Up and Down, Left and Right, Past and Future

LAWRENCE SKLAR

THE UNIVERSITY OF MICHIGAN

i

Few philosophical theses match the dramatic impact and striking illumination of Boltzmann's brilliant speculation about the reducibility of the intuitive notion of the direction of time to features of the world characterizable in terms of the theory of order and disorder summarized in the notion of entropy. Taking the progression of isolated systems toward states of highest entropy, characterized phenomenologically by the second law of thermodynamics, and given a far deeper explanation in his own theory of the statistical mechanics of irreversible processes, Boltzmann suggested that rather than viewing these theories as merely describing the asymmetric change of the world from past to future, we should find in them the very basis of our concept of the distinction between the past and future directions of time.

Building on Boltzmann's rather sketchy remarks, Reichenbach, in what many consider to be his most distinguished contribution to the philosophy of physics, elaborated for us a highly complex and subtle account of the entropic theory of time order. Yet despite Reichenbach's very impressive efforts, and the further illuminating work of others who have followed him such as Grünbaum, Watanabe, Costa de Beauregard and others, the claim that the very notion of temporal asymmetry reduces to that of the asymmetry of entropic processes in time remains, to say the least, controversial. To some it seems obviously true in broad outline, whatever details still need filling in. To many others the very idea of the program seems *prima facie* absurd.

While much remains to be done on the "physical" side of this issue, in the way of providing for us a single coherent physical account of the source of entropic asymmetry, and in the way of definitively characterizing the physical connection of this asymetry with the other fundamental temporal asymmetries of the world such as the outward

radiation condition and the cosmic expansion, I believe that some insight into the roots of the persistent controversy can also be obtained by an attempt to become a little clearer concerning some philosophical aspects of the question about which we are yet not as clear as we might be. In particular, I think we need to be far clearer than we have been on the question of in just what sense the entropic theory is claiming that the very meaning of assertions about the direction of time are "reducible" to assertions about entropic processes. At least two fundamentally different notions of meaning reduction are available to us, and I think that confusion about just which sense the entropic theorist has in mind has served to cloud the issues in a significant way.

As a means of access into this problem I would like to make some comparisons between three different asymmetries in the world: that between the upward and downward directions of space, that between left- and right-oriented systems and that between the past and future directions of time. I think that exploring the analogies and disanalogies between these three cases of "asymmetry" may make it clearer to us just what the entropic theorist is really claiming. While I don't believe that the insights we gain will resolve the question as to whether or not the entropic theorist is *right*, perhaps we will be a little clearer about just what both he and his opponent have a right to claim as evidence for and against the reductionist position.

ii

We have a concept of the left-right distinction; and more, individual concepts of left- and right-oriented systems. We can properly identify left (right) handed objects; train others to do so; communicate meaningfully using the terms ("Bring me the left-handed golf clubs"), etc.

Now there may be physical phenomena described by laws which are not left-right symmetric. Current physical theory postulates that this is so, as is revealed in the familiar examples of the parity non-conservation of weak interactions; although whether this will remain the case at the level of the "most fundamental" laws remains an open question. Certainly there are many phenomena in the world which are non-mirror-image symmetric in a *de facto* rather than lawlike way, e.g. the preponderance of dextrose over levulose, etc. But do any of these asymmetries of the world in orientation have anything to do with what we *mean* by left and right? Is there any plausible sense in which the orientation concepts "reduce" to concepts of a not *prima facie* spatial orientation sort?

Most of us think not. Of course it is the case that if we wish to teach the meaning of, say, 'left' to someone, without transporting to him a particular left-oriented object, we would need to do so by means of one

of the familiar features of the world lawlike or *de facto* associated with orientation ("Left is the orientation in which . . ."). Even then, as we know, there are the difficulties which reside in assuming that the association where he is the same as that where we are (What if he lives in a anti-matter world and CP invariance holds? What if there is more levulose than dextrose on his planet?). And, of course, if one is taking the (dubious) line that a mirror-image possible world would be the same possible world as the actual one, one would have to assume that in this mirror-image world the mirror laws and *de facto* correlations hold to make the Leibnizian argument (qualitative similarity implying possible world identity) go through. But none of this is sufficient to in any way back up the claim that left handedness just is, or that 'left' just means, some relation (term) expressible in terms of not *prima facie* orientation concepts.

Suppose, for example, that some fairly substantial miracles occurred in this world. All of a sudden electron emission from spinning nuclei begins occurring with the dominant emission in the opposite direction from the present preferential axial direction. Would we then say that the clockwise direction had become the counter-clockwise? That right-handed gloves had suddenly become left-handed? Nothing of the sort. We would indeed be astonished and look desperately for some explanation of this mirror reversal of a law. But we would, I believe, still take it that we could recognize left- and right-handed objects as before, teach the meanings of orientation terms by ostention, as before, etc.

We believe that orientation is just a basic geometric property of an oriented system. It is epistemically available to us in as direct a manner as is any geometric feature of the world. The meanings of our orientation terms are fixed for us by ostention of particular oriented objects and our facility for abstracting the right property intended by the teacher. Nothing about weak interactions is relevant here in any way. It is merely an empirical discovery of a lawlike correlation that takes place when we discover that as a matter of fact weak interactions take place in an orientation discriminating way. Were we to live in a universe in which as a matter of law, or merely as a matter of pervasive facts, all red objects were square and all square objects red, this alone would hardly be grounds for saying that redness was squareness nor that 'red' meant 'square'.

Of course our notions of handedness are complicated by reflections on the facts about dimensionality and global orientability which have been frequently pointed out. Prior to realizing the possibility that space might have a fourth spatial dimension and might be globally non-orientable we fail to notice the distinction between the partition of handed objects into two disjoint classes relative to their

being constrained to the subspace in which they are imbedded and the local region of that subspace, and the global distinction which would be well defined only if the subspace exhausts the full dimensionality of space and only if that space is orientable. Under the impact of this new awareness we may want to distinguish full handedness from what I have previously called local 3-handedness. (See [1].) And we may wish to say that the intuitive concept we had all along was the latter rather than the former. But none of this additional complication, I believe, vitiates the point here that the facts about what non-orientability features of the world are lawlike or *de facto* associated with handedness are irrelevant to a conceptual analysis of what we meant all along by handedness attributions.

iii

Considerations like those above might lead us by analogy to make the parallel remarks about entropy increase and the future direction of time. Isn't the case just like that of weak interactions: we discover a pervasive correlation in the world, this time one whose status while not lawlike is not easily thought of as merely *de facto* either. But why should this in any way lead us to think that the very concept of futurity reduces in any sense to that of entropic increase?

But Wittgenstein has warned us against the deficiency diseases caused by an unbalanced diet of analogies and we would be well advised before making a hasty judgment to look at another case which may be viewed as providing an analogy supportive of just the opposite view about time and entropy.

The suitable dietary supplement is provided for us in Boltzmann's elegant if sketchy presentation of his position in the *Lectures on Gas Theory*:

> One can think of the world as a mechanical system of an enormously large number of constituents, and of an immensely long period of time, so that the dimensions of that part containing our own "fixed stars" are minute compared to the extension of the universe; and times that we call eons are likewise minute compared to such a period. Then in the universe, which is in thermal equilibrium throughout and therefore dead, there will occur here and there relatively small regions of the same size as our galaxy (we call them single worlds) which, during the relatively short time of eons, fluctuate noticably from thermal equilibrium, and indeed the state probability in such cases will be equally likely to increase or decrease. For the universe, the two directions of time are indistinguishable, *just as in space there is no up and down. However, just as at a particular place on the earth's surface we call "down" the direction toward the center of the earth, so will a living being in a particular time interval of such a single world distinguish the direction of time toward the less probable state from the opposite direction (the former toward the past, the latter toward the future).* ([1]: 446-7)

The italics are mine.

Past and future, then, are to be viewed like up and down, and the progression toward higher entropy states like the direction of the gradient of the gravitational field (the obvious generalization of the direction of the center of the earth). It is well worth our time then to ask what we do and should say about the relationship of up and down to directions characterized in terms of gravitation and to ask for the grounds of the position we do take. We must then ask whether things are just that way with past and future and temporal directions picked out by entropic features of the world.

iv

We have a pre-scientific, pre-philosophical understanding of the distinction between the upward and downward direction of space. We can communicate with these concepts since they are teachable and suitable for an intersubjective language. We could teach the concept to someone either by an ostention which relies on observation of the behavior of objects (by and large they move, when unsupported, in the downward direction) or by reliance of our internal "sense" of the downward direction, using our sense of this direction to pick it out and then ostending it to another who can then identify it again by his own internal "sense" of down. Naively we view it as a global notion, in the sense that parallel transport of a downward pointing vector keeps it downward pointing.

But then we discover gravitation. We come to understand that it is the local direction of the gradient of the gravitational field (on the surface of the earth, the local direction of the center of the earth) which "picks out" at any point the downward direction. "Picks out," though, in a deep sense. It isn't just that the local gradient happens to point down, nor even that the local direction of the gravitational gradient points downward as a matter of lawlike necessity. Rather it is the reference to the local behavior of the gradient of gravity offers a full and complete account of all those phenomena which we initially used to determine what we meant by the downward direction in the first place.

Understanding gravity we understand why, in general, objects fall downward. We even know, understanding gravity and a few other things as well, why helium balloons, flames, etc. don't. A complete, coherent and total explanation of all the phenomena we associated with the notion of 'down', associated in the sense of used to fix the very meaning, or at least reference, of 'down' is provided for us by the theory of gravitation.

We even know (although only vaguely to be sure) why it is that we can pick out the downward direction by an "internal" sensation; why it

is that we can know which way is down without ever observing an external falling object. The explanation has to do with the forces, once again gravitationally explained, exerted on the fluid of the inner ear. A demonstration of this and a full account is presumably a matter of some complexity, but we can rely on inference from the behavior of simpler creatures. There are fish with sacks in their bodies with sand in the sack. Remove the sand and replace it with iron fillings. Place a magnet over the fish tank and the fish swim upside down. Surely it is something like that with us. In any case we don't doubt but that the ultimate physiological account of our inner apperception of down will refer ultimately to the effect of gravitational forces on some appropriate component of a bodily organ.

How should we describe appropriately the relationship between 'down' and 'the direction of the gradient of the gravitational field'? I am not looking here for the ideal description in our ideally worked out semantico-metaphysics, but rather for the sorts of things we are, initially, intuitively inclined to say.

It wouldn't be strong enough to say that the downward direction is the direction of the gravitational gradient, for that would be true were it merely a happenstance that down and the direction of the gradient coincided. We feel, rather, that the downward direction is "constituted" (whatever that means) by the direction of the gradient. Perhaps the correct locution is: Down (the downward relation itself) *is* (is identical to) the relation between points constituted by one's being deeper in the gravitational potential than the other. We *identify* the relation of *a*'s being downward with respect to *b* with *a*'s having a lower gravitational potential than *b*. (It is more complicated than that, of course, since *b* could be very remote from *a* in which case we wouldn't talk that way if there were, for example, intervening regions of higher potential, but I am deliberately going to oversimplify grossly here.) Put this way the "reduction" of the up-down to the gravitational relationship bears close analogy with substantival identifications as a means of theoretical reduction (water is H_2O, light waves are electromagnetic waves). But it is a property (relation) identification rather than one of substances.

I think that some would want to go further, arguing that the the reduction established is sufficient to allow us to say that the very *meaning* of 'down' is given by the appropriate characterization of a relation in terms of the gravitational gradient. Now meaning is a notion as yet sufficiently unconstrained by a real theory as to allow us, with some plausibility, to say any one of a number of different things. Emphasizing the connection of meaning with criteria of applicability (verification procedures, operational definitions, etc.) we would be inclined to say that although 'down' doesn't (or at least didn't) *mean* 'the direction of the gravitational gradient,' what was empirically dis-

covered was that the downward relation was the relation gravitationally described. From this point of view there is a change of meaning which has taken place when scientists, now fully aware of the gravitational account of the up-down phenomena, begin to simply use 'down' to mean the local direction of the gradient of the gravitational field.

Emphasizing, on the other hand, the association of meaning with reference, in the manner of some recent semantic claims about proper names and natural kind terms, we might, instead, be inclined to say things like: "'Down' meant, all along, the local direction of the gravitational gradient." Of course it is still a discovery on our part that gravity plays the explanatory role it does. From this point of view we might even be tempted to say that prior to the full understanding of the gravitational explanation of up-down phenomena, people simply didn't understand what they meant by 'down'. And one will, of course, now begin to claim that it is a necessary truth that the downward direction is that of the gravitational gradient, allowing into one's scheme the now familiar necessary *a posteriori* propositions which result from such a "referentialist" semantics. (Cf. [4].) I do not wish to discuss any of the arguments for or against such a view of meaning here, but only to emphasize, once again, that insofar as a reduction of the up-down relationship to one characterized in terms of the gravitational gradient is plausible at all, it is a reduction which bears very striking analogies to the reductions by means of substantival identification so familiar to us in other cases of intertheoretic reduction. It bears an even closer resemblance to such property identifications as the familiar (if abused) example of philosophers "Temperature just is (is identical to) mean kinetic energy of molecules." Oversimplified as that claim may be, the essence of what it is getting at is surely correct. "Down just is (is identical to) the direction of the gravitational gradient" seems a claim of the same order and, if anything, probably in need of fewer qualifications and reservations than are required in the thermodynamics-to-statistical mechanics case.

It is important to emphasize at this point the kind of reduction which the one in question certainly is not. Perhaps no one would ever, in this context, make the kind of mistake I am warning against here, but I believe that in the context of the problem of the direction of time just such a confusion of kinds of reduction has played some role in muddying the waters. In saying that up-down reduced to the gravitational gradient relation we are not making a claim based upon a notion of priority of epistemic access. Such a claim is familiar to us in the claims that material object statements "reduce" to sense-datum statements, spatio-temporal metric statements "reduce" to statements about the local congruence of material measuring instruments, etc. In the present case, unlike the ones just cited, there is no claim that our epistemic

access to the up-down relationship is mediated through any sort of "direct awareness" of the gravitational relationship; nor that some kind of hierarchy of epistemic immediacy tells us that up-down statements are, while initially thought of as inferred from gravitational statements, actually translatable into logical complexes of the gravitational type statements. Instead the claim is just that the up-down relationship is found, by empirical research, to be identical with a more fundamental relationship characterizable in terms of the gravitational field. Down is the direction of the gravitational gradient as water is H_2O, light electromagnetic radiation and temperature mean kinetic energy. Not as tables are logical constructs out of sense data nor as non-local congruences are logical constructs out of spatio-temporally transported rods and clocks.

It will be useful at this point to say a little about one further aspect of the reduction of up-down to that of the gravitational gradient. Prior to understanding the gravitational nature of down we intuitively viewed the downward direction in a global way: at every point the downward direction was parallel to the downward direction at every other point. (Of course this description of the situation is something of a travesty of the way in which the conceptual change occurred slowly over time. Aristarchus was well aware of the spherical nature of the earth and probably quite cognizant of the fact that down at Thebes was not parallel to down at Athens.) Recognizing the gravitational nature of the up-down relation we now realize clearly that what is down for us will most certainly not be parallel to what is down for someone at a different point on the earth's surface. We even understand that at some points of space there really won't be any downward direction at all.

Of course many ways are open to us to describe this. We can, if we wish, take 'down' to mean the direction of the gravitational gradient at the place we are located, identifying the downward direction elsewhere as the direction at that point parallel to our down. From that point of view Australians do, indeed, live their lives out upside down. We might, to eliminate confusion introduce a non-denumerable infinity of subscripted "downs", 'down_P' referring to the downward direction at the point referred to by the subscript. Then Australians live upside-down_{USA} but, of course, right-side-up_{AUST}. Alternatively, and more elegantly, we can simply take 'down' as having an unequivocal meaning but as functioning in the manner of a token-reflexive, at least to the extent that:

(1) what is referred to as the downward direction by a speaker at one place is the direction of the gravitational gradient at that place;

(2) what is referred to as downward by a speaker at another place is the direction of the gravitational gradient at that place;
(3) and there is no reason whatever for thinking *a priori* that the referents of the two utterances of 'down' will be the same.

From this point of view, there is a clear sense in which the *sense* of 'down' is the same for all speakers at all places.

v

I think it is clear that the entropic theory of temporal direction, if it is to be plausible at all, should be viewed as a "scientific" reduction motivated by an empirical discovery of a property (relation) identification, and not as an instance of the "philosophical" reductions motivated in terms of a critical analysis of the modes of epistemic access to the world available to us. Perhaps this is obvious to many. But it hasn't always been obvious to me, and at least some others have been misled. The following quote, for example, is, perhaps, indicative of this confusion of modes of reduction. I think it is appropriate here, even though it refers to a causal theory of the direction of time, since, after all, the theory has been for many years an entropic theory of temporal direction rather than a causal theory.

It is sometimes suggested that the direction of time and causation are linked because the direction of time is itself to be analysed in terms of causation. But, at least as *conceptual analysis*, this must be wrong. We can think of events' succeeding one another in time even if there are no causal links between any of them, let alone between the members of each pair of which one is earlier than the other. Moreover, *our concept of the direction of time is based on a pretty simple, immediate, experiences of one event's following straight after another*, or of a process going on—say of something's moving—with a later phase following an earlier one. It might be, of course, that our having such experiences is somehow dependent upon causally asymmetrical processes going on inside us—we might have internally causally controlled unconscious temporal direction indicators—but even if this were so it would not mean that our concept of time direction was analysable into that of causal direction.

> *Our expereince of earlier and later, on which our concept of time direction is based, itself remain primitive*, even if it has some unknown causal source. ([5]: 1)

The italics are mine. (For other expressions of skepticism about the entropic theory see [2] and [8]: 404-11. Most important, see [3]: ch. 5, "Becoming.")

But if the entropic theorist has in mind reduction of the "scientific" kind, then nothing in the way of immediate, simple experience of earlier and later events, or ongoing processes, nor any reference to an ability to imagine (think of) events being temporally ordered without being entropically related will refute the claim, meant in this sense, that the later-than relation is (is identical to) some relation characterized in terms of entropy, nor even that, in the senses of meaning we noted above, in some sense 'later than' *means* 'bears some appropriate entropically characterisable relation to'.

Since the two notions of concept reduction I have been discriminating are easily confused in general, it isn't too much of a surprise that we have not always been clear which sense of reduction is intended by the entropic theory of temporal direction. But I think that some of the very arguments used by entropic theorists have tended to ingrain the confusion. For example entropic theorists frequently ask us to consider how we would distinguish a film of events run in the proper order from the film run in reverse order, pointing out to us that the discrimination can only be done (or, rather, so it is claimed) when entropic features of the world are present, and that it is by means of the expected dissipation of order into disorder that we make the judgment about whether the film is being run in the correct direction. If this is meant only to show us that the entropic features of the world are, at least, the most prominent which are asymmetric in time order and, hence, the prime candidates for a reduction of the scientific kind, then it is harmless. But it is easy to slip from this argument into the dubious claim that we judge time order of events in the actual world by inference from apprehension of ordering of states in respect to entropy. As Mackie and others have pointed out, this is indeed dubious. But the dubiousness of that latter claim is an argument only against the "philosophical" theory of the reduction of time order to entropy. In no way would it vitiate a reductive claim of the "scientific" kind.

Again consider Reichenbach's transition from a causal to an entropic direction. If what is being said there is that the only relevant causal notion is causal connectibility, that this is temporally symmetric, and hence not a suitable candidate for a reduction basis for the relation of temporal order, then it is a point relevant to reductions of the identificatory kind. But it is easy to read the argument as saying that the causal theory won't do because we must be able to empirically *determine* which of a causally connected pair of events is cause and which effect in order to make the reduction go through, and that this determination requires first *knowing* the time order of events, and that this makes

causation unsuitable as a reduction basis for temporal direction because it lacks the necessary epistemic independence and primacy. But this latter argument, once again, suggests that it is the epistemically motivated kind of reduction which the theorist has in mind. If he then offers an entropic theory as the substitute for the causal, one is misled into thinking that the theory too is an attempted reduction of the "philosophical" sort.

There is also the fact that Reichenbach presents the entropic theory as part of a general reductivist account of spacetime. Entropy is to fix one last part of spacetime structure, the past-future distinction, after the rest of spacetime, in particular its topology, including its temporal topology, has already been "reduced" to non-*prima-facie* spatiotemporal notions. In particular, the spacetime topology is supposed to be reduced to the *causal* structure of the world.

Now I think that a kind of "scientific" identificatory reduction of spacetime topology to causal order could be argued for. For example the recent suggestions of reducing spacetime structure to some kind of algebraic relationship among quantum events might be viewed as a reductionist move of this kind. But I think that the causal theory of spacetime topology which Reichenbach offers is, rather, motivated by, and formulated in terms more appropriate to, an epistemically generated type of "philosophical" reduction. If this is correct we can see why one would easily be misled into thinking that the entropic account of time direction was also supposed to be a reduction of this latter kind. (On the causal theory of spacetime topology as an instance of philosophical reduction see [9].)

vi

But if the entropic theory of the direction of time is supposed to be a scientific reduction we must ask whether or not it is successful. Is the connection of entropy with time order like that of asymmetric weak interaction processes with left and right, merely a correlation (lawlike or *de facto*), or is the case rather like that of gravitation and up and down, where we feel it is at least appropriate to say that the up-down relation is identical to the gravitationally characterized relation, and where we are even tempted (at least on some theories of meaning) to say that 'down' means 'in the direction of the gradient of the gravitational field'?

That question I hardly intend to try and answer here. What is needed is a full-fledged attempt to try and account for all the processes we normally (pre-scientifically) take to mark out the direction of time, including our internal "direct" sense of temporal order, in terms of a single, unified account which invokes the relation of difference in

entropy and accounts for all these phenomena in terms of an identification of the time order relationship with some relationship among events characterizable (at least in part as we shall see) in entropic terms, and which does not invoke time order itself as a primitive in the characterization. Despite Reichenbach's heroic efforts in this direction, I think we can all agree that such an account is not yet available to us. (See [6].) But, of course, Reichenbach's efforts, from this point of view of the nature of the entropic theory, are at least efforts in the right direction. We must explain, entropically, why causes precede their effects (at least usually); why we have records of the past and not the future; why we know and believe so much more about the past than the future, and believe and know about them in such very different ways; why we feel we can change the future but not the past; why we have such a different emotional attitude toward the future than we do to the past ("Thank God that's over!"); why we take the past to have determinate reality and the future to exist, if at all, merely as "pure potentiality"; and, finally, why we have direct, immediate, non-inferential knowledge of the time order of events (internal and external) with which we are directly acquainted (in Russell's sense).

While many of Reichenbach's arguments in these directions are brilliantly imaginative and suggestive, I do not believe that I will be taken to be disrespectful if I assert here that they are, to many of us, far from conclusive. They serve as brilliant suggestions toward a theory, but the theory we will ultimately be given by the entropist as highly confirmative of his reductive claim is still in the future. Here I wish only to make a few rather general remarks about the entropic program, some of the difficulties it faces, and why at least some suggested objections to it are not really devastating to its aim.

(1) At least part of the problem in trying to establish the entropic theory is the rather vague grasp we have on many of the notions to be accounted for entropically in the reduction. Compare asking: "What is a causal relation?" "What is a record or trace of an event?", etc. with asking "What is a falling object?" In the gravitational theory of down at least we have, prior to the reduction, a pretty good idea of what it is that the gravitational theory must account for. In the entropic theory of time direction we don't have a very clear idea at all. Of course, it may very well be claimed by the entropic theorist that it is only in the context of the reduction that our ideas of what it is that must be accounted for will become clear. I think that Reichenbach has this in mind. For example, only when we understand the role played by entropic features of the world in our pre-scientific conceptual scheme will we really begin to understand our pre-analytically felt, but very

poorly understood, intuition that causal efficacy proceeds from past to present and thence to future.

(2) I have deliberately avoided any attempt at saying exactly what relationship among events, characterized entropically, is the one to which the 'later than' relationship is to be identified. It is clear that this identification will be one of some sublety. In the case of the up-down relationship the identification is fairly simple minded. If *b* is downward from *a* then there is a gravitational potential difference between them determined by the value of the potential at the two points. That plus some facts about the gravitational potential at intermediate points is enough to fix the appropriate "gravitational" relationship in our reduction basis.

But the temporal asymmetry case is trickier. First of all there is the fact that a later state of even an isolated system can very well be one of lower entropy than an earlier state. We must take account of the fact that the association of entropy order with time order is supposed to be only statistical. Second, there is the fact that we take the time ordering relationship to be more pervasive than that of entropic order, in the sense that there can be a later-than relationship holding between events where no obvious characterization of the events as states of affairs of a system with different entropy is at all possible.

Now one solution to this would be to postulate the existence of a "time potential" with a gradient in the timelike direction, making the time order case look far more like the up-down case than even I have maintained it to be. This is Weingard's suggestion in a recent article ([11]). I think this is the wrong way to go. I don't deny that in some possible world that is how things could turn out to be, with the existence of such a time-ordering vector field as a "real physical field" whose existence is ultimately explanatory of the familiar asymmetries of the world in time. It is just that we have no reason whatever to believe that in this world there is any such field. The usual statistical mechanical explanations of the asymmetric behavior of systems in time invoke no such fundamental field. Granted we frequently do find the statistical mechanical explanations unsatisfying, and many have the feeling that at the present state of our understanding some matters of fundamental importance have yet to be uncovered. But few physicists would presently accept as a plausible explanation the existence of such a fundamental time-ordering field as the underlying "missing link" in attempting to offer a full explanation of the asymmetry of the world in time. If the theory of time direction is supposed to be a scientifically established identificatory reduction of the later-than relation to some other more

fundamental relation, then it must be established by the real science of the world as it actually is. A possible reduction which would be satisfactory in some possible, but non-actual world, is of no help to us.

Nor need we invoke such a pseudo-field in order to have an adequate account. One direction in which to move is again available to us in Reichenbach. The whole entropic theory presupposes an underlying theory of time order—the full topology of time (or spacetime)—with the only intuitive feature removed being that of the past-future asymmetry. Of nearby pairs of pairs of events (nearby to avoid the possibility of non-temporally-orientable spacetimes) we can ask if d is in the same time direction from c as b is from a. If we can then establish the "laterness" of, say, b to a on the basis of entropic considerations, we can "project" this time order onto the c-d pair, taking d as later than c, even if none of the relevant entropic considerations appear in the c-d case. Actually, of course, the detailed theory might be much more complicated than that, making reference, possibly, to multitudes of systems and where entropies can be assigned to temporally distinct states of isolated systems, to entropic difference "parallel" for the overwhelming majority of them. Then the past-future time direction is taken as being fixed by this majority of systems, lower entropy states being earlier than higher entropy states, and thence "projected" by by local comparability of time order to all pairs of temporally related events. For our present purposes the details are inessential.

(3)What I have suggested above suggests an approach to the entropic account which offers a "definition" for time direction in terms of the entropic behavior of branch systems, in Reichenbach's terminology. (See [6]: 118-43.) I might say something here about the relevance of the branch system notion to the overall account. With what entropic feature of the world do we wish to identify the time direction? Not if Boltzmann's overall approach is correct, the entropic relationship between states of the universe as a whole (assuming that such a notion as entropy for the universe as a whole is well defined, a powerful and dubious assumption). More plausible would be an identification of the later-than relation at a placetime with the appropriate entropic relation among the states of the "single world" during the "eon" containing the placetime. This, indeed, might be the right direction for the entropic theorist to go, rather than that outlined above.

Why need we invoke the branch systems of Reichenbach? If we were holding to an epistemically motivated "philosophical"

reduction, the answer would be obvious. We have, certainly, no epistemic access of a direct sort to the total entropy even of our "single world." But, perhaps, we do to local temporarily isolated systems. So we observe them, and the entropic relationships among their states, and "infer" time order from these relationships. The reduction then consists in replacing this "inference" with a "coordinative definition" in the familiar way.

But I have been maintaining that it is not this kind of reduction which the entropic theorist is really after. What then is the role of branch systems and their entropically characterizable states? I think it is that in our explanations of the various phenomena characteristic of the asymmetry of the world in time intuitively associated with the time order of the world in our pre-scientific picture, the branch systems and their states will have to be invoked. Even if ultimately in the explanation of these asymmetries we refer to the entropic behavior of our "single world" during its present "eon", the explanation will invoke at an intermediate stage some account of how this entropic asymmetry gives rise to the entropic asymmetries of the branch systems, and will then use these "small" entropic asymmetries to account for the familiar asymmetries of causation, knowledge, traces, etc. and to account for our immediate internal sense of the time order of our own experiences.

Whether the entropic theorist will then want to identify the later-than relationship with a relationship entropically characterized among the total states of the "single world" or, instead, with some complex "majority rule" relationship among states of sets of branch systems I do not know. I think we would need more detail about the nature of the entropic theory to decide this. Or, perhaps, he has a choice and there is an element of arbitrariness in the identification he asserts.

(4) We saw that in the gravitational reduction of the concept of up and down to that of the direction of the gravitational gradient, it was no argument against the account at all that at different places in space the downward direction could vary. The same holds true with the entropic theory of time direction. Whether or not Boltzmann is right that there are at a given time "single worlds" with their time orders oppositely directed, or a single "single world" which at different "eons" has its time order in the reverse direction, this is certainly a possible state of affairs on the entropic account. And nothing about this state of affairs makes the entropic theory in any way less plausible.

> Once again we have a choice of at least two ways of describing the situation. We can take the future direction of time as fixed by the entropic relations among states of our "single world" in our "eon" and speak of entropy as going the "wrong way" in time in the counter directed worlds. Or, less parochially, we could take the past-future relationship to be quasi-indexical, letting 'future' refer to that direction in time at a spacetime point which is the direction bearing the appropriate entropic feature in that "single world" during that "eon". None of this is incompatible with the earlier remarks that the entropic theorist might wish to use *local* comparability of time order to project the past-future relationship from some system in his "single world" to others. (The arguments here are in reply to an argument of Earman's, especially to his invocation of what he calls the Principle of Precedence. See [2]; 21-3.)

vii

At this point my already very sketchy and somewhat vague paper is going to become even less the presentation of a polished, finished account. For I am here going to suggest that, at a new level, some of the standard objections to the entropic account may reappear, even if that account is interpreted in its most plausible form as an account of a "scientific" identificatory reduction.

At some point the reductive programs of the naturalistic sort which proceed by identificatory reductions of substances and properties to those more "scientifically" fundamental, and the reductive programs of the philosophical sort which proceed by "conceptual analysis" of propositions in terms of a critical examination of the total class of propositions which could serve as epistemic warrant for them, must be reconciled. One could, of course, reject the latter kind of reductionism altogether as spurious but I don't think that we can do this without at the same time rejecting some of the deepest and most well accepted portions of our recent scientific progress; for, I would allege, much of the transition from space and time to relativistic spacetime proceeds by just such an epistemically motivated "reductionist" critique. I won't argue this here, but only try to show how one aspect of "scientific" reductions introduces, in the particular case of the entropic account of the direction of time, some special difficulties closely related to the problem of working together these two kinds of reductive analysis.

A familiar concommitant of identificatory reductions is the "secondarizing" of properties. Tables are arrays of atoms. But what about the "immediately sensed" properties of macroscopic tables? Are they properties of arrays of atoms? Arrays of atoms are, in some sense,

discontinuous; but what of the sensed, continuous color patch that a table presents to my awareness? One solution (maybe not the only and maybe not the best) is to remove properties from the table (except for leaving a residuum of them as powers or dispositions) and reclassify them as secondary qualities of sense-data or, perhaps, of the sensing perceiver (who is appeared to reddishly, etc.)

Temperature is mean kinetic energy of molecules. But what of the felt quality we first used to discriminate hotter from colder objects? Easy, make it a secondary quality "in the mind" of the perceiver. Whenever we propose an identificatory reduction of some entity or property, initially identified by us by a "direct apprehension," to some other entities or properties in the world, there is at least the temptation to strip off from the object the original identifying feature and place it "in the mind" as a secondary quality related to the reducing property in the world only as the causal effect of that property's acting, by means of the sensory apparatus, on the "mind", I'm not saying that this is the only direction in which to go nor that it is the right one; only that it is a persistent, common move and one intuitively hard to resist. (See [10].)

Now we take the later-than relation to be a relation in the world characterizable in entropic terms. But what of the "pretty simple, immediate, experience of one event's following straight after another?" Our temptation is, I think, once again to dissociate the immediately sensed, directly apprehended, "later-than-ness" of events from the time order of events in the world, making it into a feature only of events "in the mind."

But now we see why many who would easily accept the claim that tables are, in fact, arrays of atoms, and that temperature is, in fact, mean kinetic energy of molecules, will balk at the claim that later-than-ness is an entropically characterizable relation among events in the world. We feel that time order is something that holds of events in the world and the events of inner experience as well. Since Kant we have been familiar with the claim that space is the manifold of experience of outer objects and time of both inner and outer awareness. But it is the same time which relates outer events and which relates events "in the mind." And if outer events are later than one another, are they not later than one another in exactly the same sense that inner experience occur in the asymmetric order of time? And if I directly experience this order among events in my inner mental life, musn't I identify that relation with the real later-than relation among events in the world? If these events in the world are also related by some relation entropically characterizable musn't that be viewed as an empirically established correlation with time order then? And isn't it then true that there is no more plausibility in identifying the later-than relation with the entropic relation than there is in identifying left-handedness with some feature

of an object characterized in terms of the behavior of weak interactions?

Notice the difference here from the gravitational case. Our inner experiences are not, really, up and down from one another. No harm then in disassociating our inner experience of down from the real down-ness relation in the world and then identifying the latter with a relation characterized in terms of the gradient of the gravitational potential. But inner events are *really* later and earlier than one another and our "pretty simple, immediate experience" of this relation cannot with impunity be detached as merely a causally induced secondary quality not properly thought of as a direct experience of the real afterness relation which exists in the world only as an entropically characterizable relation.

The following quote from Eddington suggests that it is something like this argument which is at the root of many of the strongly felt but not very well expressed objections to the plausibility of the entropic theory. It is important to note that this quote is from one of the earliest expositors of the entropic theory of time direction as I have described it.

> In any attempt to bridge the domains of experience belonging to the spiritual and physical sides of our nature, Time occupies the key position. I have already referred to its dual entry into our consciousness—through the sense organs which relate it to the other entities of the physical world, and directly through a kind of private door into the mind . . . Whilst the physicist would generally say that the matter of this familiar table is *really* a curvature of space, and its color is really electromagnetic wavelength, I do not think he would say that the familiar moving on of time is *really* an entropy-gradient. . . . Our trouble is that we have to associate two things, both of which we more or less understand, and, so as we understand them, they are utterly different. It is absurd to pretend that we are in ignorance of the nature of organization in the external world in the same way that we are ignorant of the intrinsic nature of potential. It is absurd to pretend that we have no justifiable conception of "becoming" in the external world. That dynamic quality—that significance which makes a development from future to past farcical—has to do much more than pull a trigger of a nerve. It is so welded into our consciousness that a moving on of time is a condition of consciousness. We have direct insight into "becoming" which sweeps aside all symbolic knowledge as on an inferior plane. If I grasp the notion of existence because I myself exist, I grasp the notion of becoming because I myself become. It is the innermost Ego of all which *is* and *becomes*. ([3]: 91-7)

I don't pretend to understand all the Eddington is saying here, nor to be able to give a really coherent version of my own arguments above. I do think, however, that it is very clear that our ultimate view of the world will require a subtle and careful weaving together of the naturalistic reduction of science which proceeds by theoretical identification

with the conceptual reduction of philosophy which proceeds by epistemic analysis. Until we have such a systematic overall account I think that the ultimate status of an entropic theory of time order will be in doubt.[1]

REFERENCES

[1] L. Boltzmann, *Lectures on Gas Theory 1896-1898*, Trans. by S. Brush (Berkeley: University of California Press, 1964).
[2] J. Earman, "An Attempt to Add a Little Direction to 'The Problem of the Direction of Time,'" *Philosophy of Science* 41(1974), 15-47.
[3] A. Eddington, *The Nature of the Physical World* (Cambridge: Cambridge University Press, 1928).
[4] S. Kripke, "Naming and Necessity" in D. Davidson and G. Harmon, eds., *Semantics of Natural Language* (Dordrecht: Reidel, 1972), pp. 253-355.
[5] J. Mackie, "Causal Asymmetry in Concept and Reality," unpublished paper presented at the 1977 Oberlin Colloquium in Philosophy.
[6] H. Reichenbach, *The Direction of Time* (Berkeley: University of California Press, 1956).
[7] Lawrence Sklar, "Incongruous Counterparts, Intrinsic Features and the Substantiviality of Space," *Journal of Philosophy* 71(1974), 277-90.
[8] ———, *Space, Time, and Spacetime* (Berkeley: University of California Press, 1974)
[9] ———, "What Might Be Right About the Causal Theory of Time," *Synthese* 35(1977), 155-71.
[10] ———, "Types of Inter-Theoretic Reduction," *British Jiurnal for The Philosophy of Science* 18(1967), 122-3.
[11] R. Weingard, "Space-Time and The Direction of Time," *Nöus* 11(1977), 119-32.

NOTES

[1]Work on this paper was supported in part by a research grant from the National Science Foundation. Grant no. SOC 76-22334.