer-range effects of B interaction

Fig. 3. A mechanism schema for selection.

The schema in Figure 3 individuates each temporal step of the selection process, beginning with variants in an environment with a critical factor that affects the interaction between individuals and their environments (steps A and B). The stages of effects of the selective interaction are detailed in steps C-E and are described in the Kitcher-like filling instructions I have added to make potential instantiations clear.

What I suggest the schema represented in Figure 3 provides is a unifying *connection* between domains of selection as well as a *connection* between phenomena within domains of selection. Call these kinds of unification *interdomain* and *intradomain* unification respectively. An interdomain unification of selection phenomena is a unification of selection *mechanisms*, and it is achieved by showing how the bare mechanism represented in Figure 3 can be *tied* to specific domains such as evolutionary biology, immunology and neurobiology. Tying the schema to a domain is done by filling in necessary abstract terms with domain specific content, and this is minimally satisfied by specifying the entities and effects of selection in some domain. In *natural* selection, the individuals, or spatiotemporally localized entities (see Hull 1988), undergoing the

process are Y =genes, organisms and groups and the effects of the selective interaction are C - E *BENEFITS*=survival, increased reproduction of heritable traits and lineage adaptation along with their corresponding C - E *DISADVANTAGES*. I have specified in the filling instructions the domain specific terms that *correspond* to the abstract terms in the appropriate ways. Continue this procedure for the domains of immunology and neurobiology. This task completed, a single schema results that is tied to three further, less general schemata, each tied to a specific domain. Providing this connection is providing an *interdomain* unification of selection mechanisms. Interdomain unification is *not* an explanatory unification; it is merely a laying bare of a basic mechanism, showing how it is to be connected to disparate domains via its filling instructions.

Intradomain unification of selection phenomena is achieved by instantiating the domain specific schema of interdomain unification for particular phenomena, e.g., instantiating the schema for evolutionary biology with natural selection phenomena such as the case of the peppered moth, the beaks of Darwin's finches, horse teeth, etc. The schema's instantiation is straightforward: Y =finch, P =beak length, varying short/wide, long/narrow, E =rocky environment where there are variously shaped edible seeds varying in availability, F =availability of seeds of certain shape (round or thin), C -*BENEFITS*=increased chances to survive, etc. Continue this procedure for neurobiology and immunology, resulting in intradomain unification for each domain, or unification of particular phenomena. The result of this further procedure is a single schema tied to multiple domains further tied to multiple particular cases within domains. Intradomain unification is an explanatory unification on the causal-mechanical model, showing how selection phenomena fit the mechanism (Salmon 1984, 1994, 1997). Because it is an explanatory unification, an appropriate explanation seeking question must accompany the domain restricted schema, for example, a question such as that preceding Kitcher's schema in Figure 1, or mine in Figure 2.

Unity on my view is based on Wesley Salmon's (1984, 276) insight that scientific unity on the causal-mechanical model of explanation is achieved by delineating pervasive causal mechanisms. Interdomain unification is my way of developing his otherwise underdeveloped insight. Of course, Kitcher eschews causal-mechanical explanation, and has criticized Salmon's views at length (Kitcher 1989). But recently Salmon has answered those criticisms and significantly refined his view (1994, 1997). However, even if Kitcher were satisfied with Salmon's answer to his criticisms of causal-mechanical explanation, he would likely take issue with unification on the account. According to Kitcher, unification on the causal-mechanical view of scientific explanation is a contingent matter and not an explanatory criterion. This is because the fundamental criterion of Salmon's model of explanation is the delineation of causal mechanisms and *not* unification (1989, 496-497). Kitcher's objection, however, is not one to the account advanced here. The combined notions of inter- and intra- domain unification are my attempt at retaining the Friedman-Kitcher insight that unification is a basic explanatory criterion. Interdomain unification functions to systematize our beliefs about the existence of pervasive mechanisms by representing them with schemata. Intradomain unification functions to systematize our beliefs about the phenomena governed by pervasive mechanisms.

5. Conclusion. The extent of explanatory unification on Kitcher's version of it has been shown to be limited to unification *within* scientific domains in the case of selection phenomena. On the one hand, an argument pattern from one domain of selection phenomena does not explain in another; this is unsurprising. On the other hand, a modified, more general, version of that pattern, constructed to bridge domains, unifies spuriously according to the rules of the method. Inter- and intra- domain unification, the unification of mechanisms and the phenomena governed by them, was shown to unify selection phenomena within *and* across domains. Of course, much work needs to be done refining the concepts of inter- and intra- domain unification; only preliminary work has been done here. Specifically, what counts as allowable mechanism schemata, the development of causal-mechanical explanation with mechanism schemata, and further illustrations of the view need to be worked out.

The increase in scientific unification achieved with inter- and intra- domain unification

indicates a defect in Kitcher's view of explanatory unification. Kitcher's view is wedded to the thesis that scientific understanding increases by extending scientific unification. But if his view fails to yield the available degree of scientific unification, then it must also fail to yield the available degree of scientific understanding. Kitcher claims that unification is the reduction of types of facts, or laws, scientists must accept in expressing their world view, and that it proceeds through derivation of large numbers of statements about scientific phenomena from economies of argument schemata. I suggest, in light of the evidence and argument presented in this paper, that it is very much worth exploring whether unification can be conceived of as the reduction of types of mechanism scientists must accept as targets of their theories and explanations, and whether it proceeds through the delineation of pervasive mechanisms via mechanism schemata.

REFERENCES

- Barnes, E. (1992a), "Explanatory Unification and Scientific Understanding," in D. Hull, M. Forbes, and K. Okruhlik (eds.), *PSA 1992*, vol. 1. East Lansing, MI: Philosophy of Science Association: 3-12.
- Barnes, E. (1992b), "Explanatory Unification and the Problem of Asymmetry," *Philosophy of Science* 59: 558-571.
- Brandon, R. (1980), "A Structural Description of Evolutionary Theory," in P.D. Asquith and R.N. Giere (eds.), *PSA 1980*, vol. 2. East Lansing, MI: Philosophy of Science Association: 427-439.
- Burnet, F. (1957), *The Clonal Selection Theory of Acquired Immunity*. Nashville, TN: Vanderbilt University Press.
- Darden, L. and Cain, J.A. (1989), "Selection Type Theories," *Philosophy of Science* 56: 106- 129.
- Dupré, J. (1993), *The Disorder of Things: Metaphysical Foundations of the Disunity of Science*. Cambridge, MA: Harvard University Press.
- Edelman, G. (1987), *Neural Darwinism: The Theory of Neuronal Group Selection*. New York: Basic Books.
- Friedman, M. (1974), "Explanation and Scientific Understanding," *The Journal of Philosophy* 71: 5-19.
- Hull, D. (1988), *Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science*. Chicago: University of Chicago Press.
- Humphreys, P. (1993), "Greater Unification Equals Greater Understanding?," *Analysis* 53: 183-188.
- Jones, T. (1995a), "How the Unification Theory of Explanation Escapes Asymmetry Problems," *Erkenntnis* 43: 229-240.
- Jones, T. (1995b), "Reductionism and the Unification Theory of Explanation," *Philosophy of Science* 62: 21-30.

- Jones, T. (1997), "Unification, Reduction, and Non-Ideal Explanations," *Synthese* 112: 75-96.
- Kitcher, P. (1976), "Explanation, Conjunction, and Unification," *The Journal of Philosophy* 73: 207-212.
- Kitcher, P. (1981), "Explanatory Unification," *Philosophy of Science* 48: 507-531.
- Kitcher, P. (1989), "Explanatory Unification and the Causal Structure of the World," in P. Kitcher and W. Salmon (eds.), *Scientific Explanation. Minnesota Studies in the Philosophy of Science*, vol. 13. Minneapolis: University of Minnesota Press: 410-505.
- Kitcher, P. (1993), *The Advancement of Science: Science without Legend, Objectivity without Illusions*. New York: Oxford University Press.
- Koertge, N. (1990), "Explanation vs. Unification," in P. Wiengartner and G. Schurz (eds.), *Berichte des 13: Internationalen Wittgenstein Symposiums*. Vienna: Holder-Dichler-Tempsky: 156-159.
- Morrison, M. (1992), "A Study in Theory Unification: The Case of Maxwell's Electromagnetic Theory," *Studies in History and Philosophy of Science* 23: 103-145.
- Rosenberg, A. (1994), *Instrumental Biology or the Disunity of Science*. Chicago: University of Chicago Press.
- Salmon, W. (1984), *Scientific Explanation and the Causal Structure of the World*. Princeton: Princeton University Press.
- Salmon, W. (1994), "Causality without Counterfactuals," *Philosophy of Science* 62: 297-312.
- Salmon, W. (1997), "Causality and Explanation: A Reply to Two Critiques," forthcoming in *Philosophy of Science*.
- Shapere, D. (1977), "Scientific Theories and their Domains," in F. Suppe (ed.) *The Structure of Scientific Theories*. Urbana, IL: University of Illinois Press: 518-589.