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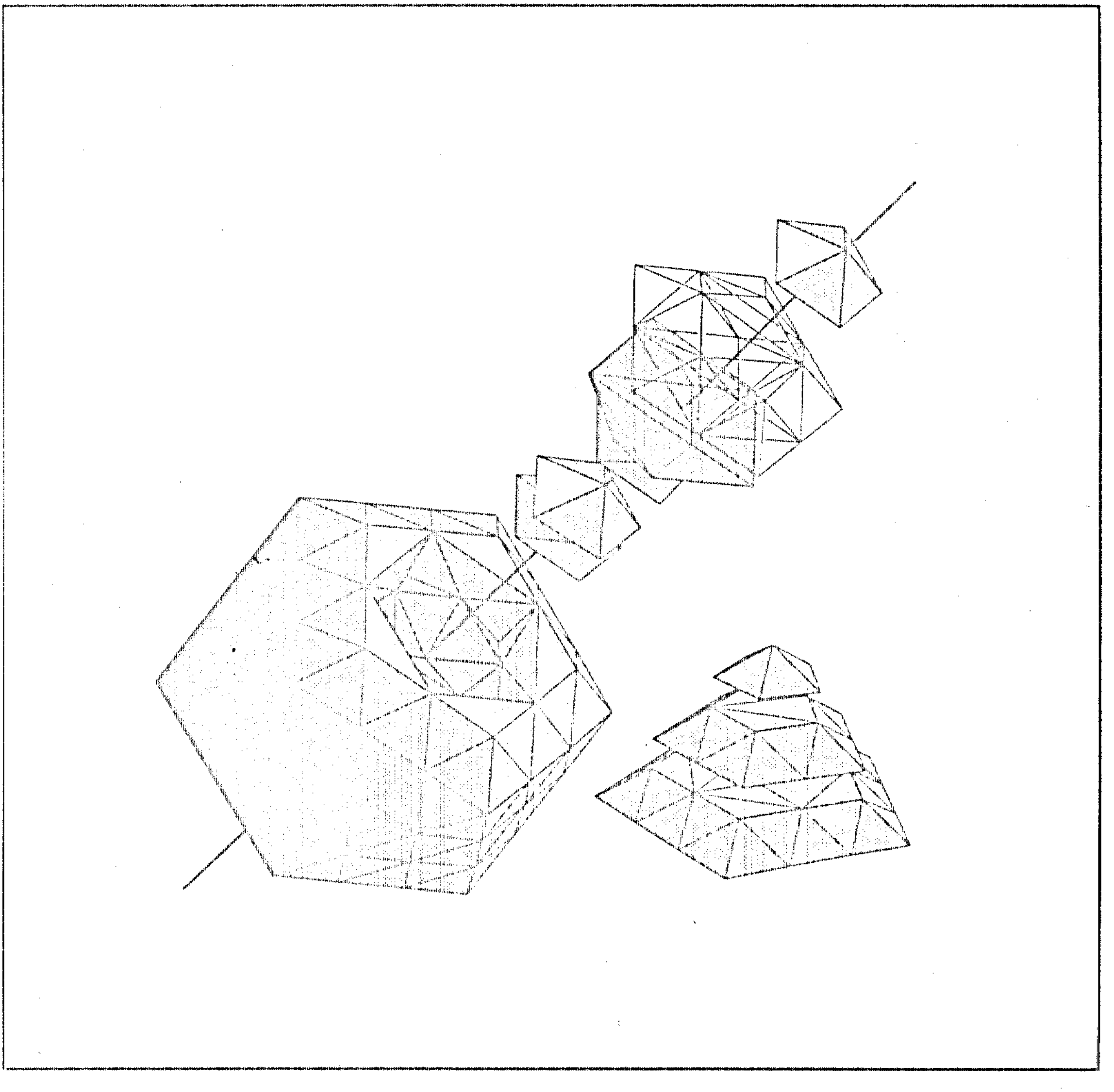

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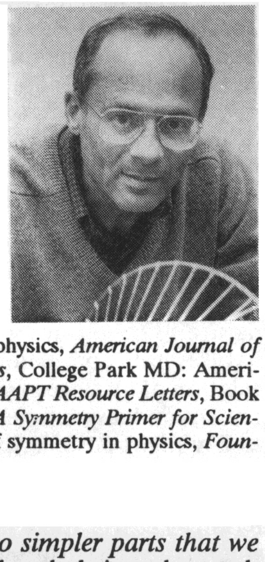
SYMMETRY: SCIENCE & CULTURE

REDUCTION AS SYMMETRY

Joe Rosen



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Science operates by reduction, whereby we separate nature into simpler parts that we attempt to understand individually under the assumption that the whole is understandable as the sum of its parts. Reduction implies symmetry, according to the conceptual formulation of symmetry as immunity to a possible change. That is so because, if a part of nature can be understood individually, then it exhibits order and law regardless of what is going on in the rest of nature, which is immunity (of aspects of that part of nature) to possible changes (in the rest of nature). Three ways science commonly reduces nature – observer and observed, quasi-isolated system and surroundings, and initial state and law of evolution – are considered and the symmetry implied by each is examined.

1. REDUCTION

For the purpose of our discussion we take *nature* to mean *the material universe with which we can, or can conceivably, interact.* The material universe is everything having a purely material character. To interact with something is to act upon it and be acted upon by it. That implies the possibility of performing observations and measurements on it and of receiving data from it, which is what we are actually interested in. To be able conceivably to interact means that, although we might not be able to interact at present, interaction is not precluded by any principle known to us and is considered attainable through further technological research and development. Thus nature, as the material universe with which we can, or can conceivably, interact, is everything of purely material character that we can, or can conceivably, observe and measure.

That is my own conception of nature. If your conception is different from mine, please set it aside for the time being, as the following discussion is based on the definition of nature just presented.

We live in nature, observe it, and are intrigued. We try to understand nature in order both to improve our lives by better satisfying our material needs and desires and to satisfy our curiosity. And what we observe in nature is a complex of phenomena, including ourselves, where we are related to all of nature, as is implied by our definition of nature as the material universe with which *we can, or can conceivably, interact*. This possibility of interaction is what relates us to all of nature and, due to the mutuality of interaction and of the relation it brings about, relates all of nature to us. It then follows that all aspects and phenomena of nature are actually interrelated, whether they appear to be so or not; whether they are interrelated independently of us or not, they are certainly interrelated through our mediation. Thus all of nature, including *Homo sapiens*, is interrelated and integrated.

Science is our attempt to understand the reproducible and predictable aspects of nature. But how are we to grasp this wholeness, this integrity? When we approach nature in its completeness, it appears so awesomely complicated, due to the interrelation of all its aspects and phenomena, that it might seem utterly beyond hope to understand anything about it at all. True, some obvious simplicity stands out, such as day-night periodicity, the annual cycle of the seasons, and the fact that fire consumes. And subtler simplicity can be discerned, such as the term of pregnancy, the relation between clouds and rain, and that between the tide and the phase of the moon. Yet, on the whole, complexity seems to be the norm, and even simplicity, when considered in more detail, reveals wealths of complexity. But, again due to nature's unity, any attempt to analyze nature into simpler component parts cannot but leave something out of the picture.

Holism is the world view that nature can be understood only in its wholeness or not at all. And that includes human beings as part of nature. As long as nature is not yet understood, there is no reason *a priori* to consider any aspect or phenomenon of it as being intrinsically more or less important than any other. Thus it is not meaningful to pick out some part of nature as being more 'worthy' of investigation than other parts. Neither is it meaningful, according to the holist position, to investigate an aspect or phenomenon of nature as if it were isolated from the rest of nature. The result of such an effort would not reflect the normal behavior of that aspect or phenomenon, since in reality it is not isolated at all, but is interrelated with all of nature, including ourselves.

On the other hand lies the world view called *reductionism*, which is that nature is indeed understandable as the sum of its parts. According to the reductionist position nature should be studied by analysis, should be 'chopped up' (mostly conceptually, of course) into simpler component parts that can be individually understood. (By 'parts' we do not necessarily mean actual physical parts; the term might be used metaphorically. An example of that is presented in section 5.) A successful analysis should then be followed by synthesis, whereby the understanding of the parts is used to help attain understanding of larger parts compounded of understood parts. If necessary, that should then be followed by further synthesis, further compounding of the compound parts to obtain even larger parts and attaining understanding of the latter with the help of the understanding achieved so far. And so on to the understanding of ever larger parts, until we reach an understanding of all of nature.

Now, each of the poles of holism and reductionism has a valid point to make. Nature is certainly interrelated and integrated, at least in principle, and we should not lose sight of this fact. But if we hold fast to extreme holism, everything will seem so fearsomely complicated that it is doubtful if we will be able to do much science. Separating nature into parts seems to be the only way to search for simplicity within nature's complexity. But a position of extreme reductionism might also not allow much science progress, since nature might not be as amenable to reduction as this position claims. So science is forced to the pragmatic mode of operating as *if* reductionism were valid and adhering to that for as long as it works. But it should be kept in mind that the inherent integrity of nature can raise its head at any time and indeed does so. The most well known aspect of nature's irreducibility is nature's quantum character (Davies and Brown, 1986; Davies 1980).

2. SYMMETRY

Symmetry at its most fundamental is the possibility of making a change that leaves some aspect of the situation unchanged, or, most succinctly, *symmetry is immunity to a possible change* (Rosen, 1990a, 1990b). This is the conceptual formulation of symmetry. It might also be called the qualitative formulation of symmetry, in contrast to the group-theoretical formulation, which might be called the quantitative formulation of symmetry. The latter is expressed in terms of transformations (or operations), transformation groups, equivalence relations, equivalence classes, symmetry transformations (or symmetry operations), and symmetry groups, and can be developed from the conceptual formulation (Rosen, 1983). For the description and treatment of many derivative applications of symmetry in science the group-theoretical formulation is the appropriate one. But for the account of the fundamental manifestations of symmetry in science it is the conceptual formulation that is the more suitable (Rosen, 1990b).

As an example of symmetry, consider a uniform metal plate in the shape of an equilateral triangle. There are many changes that might be imposed on this system, and among the possible changes there are those that indeed leave some aspect of the system unchanged. For example, rotating the triangle by 120° or 240° about its center within its plane is a change, but does not affect the appearance or macroscopic physical properties of the system. Thus the piece of metal of this example possesses symmetry under these rotations with respect to appearance and macroscopic physical properties. If the metal were not uniform or the triangle were not equilateral or had a corner chopped off, the system would not possess this symmetry. It must be emphasized that there are aspects of the system that are *not* left unchanged by these rotations. For example, molecular positions are certainly altered.

Reduction in science, the separation of nature into parts that can be individually understood, implies symmetry. The point is that if a reduction separates out a part that can be understood individually, then that part exhibits order and law regardless of what is going on in the rest of nature. In other words, that part possesses aspects that are immune to possible changes in the rest of nature. And that is symmetry, by the conceptual formulation of symmetry presented above. It is then possible to make a change (in the rest of nature) that leaves some aspect of the situation (some aspect of that part of nature) unchanged.

Reduction of nature can be carried out in many different ways. As the old saying goes, there's more than one way to slice a salami. We will now consider three ways reduction is commonly applied in science, three ways that nature is commonly 'sliced up,' and will examine the symmetry implied by each.

3. OBSERVER AND OBSERVED

The most common way of reducing nature is to separate it into two parts: the *observer* - us - and the *observed* - the rest of nature. This reduction is so obvious that it is often overlooked. It is so obvious because in doing science we *must* observe nature to find out what is going on and what needs to be understood. Now what is happening is this: Observation is interaction, so we and the rest of nature are in interaction, are interrelated, as was pointed out above. Thus anything we observe inherently involves ourselves too. The full phenomenon is thus at least as complicated as *Homo sapiens*. Every observation must include the reception of information by our senses, its transmission to our brain, its processing there, its becoming part of our awareness, its comprehension by our consciousness, etc. We appear to ourselves to be so frightfully complicated, that we should then renounce all hope of understanding anything at all.

So we reduce nature into us, on the one hand, and the rest of nature, on the other. The rest of nature, as complicated as it might be, is much less complicated than all of nature, since we have been taken out of the picture. We then concentrate on attempting to understand the rest of nature. (We also might, and indeed do, try to understand ourselves. But that is another story.) However, as we saw above, since nature with us is not the same as nature without us, what right have we to think that any understanding we achieve by our observations is at all relevant to what is going on in nature when we are not observing? The answer is that in principle we simply have no such right *a priori*. What we are doing is *assuming*, or adopting the working hypothesis, that the effect of our observations on what we observe is sufficiently weak or can be made so, that what we actually observe well reflects what would occur without our observation, and that the understanding we reach under this assumption is well relevant to the actual situation. This assumption might be a good one or it might not, its suitability possibly depending on the aspect of nature that is being investigated. It is ultimately assessed by its success or failure in allowing us to understand nature.

As is well known, the observer-observed analysis of nature is very successful in many realms of science. One example is Newton's explanation of Kepler's laws of planetary motion. This excellent understanding of an aspect of nature was achieved under the assumption that observation of the planets does not affect their motion substantially. In general, the reduction of nature into observer and observed seems to work very well from astronomical phenomena down through everyday-size phenomena and on down in size to microscopic phenomena. However, at the microscopic level, such as in the biological investigation of individual cells, extraordinary effort must be invested to achieve a good separation. The ever-present danger of the observation's distorting the observed phenomena, so that the observed behavior does not well reflect the behavior that would occur without observation, must be constantly circumvented.

At the molecular, atomic, and nuclear levels and at the subnuclear level, that of the so-called elementary particles and their structure, the observer- observed analysis of nature does not work. Here it is not merely a matter of lack of ingenuity or insufficient technical proficiency in designing devices that minimize the effect of the observation on the observed phenomena. Here it seems that the observer-observed interrelation cannot be disentangled *in principle*, that nature holistically absolutely forbids our separating ourselves from the rest of itself. Quantum theory is the branch of science that successfully deals with such matters (Davies and Brown, 1986; Davies, 1980). From it we learn that nature's observer-observed disentanglement veto is actually valid for *all* phenomena of *all* sizes. Nevertheless, the *amount* of residual observer-observed involvement, after all efforts have been made to separate, can be more or less characterized by something like atom size. Thus an atom-size discrepancy in the observation of a planet, a house or even a cell is negligible, while such a discrepancy in the observation of an atom or an elementary particle is of cardinal significance.

One aspect of the symmetry implied by the observer-observed reduction, when the latter is valid, is that the behavior of the rest of nature (i.e., nature without us) is unaffected by and independent of our observing and measuring. That behavior is thus an aspect of nature that is immune to certain possible changes, the changes being changes in our observational activities. It is just this symmetry that allows the compilation of objective, observer-independent data about nature that is a *sine qua non* for the very existence of science. It is intimately related to *reproducibility*, which was also shown to be a symmetry (Rosen, 1989a, 1989b).

Inversely, another aspect of this symmetry is that our observational activity is unaffected by and independent of the behavior of the rest of nature, at least in certain respects and to a certain degree. For example, if we had an ideal thermometer, we would make exactly the same temperature measurement regardless of the system whose temperature is being taken. (In practice, of course, things are not so simple.) The symmetry here is that our observational activity is an aspect of nature that is (at least ideally) immune to changes in what is being observed. This symmetry, as limited as it might be in practice, allows the setting up of measurement standards and thus allows the meaningful comparison of observational results for different systems. For instance, we can meaningfully compare the temperature of the sea with that of the atmosphere.

4. QUASI-ISOLATED SYSTEM AND SURROUNDINGS

Whenever we reduce nature to observer and the rest of nature, we achieve simplification of what is being observed, because, instead of observing all of nature, we are then observing only what is left of nature after we ourselves are removed from the picture. Yet even the rest of nature is frightfully complicated. That might be overcome by the further slicing of nature, by separating out from the rest of nature just that aspect or phenomenon that especially interests us. For example, in order to study liver cells we might remove a cell from a liver and examine it, still living, under a microscope.

But what right have we have to think that by separating out a part of nature and confining our investigation to it, while completely ignoring the rest, we will gain meaningful understanding? We have in principle no right at all *a priori*. Ignoring everything going on outside the object of our investigation will be meaningful if the object of our investigation is not affected by what is going on around it, so that it really does not matter what is going on around it. That will be the case if there is no interaction between it and the rest of nature, i.e., if the object of our investigation is an *isolated system*.

Now, an isolated system is an idealization. By its very definition we cannot interact with an isolated system, so no such animal can exist in nature, where nature is, we recall, the material universe with which *we can, or can conceivably, interact*. The state of our present understanding of nature, as incomplete as it might be, is still sufficient to preclude the existence of systems that are somehow observable yet are isolated from the rest of nature. The known anti-isolatory factors include the various forces of nature, which can either be effectively screened out or can be attenuated by spatial separation (Davies, 1986). Additional anti-isolatory factors involve quantum effects and inertia, which can be neither screened out nor attenuated. Thus even the most nearly perfectly isolated natural system is simply not isolated, and I therefore prefer the term *quasi-isolated system* for a system that is as nearly isolated as possible.

The separation of nature into quasi-isolated system and surroundings will be a reduction, if, in spite of the system's lack of perfect isolation, there are aspects of the system that are nevertheless unaffected by its surroundings. And the fact of the matter is that the investigation of quasi-isolated systems does yield considerable understanding, thus proving quasi-isolation to be a reduction of nature. Indeed, science successfully operates and progresses by the double reduction of nature into observer and observed and the observed into quasi-isolated system and its surroundings.

One side of the symmetry implied by this reduction is that those aspects of quasi-isolated systems that are not affected by their surroundings are aspects of nature that are immune to possible changes, the changes being changes in the state of the surroundings. This symmetry is intimately related to *predictability*, which was also shown to be a symmetry (Rosen, 1989a, 1989b). Inversely, due to the mutuality of interaction or of lack of interaction, there are also aspects of the surroundings of quasi-isolated systems that are immune to certain changes in the state of the quasi-isolated systems. That is another side of the symmetry implied by this reduction.

5. INITIAL STATE AND LAW OF EVOLUTION

The previous two ways of reducing nature – separation into observer and the rest of nature and separation into quasi-isolated system and its surroundings – are literal applications of the reductionist position. The present way of reducing is a metaphorical application, or a broadening of the idea of a part of nature. Rather than a separation that can usually be envisioned spatially – observer here, observed there, or quasi-isolated system here, its surroundings around it – the present reduction is a conceptual separation, the separation of natural processes into initial state and law of evolution.

Things happen. Events occur. Changes take place. *Nature evolves.* That is the relentless march of time. The process of nature's evolution (where 'evolution' is intended in the general sense of temporal development) is of special interest to scientists, since predictability, one of the cornerstones of science, has to do with telling what will be in the future, what will evolve in time. Nature's evolution is certainly a complicated process. Yet order and law can be found in it, when it is properly sliced. First the observer should separate him- or herself from the rest of nature. Then he or she should narrow the scope of investigation from all of the rest of nature to quasi-isolated systems and investigate the natural evolution of such systems only. Actually, it is only for quasi-isolated systems that order and law are found. (This statement is really more flexible than it might sound. The demand of quasi-isolation can be relaxed, along with a softening of what is considered order and law.)

Finally, and this is the present point, the natural evolution of quasi-isolated systems should be analyzed in the following manner. The evolution process of a system should be considered as a (continuous or discrete) sequence of states in time, where a state is the condition of the system at any time. For example, the solar system evolves, as the planets revolve around the Sun and the moons revolve around their respective planets. Now imagine that some duration of this evolution is recorded on a reel of photographic film or on a videocassette. Such a recording is actually a sequence of still pictures. Each still picture can be considered to represent a state of the solar system, the positions of the planets and moons at any time. The full recording, the reel or cassette, represents a segment of the evolution process.

Then the state of the system at every time should be considered as an *initial state*, a precursor state, from which the following remainder of the sequence develops, from which the subsequent process evolves. For the solar system, for instance, the positions of the planets and moons at every single time, such as when it is twelve o'clock noon in Tel-Aviv on 20 October 1989, say, or any other time, should be considered as an initial state from which the subsequent evolution of the solar system follows.

When that is done, when natural evolution processes of quasi-isolated systems are viewed as sequences of states, where every state is considered as an initial state initiating the system's subsequent evolution, then it turns out to be possible to find order and law. What turns out is that, with a good choice of what is to be taken as a state for any quasi-isolated system, one can discover a law that, given *any* initial state, gives the state that evolves from it at *any* subsequent time. Such a law, since it is specifically concerned with evolution, is referred to as a *law of evolution*.

For an example let us return to the solar system. It turns out that the specification of the positions of all the planets, moons, etc. at any single time is insufficient for the prediction of their positions at later times. Thus the specification of states solely in terms of position is not a good one for the purpose of finding lawful behavior. However, the description of states by both the positions and the velocities of the planets, moons, etc. at any single time does allow the prediction of the state evolving from any initial state at any subsequent time. The law of evolution in this case consists of Newton's three universal laws of motion and law of universal gravitation.

So the reduction needed to enable the discovery of order and law in the natural evolution of quasi-isolated systems is the conceptual splitting of the evolution process into initial state and law of evolution. The usefulness of such a separation depends on the independence of the two 'parts', on whether for a given system the same law of evolution is applicable equally to any initial state and whether initial states can be set up with no regard for what will subsequently evolve from them. Stated in other words, the analysis of the evolution process into initial state and law of evolution will be a reduction, if, on the one hand, nature indeed allows us (at least in principle) complete freedom in setting up the initial state, i.e., if nature is not at all concerned with initial states, while, on the other hand, what evolves from an initial state is entirely beyond our control.

This reduction of evolution processes into initial states and laws of evolution has proved to be admirably successful for everyday-size quasi-isolated systems and has served science faithfully for ages. Its extension to the very small seems quite satisfactory, although when quantum theory becomes relevant, the character of an initial state becomes quite different from what we are familiar with in larger systems. Its extension to the large, where we cannot actually set up initial states, is also successful. But we run into trouble when we consider the universe as a whole. One reason for this is that the concept of law is irrelevant to the universe as a whole (Rosen, 1981, 1991). Another reason is that it is not at all clear whether the concept of initial state is meaningful for the universe as a whole; I do not think it is (Rosen, 1987).

The symmetry that is implied by reduction into initial state and law of evolution follows immediately from the independence of the two 'parts', as described in the paragraph before last. On the one hand, laws of evolution are an aspect of nature that is immune to possible changes, the changes being changes in initial states. On the other hand, initial states are an aspect of nature that is immune to possible changes, where the changes are hypothetical changes in laws of evolution, in the sense that initial states can be set up with no regard for what will subsequently evolve from them. This symmetry, too, is intimately related to *predictability* (Rosen, 1989a, 1989b).

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REFERENCES

Davies, P. C. W. (1980) *Other Worlds: A Portrait of Nature in Rebellion: Space, Superspace, and the Quantum Universe*, New York: Simon and Schuster, chaps. 1-4.

Davies, P. C. W. (1986) *The Forces of Nature*, 2nd ed. Cambridge: Cambridge University Press, vii + 175 pp.

Davies, P. C. W., and Brown, J. R., eds. (1986) *The Ghost in the Atom*, Cambridge: Cambridge University Press, ix + 157 pp.

Rosen, J. (1981) Extended Mach principle, *American Journal of Physics*, 49, 258-264.

Rosen, J. (1983) *A Symmetry Primer for Scientists*, New York: Wiley, xiv + 192 pp.

Rosen, J. (1987) When did the universe begin? *American Journal of Physics*, 55, 498-499.

Rosen, J. (1989a) Symmetry at the foundations of science, *Computers and Mathematics with Applications*, special issue *Symmetry 2, Unifying Human Understanding*, 17, 13-15; and in: I. Hargittai, ed., (1989) *Symmetry 2, Unifying Human Understanding*, Oxford: Pergamon Press, pp. 13-15.

Rosen, J. (1989b) Symmetry in the structure of science, In: Darvas, G. and Nagy, D. eds., *Abstracts of the 1st Interdisciplinary Symposium on the Symmetry of Structure*, Budapest, pp. 492-494.

Rosen, J. (1990a) Symmetry, Analogy, Science, *Symmetry*, 1, 19-21.

Rosen, J. (1990b) Fundamental manifestations of symmetry in physics, *Foundations of Physics*, 20, 283-307.

Rosen, J. (1991) *The Capricious Cosmos: Universe Beyond Law*, New York: Macmillan, xiii + 175 pp.