Lawrence Sklar

Foundational Physics and Empiricist Critique

1

Empiricism is not a very popular methodological or epistemological stance nowadays, and we all know why. It presupposes the existence of sensory contents both as uncontaminated by theory and as present to us in a way so as to serve as the foundation of our corpus of rational belief. But Gestalt considerations tell us that the presuppositionless empirical content is a myth, and considerations familiar since the idealists tell us that only the propositional can play a role in the inferential structure of justification, and not "objects" as sense contents were supposed to be (if "objects" of a peculiar sort). To go beyond rational belief in particular facts, empiricism requires, also, rules of inductive inference supported on a priori grounds. But both traditional Humean skepticism about the rationality of induction and more recent objections based on the absence of any a priori basis for a selection of "natural kinds" relative to which inductive generalizations are to be formed, cast grave doubts on the possibility of a coherently formulated and rationalizable empiricist account of the confirmation of generalities.

Even if we could rationally found our general beliefs about observables in the manner that the empiricist suggests, his doctrine would still be inadequate as a reconstruction of scientific knowledge. For despite all the effort made to overcome the well-known long-standing problems, we still don't understand how, beginning with empiricist preconceptions, we can explicate our understanding of theoretical concepts, realistically construed, nor rationalize our inference to theory that posits what, to the empiricist, are unobservable entities and structures in the world. Indeed, if the perceptual basis is confined to the familiar empiricist realm of the private contents of sensory awareness, it is hard to understand how we could, on empiricist precepts, develop an intersubjective account of the world at all.

Worse yet are the difficulties the empiricist faces in giving us an adequate reconstruction of how we come to grasp the meaning of the terms essential to frame our scientific hypotheses. The empiricist semantic foundation of basic words acquiring meaning in the presuppositionless way by means of the intentional association of the word with an "idea in the mind" ostensively presented is, for a variety of reasons (some of which overlap the skeptical arguments against the empiricist notion of the "given" as an epistemic foundation), a dubious ground on which to base a theory of meaning or the grasp of meaning. And – in a manner similar to the epistemic doubts that, even given an empiricist foundation for knowledge, we could on the basis of that foundation reconstruct the body of objective, scientific knowledge – the empiricist semantic foundation, even if it existed, provides too subjective and too flimsy a ground on which to base our comprehension of the meanings of the terms in a public, scientific language fully possessed of the resources to refer to and describe even the unobservable.

In the face of these difficulties with traditional empiricism, we have been presented with alternative models of scientific meaning accrual and scientific epistemic justification. Various varieties of "realism" and "pragmatism" share common objections to empiricist presuppositions and common alternatives to some empiricist claims, even though they at least seem, in places, to differ from one another in their own reconstructive approaches.

For the realist the analysis of any such notions as the delimitation of the domain of the observable, the reference of language to the world, or the distinction between justified and unjustified rules of epistemic inference is a matter for our best available natural science to explore, not any matter of a priori armchair philosophizing. We can, indeed, explore our place as observers in the realm of nature by means of neurophysiology and empirical psychology, but cannot hope to found our already existing best-available science on some myth of the prescientific given. We can also naturalistically study our place as language users in the natural world, but can't hope for some philosophical semantics that will offer us an analysis of what meaning in general must be, again in advance of any naturalistic scientific theory being accepted by us. And we can, from the standpoint of an accepted scientific world view, ask which rules of epistemic inference will reliably lead us to the truth; but we can have no hope of justifying, in advance of accepting a scientific picture of the world, some general principles of rational inference that would ground the scientific enterprise in the first place.

The pragmatist shares with the realist skepticism toward any element grounding epistemology or semantics outside our currently accepted scientific framework. But he shows rather more sensitiveness to the frequent objection to realist naturalism that its purely "externalist" stance fails to do justice to the questions the empiricist tried to answer. For the pragmatist the question of the origin of the "normative" aspect of meaning and justified belief is to be found in the practices we actually engage in. Observations ought to play a special role in our accepting and rejecting theories, because they are the statements we do, in fact, accept and come to consensus about. Rules of inference from data to theory, even rules relying on apparently arbitrary classifications of phenomena into chosen "natural kinds" for inductive projection, or rules as seemingly unconnected with "truth" as rules for accepting simpler hypotheses in preference to the less simple, are again reasonable rules because they are but the normative idealizations of the rules for inference we are inclined to accept. Here, of course, the familiar objections about the arbitrariness of our conceptual scheme, the possibility of equally "rational" alternative schemes, and so on, are deflected either by arguments concerning translation (denying the real possibility of alternative conceptual schemes) or by deflationary views about truth and correspondence combined with arguments about the incoherence of even stating (from within a chosen framework) the relativistic thesis.

And of course there are those who think they can have the virtues of both positions (by being "internal realists") or, rather, that properly understood the positions coincide. All, in any case, are agreed about a number of things. While a "soft" distinction between what is observable and what is not may play some role in our epistemology and in our semantics, no hard-and-fast, once-and-for-all, theory-independent distinction of this kind can be drawn. While the data of observation may indeed play a role of some special importance, again in both our understanding of how meaning accrues to our terms and our understanding of how believability accrues to our theories, no special importance of the kind the empiricist attached to the "data of immediate awareness" can be attributed to the role of observation. Observation may be part of the web or network of meaning accrual and belief accrual, and a part with some distinctive virtues, but a *foundation* for meaning and rational belief it is not. For there is no such foundation, and the whole "hierarchical" model of semantics and epistemology that words like *foundation* suggest is a misconstrual of how we get on in science.

2

But one still finds many philosophers of science enamored of the empiricist approach to theories. It is something of a paradox, I suppose, that the empiricist approach to theory seems to be favored most by those philosophers of science who spend their time dealing with the structure of fundamental physical theory. But, on reflection, this is perhaps not so surprising. It is all very well from a general methodological standpoint to tell us that our epistemology and semantical theories, insofar as there can be such things at all, ought to rest upon the "accepted best available scientific theory to date," having in mind, usually, the most contemporary version of fundamental theoretical physics. But it is another matter to look closely at these foundational physical theories and discover how little naive confidence one ought to have in them, and how puzzling the understanding of their fundamental concepts can be. At this point, the idea that the epistemology and semantics of theories itself rests upon the naive acceptance of these fundamental theories becomes disorienting indeed, and one looks for some other access into questions of justification and meaning accrual.

It can be argued, with some plausibility, that empiricist preconceptions are, in fact, "built-in" to many aspects of our most fundamental physical theories. Of course, if this is true it might be true merely because the theories as usually presented are infected with misguided philosophy of science. Could it not be that while the theories, properly understood, do indeed serve as our "best available physical theories to date"—for who in the philosophical community will these days have the courage (or foolhardiness) to refute the conclusions of the physicists by theorizing from his armchair—their empiricist elements are inessential to them? If this were so we could disabuse the philosophers of physics impressed by the apparent empiricist preconceptions of foundational physical theory of the misunderstanding that if they accept these physical theories they must accept elements of empiricism as well.

But to begin exploring this, let me first rehearse some of the foundational physics that does at least appear to many to rest upon empiricist (or, at least, empiricistlike) preconceptions, beginning with theories of space and time.

3

Faced with the null results of the round-trip light experiments designed to determine which inertial reference frame was the ether frame, physics constructed many "compensatory" theories, designed to save the ether frame by "explaining away" the null results as the joint interaction of two compensating changes, the changed velocity of light due to the observer's motion compensated by the effect of motion with respect to the ether on the observer's rods and clocks.

Einstein's revolutionary reinterpretation of the facts that these theories were trying to deal with is justly famous. A new theory is proposed that makes no predictions that would not follow from the "compensatory" theory if its consequences had been fully followed out. But the new theory is, rightly, considered by all a vast improvement over its predictively equivalent but inferior predecessors. And, at least as surface appearances go, the novelty of the new theory rests almost entirely on its empiricistically motivated critique of some of our most familiar concepts. The fundamental move is to focus on our understanding of what it is for two events to be "simultaneous" when they are spatially separated from one another. Since whether or not two such events are simultaneous is not, it is argued, a matter open to our direct observational knowledge, some *inference*, mediated by some causal process, must ground our beliefs about distant simultaneity.

Next Einstein criticizes several approaches to establishing distant simultaneity relations that might have worked but that, in the face of new observational results, cannot. Limitations on the velocity of transmission of causal signals makes it impossible to establish simultaneity by using causal signals of arbitrarily high velocity and so ever narrowing down the transmission time from the emission to the reception of the signal. We might think of using transported clocks to establish distant simultaneity, but the very necessity of the compensatory theory introduced to explain away the null results of the round-trip experiments makes it clear that transported clocks will not even provide a unique specification of the event at a distance simultaneous with a given event. Finally Einstein suggests the famous "radar" method, using reflected light beams and local clocks, to establish simultaneity; and he clearly demonstrates how such a specification of the simultaneity relation will lead to one that gives different pairs of events as simultaneous relative to the state of motion of the agent carrying out the radar stipulation of simultaneity.

The point to be made here is just how strong one empiricist assumption is that is being built-in to this whole critical program. Simultaneity for events at a point and continuity along lightlike paths are taken for granted as "observables" in the Einstein argument. But the empiricism doesn't really rest in any assumption that these relations are themselves immune to a critique that shows them not to be in some sense theoretically untainted "direct observational" features of the world. Rather it is in the assumption that, whatever counts as observational, distant simultaneity is *not* a legitimate observational feature of the world that is the characteristically empiricist move. Without the assumption that simultaneity for spatially separated events is "in principle" unavailable to our direct inspectional access, now and forever, independently of which theoretical framework we pick as the correct one to describe the world, it is hard to see how Einstein's argument ever gets going.

Once this general assumption is made, there are, to be sure, many alternative reconstructions of the relativistic argument that can be formulated. Einstein himself, of course, at least at this stage in his thinking, takes the method for the determination of simultaneity he has proposed as "definitional." It is, according to him here, a *stipulation* on our part that it is events so related by reflected light signals that we will take to be simultaneous. This approach leads to a long development of the school of thought that takes this aspect of the space-time structure (and other aspects as well) to be a matter for "conventional choice" on our part, and to a general line that the underdetermination of full theoretical content by all possible observational data can only lead to skepticism, permissivism, or conventionalism with regard to theoretical truth.

Certainly that is not the only direction in which we could move to reconstruct the epistemology of the situation. A major alternative to such a conventionalist reading of the situation would be any one of the realist approaches to theory that attempts in one way or another to rationalize the selection of the special relativistic space-time against the number of observationally equivalent theories as the "most rationally believable" theory that accounts for the data. Whether the approach be one through the construction of a confirmation theory that assigns differing degrees of "probability" to theories that are observationally indistinguishable, or one that proposes some defensible notion of "inference to the best explanation," or one or another of those approaches that relies upon considerations of simplicity or methodological conservatism to motivate the choice of theory, one is (unless these lead too quickly to a pragmatist rereading of the whole situation) still within the realm of a basically empiricist approach to theoretical belief, so long as the very special role of the observable as "ground" of epistemic access to reasonable belief is held onto. Only if one were to begin to deny the Einsteinian presupposition that a feature of the world like the simultaneity of separated events was truly distinguishable in principle from local simultaneity and continuity along a lightlike path, in being, unlike them, "in principal immune to observational determination," would one begin to reconstruct the selection of special relativity in a fundamentally anti-empiricist way.

A similar characterization of the situation holds when we look at the Einsteinian semantical analysis of distant simultaneity as holds when we explore the epistemological aspects of his critique. Einstein, taking distant simultaneity to be outside the range of observable features, argues that the concept 'simultaneous' must be explicity defined, using only concepts referring to "observables" in order to have meaning within a physical theory. Those skeptical of any hard-and-fast analytic/synthetic distinction among the propositions of physical theory will likely allow for a looser connection between the terms purporting to refer to the unobservables and those referring to the observables. A favorite account is the familiar one in which terms in theories get their meaning from the place they hold in the entire theory so that the meaning to be attributed to a term referring to an unobservable becomes dependent upon the role played by the term in the theory as a whole and upon the global structure of the theory which, as a whole, gives rise to its body of observational consequences.

Here, once again, there will be many options and many consequences of them. If one's theory of meaning accrual for the nonobservational part of the vocabulary is one that results in all theories having the same observational consequences being declared "equivalent" to one another on the basis of the way meaning is acquired by the theoretical vocabulary, one will have an easy time undercutting the threat of skepticism raised by a plethora of observationally equivalent theoretical alternatives. But one will find one's "realism" with regard to theoretical reference slipping out of one's grasp, and the pressure toward some "eliminationist" account of theoretical reference hard to resist. On the other hand a finer-grained notion of theoretical equivalence, perhaps demanding that theories be taken to "say the same thing" only when they both "save the same phenomena" and bear to one another some appropriate structural interrelation at the theoretical level (such as interdefinability of their theoretical terms), will make it easier to remain a realist but will make it harder to solve the epistemic problems raised by underdetermination. Is the special theory of relativity "saying the same thing" as the compensatory ether theories, but in a "descriptively simpler" way; or is it the case, rather, that the theories are quite distinct in "what they say about the world," with, perhaps, special relativity to be preferred as the *true* alternative on the basis of some notion of simplicity as a mark of believability, where simplicity is not merely simplicity of expression?

The main point here is that all of these familiar alternatives are basically in the empiricist mold. A theory of meaning accrual that dismisses the semantic import of the distinction between observables and nonobservables, or one that bases the very notion of meaningfulness on features not related to observation and ostensive definition, is anti-empiricist. But one that places observation terms in a special, "grounding" category, and that tries to understand the accrual of meaning by the other terms in the vocabulary by their connection through theory to the observables (however weakened that connection is taken to be from the rigid demand of explicit definition) is basically an empiricist theory of meaning. And the standard variants on the role of terms like *simultaneous* for separated events in the foundation of special relativity almost all gravitate toward some variant or other of such an empiricist semantic account.

But it is not only in the foundations of the special theory of relativity that we find empiricist epistemological and empiricist semantic assumptions "built-in to" the physical theories themselves. The general theory of relativity, Einstein's second great contribution to modern space-time theories and second great revolution in our conception of space and time, rests in a structure of argumentation that almost exactly parallels his founding of the special theory in a basically empiricist critique of the compensatory ether theories. The problem with the compensatory ether theories is that there are too many of them all equally compatible with the same class of observational data. Special relativity, with its denial of a preferred inertial frame, obviates the need to pick one inertial frame as special. But the same problem infects the theory of gravitation, even Newtonian gravitation. As Maxwell[1] argued in the late nineteenth century, within the Newtonian gravitational theory we could not observationally distinguish a world with no uniform gravitational force from one with a uniform gravitational force everywhere of whatever magnitude you liked. Later researchers exploring the possibility of cosmological models in the Newtonian framework realized that the most common models, of a uniformly filled cosmos in slowing expansion or accelerating contraction, would, in the Newtonian framework, have as comoving observers one distinguished by being inertial while all the others were accelerated. Yet each of the accelerated observers would be unaware of their acceleration since, being due to gravity, it would not be indicated on their acceleration measuring devices attached to their reference frames. Both of these "paradoxical" elements of Newtonian theory of gravitation are due, of course, to the special "universal" nature of gravitational force, which accelerates everything on which it acts to the same degree independently of the constitution of the test object and its size. The result of this special nature of the gravitational force is that within Newtonian theory there will be many possible worlds indistinguishable from one another by any observational test.

It is just this otioseness of theory that Einstein, once again, obviates by the theory of general relativity. Here gravitational force is replaced by the curvature of space-time, with the paths of "free" particles taken to be timelike geodesics in the space-time and the paths of light rays to be null geodesics, where 'free' now means free of all forces other than gravity. Of course this new theory doesn't differ from the Newtonian in just this way. The greatest modification necessary to the Newtonian picture is one that is almost forced on the theorist by relativistic considerations. The net result of the relativistic considerations is a series of plausibility arguments to the effect that in a relativistic context we may expect gravity to have metric effects, revealed by the standard measuring instruments of measuring tapes and clocks, as well as its familiar dynamical effects. These additional observationally determinable results of the presence of gravity are neatly encompassed also in the picture of gravity as curvature of the space-time manifold.

What needs to be emphasized here is the importance for Einstein's arguments of aspects of the empiricist account of our access to the world and to meaningful assertion about it. Again a standard repetoire of features is presupposed open to observational determination: the paths of free particles and of light rays; coincidences among measuring tapes; and the readings of the standardized clocks, which also tick in coincidence when brought to the same place. Much more importantly, there is, in this physical construction, a presupposed standard repetoire of quantities that are taken without question to be in principle, forever, *immune* to observational determination. Were the structure of space-time itself—rather than that which is revealed to us by moving particles, light rays, measuring tapes, and clocks—available to our direct inspection, the whole ground of the plausibility of the Einstein arguments for expecting gravity to reveal itself in nonflat metric aspects of space-time would be severely weakened. And were "the gravitational field strength" itself available to our inspection, rather than the effect of gravity as revealed in motion and in metric measuring instruments, the virtue of general relativity (as opposed to the theories that posit gravity as a field superimposed over an underlying space-time structure), that is, its virtue of replacing a manifold of observationally indistinguishable possibilities by a single space-time model, would vanish.

The pattern of thought here, which consists in characterizing a portion of the consequences of the existing theories as immune in principle from observational determination, of then locating the features of the theory that result in the theory having parameters immune in perpetuity from observational determination, and of then replacing these theories with one with a "thinned-down" ontology less subject to the underdetermination by observation difficulties; exactly parallels the way in which special relativity is introduced as superior to the compensatory ether theories. In both cases an epistemological and semantic critique of already existing theory, founded on presuppositions that at least appear to be empiricist, is at the core of the scientific revolution.

At this point, of course, many alternative options for understanding the epistemology and semantics of the situation can be imagined. Reductionist approaches take the meaning of the theories to be encompassed in their observational consequences, and vitiate the skeptical threat by declaring all of the observationally equivalent alternatives mere alternative expressions of one and the same theory. Anti-reductionists take the theories (general relativity vs. any of the flat-space-time-plus-gravitational-field alternatives) to be inequivalent to each other, relying upon some account of meaning in theory that, one way or another, attributes meaningful content over and above the sum of observational content to the theories. Then they try, again one way or another, to rationalize our theory choice among alternatives observationally indiscriminable from one another—be this by simplicity, methodological conservatism, a priori plausibility of theory, or whatever. But the common empiricist aspects to all these accounts are clear. Some parts of theory are in principle immune from observational determination. If we are to understand the meaning of the parts of theory dealing with the in principle unobservable, it must be by some manner in which understood meaning of the observational part of the theory works upward into the part dealing with the unobservable. And if we are to believe the assertions of the theory dealing with the in principle unobservable, it can only be by an upward motion of confirmation from the observable confirmed by its connection with empirically available experimental result, however such observational results are utilized in some confirmatory scheme.

4

We have looked at two cases, both from space-time theories, in which theories have been "thinned" of some of their concepts and their ontologies "thinned" of posited features of the world on the basis of a semantic and epistemological critique that is fundamentally empiricist in nature. It might be worthwhile looking at at least one case, again from space-time theories, that illustrates the claim that such conceptual and ontological pruning of theories is not a completed task, but one that will undoubtedly result in further critical assaults on current concepts and current ontology as our theory develops.

There is a long-standing program in the philosophy of space-time that advocates the claim that some or all of our space-time features can be "reduced" to causal features of the world. Sometimes it is said that the direction of time is "causally definable." Sometimes the claim is that the space-time metric or the space-time topology is "reducible to causal features of the world." There is not just one program called the "casual theory of space-time," but, rather, a plethora of such programs. And the programs differ from one another in their claims, in their motivations, and in the empirical and philosophical arguments they use to defend their theses. While some of the claims of "reducibility" would like to argue that space-time features of the world "reduce" to causal features in a manner analogous to the way light reduces to electromagnetic radiation or tables reduce to arrays of molecules, other causal reductionist theories bear a closer analogy to the phenomenalist's claim that material objects "reduce" to sense data. The former style of programs relies upon some alleged scientific discovery (or possibility of scientific discovery) that one class of entities of features in the world "is identical to" some other class of entities of features, an identity allegedly established by empirical discovery in science. The latter style of program relies, rather, on a semantic-epistemic critique of theories, in the empiricist vein, similar to the critiques we have discussed above. It is to the latter style of "causal theory of space-time" that I will direct my attention.

We can begin with Robb's attempt,[2] early in this century, to formulate the space-time of special relativity entirely in terms of the single primitive 'after', taken as the relation between events when one is, in relativistic terms, absolutely after the other, i.e., after it and causally connectible to it. Refinements of Robb's approach show us that we can, indeed, define all of the metric features of the space-time of special relativity solely in terms of one event being causally connectible to another. This suggests the possibility of at least some version of a "causal theory of the space-time metric" in the theoretical framework of special relativity.

For reasons I will not go into here I think it implausible to claim that the results of Robb, and of those who have refined his methods, really do show us that within the context of special relativity we really can (or, rather, ought to) define the space-time metric in terms of causal connectibility among events. In any case the program falls apart when one moves from the world of special relativity to the many different space-time worlds allowed by the general theory of relativity. In this broader context, it turns out that there are many space-time worlds whose metric structures differ greatly from one another, but that are exactly alike as far as the causal connectibility relations among the events in the worlds are concerned. These are all the worlds that, although metrically unalike, are related to one another by a so-called conformal isomorphism.

For this reason, in the general relativistic context it is usually the weaker structure of the topology of the space-time, rather than its metric structure, that is alleged to be "causally definable." Here the claim is that the full specification of the causal structure of the space-time is already a full specification of its topological structure. But, again, the issue is not a simple one.

If we take causal connectibility among events as the basic causal structure of the world to which all topological structure of space-time is to be reduced, then we run into a problem blocking this program if we allow as a possible general relativistic world any space-time world consistent with the basic equations of the theory. There are possible space-time worlds that have "pathological" causal structure. An example is a world with a closed timelike loop in it, which is a one-dimensional collection of events, all timelike related to one another, but whose topology is that of the circle rather than the open line. Events in this loop cause later events (in the local sense), but the casual chain ultimately arrives back at the initiating event. Even if we bar such closed timelike lines, weaker causal pathologies are still possible in the form of "almost closed" causal (i.e., timelike or lightlike) one-dimensional paths. A variety of restrictions on such causal pathologies can be imposed, the strongest being the demand for "stable causality," which is the demand that there not be any closed causal paths obtainable by any infinitesimal distortion of the actual space-time structure. For present purposes what is interesting is that if causal pathologies are permitted, then there can be, in violation of our first version of a causal account of space-time topology, worlds that are alike in causal connectibility structure, but that are unalike topologically.

One solution to this dilemma is to insist that causal pathologies not obtain, although it isn't fully clear why one ought to believe that this is necessarily so. A more interesting move is to try to restore the possibility of casual specification for the topology by moving to a richer notion of the causal structure of the space-time. An important result (due to D. Malament[3]) tells us that, if we confine our attention only to the standard manifold topologies usually taken to be the topologies of space-time, then in any world compatible with general relativity the totality of continuous causal paths fully determines the topology of the space-time. That is where the totality of facts as to whether or not two events are connected by some continuous causal path of events or other will not fully fix the topoplogy; the specification of what does or does not constitute a continuous segment of causally connectible events will do the job.

Why is such a result relevant to our pursuit of empiricist presuppositions in physical theories? The relevance is clear when one considers the importance granted to "causal" paths in these results. Why should we *care* whether or not the set of continuous causal (or even merely timelike) paths determines the topology? The set of continuous spacelike paths, for example, also fully fixes the manifold topology. I think exploration into the motivation behind this version of a "causal" theory of space-time topology reveals to us the presupposition that it is continuity along timelike paths that is the revelation to us by observational means of the topological structure of the space-time. Continuity along timelike paths is available to us because timelike paths are the kinds of paths we as observers, or idealized pointlike versions of us, can traverse, and they are, therefore, the kinds of paths whose continuity we can "observationally" determine. The presupposition here is similar to Einstein's presupposition in his critique of distant simultaneity, that we are entitled to assume that we can determine the selfsame identity through time of the light signal sent, reflected, and received, to determine which event at a distance is simultaneous with a given local event. From this perspective the so-called causal theory of space-time topology seems misnamed. It is rather an epistemologically motivated critical examination, just like those that founded special and general relativity, but now into the components of the newer theories, once again looking for the "hard observational facts" underlying the meaning accrual of the terms in the theory and the warrant accrual of the propositions. But in this case any relevant "thinning down" of theoretical concepts and theoretical ontology remains in the future. For we do not yet have the theory that would replace the full space-time theory in the event our critique showed it to be still otiose from the point of this empiricist-critical examination.

That the theory still is otiose in this way seems to be indicated by some additional facts about topology. The results we have discussed above tell us that, so long as we stick to one of the usual manifold topologies presupposed by general relativity, the totality of information about what constitutes continuous timelike (or timelike and lightlike, i.e., causal) paths in the space-time fully fixes the topology of the space-time. But there are many other possible topologies than these usual manifold topologies. Typical alternative topologies of mathematical interest are the "finest topologies compatible with the continuity along causal curves" generated by taking as a basis of open sets in the space-time all those sets of points (i.e., event locations) whose openness is compatible with the continuity specifications along the causal world lines. Since the specification of the basis of open sets in a space fully determines its topology, this specifies a new kind of topology for the general relativistic space-times. Such topologies, in certain interesting ways, "code" the causal structure of the space-time more naturally than the usual manifold topologies.

But such topologies also lead us to talk of the topology of the space-time in a radically different way from our usual description of it in terms of the standard manifold topologies. What are we to make of these novel topologies? The situation seems familiar on reflection. Once again it seems as though we have a variety of theoretical accounts of the space-time of the world from which we must select an accepted theoretical account. Once again we have the intuition that our full body of possible observational data, now taken to be all the facts about continuity along causal (or, perhaps, epistemically traversable) paths, is insufficient to do the selection for us. Once again the usual thoughts arise. Shouldn't we say that the alternative topologies, all of which agree on continuity along causal paths, are all "equivalent" to one another, presenting merely alternative *descriptions* of one and the same world? Or, rather, should we maintain that these topologies present genuinely alternative pictures of the world, and that we must seek for some methodological rule (simplicity, conservatism, a priori plausibility, or what have you) to tell us which of these empirically equivalent, but not fully equivalent, accounts of the structure of the world is the most reasonable to believe? Or should we just despair as skeptics of ever knowing the true structure of the world? Or advocate one or another version of permissive conventionality?

It will be interesting to await further developments in the physical theory of space-time. It seems clear that we cannot assure ourselves that the kind of critical "thinning" of ontology that Einstein gave us in the discovery of the special and general theories of relativity has reached its climax. One cannot foretell what future physics will look like, but it seems clear that we can expect this critically motivated endeavor to continue.

5

One further case might be useful to illustrate the point being made here, since it, unlike the others, is not drawn from the physics of space and time.

The early history of quantum mechanics is a familiar story. Working from quite different perspectives Heisenberg (attempting to turn traditional Fourier analysis into a kind of "two-dimensional Fourier analysis" in order to predict intensities of spectral lines, known to be coded by two parameters instead of the traditional one parameter specifying harmonic level) and Schrödinger (looking for an equation whose solution would be the de Broglie wave posited by the latter as being dual to all particle motions in analogy with the Planck-Einstein wave-particle duality of light) both invented theories that were able to predict the same quantities, the energy levels of electrons in atoms undisturbed and disturbed, frequencies and intensities of spectral lines, etc. Astonishingly the predictions were numerically identical despite the apparently radically different nature of the two theories.

The situation was finally clarified when Schrödinger, in a justly famous paper, showed the "equivalence" of the two theories, by demonstrating a structural relation between them that guaranteed identity for their "observational predictions." Later theorists, in the so familiar manner, found ways of expressing the common features of the two theories in a more abstract format, which relinquished some of the aspects of the two approaches where their apparent differences lay. And physicists from that time on spoke of the "Heisenberg representation" and the "Schrödinger representation" of quantum mechanics. Both "representations" assign mathematical structures to systems "prepared" by appropriate experimental procedures. Both "representations" assign distinct mathematical structures to quantities we wish to observe by some measuring experiment. Both compute the theories' "outcomes," now taken to be "possible values" of the observable to be measured and assignments of probability distributions over the set of such possible outcomes, by combining their mathematical structures for prepared "states" and selected "observables" in appropriate ways. And both predict the same possible outcomes for any observable; and, for a given preparation, a given time interval, and a given dynamic intervention into the system in question over that time interval, predict the same probability distribution over those observable values. Where they differ, fundamentally, is that the Schrödinger picture puts the changes over time into a mathematical evolution of the representative for the prepared state, and the Heisenberg picture puts it into a mathematical evolution over time of the representative of the measured observable.

For our purposes the structural similarities with the space-time cases are clear. In order for this understanding of quantum mechanics to go through, there must be firm agreement that certain quantities, the mathematical representatives of prepared states and of observables, be taken to be, in principle, not quantities open to observational determination. Otherwise we could not be assured that mere commonality of probability distributions over observable values, or such commonality plus the appropriate isomorphism at the theoretical level, would be enough for us to declare the two accounts mere "representational variants" of one another. It is our assurance that "states themselves" cannot ever be an object of "direct observational determination," which makes us reject the claim someone might make that Schrödinger and Heisenberg don't "say the same thing," because in the Schrödinger picture states change and in the Heisenberg picture they don't; and that we might "someday be able to 'look and see' which really occurs." And beginning with this assurance that some aspects of the theoretical structure are, in principle, immune from observational determination, we continue with the familiar program of "thinning out" the theoretical structure to get rid of the otiose elements that make alternative representations give the false appearance of offering alternative theories of the world.

6

All of these cases have, then, a series of common elements. First there is an intuitively accepted distinction between what is observable and what is nonobservable, which is taken to be a distinction "in principle" and one relative to which a critical semantic and epistemological attitude toward the existing theoretical structure is necessary. This requires not an intuitive agreement of what are to count, now and forever, as the true "observables," relative to which the theory can be tested, but, rather, an agreement that some features spoken of by the theories are, now and forever, in principle *unobservable*. It requires, that is, some assurance that we will never be able to bring "direct observation," however we understand that phrase, to bear on determining what goes on with regard to some specific quantities putatively posited of the world by the existing theoretical structure.

Next there is the awareness that a multiplicity of theories talking about such putative unobservable structures of the world, and saying incompatible things about it, will agree on the remaining facts derivable from them. That is, that there are many apparently distinct theories, all of whose distinctness is "trapped" in the realm taken as being that of in principle unobservability.

Finally there is the program of reconstructing the existing theory in a novel way that will, in response to this problem of the underdetermination of theory by evidential data, look for some new alternative account that is at least less infected with undeterminable features, features posited but characterized by some class of parameters whose values can't be fixed by observational determination, than were the existing theories that are now realized to be so infected.

It is interesting to reflect a bit on some of the reasons why it is fundamental physics that seems to attract this continuing program of semantic-epistemic critique. One reason, surely, is that the striking and unexpected facts revealed to us by the ever-increasing power of experimental observation are frequently so startling in their nature as to require some radical revision or other of our concepts and our hypotheses. Faced with the null results of the round-trip experiments that experimentally ground the special theory of relativity, or the manifold of puzzling and anomalous results that led to quantum mechanics, the scientific community is faced with the realization that something quite radical must be done to make our physical theory accord with the observational facts. In the face of such a need for radical revision of one sort or another, it is not too surprising that at least some insightful thinkers are impelled to reexamine the presupposed fundamental concepts and hypotheses of the most familiarly accepted background theories to see if something in them must be challenged. In the face of extraordinary puzzles with the data, the comforting admonition to rely upon "general accepted background science" in a conservative way seems less than persuasive as the most fruitful way to go about things. It is in circumstances like these that the empiricistically motivated doctrine of looking at the earlier theories, to see to what degree the "hard facts" really impelled us to accept them, becomes a promising scientific strategy.

The fact that the novel hypotheses introduced to account for the novel data are themselves so radical in nature also cries out for a semantic-epistemic appraisal of them. Special relativity introduces space-time, with its denial of an absolute simultaneity relation, to replace our traditional notion of space through time. General relativity introduces pseudo-Riemannian curved space-time to replace traditional flat space-time and traditional gravitation as a field within space-time. Quantum theory introduces the novel notions of the state function and the observables to replace the traditional notion of a state as a point in classical phase space.

But how are we to understand these novel concepts and hypotheses? And why ought we to believe in the hypotheses that utilize them? Here the very novelty of the conceptual structure seems to demand of those introducing them that something substantial be done to explain to the scientific community how the concepts and the hypotheses in which they appear are to be understood (i.e., what meaning is to be attributed to them) and how they are related to possible observational data in ways appropriate to allow the data available to us to provide observational tests of the truth of the new hypotheses. We cannot take such questions for granted, as understood, or as built-in to previous scientific practice in well-understood ways, when such radically new conceptual structures are being proposed. Even "analogy" with older concepts and hypotheses, the sort of thing that works when we explain molecules, say, as "like tiny billiard balls too small to see," fails us in contexts like these. Instead, a radical appraisal of how these new concepts and the hypotheses in which they appear are related to possibilities of evidential experience seems to be what is in order; and this is just the sort of appraisal the importance of which is the core of the empiricist program in philosophy.

Another feature that tends to give rise to such semantic-epistemic critical appraisals in these foundational physical contexts is the ability of these problem situations to realize in concrete form a familiar philosophical puzzle. Since Descartes and Hume we have been concerned, as philosophers, with alternative hypotheses to our familiar ones that "save the same phenomena." Descartes introduces perpetual dreams and malevolent demons. Hume tells us to consider the fact that our belief in the continuity of phenomena when we are not perceptually aware of them is grounded more on imaginative projection than any counsel of reason. But the alternatives to our usual world scheme proposed by such philosophers are usually taken to be puzzles, rather than seriously alternative hypotheses about the nature of the world. We take it, as philosophers, that our job is to refute the skeptical threat such imaginative alternative world views suggest, but that we ought not to seriously consider that the world might really be so radically different from the way we usually take it to be. Witness the pragmatist distinction between real doubts and the "mere" skeptical doubts of the philosophers, or Hume's admission that, no matter how seriously we will think with the learned in our philosophical studies, we will always act with the vulgar in the world.

But in the context of foundational physics we seem to have presented for our epistemic appraisal radically different alternative world views. They are fully filled out in all detail, unlike the mere sketches offered by the philosophers. And nothing initially seems to tell us that only one of these alternative world hypotheses is worth serious consideration, the others to be taken even as hypotheses for consideration only with a grain of salt. All of the underdetermined alternatives seem, at least initially, on a par as genuine scientific alternatives, and it is no surprise that, in this context of *genuine* scientific indecision, a reappraisal of how observational data is to relate to scientific belief seems in order.

Finally we ought to note that there are special features of the particular foundational theories we have been dealing with that also play a role in suggesting that, in our scientific search for new hypotheses, semantic-epistemic critical appraisal is in order. The postulation of space itself, or space-time itself, as a theoretically inferred structure of the world, has always been one that has been treated with skeptical doubt. Witness the skepticism toward Newton's "space itself" from Leibniz through Berkeley to Mach. Both the peculiarity of "space" as an "entity" over and above the ordinary material inhabitants of the world, and such special problems as those suggested by Leibniz in his use of the principle of the identity of indiscernibles to criticize the postulation of a space, all of whose infinity of points were indistinguishable by anything in their own nature from one another, have led many to be all along skeptical of the legitimacy of positing space itself as one more inferred theoretical structure in the world. For this reason scientists and philosophers are "primed" in the kinds of situations of scientific revolution described above to be receptive to empiricistically minded semantic-epistemic critiques that throw doubts on the way in which such theoretical concepts have been used without sufficient questioning in the past.

A similar situation holds in quantum mechanics. The theory itself arises, at least in part and from the Heisenbergian point of view, out of a despair with the prospects of reconciling some traditional theoretical notions (the usual notions of definite trajectories for the subatomic charged particles and the usual rules associating such motions with detectable emitted radiation) with the rules governing the observables discovered in experiment. From the very beginnings of the theory, there is a tendency to avoid premature commitment to some definitive theoretical structure and to look for some calculational system that will predict the right correlations among observables without saying too much about explanatory theoretical structures that might account for these correlations. Heisenberg, at least, is quite self-consciously "positivistic" in his motivations behind the discovery of matrix mechanics.

Later the manifest peculiarities of the theoretical structures introduced in the developed quantum mechanical formalism, peculiarities such as the instantaneous change of the state vector upon measurement in a manner totally unaccountable in the rules for its dynamic evolution in ordinary processes, or the peculiar nature of quantum states as introducing probabilistic correlations for events at spacelike separation that cannot be accounted for in any straightforward way in terms of previously fixed local parametric hidden variables, again lead to a skepticism, based on the special nature of this particular physical theory, with regard to taking its apparent theoretical posits in an uncritical manner. Once again an empiricist injunction to "see what the hard data actually forces upon us" will be welcomed in the context in which an already critical and skeptical attitude to the apparently posited theoretical structure has been forced upon us by its intrinsic peculiarities.

7

The considerations we have gone through indicate, then, that at the level of foundational physical theories, and especially when these theories are subject to the severe difficulties encountered when they are radically in conflict with the observational data, a skeptical attitude with regard to the meaning of some of the fundamental concepts and a skeptical attitude with regard to the warrant with which fundamental hypotheses had previously been supported, become not the idle speculations of the philosopher but integral parts of the ongoing process by which our most important and most general theories of the world are refined and, if necessary, replaced.

That doubts about the intelligibility of concepts or about the warrant that really accrues to hypotheses will cause one to reflect on "what the hard data of observation really provides us" seems inevitable. It is in precisely such conditions of instability of fundamental theory that are incipiently revolutionary that the consoling advice of the pragmatist to rely upon "what we have previously practiced" or of the realist to rely on "what our best available science tells us about the world" seem out of place. It is just such notions as "what we have practiced" and "what our theories have told us" that are in doubt in these contexts. It is when a scientific "form of life" has proven to be a failed form, by that most important of test of success in scientific life—the ability to correctly predict the data of observation, that the sense of a need for a radical exploration into the grounds by which we have taken meaning to accrue to our theoretical concepts and warrant to accrue to our theoretical hypotheses is intuitively felt to be called for. And it is in just these circumstances that the resort to "what we really have available to us from observational experience" naturally arises as the touchstone on which such a critique of existing concepts and hypotheses is to be grounded.

Can the notion of "what the data provides us" be understood here in a pragmatist or realist vein? I think not. For the pragmatist, the distinction between what is observable and what is not is a fluid one. Most pragmatist accounts will rely on some notion of spontaneous communal agreement to pick out some body of sentences quickly assented to by the population in general in a stimulus situation to fix on what, if anything, can be called observational assertions. From this point of view, what would be to the empiricist inferred propositions (but inferred on the basis of inference licenses so deeply rooted as to result in unconscious and spontaneous inference) would, to the pragmatist, count as assertions just as fully observational as those the empricist takes to be truly based on observation alone. But examination of such features of the physical critique we have been exploring as Einstein's critique of our universally held idea that we knew what we were talking about when we spoke of events "being at the same time," and that we meant the same thing by this for spatially separated as for coincident events, shows us that the notion of observability (or, again, more importantly, nonobservability) that the physicist has in mind in these critiques is not the merely psychological feature of spontaneity of judgment that the pragmatist has in mind.

Nor, I think, does what the "realist" tells us about the observational/nonobservational distinction do full justice to the critical context we have been exploring. From the realist perspective, "what is observable" is a matter for our best available science, including psychology, neurophysiology, etc., to determine for us. But in the critical contexts of physics, where distant simultaneity is rejected as an observable simply because it is not a local notion; where the gravitational field magnitude is rejected as an observable because it is not by itself expressed in the motions of bodies or light rays or in the readings of metrical measuring instruments; where the spacelike continuity of lines is rejected as observable because of its "in principle nonsurveyability;" and where the state vector itself of quantum mechanics is rejected as observable because its values are not the values of what is taken, in the theory, as a primitive, undefined notion of the results of measurement processes; there seems to be an at least quasi a priori element presupposed in the characterization of where to draw the line between that which at least might be characterized as directly observable and that which certainly can not so be characterized.

Once this characterization is drawn, of course, then "what the theories themselves tell us about the world" does, indeed, become essential to the critical program. If we take local relations among events and continuity along paths traversable by an "observer" as the full body of observational data relevant to a determination of the topology of space-time, for example, then it is indeed our "best available theory," relativity, that tells us that some paths, the spacelike ones, posited in our theory are "out of bounds" when it comes to critically examining the semantic and epistemological basis on which our account of the world's topology rests. For given this scientific theory as true, paths of that kind are not so traversable. But the restriction to local data as the only data available to an observer in the first place, the core of what gets the critical program going, is not a consequence of our "best available physical theory" in any reasonable sense, but is presupposed by us on some other basis.

The immediate inspiration for the semantic-epistemological critique of existing theory is invariably the discovery that, in the light of one's presuppositions, certain facts are in principle immune from direct observational determination, in the light of novel observational facts, and in the light of the realization that novel theoretical options are available to us, it turns out that our theoretical structure of the world is, in its current form, apparently radically underdetermined by the data. Too many theories we take to be inequivalent to one another all seem equally good in the face of all possible observational results: too many ether theories, once the null results of the Michelson-Morley experiment are in; too many gravitational theories, once some version of the principle of equivalence is established; too many space-time topologies, once it is realized that a variety can be made compatible with all topological facts along traversable paths; too many versions of the dynamics of quantum states compatible with the probability distributions among the values of observables that are the outcomes of the theoretical manipulation.

It is in the face of this newly realized problem of underdetermination (or, in some cases, in a reawakened interest in an underdetermination problem that had existed for a long time but had been swept under the rug) that the critical examination of our access to theoretical meaning and our warrant for theoretical assertion is undertaken. And it is in these contexts that the suggestion is inevitably made that the most reasonable response is to thin out our theoretical conceptual structure, eliminating some apparent theoretical reference and some putative theoretical assertion, in order to arrive at a "cleaner" version of theory less subject to the infection of undeterminable theoretical parameters and underdetermination of the theory by data in general.

Need such empiricistically motivated semantic-epistemic criticism of existing theory always lead us down a slippery slope to an ultimately positivist view of the world, where all theoretical reference is taken as at best instrumental in nature, with the only real reference being reference to some fixed basis of "directly, immediately observational sensory contents"? It just isn't clear. For we don't yet really understand enough about how such empiricist critique from within an ongoing context of realistic science is supposed to work. Much depends upon how we ultimately resolve crucial questions about meaning accrual and warrant accrual.

Consider, for example, the "realist" view with regard to theories that, while starting from the empiricistic critical position we have been exploring, holds that the end of such criticism is not some phenomenalistic eliminativist program of taking all observationally equivalent theories to "say the same thing;" but is, instead, the selection of a preferred theory from the set of all the phenomenally equivalent alternatives, or, rather, from all those alternatives presently under consideration whose disagreements with one another are, we are sure, trapped at the nonobservational level.

Special relativity, the argument frequently goes, is preferred to the alternative ether theories since it, unlike them, does not introduce absolute velocity as an undeterminable parameter. It is preferred on the basis of ontological and conceptual parsimony or simplicity. But it is still a realistic theory positing "space-time itself" as an explanatory structure. The "inertial frames" of space-time remain as "not directly observable," but as the reference frames relative to which acceleration shows up in mechanical effects (inertial forces) and optical effects (non-null results for round-trip experiments, for example). But special relativity is to be preferred also, it is alleged, to the mere set of its observational consequences taken as a theory. For that latter "theory," unlike the special theory with its theoretical space-time structure, fails to offer genuine *explanations* of the observable phenomena.

An almost identical stance can be taken with regard to general relativity as opposed to any of the flat-space-time-plus-gravitational-field alternatives to it with the same observational consequences. Here again it can be argued that general relativity is preferrable to its theoretical alternatives on grounds of conceptual and ontological parsimony and in not having, as the other theories do, an intrinsically undeterminable parameter at the theoretical level. And, again, it can be argued that it is superior to its purely phenomenal alternative in that it still offers an explanatory account of the observational facts.

Such a realist approach is still basically empiricist in its structure. It is now a variant, not of the kind of eliminative empricism that results in phenomenalism, but of the realist empiricisms that, while taking observation as the starting point for meaning and warrant accrual, allow for the possibility of semantic principles that allow for the legitimation of meaning attribution (of a not merely instrumentalist or representationalist sort) to terms going beyond reference to the observable, and for the possibility of epistemic principles legitimizing warrant accrual to hypotheses whose content outruns the observable and correlations among its particular contents.

What seems clear, however, is that realist and pragmatist accounts of meaning and warrant will not do full justice to the semantic-epistemological situation in these cases where it is the most general and fundamental background theories of our scientific world view, and the most entrenched of our scientific communal linguistic and inferential practices, that are up for questioning. At least some of the ingredients of an empiricist approach are called for here: a rather rigid and theory-independent notion of what is in principle immune from direct observational determination, a scrutiny of meaningfulness for theoretical concepts rooted in an examination of how they relate to what is available to us in direct experience, and a critical scrutiny of the warrant by which we have held our theoretical hypotheses, again rooted in an exploration of the extent to which they can be held to account by the observational data or by that data in combination with some inferential rules that are themselves "above" the standards of justification provided by resort to "what our present science tell us" or "what is entrenched in our present scientific practice."

This kind of empiricism-as-critique, practiced in the context of an ongoing *refinement* of the existing theories in our background science, would seem to require that we always be in a state of readiness to rethink the grounds of meaningfulness for our theoretical concepts, the grounds for positing our theoretical ontology, and the grounds for accepting our most basic and pervasive theoretical hypothesis from what is, essentially, an empiricist perspective. This is not an empiricism that tells us that we can find some theoryless observational language to which all of our theoretical assertions can be reduced by translation. For, at least on its surface, it neither requires for its critical stance belief in the accessibility of some once-and-for-all-time "detheorized" observational language as basis, nor a belief in the reducibility or translatability, once and for all time, of all the theoretical discourse we have or will encounter into such a pretheoretical observation language.

The kind of empiricism that seems to be called for by the essential role played by semantic and epistemic critique in foundational physical theory does require that we take a "hierarchical" attitude toward our concepts and hypotheses, giving those "closer to the pure observable" primary status in the work of meaning accrual and the accrual of warrant for belief. The reader will, perhaps, be reminded in this context of some of C.I. Lewis's attitudes toward the "given" as a kind of inexpressible limit ideal and of Popper's remarks in *The Logic of Scientific Discovery* on the "conventionality" of what at any time is taken as the level that counts for theoretical purposes as the level of "observation." What would be called for to make this sense of empiricism more plausible as a viable account of our scientific method would be to accompany this attempted demonstration of the way in which such a critical empiricist attitude is presupposed, and, indeed, "built-in" to our contemporary foundational physics, with some extended understanding of how such a critical empiricism differs from more traditional "bottom-up" foundational empiricism and how, when all of the consequences of the critical empiricism are thought through, it can avoid the familiar difficulties with that more traditional empiricism that drove away so many of its sympathizers to the alternative pragmatist or realist perspectives.

Notes

1. J. Maxwell, *Matter and Motion* (New York: Dover, 1954), 85.

2. A. Robb, *A Theory of Time and Space* (Cambridge: Cambridge University Press, 1914); and *The Absolute Relations of Time and Space* (Cambridge: Cambridge University Press, 1921).

3. D. Malament, "The Class of Continuous Timelike Curves Determines the Topology of Spacetime," *Journal of Mathematical Physics* 18(1977): 1399–1404, esp. p. 1401, Theorem 2.