Pergamon

*Stud. Hist. Phil. Sci.*, Vol. 29, No. 3, pp. 391–408, 1998

Printed in Great Britain
0039–3681/98 $19.00+0.00

# Semirealism

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## 1. Introduction

The intuition of the naïve realist, miracle arguments notwithstanding, is countered forcefully by a host of considerations, including the possibility of underdetermination, and criticisms of abductive inferences to explanatory hypotheses. Some have suggested that an induction may be performed, from the perspective of present theories, on their predecessors. Past theories are thought to be false, strictly speaking; it is thus likely that present-day theories are also false, and will be taken as such at an appropriate future time.

Let us begin with the assumption of an external, mind-independent reality, add to this the further tenet that our theories concerning this reality have truth values and are to be literally construed, and set ourselves the project of determining circumstances under which we might be justified in believing such theories to be true. Let us entertain the notion that many past theories were rejected, not merely because they were false, but because they were *only partially true*. On this hypothesis, our task naturally becomes one of identifying what these elements of truth might be, and determining principled grounds which permit such identification.

What if it could be demonstrated that some particular aspect of each theory within a succession of theories in some domain was retained throughout? The identification of such retained elements with the truth of empirically successful theories about the natural world is the proposal of *semirealism*. Semirealism is committed to the truth—but of a restricted subset of claims made by particular theories. This position thus defines the aim of scientific inquiry in terms of preserving and increasing truth content by way of preserving restricted truth claims, and

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*Received 18 August 1997; in revised form 12 November 1997*

**PII: S0039-3681(98)00013-2**

increasing their number. This is what it means for there to be cumulative scientific progress, and for there to be continuity in the practice of scientific theorizing.

In what follows, I examine two possibilities for semirealism: entity realism (ER), and structural realism (SR). These positions, or so it is thought, attach truth to very different aspects of scientific theories. By considering the epistemic viability of these accounts in the light of certain criticisms, their basic metaphysical commitments are illuminated. These commitments, however, point to a surprising result: ER and SR, properly construed, entail precisely the same conclusions regarding the existence of entities, and knowledge of their properties. Thus it turns out that, so far as the project of identifying those aspects of theories about which we may feel confident is concerned, ER and SR imply one another. The resulting combined position, semirealism, defines principled grounds separating theoretical claims which are likely to be true from those which we are not in a position to endorse. Finally, some reflections are offered regarding the promise of this approach for an appropriate conceptualization of scientific theories.

## 2. Entities: Detection Properties, Auxiliary Properties

Entity realism holds that most of the entities referred to in scientific theories are actual inhabitants of an external, mind-independent reality. It is this aspect of theory—the existence of particular theoretical entities—that we may reasonably believe to be true. ER has proven uncontroversial (so long as no one invites the opinion of the idealist or solipsist) where macroscopic objects are concerned, for it is claimed that the reality of such objects is clearly demonstrated by simple ostensive presentation. Those objects too small to be detected by the naked eye, on the other hand, have suffered remarkable discrimination. Recent debate has addressed van Fraassen's (1980, p. 12) claim that acceptance of a scientific theory entails, or should entail, only the belief that it is empirically adequate, meaning that 'what it says about the observable things and events in this world is true'. Newton-Smith (1981, pp. 19–28) discusses the contention that claims concerning unobservables are riskier, given that their detection depends upon sophisticated equipment and theoretical assumptions, and that for this reason observables are epistemically privileged. The case, however, for denying that different epistemic attitudes with respect to entity existence should be brought to bear on information derived from the employment of human sensory modalities in isolation, as opposed to information obtained from combinations of human and technological sensory machinery, has been made persuasively.[1]

[1]Incisive critical responses to 'selective scepticism' (i.e. that with respect to the existence of unobservables, but not observables) are found in Hacking (1983), Churchland (1985), and Musgrave (1985), among others. Compelling arguments suggest that perceptions of observable and unobservable entities rely upon inferences which are of fundamentally the same type, and that no obvious relation obtains between the length or complexity of the causal chains via which entities are detected, and the likelihood of a good detection. The detection of an unobservable entity is thus in no principled way different from

Thus, resolving not to go the way of discrimination, let us invoke a commonplace regarding why it is that we believe in the objects of our perceptions: we believe that our sensory experience is brought about by *the very things of which we have experience*. Objects exist, and they affect us in such a way that we are confident, by virtue of their affecting us (us perceiving them), that they exist. Admittedly, this is vague, but it may be the best that we can do. At the very least, let us elaborate on what it might mean to 'be affected' or to 'perceive' in the manner indicated. This we do in terms of a familiar story about how empirical information is acquired by the human subject: things happen in the world, some of these things interact with our sensory apparatus, sensory machinery translates this information into signals which are processed by the brain, we perceive. In other words, information about real entities in the world is communicated to us by a *causal chain* of events; it is on the basis of such causal chains that we believe these entities to exist. We can and do believe in the existence of external objects pre-philosophically, but once we stop to justify such beliefs, we are driven to explanations in terms of causal interactions.

The version of the pessimistic induction alluded to above seemingly represents no threat to ER, since this argument reasons from the falsity of past theories, but not specifically past failure of reference on the part of theory terms, to doubts about current theories. Let us, however, intensify the challenge of the pessimistic induction. Consider the idea that the meanings of entity terms are to some extent defined by the theories in which they occur. How can we ascribe reality to some object x, if it turns out that we were, and may well now be wrong about what x *is*? Is it intelligible to assert that x exists, and yet be open to the possibility that our conception of x (the set of defining properties with which a particular theory picks out x) may change? If the meaning of 'x' changes, to what extent can we be said to be discussing the same entity? According to certain referential models of meaning (discussed by Kitcher (1993, pp. 76–78), and earlier by Putnam (1975, pp. 249–251, 269)), the set of descriptions with which any given referent is picked out may evolve, while the collection of modes of reference continues to refer to the same entity. It is this picture of meaning that we adopt when we say that Thomson, Lorentz, Bohr, and Millikan were all concerned with the same entity: the electron. To whatever extent our concepts and detections of observable and/or unobservable objects are theory laden, this should not stand in the way of legitimate beliefs in the *existence* of putative entities, however we may conceptualize them with different theories. Thus our beliefs with respect to the existence of causal agents need not suffer with changes in our attitudes toward the theories in which such agents play a role. And what about that rogues' gallery of non-referring entity terms from celebrated theories of the past—'phlogiston', 'ether', and their ilk—do

the detection of its observable counterpart. Insofar as they frequent the same dangerous waters, they sink or swim together.

they not speak volumes against the wisdom of adopting ER?[2] If there is anything intrinsic to practices of detection that suggests which causal agents will survive theoretical changes, it is the possibility of corroboration by alternative forms of detection. The greater the extent to which such corroboration takes the form of theoretically independent evidence, the greater its power of confirmation.[3] Highly corroborated entities are vindicated and take their place in our ontology; those that cannot be substantiated by this form of risk management more often than not take their place in the 'failures' chapter of our history of scientific ideas.

It may be instructive to think about why the above reformulated version of the pessimistic induction is generally targeted at unobservable entities. I suggest the reason is that our *prima facie* intuitions lead us to believe that unobservables are particularly susceptible to such arguments. Thus, it is thought obvious that both my opponent in the debate, the president of the flat earth society, and I refer to the same object when we speak of 'the earth'. Here we identify an entity despite differences in associated properties, about which we could argue all day. The same, of course, applies to the example of different theorists and their views on the electron, and to other corroborated unobservables, thus telling against our *prima facie* intuitions. But now we seem to have muddled things up, for surely we identify objects on the basis of certain properties—namely, those described by causal processes in virtue of which entities interact with our means of detection—and yet simultaneously we speak of identifying objects in spite of differences in the properties we attribute to them. Just what sorts of properties are we talking about here?

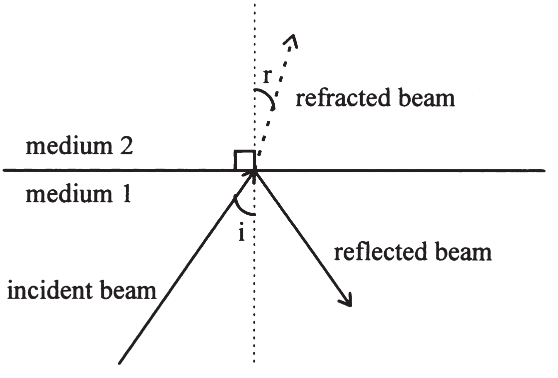
In his discussion of ER, Devitt (1991, p. 46) contrasts the position with what he portrays as the alternative for the realist, 'theory realism', which he describes as 'a stronger metaphysical doctrine' according to which 'science is mostly right, not only about which unobservables exist, *but also about their properties*'. But as the confusion cited above suggests, this may be painting with too broad a stroke. A more refined consideration of properties is required if we are to make sense of the seeming tension between identifying an object and differing about its attributes. For one thing, it is not clear that all properties are of the same type; distinguishing kinds of properties may in fact distinguish forms of realist commitment. What sorts of properties allow us to establish the existence of an entity? The answer, according to the account given above, is those properties which delimit causal interactions and which are, by virtue of this fact, exploited by us by way of detection. We infer entity existence on the basis of perceptions grounded upon certain causal regularities having to do with interactions between objects. Let us thus define *detection properties* as those upon which the causal regularities of our detections depend, or in virtue of which these regularities are manifested. *Auxiliary properties*, then, are those associated with the object under consideration, but not essential (in the

[2]For related discussion, see Laudan (1981).

[3]Salmon (1984, pp. 217–219) and Hacking (1983, p. 201) give convincing examples of entity detection employing various methods whose underlying theoretical assumptions are remarkably distinct.

sense that we do not appeal to them) in establishing existence claims. Attributions of auxiliary properties function to supplement our descriptions, helping to fill out our conceptual pictures of objects under investigation. Theories enumerate both detection and auxiliary properties of entities, but only the former are tied to perceptual experience.

Perhaps an example will clarify the property distinction at issue. In a paper on structural realism, Worrall (1989) features the case study of transition from the wave optics of Fresnel to the electromagnetic theory of Maxwell. Worrall considers a set of equations developed by Fresnel, relating intensities of reflected and refracted light to that of an incident beam passing from one medium into another of different optical density.




Then, as Worrall relates (1989, p. 119, square brackets mine):

> Ordinary unpolarized light can be analysed into two components: one polarized in the plane of incidence [the plane containing the incident, reflected, and refracted beams], the other polarized at right angles to it. Let $I^2$, $R^2$, and $X^2$ be the intensities of the components polarized in the plane of incidence of the incident, reflected, and refracted beams respectively; while $I'^2$, $R'^2$, and $X'^2$ are the components polarized at right angles to the plane of incidence. Finally, let $i$ and $r$ be the angles made by the incident and refracted beams with the normal to a plane reflecting surface. Fresnel's equations then state
>
> $$R/I = \tan(i - r)/\tan(i + r)$$
>
> $$R'/I' = \sin(i - r)/\sin(i + r)$$
>
> $$X/I = (2 \sin r.\cos i)/(\sin(i + r)\cos(i - r))$$
>
> $$X'/I' = 2 \sin r.\cos i/\sin(i + r)$$

Fresnel attached a particular metaphysical picture to these equations—that of an entity, light, constituted by vibrations in an elastic, solid, all-pervading medium, the ether, occurring at right angles to the direction of light propagation. These vibrations may be resolved into two components: one in the plane of incidence, and one in a plane normal to the incident plane. The larger the vibration (i.e. the greater the displacement of the ether), the more intense the light; *I*, *R*, and *X*, the square roots of the intensities, represent the amplitudes of vibration. Maxwell's equations were eventually accepted in the context of a very different metaphysical picture—that of oscillating electric and magnetic field strengths. Nevertheless, they entail precisely those equations of Fresnel given above. We shall return later to consider the issue of the role played by theoretical structure in this example. In the meantime, let us focus our attention on the relations expressed by Fresnel's equations. What are these relations *between*? The answer is amplitudes or intensities, and angles or directions of propagation. In other words, light is something which, on the basis of these mathematical relations, we associate with the following: influences propagated rectilinearly and made up of two components manifested at right angles to one another and to the direction of propagation; each component has an amplitude or intensity, the magnitude of which oscillates in a specific manner. Those properties of light which compose or give rise to precisely these influences are *detection* properties, that is, properties having to do with causal regularities on the basis of which we infer the existence of the entity possessing them: light.

Empirical theories offer explanatory frameworks which incorporate both detection and auxiliary properties. It is this combination which in a sense constitutes our causal understanding of the entities and phenomena under investigation. Mere reflection on theoretical causal stories, however, does not enable one to distinguish between the detection and auxiliary property components of such combinations. In order to distinguish these properties, we must turn to the equations with which we attempt to capture phenomenal regularities, and ask: what do these mathematical relations *minimally demand*. We must consider not what possible metaphysical pictures are consistent with these equations, but rather what kinds of property attributions are *essential* to their satisfaction—i.e. consider not what is possible, but what is *required*. For only these properties are tied directly to the detections we employ so as to construct mappings of natural phenomena in terms of mathematical relations. What, then, do Fresnel's equations require? They demand some kind of influence, propagated rectilinearly and resolvable into two components, oscillating at right angles to one another and to the direction of propagation. The property or properties of light in virtue of which such influences are realized are detection properties. By way of contrast, consider an auxiliary property attributed to light by Fresnel's optics: here we find not merely amplitudes, but amplitudinal displacements in an elastic solid medium. This is not to say that being a displacement in the ether could not be linked to a detection property under different circumstances, but merely that these particular equations of Fresnel do not appeal to any such detection property. Rather, Fresnel and his supporters incorporated certain auxiliary properties into their interpretation of these equations. It is, of course, possible (in principle) to imagine further relations involving properties of the ether on the basis of which we could detect it, corroborate it, and satisfy ourselves as to its existence. The fact that we have been unable to do so is not unrelated to our present conviction that there is, in actuality, no such thing.

Note that the distinction between detection and auxiliary properties, to refer once again to our example, does not necessitate that light *itself* be rectilinear, transversely oscillatory, etc. Rather, light has the property that (or properties such that) when subjected to specific forms of detection, certain characteristics are causally manifested and detected. Whether one prefers to say that light is composed of such properties, or alternatively that light possesses such properties, will depend on one's metaphysics of properties and objects. For present purposes, however, the metaphysical details are of little importance. What is crucial is the understanding that certain properties can be attached to certain entities by way of detection. Theories employ both detection and auxiliary properties of entities, but only detection properties are directly linked to our detections of those entities. Suddenly, it seems, knowledge of the existence of entities has opened the door to a wider realm of knowledge, consisting of those regularities in virtue of which we know them to exist, or more specifically, properties having to do with (causal) relations defining entity behaviour. It might even be possible, in some sense, to think of such relations as embodied by the *structure* of physical theories.

## 3. Structures: SR, and its Relation to ER

What is the connection between the kinds of relations we invoke to make sense of our detections of objects, and the structure of physical theory? Let us first direct our thoughts to the question of what, in this context, a structure might be. Consider the following definition by Russell (1948, pp. 267, 271): 'To exhibit the structure of an object is to mention its parts and ways in which they are interrelated'; 'structure always involves relations'. He then goes on to define structural identity for dyadic relations in the following way. 'We shall say that a class $\alpha$ ordered by the relation R has the same structure as a class $\beta$ ordered by the relation S, if to every term in $\alpha$ some one term in $\beta$ corresponds, and vice versa, and if when two terms in $\alpha$ have the relation R, then the corresponding terms in $\beta$ have the relation S, and vice versa.' (Definitions of structural identity for relations of higher order are definable intuitively by iteration.) Now think of a physical theory in terms of the class of entities specified within, ordered by specific relations. The structure of a theory is thus illuminated by considering those relations proposed by the theory to conjoin the entities specified. What would it mean for there to be structural identity between theories? Imagine two distinct theories, A and B. If the relations belonging to A are present in B and vice versa, the structure of the two theories is *identical*. If the relations belonging to A are present in B, but not vice versa, there is a sense in which the structure of A is *preserved* within B. In both cases, the two theories, though different, share structural elements.[4]

[4]No doubt other notions of structure are possible. The approach taken here, however, is a natural (not to mention highly intuitive) one. Note the contrast with the collection of views coming under the heading of structuralism in the philosophy of mathematics. Structuralists hold that 'mathematical objects have no distinguishing characteristics except those they have by virtue of their relationships to other positions in the structures to which they belong' (Resnik, 1996, p. 84). Mathematical structure is here defined in much the same manner as in Russell above (e.g. see Shapiro (1989, pp. 508–509) and Parsons

The association of notions of structure with fundamental physical theories is found in the writings of many, including Poincaré and Duhem, and more recently in the work of Worrall. In his discussion of 19th-century optics, Poincaré (1952 (1905), p. 161) reflects on the fact that various mathematical equations were retained in the transition from Fresnel's theory of light to that of Maxwell. '[T]hese equations express relations, and if the equations remain true, it is because the relations preserve their reality.' Poincaré suggests that it is these relations between objects which constitute our knowledge of reality. This knowledge may be possessed while the images with which we cloak objects are modified, changed, and substituted, the objects themselves remaining forever beyond our grasp. Similarly, Duhem distinguishes between what he calls the 'representative' and 'explanatory' components of theories. The representative aspect consists in mathematical relations representing physical laws, which may be subjected to empirical test. The explanatory aspect is constituted by some account of the hidden reality underlying the phenomena. Duhem (1954 (1914), p. 32) is clear that it is to the representative aspect of theories that we owe our allegiance; explanatory devices mislead, offering pictures of reality whose truth we cannot know: 'whatever is false in the theory … is found above all in the explanatory part; the physicist has brought error into it, led by his desire to take hold of realities.'

Structural realism (SR) holds that most structures of fundamental physical theories correctly mirror relations present in an external, mind-independent reality. Some of the philosophers mentioned above state this case so forcefully that one might be led to believe that SR is a metaphysically severe doctrine. Poincaré (1982 (1913), p. 352), for example, maintains that 'the sole objective reality consists in the relations of things whence results the universal harmony', and further claims that hypotheses extending beyond such relations have no real meaning, but a metaphorical sense only. Despite the rhetorical emphasis on structures, however, it is not the case that SR disavows the reality of things other than relations. Traditional SR is a strict epistemological doctrine, claiming reality for both relations and objects, but substantive knowledge of only the former. Here I assume the perhaps obvious contention that relations without relata are of no interest to a discussion of the truth of scientific theories concerning natural phenomena.[5]

How might structures be preserved across theoretical change? Proponents of SR

(1990, p. 305), where notions of structural identity and preservation are presented formally). But while the ontological status of mathematical objects is a matter of debate even amongst mathematical structuralists, the structures I am concerned with in this paper deal with relations between existing, causally efficacious constituents of the natural world. Furthermore, while mathematical structuralism is a strict metaphysical doctrine, disallowing properties of mathematical objects not derived from the structures with which we define them, the account of structural realism developed below is not in this way restrictive.

[5]This stand argues neither for nor against Platonism regarding structures or relations. While the account presented here does not rule out such a possibility, it does suggest that any extreme Platonic view preoccupied with relations not instantiated by the natural world has little to offer a discussion of scientific truth.

suggest two mechanisms: either mathematical equations survive intact from one theory to the next, or more commonly, old equations are limiting cases of newer ones. Two sets of equations may strictly contradict one another, and yet the newer equations may tend to the older in the limit of some quantity. (This is often claimed for relativistic and Newtonian equations, for example, as velocities tend to zero.) As different and more precise measurements are made possible, new terms may be added to formulae so as to more accurately capture the complexity of natural phenomena. This notion of preservation of structure from one theory to another has been called the 'correspondence principle'. In his response to Worrall's recent excavation of SR from the history of philosophy, Psillos (1995, p. 20) summarizes the commitments necessary to SR and the correspondence principle as the following: (i) scientific theories reveal the structure of physical reality by means of their mathematical structure; (ii) mathematical equations preserved across changes in theory express real relations, but nothing about relata other than the fact that they stand in these relations; (iii) different ontologies are consistent with the same mathematical structure; we have no reason to believe in any particular ontology. The first point is well taken, but the second is ambiguous, and the third, I believe, is not a feature of SR, properly construed. In order to better understand these points of difference, let us examine more carefully the relationship between SR and ER.

Consider the idea that SR tells us nothing about entities that partake in relations. This is false in at least the banal sense that, as noted earlier, the existence of relations allows us to ascribe, if nothing else, existence to the entities so related, whatever they may be exactly and however we may describe them. A famous dictum of Quine's holds that 'to be is to be quantified over' in some first order language. How might the proponent of SR view this statement? No matter how determined she is in her attempt to focus on relations between entities, not entities themselves, she finds herself committed to the existence of at least some entities. For if the domain of interpretation of some first-order language is a set of objects (entities over which individual variables range), the existence of relations here implies the existence of whatever elements of the set are implicated. This much must seem obvious—one cannot intelligibly subscribe to the *reality* of relations unless one is also committed to the fact that *some things* are related. In other words, SR entails ER.

But how can this be? Orthodox SR maintains, does it not (as Psillos makes explicit in his characterization), that those relations which command our belief radically underdetermine the specific entities satisfying them? This is, after all, why proponents of traditional SR are drawn to the position. For theoretical entities to them seem fickle companions next to structures—entities come and go, while structures are retained. This sentiment follows from our habit of attaching to objects the full complement of detection and auxiliary properties with which they are associated in particular theories. As a consequence, entities identical in their detection properties but differing in their auxiliary properties are thought to be *different* entities. This may seem a natural idea, but one of the most important lessons of ER is that this way of thinking will not do. ER explains the fact that we have continuity of reference across theory change by appealing to unchanging attributions of those detection properties which underwrite the causal interactions we exploit by means of detection. It is precisely these properties which entities satisfying particular structural relations (describing causal interactions) must possess, for it is in virtue of these detection properties that entities partake in such structural relations in the first place. More speculative notions concerning auxiliary properties are apt to change when theories do. Clearly then, structural relations *do not* underdetermine entities, but merely their auxiliary properties; strictly speaking, different ontologies are *not* consistent with the same mathematical structure. Structural knowledge implies knowledge of both the existence of entities satisfying structures and certain of their detection properties. SR entails ER.

It may now seem that we would be correct in thinking realism about structures to be a broader position than realism about entities, but here comes the interesting result. ER allows us to identify particular entities which have played roles in different and often conflicting theories. This we are able to do because in such cases, the objects concerned have the same causal powers or relations to other objects no matter what theory we are considering. In other words, the existence of entities is established on the basis of certain detection properties, and the causal relations which connect these properties are retained wherever we recognize the presence of such entities—e.g. in subsequent theories. These relations describe interactions between entities which compose the very phenomenal regularities we attempt to map with mathematical equations in our fundamental physical theories. The existence of relations of this kind is what permits our practices of entity detection. Belief in entities thus requires such relations. The amazing conclusion here is that ER entails SR.

It may be objected that surely not *all* structures have to do with causal relations involving the detection properties of entities. Clearly we can imagine different kinds of structures, such as ones linking auxiliary properties. But for the advocate of SR, such flights of fancy are not particularly helpful, for not just any structure will do. SR requires *stable* structures—ones which are, in fact, likely to be preserved. Confidence in theoretical structures is achieved by means of their success in mirroring the phenomenal world, and structures which map phenomenal regularities are those composed of relations between detection properties. Relations between auxiliary properties are by definition undetected relations between undetected properties; they have, in this sense, no empirical content. The relations of SR, on the other hand, are held to be representative of the phenomenal world, and as such they are concerned with phenomenal regularities involving detection properties.

The metaphysical intuition that there are causes at work wherever we detect phenomenal regularity is supported by reflections on event probabilities. Consider, for example, Russell's (1948, p. 483) advice: 'When a group of complex events in more or less the same neighbourhood and ranged about a central event all have a common structure, it is probable that they have a common causal ancestor.' This might be thought of as a version of Reichenbach's principle of the common cause. But all we require is the weaker claim that it is reasonable to think of well-confirmed relations between detected physical properties as evidence of causal activity, whatever the mechanism of causation. If by 'group of complex events' we understand those events described by the mathematical formalism of a theory in some particular domain, we are led to the conclusion that structures and the relations composing them take as their subject matter the causal entities of ER, be they observable or unobservable. Thus we take mathematical equations relating detected objects, or more specifically, detection properties, as expressing causal relations between those objects. When one parameter of an equation is varied, we expect to see changes in other parameters, since they are causally related, either through a common cause as suggested by Russell above, through some direct causal link, or via some combination of the two. If it is a succession of theories in some particular domain that we are interested in, we expect newer theories to resemble their predecessors in illuminating causal relations between certain theoretical entities. All structures of interest may be accounted for in terms of causal relations which identify specific entities. Thus, ER entails SR.

## 4. Form, Content, and Semirealism

Given the argued equivalence of realism about entities and structures, it will come as no surprise that SR, like ER, is ready and able to do battle with pessimistic inductions. If asked to consider the falsity of past theories, SR responds with a consideration of the truth of past structures. Undue focus on the explanatory aspect of theories, to co-opt Duhem's terminology, may paint an historical picture of revolutions in scientific theorizing over particular ranges of phenomena, but attention to the representative aspect demonstrates the extent to which structures are preserved.[6] 'When the progress of experimental physics goes counter to a theory and compels it to be modified or transformed, the purely representative part enters nearly whole in the new theory, bringing to it the inheritance of all valuable possessions of the old theory, whereas the explanatory part falls out in order to give way to another explanation' (Duhem, 1954 (1914), p. 32). But contrary to the spirit of Duhem (for we have argued that *some* of the explanatory component *must* accompany the representative), since SR implies ER, it is likewise impervious to the version of the pessimistic induction which seeks to promote scepticism about theoretical entities. If two theories possess the same structure, or if the structure

[6]Several philosophers have cited examples from the history of science demonstrating the preservation of structure from one theory to a successor within a particular domain. See, for example, Worrall (1989, 1994); Psillos (1995); Zahar (1996).

of one theory is preserved in that of a second, the theoretical entities invoked by one may be mapped onto their counterparts in the other.

Nevertheless, it is the apparent emphasis on structures at the expense of entities that generates the most obvious unease about SR. An emphasis on structures encourages the view that when scientific theories appear to be on the right track, that is, when we observe preservation of structure across theoretical change, SR asserts the truth of the relations described, but not the truth of our descriptions of the objects so related. But, so the objection goes, this separation of truth where relations are concerned from truth with respect to relata is unintelligible. Let us think of the *form* of a fundamental physical theory as composed of mathematical equations which represent the structure of physical phenomena or processes. The *content* of a theory, then, consists in the meanings of terms occurring in such equations, and is thus concerned with the nature of the entities partaking in physical phenomena or processes. Now, as mentioned earlier, relations and thus structures are not meaningful (or, at least in the present context, not interesting) concepts in the absence of actual things which are putatively related according to the structures considered. SR, in its emphasis on structures, attempts to separate form from content, but since theoretical content is required to make sense of the form of a theory, SR attempts the impossible.

The objection, however, is plausible only so long as it fails to consider carefully what we mean when we use the terms 'structure' and 'entity'. By 'entities' we refer to causal substances, which we associate with two kinds of properties: detection properties, on the basis of which we infer entity existence, and auxiliary properties, which further describe or supplement our conception of the entities present within a particular theory. 'Structures', on the other hand, have to do with relations (in the manner given by our definition of structural identity) which are themselves descriptive of causal regularities. What the objection fails to appreciate, then, is the distinction between detection and auxiliary properties, and the fact that SR depends upon the existence of entities and consequently knowledge of certain detection properties, but not upon descriptions of entities in terms of the auxiliary properties with which they are associated in particular theories. In other words, SR does *not* attempt to separate the form and content of theories, as charged. Rather, SR attaches theoretical form—mathematical equations representing the structure of causal processes—to that *part* of theoretical content consisting in detection properties, but remains agnostic about that portion of content provided by descriptions of auxiliary properties. The misunderstanding of this point is encouraged by loose talk on the part of SR advocates, who in their rhetorical zeal to escape pessimistic inductions seem to suggest doing away with talk of entities, or at least their natures, altogether. But this would be a case of throwing the detection property baby out with the auxiliary property bath water.[7] Upon reflection, even the most ardent pro-

[7]It is being thus misled by supporters of traditional SR that leads Psillos (1995, p. 29) to offer the following consideration as an argument against it: 'if the predictive success of a theory can at all support the claim that a theory has got it right about how the world is, it also supports the claim that *some* of

ponent of SR must realize that her antipathy toward entities is misguided; it is properly an aversion not to entities, but to their auxiliary properties. For it is sets of auxiliary properties that fall victim to pessimistic inductions, and entities referred to by their detection properties are, after all, what structural relations *relate*.

It cannot be denied, however, that much of the cognitive energy expended in the construction of scientific theories is directed precisely toward developing accounts of the furniture of the world in terms of auxiliary properties. Clearly, the traditional realist wants more than it appears semirealism can deliver. For to be satisfied with semirealism is to accept a maximal description of scientific knowledge such as that offered by Russell (1948, p. 273): 'Every interpretation that preserves the equations and the connection with our perceptive experiences has an equal claim to be regarded as *possibly* the true one, and may be used with equal right by the physicist to clothe the bare bones of his mathematics …. The reason is that the physical world can have the same structure, and the same relation to experience, on the one hypothesis as on the other.' Poincaré was so comfortable with this view of the limits of scientific knowledge that he readily accepted it as defining the proper aim of scientific inquiry. This aim, he held, is exhausted by the prediction of natural phenomena. Thus, the overthrow of 18th-century corpuscular theories of light by Fresnel's wave theory marked an important juncture in the history of optics not because Fresnel was correct about light being a disturbance propagated through an all-pervading medium, the ether, but because his equations correctly predict certain optical effects. These equations continued to provide perfect predictions even when Fresnel's theory had been supplanted by Maxwell's electromagnetic theory. In Poincaré's estimation, if there are truths to be grasped here, they are those of relations which determine or govern the behaviour of light—in other words, those relations resting upon detection properties. Theories which appeal to identical relations but attribute different auxiliary properties to the entities related are in a sense all true; figuratively speaking, it is as if they express the same true relations but in different languages. And as far as these differences are concerned: 'These questions which we forbid you to investigate, and which you so regret, are not only insoluble, they are illusory and devoid of meaning' (1952 (1905), p. 163).

Semirealism need not, however, be thought of in such hard-line terms. The more reasonable view is that descriptions of entities which are inclusive of all properties attributed to them within the confines of some theory have meaning, but that we may not be in a position to evaluate truth values beyond the properties in virtue of which entities participate in certain relations. But if this is the case, why do we

the physical content of the theory is correct.' But of course, the advocate of SR should agree with this statement. Psillos' argument thus misses the target of SR properly construed, which does *not* maintain that *none* of the physical content of an empirically successful theory is true. (Matters are somewhat further confused in Psillos' subsequent discussion (pp. 31–32) of the nature and 'structure' of 'mass'. 'Mass' is not an entity, an entity behaviour, or a theory describing entity behaviour—it is not something to which SR applies the concept of structure. Rather, it is a property of some entities occurring in some theories.)

bother formulating full-blown descriptions which specify both detection and auxiliary properties? Why do we waste our time? This, ultimately, is where the traditional realist critic of semirealism must make a stand. She must offer compelling reasons for the belief that more than structures and detection properties should be preserved in successions of theories. Alternatively, she must identify conditions which would justify us in believing that full-blown descriptions of entities within theories are likely to be true. The traditional realist accepts these tasks on the basis of the intuition that what semirealism provides is less than that to which scientific knowledge should properly aspire. The possibility of undertaking such tasks in such a way as to provide protection from standard criticisms seems unlikely.

Semirealism, however, has its own reasons for embracing the activity of constructing descriptions of theoretical entities which go beyond their detection properties. Such descriptions give rise to further investigations whose aim is to determine whether specific auxiliary properties are *actual* properties of the object under consideration, by detecting them and placing them in newly discovered relations. In the process, auxiliary properties are converted into detection properties; conversely, we may rule out particular relations or detection properties, or suggest others that had not previously been considered. Pending further analysis, the potential heuristic value of speculating with regard to entity descriptions in promoting more accurate structures cannot be discounted. Semirealism is a commitment to those detection properties of entities which underwrite our detections and compose structural relations. The limited epistemic vision of this position incorporates auxiliary properties, not as substantive knowledge, but as methodological catalysts. These commitments stand in contrast to those of naïve realism, which accepts the restricted truth claims of semirealism, but goes further in claiming truth for auxiliary properties associated with entities in fundamental physical theories. Here semirealism will not go, for it is by restricting itself to detection properties inhabiting structures that it escapes doubts such as pessimistic inductions that plague its more liberal cousin.

Worrall's reconstruction of the historical transition from Fresnel's to Maxwell's optical theories concludes that '[t]here was continuity or accumulation in the shift, but the continuity is one of *form* or *structure*, not of content' (1989, p. 117). We have already discussed the error of speaking in such unqualified terms about the separation of form and content. Let us change the focus, then, to a consideration of what was preserved in this instance of theoretical change. Much of the ambiguity surrounding the issue of separating form from content stems from an unsatisfying vagueness in previous treatments of SR. While generous attention is given to the idea that relations expressed by mathematical equations might represent some aspect of the natural world, rarely do they stop to consider that which is, presumably, so related. Careful attention to the relata employed by theories is important for at least two reasons. First, it clarifies what is meant by saying that elements of theories are related in certain ways. Vague talk of relations between objects is spelled out with precision in terms of specific properties of objects which are related in the ways described by mathematical equations of fundamental physical theories. We identify these entities on the basis of our detections of their properties. The second virtue following from a serious consideration of relata is that it makes transparent the distinction between that aspect of theoretical content for which semirealism claims knowledge (specific detection properties of entities), and that aspect regarding which it remains agnostic (auxiliary properties attributed to entities by particular theories). These considerations help to distinguish the open-minded semirealism we have constructed from the hard-line position of traditional SR supporters.

Let us illustrate one important further difference in the context of another example. Worrall argues that from the perspective of his SR, several of the conceptual difficulties associated with attempts to understand quantum states in classical terms cease to be difficulties at all, since they concern aspects of nature which exceed our knowledge of theoretical structures and the relations they contain. He draws upon an analogy to Newtonian gravity. The argument was made at the time of Newton, in a manner of speaking, that to accept the theory of universal gravitation was to give up realism, for to accept this theory was to accept the unintelligible notion of action-at-a-distance, as opposed to the innocuous metaphysics of contact action. But such worries, claim Worrall, do not trouble the structural realist, who is free of unhealthy desires for knowledge of underlying metaphysical mechanisms; rather, she is content merely with the understanding that Newton and the pioneers of QM discovered certain relationships in the world and represented them to the best of their ability in a mathematical formalism. To the extent that they were correct, these structures are preserved in later theory. No further explanation is required, or wanted. But where incentive for further inquiry seems lacking in the person holding this view, the proponent of semirealism is just beginning.

Semirealists know that it is the exertion of attempting to discover or establish new relations, and sometimes even new relata, that drives the scientific enterprise. Of course, many of the auxiliary properties referred to in present-day theories may be chimeras, but the task of inquiry is to attempt either to falsify them, or to transform them into detection properties in virtue of which previously unknown relations are brought to light. In the process, auxiliary properties are either rejected or provide means by which entity existence may be established or further corroborated, and new theoretical structures illuminated. In quantum mechanics, analyses of hidden variables programs have demonstrated that some such possible accounts are untenable. If in future empirical tests were designed for the presence of properties such as hidden variables—though today this must seem the stuff of science fiction—they would be shaped by these early findings. Semirealism walks a line between the hard-headed realist who lacks sufficient patience to seek the truth of universal gravitation or QM because these theories contain things she cannot explain, and equally stubborn characters (instrumentalists and Poincaré-type structuralists) who claim not to care about deeper questions. The semirealist believes in the entities and structures she can, and sets to work on the rest.

The strengths of this position go beyond merely helping to ground whatever sympathies we may have for miracle argument considerations, or rebutting pessimistic inductions. The understanding that ER and SR embrace one and the same set of epistemic and ontological commitments is important for at least the following additional reason. Perhaps the most serious weakness of previous accounts of SR has been that even if one accepts the historical reconstructions of theory change offered, we are given no reason to believe that such incidents are typical. Why should theory change *in general* preserve structures in the way indicated by the Fresnel/Maxwell case study? Why should we be won over by a couple of (some might suggest) well chosen examples? Semirealism, on the other hand, provides principled grounds for believing that structures will be preserved. Risk management in the form of corroboration gives independent reasons for believing in the existence of entities, and with this much in hand, structures representing relations between detection properties of these entities are likewise substantiated. Once we separate detection properties from auxiliary properties and consequently appreciate the ties that bind ER and SR, it is no surprise that structures and entities line up together the way they do—it would be a miracle if they did not.

Philosophers define the proper aim of scientific inquiry in terms of what they take to be the epistemic limitations of its practitioners. Thus van Fraassen, who believes that we can have knowledge about observables but not unobservables, defines the aim of scientific inquiry in terms of developing theories which are correct in what they say about the world of unaided perception. Poincaré, who believes that we can know only structural relations, dismisses the rest of theoretical content. Perhaps the fact that semirealism appears less extreme is due to a greater proximity to the actual practice of generating theories about fundamental physical phenomena. Instrumentalism of various stripes and previous versions of ER and SR criticize unreflective scientific theorizing for exceeding its grasp. Semirealism validates knowledge of relations involving specific detection properties of entities, and accommodates attributed auxiliary properties as part of the impetus behind the discovery of new relations and an increased knowledge of a greater diversity of properties. In this sense, semirealism is less ambitious than the above positions, for it does not seek to radically reform intuitive realist presuppositions about theories, but to demonstrate the great extent to which they are reasonable.

## 5. Conclusion

In summary: entity realism holds that most of the entities referred to in scientific theories are truly existing constituents of the natural world. Claims regarding the existence of objects are justified, so far as justifications go, in light of the presence of causal interactions linking objects of perception to perceivers. We differentiated two kinds of properties: those we detect, in virtue of which entities partake in the causal regularities which allow us to infer their existence (detection properties), and others associated with entities in particular theories (auxiliary properties). Phenomenal regularities are accounted for in terms of relations between entities, or more specifically, their detection properties, which in turn define the structure of the theory containing them. That is to say, the study of such regularities by means of observation and experiment results in our representing relations between detection properties in terms of mathematical formulae; these mathematical relations, in turn, we take to define the structure of the theory concerned. Notions of 'structural identity' and 'preservation of structure' may be defined, as can structural realism, the view that most structures of fundamental physical theories correctly represent relations between objects in the natural world. Reflections on the relation between ER and SR led to the realization that these positions, in fact, contain one another. The resulting combined position we referred to as semirealism.

With hindsight incorporating the above analysis, it would seem that the relation between ER and SR has been seriously misunderstood. Critics of these alternatives to naïve realism are not entirely to blame, for the respective proponents of these doctrines often present ER and SR as opposed positions, committed to knowledge of different aspects of reality. This opposition is, of course, plausible—entities and structures describing entity behaviour are very different things. It is an interest in seemingly different subject matters that has landed advocates of ER and SR on different and competing teams. But when we look carefully at their respective game plans, we find that entities and structures, though metaphysically separable, are for us epistemically interwoven, and always come as a package. Misrepresentations of ER and SR are exposed as such when we take seriously the prospect of consistently holding these positions. Traditional ER is often presented in terms of commitment to the truth of existence claims regarding theoretical entities only. But such commitment cannot be held in isolation; it is established on the basis of certain relations between objects. Advocates of traditional SR often speak as though their interests are confined to the truth of relations. But such relations contain substantive information about entities: namely, regarding detection properties, which allow determinate reference to the entities related. Once we identify and correct the deficiencies of these traditional accounts, the positions fold one into the other. It is for this reason that we say that ER and SR entail one another; they are, in fact, one and the same position: semirealism.

*Acknowledgements*—I am grateful to Peter Lipton for numerous discussions and comments which helped me to clarify these ideas, as well as to Nick Jardine, Michael Redhead, Stathis Psillos, and anonymous referees for helpful comments.

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